ISOCARP

60th ISOCARP WORLD PLANNING CONGRESS

REINVENTING THE (IN)VISIBLE CITIES

8-12 OCTOBER 2024 | SIENA | ITALY

International Society of City and Regional Planners
Release Date: June 2025

ISOCARP's 60th World Planning Congress
Diamond Anniversary Series

Proceedings of the
60th ISOCARP World Planning Congress

60th ISOCARP World Planning Congress
Reinventing The (In)visible Cities
Siena, Italy, 8-12 October 2024

Editors: Rajshree Kamat,
Aleksandra Stupar

Technical Editor: Maryte Litvinaite

©ISOCARP 2025
Produced and published by ISOCARP

Congress Hosted By:

COMUNE DI SIENA

The editors of this publication are not responsible for opinions, statements, or copyright matters related to the content of this Proceedings. These are the sole responsibility of the authors who submitted abstracts to the 60th ISOCARP Congress.

#ISOCARP

ISOCARP - International Society of City and Regional Planners

@ISOCARP65

ISOCARP.ORG

60th ISOCARP World Planning Congress Proceedings
ISBN 978-90-75524-81-9

CONTENTS

1. Introduction **4**

ISOCARP President 4
WPC60 Congress Director 6
WPC60 Programme Chair 8

2. About the Congress **10**

Congress Team 10
General Rapporteurs 18
Curator, team leader of the Special Sessions and the Urban Conversations 26

3. Paper Index **48**

4. Author Index **64**

5. Track 1: Cultural Heritage for Sustainable and Climate-Resilient Futures **70**

6. Track 2: Innovation, creativity, legacy: Cities of/for Tomorrow **554**

7. Track 3: Urban Memories and Inclusive Regeneration **1234**

8. Track 4: Sustainable Urban Density **1760**

9. Track 5: Circular Urbanity **2156**

Introduction

Reinventing the (In)Visible Cities: From Heritage to Innovation, Forging Pathways to Resilience marked a defining milestone in the evolving discourse on urban and regional planning.

Held in Siena from 8 to 12 October 2024, the congress was far more than a commemoration of sixty years of ISOCARP's legacy, it was a profound reflection on the contemporary challenges reshaping cities and regions and on the shifting role of planners in an age defined by uncertainty, complexity, and transformation. It brought together a global community, offering a vital platform for the exchange of ideas on how heritage, innovation, and resilience can be interwoven into the fabric of sustainable urban futures. For me, as President of ISOCARP from 2021 to 2024, the Siena Congress represented the culmination of a journey devoted to expanding the society's international reach and deepening **its commitment to inclusivity and innovation.** Over these three years, ISOCARP has reinforced its standing as a leading platform for interdisciplinary collaboration, one that embraces a holistic vision integrating urban morphology, socio-economic dynamics, cultural and environmental imperatives. The Congress itself embodied this ambition, convening **more than 500 participants from over 70 countries, showcasing over 430 research papers, 20 Urban Conversations and Special Sessions, and keynote lectures delivered by some of the most distinguished voices in the field**

This congress also underscored my strong commitment to ensuring that ISOCARP operates as a truly global society—one that fosters

Pietro Elisei
President,
ISOCARP
(2021-2024)

equitable representation and knowledge-sharing across diverse geographical, cultural, and socio-economic contexts, particularly **by empowering regions and communities that have historically been less visible within global planning narratives.** Despite the presence of dissonant voices within the organisation—advocating for an internationalism often shaped by particular interests rather than emerging from bottom-up inclusivity—I have remained resolute in promoting a more balanced and just planning discourse. **Inspired by Italo Calvino's Invisible Cities**, the congress explored the hidden dimensions of urban and territorial life, transcending conventional urbanist frameworks to incorporate spatial, environmental, and socio-economic perspectives. Such a multidimensional approach has never been more vital, as the very foundations of globalisation are being redefined and cities worldwide grapple with overlapping crises: climate change, socio-political instability, and widening economic disparities.

In line with ISOCARP's enduring commitment to advancing both theoretical and applied research, the congress placed particular emphasis on the relationships between local identities, spatial interdependencies, and planning

methodologies. It highlighted the importance of territorial cohesion and responsible resource management, calling for innovative and adaptive governance models capable of addressing the deepening challenges of sustainability, equity, and resilience. The fi e thematic tracks of the congress framed a coherent and ambitious agenda, offering a roadmap for regenerative urban development and the enhancement of quality of life in cities, metropolitan areas, and regions:

- **Cultural Heritage for Sustainable and Climate-Resilient Futures**
- **Innovation, Creativity, and Legacy: Cities of/ for Tomorrow**
- **Urban Memories and Inclusive Regeneration**
- **Sustainable Urban Density**
- **Circular Urbanity**

Each track illuminated urgent contemporary issues, demonstrating how a comprehensive and inclusive vision can serve as a foundation for more sustainable, just, and forward-looking urban transformations.Together, they reaffirmed the critical need o:

- Integrate cultural heritage conservation within sustainability and climate resilience strategies;
- Promote innovation at the heart of governance structures;
- Support economic and environmental models rooted in long-term sustainability.

Among the most powerful takeaways from the congress were:

- The imperative to weave cultural heritage into the fabric of climate adaptation and sustainability policies;
- The transformative potential of digital tools, geospatial technologies, and participatory planning in shaping more adaptive, equitable urban futures;
- The need to strengthen multi-level, transnational, and cross-disciplinary cooperation to bridge widening territorial disparities;
- The importance of embedding circular economy principles within urban and regional development frameworks to optimise resource management and resilience.

The proceedings of the congress now stand as a comprehensive resource—a compendium of academic inquiry and practical wisdom that will guide scientists, scholars, and practitioners seeking to construct a more balanced, inclusive, and responsible, sustinable model of urban development. They challenge conventional paradigms, urging us to rethink the economic and governance structures needed to ensure that every citizen, irrespective of geography, can live free from the existential threats posed by climate change, conflict, and economic olatility.

Above all, the Siena Congress reaĀ rmed ISOCARP's role as a dynamic, forward-looking society. A society that not only responds to the emerging urban challenges of our time but actively shapes the future of the discipline. A society capable of producing original contributions, positioning itself as a leader in global urban and regional discourse, not merely an echo chamber of ideas forged elsewhere.
The ideas, research, and visions exchanged in Siena will continue to inspire the collective effort to create more inclusive, resilient, and sustainable urban environments across the globe.

Introduction

The **60th World Planning Congress was unique in the history of ISOCARP.** It was an extraordinary experience due to the creativity and innovation of Isocarp members and the City of Siena. The Congress was prepared by more than 50 members and a core team of the Municipality of Siena fully involved in the intellectual and organization components to provide high platforms of dialogue and exchange of experience between members. The originality of the Congress was based on the magic of the historic city, full of mindset for planners: the City of Italo Calvino, the author of the Invisible cities, the location of the fresco of the good government with the meaningful fresco representing the relation between urban and rural areas, the city who invented the pedestrian street. It is also the format of the Congress who not only delivered **430 papers** discussed within **5 tracks** and create **3 new awards (films, sketches and short texts),** but also offered **Urban conversations** for real dialogues between members on key challenges of the contemporary world.

The Congress was rooted in the City of Siena with meetings and cocktails disseminated in the City, a dinner in a local community (contrada) that represent the contemporary tradition, sites visits, and by the production of projects **(mini UPAT and YPP)** for the City of Siena.

The high level of keynote speakers put the debate at the level of the contemporary challenges: how to connect heritage and innovation with **Jyoti Hosagrahar from the World Heritage Center of UNESCO**; how to adopt the new international paradigm of planners with

Eric Huybrechts
WPC60
Congress Director

Carlos Moreno from Sorbonne University, how the architecture can change city life with **Massimiliano Fuksas one of the most famous Italian architect**, how heritage adopt the integrated planning concept and methodology with **Jad Tabet** who **participated to** the preparation of the **Historical Urban Landscape Recommendation of UNESCO**, with **Orna Rosenfeld** from the **European Commission**, and how the narrative on cities drive city developments with **Chris Elisara funder of "A Story can change a city"**. Climate change, AI, social integration, resilience among other subjects were discussed.

More than **500 participants** coming **from 70 countries** shows the vitality of ISOCARP able to mobilize all generations, renew its format, and deliver a **Congress Declaration** based on the debates to deliver key messages to the world.

Infinite thanks to the City of Siena, the large Congress team and all the participants that make the Diamond anniversary Congress of ISOCARP a fi ework.

60th ISOCARP WORLD PLANNING CONGRESS

REINVENTING THE (IN)VISIBLE CITIES

8-12 OCTOBER 2024 | SIENA | ITALY

Siena © Municipality of Siena

Introduction

Rolf Schuett
WPC60
Programme Chair,
Director Young
Professionals
Programme,
ISOCARP Board
(2022-2025)

It is an honor to contribute my personal perspective to the final proceedings of this remarkable event. Siena, with its rich history, is not only a jewel of Italy but a symbol of our shared civilization. Tuscany, the birthplace of the humanistic Renaissance, is also where many branches of natural science and creativity as a movement began.

For me, Siena represents a renaissance moment for ISOCARP, both as a nonprofit organization and as a network of professionals, educators, and friends. Historically, ISOCARP was predominantly European, but this event marked a shift. The statistics speak for themselves: two-thirds of the registered participants came from countries outside high-income regions - countries outside the EU and industrialized nations, many of whom had to apply for visas to attend the event. What's even more inspiring is that half of them were under **35, representing a new generation of Young Planners and Young Professionals**. ISOCARP is no longer just an institution attracting senior professionals; we have truly become global and inclusive.

ISOCARP now has the potential **to be a platform for underrepresented researchers and professionals from key regions outside Europe**—particularly the younger generations, who bear the responsibility of addressing the challenges that our generation has yet to resolve.

Reflecting on my takeaways from Siena: the discussions highlighted the ongoing tensions between global political forces, market interests, and our collective responsibility to apply evidence-based planning. **Key themes such as inclusivity, heritage, identity, and accessibility** emerged time and again. As planners, we are tasked with advising on the best possible solutions, with our abilities limited only by our experience, our technical tools, and our creativity. Individually, we may not be able to offer complete solutions, nor can we expect to develop standardized tools and methods. However, as international, multicultural, and multigenerational teams, we are increasingly able to refine approaches that respond to the challenges facing global communities.

Most importantly, because every case is unique, and each city holds its own identity that requires tailored solutions, the diverse mix of disciplines, generations, and perspectives reaffirm that we must act locally but think globally. And now, as we connect, we should also embrace that global expertise.

I would like to express my deepest gratitude to all those who worked tirelessly to make this event a reality. The **WPC60 in Siena was a once-in-a-lifetime experience for all** of us, and the success of the event stands as the best reward.

Siena © Municipality of Siena

About the Congress

Congress Team

Pietro Elisei
President, ISOCARP
(2021-2024)

Town and **regional planner, senior researcher, and policymaker.** He collaborated, as consultant, with ministries, cities and towns all over Europe, holding important positions in international organizations dedicated to urban planning (PLANUM SG, ISOCARP VP).

International expert in urban regeneration policies, integrated planning for small-medium sized cities and topics related to smart cities and strategic planning. A collaborator with EU universities and research centers, he works as international expert with international institutions (European Commission: URBACT and UIA Secretariats, UN-Habitat, UNECE) for important urban and territorial planning research/planning tasks. Dr. Elisei also routinely holds keynote speeches in international conferences and publishes a number of scientific articles on topics related to urban planning. Founder and Director of URBASOFIA (www.urbasofia.eu)

Eric Huybrechts
WPC60
Congress Director

Eric Huybrechts is a **senior Architect and Urban/Regional Planner**, co-chair of Habitat Professional Forum of UN-Habitat, Secretary General of the Metropolitan and Territorial Planning Agencies global network (MTPA-gn), ex-Board member of ISOCARP, member of ICOMOS (CIVVIH expert), and Office of the Royal Order of Sahametrey (Cambodia). He is Canadian, French and Belgian.

He is the Head of the International affairs of the Institut Paris Region (www.institutparisregion.fr), one of the largest spatial planning institutes in the World. He has developed a considerable experience in the field of Urban and regional planning as an expert and team leader at all scales from public space, and historical urban center, to megacity, region and country in more than 20 countries. He has an academic experience as a scientific researcher in France and Middle East countries and as a lecturer in several universities in France and abroad (Paris universities, MIT…) mainly on Spatial planning in the Global South.

Rolf Schuett
Programme Chair,
Director YPP,
ISOCARP Board
(2022-2025)

Rolf Schuett was born in Bolivia. After finis - ing high-school in Hamburg he studied architecture and urban planning in Konstanz. He holds a masters degree in heritage studies from the Cottbus University of Technology. Rolf has worked in Bolivia, UK, Poland and Germany. He is a member of Isocarp since 2008 and has participated in several UPATs and YPP activities in the Middle East, Europe and Asia.

Rolf is also vice chair of the International Association of World Heritage Professionals, based in Bamberg, Germany. His **expertise includes architectural design** (air transport, oil industry, commercial, culture, residential), **urban conservation, community development, resilience planning for informal settlements, urban revitalisation, GIS and digitalization**. His current projects include the design of sustainable local development schemes for the Stuttgart metropolitan region, development of strategies for healthy neighbourhoods and international research projects linked to heritage conservation.

Darinka Golubovic
Board Member,
Treasurer
(2021-2024)

Darinka Golubovic Matic is a full professor in the Faculty of Construction Management (Architecture and Urbanism; Civil Engineering) at the University of Union Nikola Tesla in Belgrade (Serbia). She is a **consultant, researcher and academic with experience in the field of civil engineering, urban and regional planning and environmental assessments** in different European countries. She has been a project manager and team member of different technical and advisory development projects. She is the author or co-author of more than 10 papers in international journals and has more than 20 conference contributions. Since 2003 she is a member of ISOCARP and The Serbian Chamber of Engineers. Her research interest is focusing on land use management, environmental assessment, civil engineering, transportation, urban mobility and GIS methods.

Sabina Reichert
Board Member
Communications
(2021-2024)

Executive Committee and Board director for Communications of the International Society of City and Regional Planners (ISOCARP), deputy director of URBASOFIA and former president of the Romanian Professional Planners Association. As an **urban and regional planner**, she is a **consultant and portfolio manager experienced in strategic planning, participatory processes, planning for nature-based solutions, decarbonization and new forms of urban governance.** With a PhD in instruments for integrated and sustainable planning in multi-level metropolitan contexts, her focus is on bridging development and policy gaps, more recently pertaining to support for the twin transition and net-zero land take objectives. She has also been involved in writing, implementing, and supporting city access to international research & innovation and cooperation projects, mostly under flagship European Commission programs. As a planner, she has worked on several national and regional studies, integrated urban development strategies for middle-sized cities and metropolitan areas in the EU, Sustainable Urban Mobility Plans, and sectoral strategies.

About the Congress

Congress Team

Ali A. Alraouf
Deputy

Ali A. Alraouf is an **architect, urban designer and planner interested in research and practice related to comprehensive sustainable design and urban planning.** He was a Visiting Scholar at the University of California at Berkeley-USA. Alraouf has held permanent and visiting teaching and research positions at regional and international universities. Alraouf is a registered architect and urban planner in Egypt, Bahrain and Qatar. He is an associate member of the American Institute of Architects, Middle East and Gulf Chapter. Alraouf published more than 105 journal refereed papers, critical reviews, essays, in addition to books and book chapters. Alraouf's current research interests are: Knowledge-based Urban Development, Post-Carbon Contemporary Gulf Cities, Museums in the Gulf, Urban vitalisation of historical districts, Knowledge and Creative cities. He serves on editorial boards and acts as a reviewer for international journals and conferences. He provides consultancy in numerous projects regionally and internationally and acts as a consultant for international organisations including UN-Habitat, UNESCO, ESCOWA, ICOMOS among others. He serves on editorial boards and acts as a reviewer for international journals and conferences.

He delivered lectures and presentations in over 25 countries and has been invited to present his research work at international institutions such as University of Oregon, Illinois Institute of Technology, Drury University, Cambridge University, University of Seoul, Malaysia International University, University of Belgrade, and American Universities in Beirut, Sharjah, Kuwait and Cairo. Alraouf is the recipient of number of awards including the innovation award in environmental and sustainable planning from Ministry of scientific research in Egypt 2000, Modern Science and Arts University (MSA) Teaching Excellence Award 2004, Best Research Paper in Sharjah International Conference for Urban Planning 2008 and Research Publication Achievement Award from University of Bahrain 2009. Alraouf was selected as a member of 2012 Excel campaign at Qatar University and the distinguished speaker of the Arab Future Cities Summit 2016.

His book "Knowledge-based Urban Development in the Middle East was awarded by ISOCARP in 2018. Alraouf's research paper was also awarded as the best research paper by a scholar at the UC- Berkeley biannual conference in 2018. Alraouf currently acts as Head of capacity building, training, research and development unit at Ministry of Municipality and Environment (MME) in Qatar. He is also a visiting professor at HBK University in Qatar-Education City, and the leader of Green Urbanism and Planning Group at Qatar Green Building Council (QGBC).

Wafa Al-Daily
Deputy

Dr. Wafa Al-Daily is a **senior urban planner, a researcher, a lecturer, and an international development expert** with a demonstrated working history for about two decades in academia, government agencies, NGOs, CBOs, local communities, and the private sector in the USA and the MENA region. She is experienced in urbanization, metropolitan planning, management and governance, urban recovery, smart/sustainable development, e/governance, DRRM, and informal settlements. She also has extensive management experience in international education and program administration and partnership development, global initiatives, capacity building, grants writing and implementation, and strategic planning. She is passionate about inclusive planning and has dedicated part of her professional career journey to supporting underserved and marginalized populations. Her experience spans a variety of groups, including women, youth, immigrants, people with disabilities, and indigenous peoples in both the USA and the MENA region.

Dr. Al-Daily is the Co-Founder and Executive Director of EHAAR International, LLC. She is the Lead of the International Metropolitan Fellowship Arabia Chapter and a member of the Board of Directors of the International Metropolitan Fellowship. She is an affiliate member, fellow and researcher of a number of centers and institutes, including the for Cooperative Problem Solving and Institute for Policy and Governance at Virginia Tech University in the USA, International Metropolitan Fellowship in Spain, American Planning Association in the USA, International Society of City and Regional Planners in the Netherlands, Arab-German Young Academy of Sciences and Humanities in Germany, Gulf International Forum in the USA, and NAFSA Academy for International Education) in the USA. She has worked in a consulting capacity with a number of organizations, including the United Nations Children's Fund, URBAConsulting/World Bank Group, Social Fund for Development, and Qatar National Research Fund.

Dr. Al-Daily was a recipient of prestigious awards and fellowships including the American Association of University Women International Fellowship and Who's Who Among Students in the American Universities and Colleges. She was nominated for the President's Award for Excellence and the Alumni Award for International Outreach at Virginia Tech University in 2020.

Dr. Al-Daily is a certified practitioner of Kirton Adoption-Innovation Inventory Problem Solving and Cognitive Style, and a facilitator of intergroup dialogue and human relations. She earned a Ph.D. in Planning, Governance and Globalization from Virginia Tech (USA), a Master of City and Regional Studies from Rutgers University (USA), a Non-degree Diploma in Urban Planning and Community Development from Rutgers University (USA), and a Bachelor of Science in Architectural Engineering from Sana'a University (Yemen).

About the Congress

Local Organizing Committee

Paolo Bonari

Head of the Tourism Bureau of the Municipality of Siena, the first City of Art in Italy to be certified as a sustainable tourist destination based on GSTC standards. "Our daily commitment is to transform Siena into a modern tourist destination with well-organized services focused on environmental, cultural, and socio-economic sustainability."

Niccolò Fiorini

Postdoctoral Researcher in the Department of Business and Law at the University of Siena. He holds a PhD in Economics, Markets, and Institutions from the IMT School for Advanced Studies Lucca. His international academic background includes periods at the University of Cambridge, Fraunhofer Institute for Industrial Engineering IAO, WHU – Otto Beisheim School of Management, and University of Applied Management Studies (HdWM). Dr Fiorini is an accomplished lecturer at several Italian universities, where he also supervises theses and serves on multiple scientific committees. His research expertise lies in entrepreneurship, business, marketing, and innovation management. He is the Editor of Progress in Industrial Ecology, An International Journal, and has an extensive record of publications in peer-reviewed journals. Additionally, he has been actively involved in a broad range of research projects and consultancy engagements.

Daniele Vettorato

Daniele leads a research team in urban and regional energy systems in the institute for Renewable Energy at EURAC Research, based in Bolzano, Italy. He holds a PhD from the University of Trento, focused on sustainable energy in cities and regions. Daniele has co-authored over 50 and has been invited as lecturer and speaker in more than 50 events.

Mariapiera Forgione

Communication and events consultant for the Municipality of Siena. Degree in Communication Sciences. Marketing and communication consultant, project planning and fundraising specialist, she works with public administration, also for European projects, and non profit o ganizations.

Daniela Occhionero

Founder of FINE LIFE, a DMC and Tour Operator that provides tailor-made travel design and MICE services. After graduating in Law, she spent 8 years in China working in Communication and Hospitality. Once back in Siena, 12 years ago, she decided to establish FINE LIFE with a local partner to combine an international approach to a deep knowledge of the Region.

Mattia Barana

Communication and event consultant for the Municipality of Siena.
Degree and specialization in Art History; co-founder of belong.in, a start-up within the Department of Excellence in Political, Cognitive, and Social Sciences at the University of Siena, recognized as a university spin-off.
The start-up manages the communication for numerous prestigious cultural institutions in Siena and Florence. These include Teatri di Siena (up to 2924), Fondazione Musei Senesi, the "Pietro Farulli" Music Center, the international event "Saranno famosi nel vino," several medical and clinical centers and various University Master's Programs.

Fernando Nardi

Hydraulic engineer and hydrologist, is associate professor at the Department of Civil Engineering and Computer Science of University of Rome Tor Vergata. He is visiting professor at the Institute of Environment of Florida International University (FIU) and member of the FIU UNESCO Chair on Sustainable Water Security in Miami. Dr. Nardi is a water engineering expert with relevant experience in the coordination and execution of EU and international research and innovation programs fostering climate change adaptation, disaster risk reduction and resilient urban planning. His major academic publishing and technology transfer achievements relate to hydro-meteo risk, floods and droughts, numerical data and models, geospatial and earth observation intelligence, nature based solutions, NATCAT models for insurance and real estate risk mitigation. Prof. Nardi most recent efforts focus on transdisciplinary projects fostering synergies of engineering and earth sciences with social sciences and humanities.

Luri Bruni

Head of the Culture and Tourism Directorate of the Municipality of Siena.

About the Congress

The 60th ISOCARP World Planning Congress - "Reinventing the (In)Visible Cities: From Heritage to Innovation, Forging Pathways to Resilience" was held in the historic Italian city of Siena, from the 8th to 12th October 2024. The congress represented the highlight event of this special year and a part of the **ISOCARP's 60th World Planning Congress Diamond Anniversary Series, celebrating 60 years of congresses**. Inspired by Italo Calvino's visionary work in "Invisible Cities", the comprehensive program encouraged all participants to imagine the unseen and strive for urban utopia(s) in a setting which stands both as a shining example of good governance and the symbol of the strong relationships between the city and the hinterland, depicted in Lorenzetti's frescoes.

Prepared by ISOCARP with **50 volunteers,** the Congress attracted **500+ participants,** coming **from 70+ countries** to discuss on **430 papers**, participate to **20 Urban conversations and Special sessions, 9 high-level Keynotes** in plenary sessions, attend to **6 awards**, and mobilise **16 young planners** and **13 high-level professionals** on **placemaking charette** for the City of Siena. The Congress was rooted in the city through urban spaces which hosted sessions (famous Teatro dei Rinonovati, Santa Maria de la Scala museum, University) and various events - from site visits and projects with local partners to gala dinners and gatherings in both historical sites and neighbourhood centres.

Siena, with its rich tapestry of history, commitment to innovation, and dedication to heritage preservation, was selected as a living embodiment of the main theme. Its pioneering spirit is evident in its historic contributions to walkability and banking, showcasing a legacy of urban inventiveness that continues to shape its identity. As a vital stop along the historic Via Francigena pilgrimage route and the home of the vibrant Palio horse race, **Siena exemplifies the power of connection, tradition and progress, where culture and planning are embedded in communities.** Consequently, the UNESCO-listed centre, anchored by the iconic Piazza del Campo, provided a scenic canvas for envisioning the cities of tomorrow, while the treasures housed within the Duomo continuously showcased the city's enduring excellence. Symbolising transformation, Santa Maria della Scala reflected the ISOCARP's mission to bridge past and future, providing a fitting venue for discussions on urban resilience and innovation.

By reimagining city planning and design to accommodate innovation in all fields, the congress delegates honoured Siena's unique historical significance **focusing on topics such as urban regeneration, leveraging cultural heritage for sustainable development, and combating climate change.** Gathering within city's timeless embrace we were charting a course toward the future based in revitalised cities with sustainable urban legacy, healed and liberated from systemic inequalities. Through collective vision and shared commitment we were able to face the challenge of reinventing our cities - to meet the needs of the present, while preserving the essence of our past.

Congress Team

Siena © Municipality of Siena

About the Congress
General Rapporteurs

Aleksandra Stupar

Dr. Aleksandra Stupar is full professor at the University of Belgrade – Faculty of Architecture, where she graduated and obtained her magister and PhD degree. **The head of the Department of Urbanism (2017-2024)**. She has participated in numerous research projects and workshops, published articles and chapters in national and international journals and monographs focusing on the problems of contemporary cities. She is the author of two awarded books – 'Grad globalizacije – izazovi, transformacije, simboli' ('The City of Globalisation – Challenges, Transformations, Symbols', 2009) and 'Grad – forme i procesi' ('The City – Forms and Processes', 2016/2019/2024).

Her professional experience (research, education, practice) is related to the areas of urban studies, urban planning and urban history. Due to her focus on the themes of urban transition and urban innovations, especially their spatial, environmental and social implications, she conducted her work in a number of multidisciplinary teams gathering experts from various complementary fields (cultural studies, history, STS studies, sociology, anthropology, future studies etc.). Through the organisation and moderation of sessions, workshops and roundtables Dr. Stupar has addressed the occurring urban phenomena, the challenges of urban continuity and the emerging realities which influence the sustainability and resilience of our habitats.

She has been a **visiting researcher** at the Institute for Advanced Studies on Science, Technology and Society (IAS-STS) in Graz (2007, 2011), the University of Tampere – School of Humanities and Social Sciences (2010-2013), as well as a guest lecturer at the Sapienza Università di Roma – Facoltà di architettura Valle Giulia (2006,2008-9), Urban Design Group, London (2014), University of Helsinki – Faculty of Social Sciences (2019) and Yildiz Technical University, Istanbul (2021).

Dr. Stupar has been a member of ISOCARP since 2003, served as the BM of the National Delegation of Serbia (2006-2015) and a member of Scientific Committee (2013-2016). S**he is also a member of EAUH and was a national representative in AESOP (2018-22). She received the 2007 Honorary Mention of the Gerd Albers Award, and the 2008 Gerd Albers Award for her publications.**

Rajendra Kumar

Rajendra Kumar is architect, urbanist, **author** based in New Delhi, India and **Director of School of Architecture and Design,** Lovely Professional University, India. He is awarded as 'Most Admired Education Influencers in India 2022' and 'Global Educational Influencer 2020', 'Indian Young Achievers Award 2009. He graduated from Chandigarh College of Architecture, India and Post-graduation from Politecnico Di Milano, Italy. He was listed as 12 notable alumni of Politectnico di Milano in 2022. He is Local Ambassador of Royal Institute of British Architects (RIBA), UK.

He is **member of International Society of City and Regional Planners (ISOCARP), Netherlands, Council of Tall Buildings and Urban Habitat (CTBUH), USA.** Received fellowship by Congress for New Urbanism, USA. He is actively involved in academia and research. Advisory member of various think tanks of national and international importance, invited members for various projects with global leaders including Prime Ministers, Governors, Ambassadors, Mayors, Policy makers, United Nation, WHO, UN Habitat etc. He has been Jury member of many prestigious awards including 'World Architecture Festival', advisor to Pritzker etc. During G20 Summit in India, he served as task force member for 'Y20 (Young 20) and invited expert member in 'Urban20' engagement groups of G20 Summit'.

He is **equipped with mixed experiences of varied scale projects, ranging from urban scale to buildings and interiors**. Appeared in TV Channels, Radio, Print and Online Media in India and abroad. 100+ publications and invited lectures, in national and international conferences. He lectured on many national and international forums on various issues related to cities, social issues, sustainable environment etc. at national and international forums in India, Spain, USA, UK, Poland, Portugal, Hong Kong, South Africa, Slovenia, Italy, Germany, Thailand, Malaysia, Russia, South Korea, Taiwan, including Columbia University, New York, Cambridge University, AA London, UK, FUAP Porto, University of Ljubljana, Slovenia, Gdansk University, Poland, and many more.

Introduction by General Rapporteurs

Marking a significant jubilee of the **International Society of City and Regional Planners and the 60th edition of world planning congresses,** the 2024 WPC organised in Siena represented the culmination of the Diamond series which, once again, **celebrated an incredible amount of professional dedication, academic excellence and human interconnectedness,** generated by the members of our Society. This year, under the title 'Reinventing the (In)Visible Cities: From Heritage to Innovation, Forging Pathways to Resilience', our attention was directed toward the issues which influ nce the contemporary urban reality exposed to climate extremes, hyper-urbanisation, technological acceleration and growing instability. Within this scope, a variety of emerging topics was tackled by delegates, targeting a synergy between cities, urban society and development trajectories, while confir ing both the complexity of recent theories and the contradictions of ongoing practice.

The program of the congress was multidimensional and immersive, structured around fi e main tracks. They were complemented by **mind-provoking keynote speeches (Carlos Moreno, Massimiliano Fuksas, Jad Tabet, Orna Rosenfeld, Chris Elisara), intriguing Urban Conversations, globally and locally alluring Special Sessions and creatively conceived mini-UPATs.** Highlighting the upcoming challenges, their causes and effects, the main tracks presented an opportunity to identify, study and resolve accumulating urban issues under diverse thematic frameworks - 1) **Cultural Heritage for Sustainable and Climate-Resilient Futures, 2) Innovation, creativity, legacy: Cities of/for Tomorrow, 3) Urban Memories and Inclusive Regeneration, 4) Sustainable Urban Density, 5) Circular Urbanity.** Focusing on both the historical and the emerging cities around discussing the methods and tools for the world, their different levels and scales, the sensitive condition of our cities was explored across **23 sub-themes.**

The **first track** addressed the possible roles of preservation and utilisation of cultural heritage within sustainable imperatives. It also considered the benefits of traditional knowledge, technological innovations and community-driven actions in achieving climate resilience and overcoming environmental risks. The **second track** was focused on innovative solutions which would support urban systems (mobility, accessibility, effici - cy), upgrade planning process, and facilitate sustainable transition. The ideas related to governance (i.e. community engagement, collaboration, participation), inclusive urban design and digital advancement were also shared, along with the possibilities of restorative urbanism. The **third track** was dealing with a subtle relationship between urban memories, regeneration and community, emphasising several aspects and levels of its influenc on planning methodologies and spatial/urban development - from culture and identity to health, general wellbeing and inclusivity.

The **fourth track** examined the problems related to sustainable urban density, climate adaptation and resilience while considering the elements of morphology, everyday life,

urban environment, data and normative frameworks. The promotion of mixed-use development, integrated green infrastructure and sustainable building practices and transportation systems were also elaborated, tracing the future development and further studies. The **fifth track** represented a stage for circular urbanity - its applicability, multidisciplinarity, strategic possibilities, but it also revealed numerous challenges - due to complexity of circular processes and their fragmentation.

The intensive congress program encouraged dynamic debates, as well as local and global cooperation. Balancing between tradition and innovation, nature and technology, potentials and setbacks, all tracks explored a fragile structure of human settlements affected by the increasing uncertainty, multiplying global fears and anxieties. While confronting the ecology of fear with the ecology of hope some new horizons were outlined - based on sustainable transition, resilience, and benevolent socio-technical and ecological transformations.

Through merging, upgrading and refining of both the academic knowledge and professional achievements our intention was to identify the accurate condition of built environment and urban society, as well as the implications of ongoing and upcoming global processes. While searching for innovative responses, methods and tools, which could facilitate the inevitable urban shift to preferred development paradigms, the presented contributions also introduced new modes of comprehension and action.

All these outcomes might ease the rising tensions caused by the combustible reality around us. They could also support the anticipated sustainable transition or even increase urban resilience. However, additional steps are needed on our way to materialise wishful thinking or resonant global agendas. Each track turned the spotlight on many augmenting dilemmas of contemporary planning, development and transformations, encouraging open discussions and a dynamic transfer of information and experiences. The outcomes influenced and shaped key-fin - ings and recommendations within the tracks, but some overlapping issues were identified and they should be underlined as the immanent features of forthcoming planning actions and cross-disciplinary considerations:

- The holistic, future oriented approach in planning as a response to the anticipated dynamism, flexibility and adaptability of urban environment;
- The application of multifaceted methodologies based on the emerging trends/ innovative tools which would incorporate the imperatives of sustainability, resilience, inclusivity, fairness;
- Civic engagement and inclusive decision-making;
- The synchronisation of the material and the digital realm leading to the synergy of natural, built and digital performances;
- The coordination and co-action between long-term perspectives and short-term plans;
- The sustainable and productive balance of international collaboration/programs/ frameworks and bottom-up initiatives;
- The synchronisation of adopted strat egies

and available/adequate toolkits, guidelines and recommendations;
- The re-utilization of resources and the management;
- The upgrading and intensification of circularity.

The contributions presented during the congress sessions also defined signposts for professionals involved in the future of environmental, territorial and urban transformations. Highlighting the importance of education, awareness, innovativeness and promotion, the imperatives of co-creation, co-production and co-benefits were frequently distinguished. Additionally, the necessity of multi-sectoral collaboration was stressed, including the intrinsic one - between architecture, urban design and urban planning, emanating beyond the elusive and often self-imposed professional margins.

The 60th ISOCARP World Planning Congress was a tremendous achievement and an incredible group effort. The selected team of track rapporteurs had a challenging task, which lasted several months, occasionally testing their physical endurance due to a high number of submitted proposals and participants, as well as the dense schedule of sessions. However, their dedication and professionalism have successfully and efficiently overcome all organisational challenges imposed by spatial limitations or technical obstacles. Therefore, we would like to express our gratitude to this amazing group of accomplished professionals who ensured the highest scientific level of the congress and these proceedings.

An omnipresent protagonist of the Diamond ISOCARP WPC should also be acknowledged - the City of Siena, representing a living embodiment of the congress topic due to its inherent urban sustainability and the legacy of community wellbeing, justice and wisdom depicted by Simone Martini and Ambrogio Lorenzetti. While its principal meeting node - Campo - continuously radiates its centrality and collective dynamism, the iconic event Palio could be seen as a metaphor for multiple global turbulences, completely in line with the famous poem of the Italian Nobel Prize winner Eugenio Montale (Palio, 1939). Considering this thematic and substantial overlapping, maybe the best guidelines for our future actions - IN and FOR our cities, as well as the built and the natural environment - could be found in the work of Guido Piovene, who described Siena as a place in which the past and the present, the near and the astral, seem to be a part of the same time (Viaggio in Italia, 1957).

And indeed, this transcendental quality of our host city represented a unique secret ingredient and a catalyst of all congress activities - able to annul the negative effects of colliding global forces, while ensuring a more sustainable, equitable and just urban future for all.

Grazie Siena, un laboratorio senza tempo di visibili ed invisibili città!

General Rapporteurs

Siena © Municipality of Siena

Congress Tracks

Track 1. Cultural Heritage for Sustainable and Climate-Resilient Futures

Explore how preservation and utilization of cultural heritage can serve as a catalyst and/or powerful driver for sustainable urban development of resilient cities and regions.

- Integrating Traditional Knowledge into Contemporary Planning: Utilize indigenous and historical building techniques that emphasize sustainability and climate resilience in contemporary urban design.
- Cultural Heritage Tourism: Develop sustainable tourism strategies that leverage cultural heritage sites, boosting local economies while ensuring conservation.
- Adaptive Reuse of Historical Structures: Transform heritage buildings for modern uses, maintaining historical integrity and reducing the carbon footprint of new construction.
- Energy-EĀ cient Restoration: Retrofit heritage buildings with modern, energy-eĀ cient technologies to reduce carbon emissions and enhance climate resilience.

Track 2. Innovation, creativity, legacy: Cities of/for Tomorrow

Discover innovative solutions for revitalizing cities and metropolitan regions, improving their mobility and efficiency, shaping their dynamic future and directing their evolution. Investigate creative and inventive technological, social and spatial solutions and planning approaches which support equity, inclusiveness, cooperation and collaboration, as well as digital upgrading, urban management and the efficiency and modernisation of urban systems.

- Smart Infrastructure: Implement advanced technologies like IoT and AI to optimize urban infrastructure, enhancing mobility, energy effi ency, and public services.
- Inclusive Urban Design: Create spaces and systems that promote accessibility and equity, ensuring all community members benefit f om urban improvements.
- Collaborative Governance: Foster partnerships between government, private sector, and citizens to co-create solutions that address urban challenges.
- Digital Urban Management: Upgrade city management with digital tools for real-time monitoring, data analysis, and eĀ cient resource allocation.

Track 3. Urban Memories and Inclusive Regeneration

Explore the preservation of intangible urban memories and inclusive regeneration practices, empowering communities and fostering social inclusion.

- Community-Driven Preservation: Engage local communities in documenting and preserving their intangible cultural heritage, ensuring their stories and traditions are honored in urban regeneration projects.
- Inclusive Public Spaces: Design and revitalize public spaces that reflect the diverse cultural histories and memories of all community members, promoting social cohesion.
- Participatory Planning: Involve residents in the planning and decision-making processes, ensuring regeneration efforts meet the needs and aspirations of all

groups, particularly marginalized populations.
- Cultural Programs and Events: Develop programs and events that celebrate and revive local traditions, enhancing community pride and connection to place

Track 4. Sustainable Urban Density

Examine approaches to sustainable urban density, balancing population growth with green spaces and sustainable design principles to create livable and resilient urban environments.

- Mixed-Use Development: Promote mixed-use developments that combine residential, commercial, and recreational spaces to reduce the need for extensive transportation and enhance community interaction.
- Green Infrastructure: Integrate green spaces, parks, and vertical gardens into urban design to improve air quality, manage stormwater, and provide recreational areas.
- Car lite strategies: Develop and expand efficient public/private transportation systems to reduce reliance on cars, lower emissions, and support higher density living.
- Sustainable Building Practices: Implement sustainable building techniques and materials that minimize environmental impact and enhance the energy efficiency of urban structures.

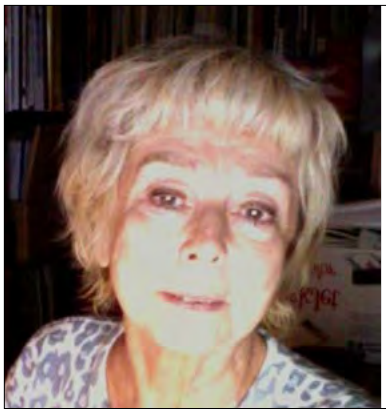
Track 5. Circular Urbanity

Discover strategies for implementing closed - loop systems and zero-waste planning in cities, fostering resilience and sustainability while minimizing environmental impact.

- Zero-Waste Initiatives: Promote policies and practices that reduce waste generation, encourage recycling, and support composting, aiming for a circular economy.
- Resource Recovery: Develop systems for reclaiming and reusing materials from construction, industry, and consumer goods to minimize landfill use and resource depletion.
- Sustainable Urban Agriculture: Implement urban farming projects that utilize organic waste for compost and reduce food transportation emissions, creating local, sustainable food sources.
- Water Recycling Systems: Integrate advanced water recycling and rainwater harvesting technologies in urban planning to reduce water waste and ensure sustainable water management.

Urban Conversations and Special Sessions

by Judith Ryser
Curator and team leader of the Special Sessions and the Urban Conversations, with the contribution of the facilitating and mentoring team: Hadeel Abuzaid, Monica Bonu, Elena Batunova, Ronit Davidovici-Marton, Mani Dhingra, Serin Geambazu, Nasim Iranmanesh, Hanna Obracht-Prondzyńska, Holly Pearson, Jonila Prifti, Shinjini Saha, Priyanka Sawant-Purohit, Rolf Schuett, Abimbola Tofowomo, Eunice Yorgri



Judith Ryser
Curator,
Team Leader,
Special Sessions
and Urban
Conversations

The ambition of Pietro Elisei was to make the congress in his home country a very special event during the last year of his ISOCARP presidency. He conceived Urban Conversations and Special Sessions to provide informal opportunities for the participants of the ISOCARP 60th anniversary congress to share their wealth of practical and tacit knowledge. The aim of Pietro Elisei's initiative was to offer individual and corporate members of ISOCARP opportunities to exchange experiences, projects and research of their choice, face to face, in the exquisite historical spaces the host city had made available, and to develop ideas together at informal discussions towards a more sustainable urban future.

These innovative gatherings formed an integral part of the deliberately multivariate congress programme Pietro Elisei had developed with the host city Siena. This included the innovative Urban Conversations and Special Sessions held in historical settings of the city centre, at universities and other public buildings. Globally reputed as a unique jewel of urbanity, honoured by a UNESCO Cities of Culture Award, venerated worldwide by many professional and cultural organisations, Siena was the perfect place to reflect on the essence of 'The City': complex beyond grasp, ambiguously formless, in constant flux, inviting to get a feel for Siena rather than to merely appreciate its unique architecture and urbanism; in Italo Cavino's words: "You take delight not in a city's seven or seventy wonders, but in the answer it gives to a question of yours".

The complexity confronting planners when seeking meaningful solutions to the pressing challenges cities are facing was reflec - ed in the wide variety of topics selected by the initiators of Urban Conversations and Special Sessions. Thanks to the competent assistance of the dedicated team of ISOCARP volunteer mentors and facilitators the eight Special Sessions and ten Urban Conversations stimulated new encounters and constructive exchanges at these face to face events.

Read More About
the Congress

Siena © Municipality of Siena

Special Sessions by Institutional ISOCARP Members

"Reinventing the (In)visible City"

UNESCO took up this theme at its Special Session on ***"UNESCO World Heritage Sites: Between Overtourism and Everyday Life"***, exploring how heritage issues affecting real cities could be made visible. [allocated mentor/facilitator Ronit Davidovici-Marton].

Post-pandemic dynamics and climate change triggered profoundly new social dynamics which calls for innovative forms of spatial planning and territorial development for all heritage sites, ranging from big cities to small towns, in urban and rural settings. It became a matter of balancing the difficul equilibrium between globalisation and local identities, tourism dynamics and local economies, stereotypes and everyday life of "invisible" citizens. This necessitates the participation of civil society at all levels: from collaborative regional planning and design to urban co-design in neighbourhoods. Six different stakeholders were unravelling the relation between management plans for the UNESCO sites, local policies and strategies and "statutory" planning: Carlos Francini on Florence, Iago Lestergas Tizon on Santiago De Compostela, Galicia Spain, Katia Basili on Venice, Li Fan on China, Manana Tevzadze on Giorgia, Chiara Ronchini on Spa Towns in Europe and the participation of hosts.

"Sustainable Heritage Preservation and Regeneration"

The City of Siena selected this theme to focus on its own specific challenges of cultural heritage: ***"Santa Maria della Scala SM Scotte: Past, Present and Future of the Connection between the Hospital, the Museum Complex and the City"***. [allocated mentor/facilitator Elena Batunova].

Leone Chiara Valdambrini provided an in-depth overview of the evolution of Santa Maria della Scala, a vast architectural complex in Siena. Founded in the late 12th century as a medieval hospital, it expanded significantly by the mid-15th century to serve pilgrims, the sick, and the poor, including abandoned children. After ceasing to function as a hospital by the end of the last century, it became the focus of an extensive restoration project starting in the 1980s, enabling it to maintain its historical legacy of hospitality. Today, Santa Maria della Scala functions as a museum, and is aiming to become an inspiring cultural and creative centre by repurposing unused areas to foster artistic and cultural activities as complement to the existing museum, and to expand its role as a hub for diverse forms of cultural expression. Antonio Davide Barretta presented the evolution of healthcare in Siena, focusing on the transformation from Santa Maria della Scala to the modern complex at Santa Maria alle Scotte. Initially a medieval refuge for pilgrims SM Scotte gradually merged with the university in the 19th century, laying the groundwork for today's hospital, which integrates research, education and medical care and is evolving into a state-of-the-art facility. The hospital's new masterplan will significantly reshape its infrastructure and connection with the city, thereby benefitting both the local population and its broader, national audience. This transformation reflects the hospital's continuous commitment to innovation, preserving the historical legacy while modernising to meet contemporary healthcare needs.

The city of Siena elaborated further on the connection between the city and its universities at its Special Session on ***"Territories and University Cities"***.

The China Urban Planning Society presented a number of sustainable heritage cases to explore ***"Sustainable heritage, Innovating for Tomorrow while Honouring the Past: the State of the Art in China"***. [allocated mentors/facilitators Eunice Yorgri, Hadeel Abuzaid, Pryianka Sawant-Purohit].
Senior planners presented impressive regeneration projects and realisations of China's most prominent heritage sites: the Forbidden City of Beijing; the Grand Canal National Park with its 13 port cities; the Ming Dynasty tombs area; the innovative reuse of a national heritage park. In a more theoretical paper an author explored the co-occurrence of virtuality and reality, by using digital technology for urban conservation and regeneration. This session was transmitted to China with simultaneous transcripts in English and Chinese, arguably the most impressive application of AI at the congress.

"Climate Resilience"
UN HABITAT and IFLA chose this topic to deliberate on ***"Landscape Architecture and Planning for Climate-Resilient Cities: From Vision to Implementation"***. [allocated mentor/facilitator Elena Batunova].
Maria Gabriella Trovato presented "Cities, Landscapes and Planning for socio-environmental justice", discussing how landscape architects are playing a critical role in addressing climate impacts and fostering resilient communities. Nature-based design was contributing to reduce risks for communities facing severe climate threats. By focusing on resilience, safety and long-term well-being, landscape architects create sustainable solutions that improve overall community health. The Kounkuey Design Initiative undertook work in under-resourced communities, aiming to advance equity and activate the untapped potential of neighbourhoods through collaborative design efforts. "Addressing Climate Resilience from Regional to Neighbourhood Planning: The Case of Conakry, Guinea" Irene Solà Comalada focused on strategies for climate resilience at different scales, using Conakry, Guinea as a case study to illustrate the challenges and solutions for adapting urban and regional planning to climate impacts.
A lively discussion unfolded with contributions from notable experts: Pietro Elisei, President of ISOCARP; Sabina Reichert, José-Luis Cortés Delgado and Mona Rady. The conversation focused on the future of urban and regional planning, underscoring the need for collaborative strategies to enhance resilience and tackle environmental challenges. A shared conclusion emerged: the necessity to unite efforts and embrace transdisciplinary approaches to effectively address the complex issues facing contemporary urban development.

The European Union reported on ***"100 Climate City Contracts: What Urban Design for Climate Neutral Smart Cities?"*** organised by ASSURB. [allocated mentor/facilitator Elena Batunova].
The session focused on sharing the outcomes of policy implementations by Italian cities to achieve climate neutrality under the EU Mission for Climate-Neutral and Smart Cities. This initiative aims to guide 100 cities to climate neutrality by 2030, positioning them

as innovation hubs to inspire broader European change by 2050. These cities created Climate City Contracts, detailing action plans with local stakeholders, thereby receiving an EU Mission Label to aid funding and implementation. The mission drives green and digital transformation supporting the emission reduction targets of the European Green Deal. Adriano Bisello and Niccolò Fiorini introduced the session, followed by Elena Ricci on "Net Zero Cities". Part of the Horizon 2020 Research and Innovation Programme. The project aims to support cities in achieving climate neutrality by addressing structural, institutional, and cultural barriers. In Italy 11 cities are involved in the project: Bergamo, Bologna, Florence, Genoa, L'Aquila, Milan, Padua, Parma, Prato, Rome, Turin. The cities are also pilot cities of "Let's Gov!" (Governing the Transition through Pilot Actions), financed by the EU. The main focus was on differences of the objectives and actions of these cities towards climate neutrality depending on their current situations (industrial and infrastructural development, economic specialisation, etc.). Parma, Florence and Padua presented their practical experiences in implementing policies to achieve tangible results by 2030.

Participants of the ensuing discussion included Pietro Elisei, President of ISOCARP, Markus Hedorfer, Chiara Panigatta, Maria Beatrice Andreucci, and Israa H. Mahmoud. The discussion highlighted the challenges affecting the adaptability of urban planning and the need for flexibility in regulatory frameworks. It also emphasised effective communication between public and private sectors and a well-defined role for urban planning, especially in rural areas. Engaging citizens and translating technical language into more accessible terms were deemed essential, along with involving social sciences to collaborate better with stakeholders. The discussions stressed the importance of understanding the role of urban planning professionals and fostering cooperation with universities to improve methodologies and outcomes.

Siena © Municipality of Siena

Urban Conversations Initiated by Individual ISOCARP Members and the ISOCARP Institute

The topics varied widely. Urban regeneration was considered from both the planners' and the users' point of view, including minority groups like people with visual impairments. Others focused on how to alleviate adverse climate change by focusing planning on energy and environmental issues and accelerating green transition by resorting, inter alia, to nature base solutions. Most Urban Conversations were concentrating on community engagement, participation and co-creation, by applying different planning tools, including AI and gaming. There were also experiments with story-telling and other qualitative innovative approaches for community development and the preservation of social values during the regeneration process.

More specificall , the Urban Conversations concentrated on the latest technical planning tools: the use of generative artificial intelligence in planning; action-positive energy districts; integrated urban investment; nature-based solutions; techniques to plan for blind and partially-sighted city users; co-creation methods to stimulate active travel; the use of the storytelling method in participatory planning; and purpose-designed participatory games for more equitable community involvement. At the strategic level, they explored new policies adjusted to sustainable regeneration and better integration between cultural and physical heritage, as well as explicit measures to preserve social values. The sessions held in a round without technical props were the most conducive to generating inclusive participation of all those present, and thus to harness the collective knowledge of both practising planners and academics.

Urban regeneration

Yoann Clouet of the ISOCARP Institute used four case studies of its extensive work on ***"Regeneration of our Urban Environment, Rethinking How and Where we Live"*** to identify common planning challenges. [allocated mentors/facilitators Eunice Yorgri, Abimbola Tofowowo]. Anneloes Van Noordt commented on the "Climate Neighbourhoods" project in Belgium Flanders, with pilot sites in Kortrijk, Leuven, and Mechelen. Clotilde Havard discussed how the French programme ***"Small Cities of Tomorrow"*** supports smaller municipalities in the regeneration of their urban centres by allocating funds and capacities. James White and Gareth James highlighted the UK perspective of addressing ***"Large-Scale Retrofitting"*** efforts through a coordinated approach by bringing together government bodies, private sector stakeholders, and local communities to drive impactful change. Nur Muhammad Gito Wibowo reflected on the efforts to retrofit Jakarta's built environment, resorting to the relocation of the Indonesian capital to the ***"New capital City of Nusantara"***. Niccolo Fiorino added the perspective of the host city Siena.

Common planning challenges included the need of ***"Capacity Building"*** to improve mixed governance; better coordination across sectors and scales; tackling gentrification, lack of inclusion and power imbalance between the developers and local communities. All these issues required improved governance frameworks but, most of all, better communication and engagement with local communities to include their aspirations. This could be achieved practically by early and continuous

community involvement and trust building; innovative approaches, such as allocating dedicated spaces for continuous interaction between the planners and the planned; and dealing with obstacles which are slowing down the implementation process.
Regeneration also raises the issue of ***"Balancing between Preservation and new Development"***. The preference went to reusing older buildings better, instead of demolition and reconstruction driven by speculative developers who produce unused surplus - "ruins of the future" in some viewpoints. ***"Principles of Degrowth"*** were evoked, as well as prioritising quality of life. Scaling up of such local initiatives was a future aspirations and remains to be realised.

Manfred Schrenk and his team of researchers addressed ***"Really Invisible Cities, a Reality for Blind and Visually Impaired Persons"***, researched in the CE-Spaces4All project, supported by the European Disability Forum, the European Network for Sustainable Tourism which researched ***"Invisible Cities for Travelling and Tourism"***, and ONCE an internationally campaigning Spanish organisation for the blind. [allocated mentors/facilitators Hadeel Abuzaid, Jonila Prifti].
The purpose of discussing ***"Inclusive Invisible Cities, how to deal with blindness and visual impairments in urban and regional planning"*** was to bring 'real invisible cities' into the visibility spectrum of the global planning community. Blaz Barboric elaborated ***"The Purpose of Planning is to create Accessible Places for All"*** with focus on impaired tourists. Rachele Paolucci informed on latest work of Siena towards the European Network for Accessible Tourism. When talking about ***"Invisible Cities in Everyday Life"*** Daniele Marano passed round 'glasses' for the audience to experience partial visual impairment and its impact on the need to use the urban environment by resorting to their other basic senses. The EU initiative for "AccessibleEU" is corroborating the rights of persons with disabilities. The discussion concluded that there was a pressing need for planning to dedicate more attention to the special needs of all minority groups in cities when elaborating urban regeneration strategies.

Ulrich Graute from the ISOCARP Scientific Committee initiated the debate on ***"AI applications as Tools and Co-Pilot to make Cities more Inclusive, Prosperous and Sustainable – AI Ethics"***, together with the UNSW Cities Institute, Sydney. [allocated mentors/facilitators Hanna Obracht-Prondzynska, Mani Dhingra].
The growth and demands of cities are rapidly changing and are adopting new planning systems and tools. Artificial Intelligence (AI) can provide a transformative potential in managing and planning cities. It can support, analyse and predict the impact of policy changes, demographic shifts and development plans. It can facilitate a valuable foundation for productive dialogue and constructive debate between the key stakeholders of city planning, including municipal authorities, citizens, and both the public and the private sector generally. Nevertheless, the rapidly evolving technology landscape requires awareness of the risks and pitfalls of planning professionals and key decision-makers. The discussion on the use of AI cannot be left solely to engineering experts and requires planners, architects and city managers to adopt AI to their professional benefit. For that reason the urban conversation had brought together planning practitioners and

experts from city-making to discuss the use and potential impact of AI on urban planning and management and the related leadership of ISOCARP in the global dialogue on AI governance and capacity building of planners. Sarah Hill gave a highly informative keynote on Aerotropolis, the new city of Bradfield in Western Sydney Australia to illustrate ***"21st Century City Making through community, creativity and innovation"***. Sunil Dubey, showed examples of how the UNSW Cities Institute Sydney, as well as well Saudi cities were employing data and AI to manage daily urban operations.

The panel discussion between ISOCARP president elect Elisabeth Belpaire and the congress director Eric Huybrecht, moderated by Ulrich Graute, highlighted the use of AI in stakeholder collaboration, public consultation and management of widely available big urban data. As the machine-readable AI language is evolving rapidly, the time and context of AI applications are extremely critical. The session advocated a necessary balance between the responsible use of data for building people's trust in AI and digital technologies and its mindful adoption for urban decisions.

Climate change alleviation

The purpose of the session on ***"COST Action Positive Energy Districts European Network (PED-EU-NET)"*** was to mobilise researchers and stakeholders to drive and deploy Action Positive Energy Districts more widely. [allocated mentor/facilitator Serin Geambazu, Monica Bonu]. Maria Beatrice Andreucci and Ghasal Etminan of Working Group 4 in charge of dissemination explained the holistic evaluation approach and organisation of ***COST***. Adriano Bisello, Marco Volpatti, Elena Mazzola and Matthias Haase presented the EURAC research of COST's scientific Working Group 3 on the success factors of PED Labs towards the transition to green energy. They showed how their work also advanced the ESG criteria of resource circularity, fairness and governance co-creation. The longer term objective of COST is to scale up PED by introducing new practices in urban construction and regeneration activities.

The ISOCARP Institute promoted sustainable practices in the urban regeneration process by implementing the EU funded JUSTNature and VARCITIES projects on ***"Nature Based Solutions for Urban Regeneration"***. [allocated mentors/facilitators Nasim Iranmanesh, Shinjini Saha]. Tanya Pico presented the transformative potential of nature-based solutions (NbS) in addressing urban challenges such as climate resilience, biodiversity loss, and sustainable urban development. Examples provided insights into diverse applications of NbS. Dundalk (Ireland) focused on mitigating urban heat islands and enhancing stormwater management through green roofs and other vegetation-based infrastructure. Surat (India) combined green mobility (NMT and PBS) with coastal resilience, emphasising integration with local biodiversity conservation and stakeholder capacity-building. Bolzano (Italy) prioritised stream restoration projects to improve water quality and create multifunctional public spaces that encourage community interaction and ecological benefits. Quito (Ecuador) highlighted biodiversity preservation within the urban landscape, integrating sustainable urban planning with ecological conservation to strengthen resilience. These projects showcased the versatility of NbS in fostering ecological balance,

Siena © Aleksandra Stupar

improving public health, and promoting social inclusion by integrating nature into the fabric of urban areas.

The presentations identified key enablers that drive the success of these projects, such as strong policy frameworks, fina - cial support from entities like the European Union, collaboration between public and private sectors, and inclusive stakeholder engagement. They also outlined the barriers to implementation, including financial constraints, geopolitical uncertainties, lengthy timelines due to differing stakeholder priorities, and the lack of a shared understanding of what NbS entails. They argued that these challenges underscored the necessity for adaptive governance structures, robust funding models, and participatory approaches to navigate complexities and maximise the impact of NbS initiatives. Critical success factors of NbS were effective institutional frameworks, availability of financial resources (e.g. EU funds), and strong multi-stakeholder collaboration in ensuring the design, implementation, and long-term maintenance of NbS projects. The importance of community engagement was highlighted, ensuring that solutions are contextually relevant and widely supported. They also identified common challenges and barriers of NbS despite their potential, such as limited financial resources, lack of technical knowledge, and delays caused by conflicting stakeholder priorities. A significant challenge was the lack of a clear and unified understanding of NbS among stakeholders, which hinders effective implementation. These barriers were seen to be particularly pronounced in cities with limited policy and financial suppo t structures.

The examples showed that NbS projects were able to provide a wide array of benefits, including ecological restoration, improved public health, climate resilience, and social inclusion. Surat and Dundalk demonstrated how locally tailored approaches could be replicated or scaled up to similar environmental and socio-economic contexts. The comparison of successful NbS implementation across cities with varied socio-economic and climatic contexts was promising for scalability. However, the replicability of NbS as a strategic approach to urban sustainability depended on the adoption of integrated planning, aligning environmental goals with social and economic development objectives. Overall, the examples highlighted that co-creating solutions with communities to enhance ownership and long-term sustainability were reinforcing NbS as a critical tool for building resilient, inclusive, and liveable urban environments.

Another innovative topic initiated by the ISOCARP President Pietro Elisei and his team was ***"Integrated Urban Investment, Planning, Monitoring and Green Transition"***. [allocated mentor/facilitator Serin Geambazu, Pryianka Sawant-Purohit].

The aim was to explore the complexities of coordinating urban investments in today's rapidly changing environment, with focus on how to integrate various funding streams—national, regional, and EU programmes such as NextGenerationEU, while addressing sustainability and social equity in urban planning.

The specific issues addressed were: the need for better coordination between national, regional, and EU funding sources to ensure alignment across different levels of governance and thereby promoting place-based approaches that balance regional development

and reduce urban-rural disparities; methods to optimise the relationship between funding for territorial and social cohesion policies; national and urban strategies to ensure that these investments accelerate the green transition and, in particular, the effectiveness of existing EU policies (UIA, URBACT, ESPON etc) in achieving the goal of resilience and recovery while maintaining social and territorial cohesion.

Community Engagement and Participatory Planning

Involved in the "i3.0 Partnership", the EURAC researchers Alice Borsari, Elisa Elena Basiliu, Irene Bertolami and Adriano Bisello, organised a highly interactive participatory game to explore the use of ***"Innovative Approaches for Local Community Development: the Dive-Into-Springfield Game"***. [allocated mentors/facilitators Mani Dhingra, Holly Pearson].

Applied to a fictitious place the game was based on small isolated Croatian communities presented by Federica Maino, Cvjetana Plavša, Lidija Žganjer Gržetić and Đurđa Vrljević Šarić. Approximately 60% of the European population lives in small towns, suburbs, and rural areas and deals with consistent local challenges, such as ageing demographics, economic issues, population decline, and digital and social divide.

The participatory experiment carried out by three groups with six participants in each group focused on sustainable development of culture, digital knowledge and philanthropy for a fi e year timespan, by impersonating citizen types provided for the game on cards to advance innovative strategies of community engagement and, in particular, stimulate collaboration between diverse social groups. The aim was to identify local strengths and reduce existing weaknesses through innovative local strategies. The participants deliberated these problems and challenges by using a map of this imagined community. They proposed solutions together, based on the identifie needs and types of community members attributed by drawing cards. It was a very hands-on exercise for the participants who enjoyed playful brainstorming, sketching, and pasting stickers to present the outcome of their discussions to each other during the communal final discussion. The outcomes represented a series of diverse innovative proposals by each group to channel local knowledge and skills transfer between elderly and youth, build social connections, harness local economic opportunities and leverage existing conditions for preserving community values of social cohesion, environmental sustainability and cultural vitality. What united all the groups was giving high priority to local identity and character of rural and small-scale communities.

The debate on ***"Social Value in Regeneration"*** organised by ARU, Homes England, and the Quality of Life Foundation aimed to challenge the status quo of built environment practitioners worldwide which attracted a lot of interest. [allocated mentors/facilitators Holly Pearson, Shinjini Saha].

Ioana Ghergel and Riccardo Bobisse noted that in the built environment industry social values were often tokenistic and addressed only at the late project stages. Their research aimed to understand social needs of the community better and to develop a method to measure social impacts of urban regeneration to enable inclusion of genuinely meaningful, place-specific responses early into the implementation of projects. Aware of this

politically sensitive, and resource and time intensive process, they expected the participants to contribute ideas and practical solutions to their approach. They aimed to facilitate knowledge sharing by exploring locally specific social outputs, barriers to social value implementation. They introduced Place-Based Indicators and post-occupancy evaluation methods developed by the Quality of Life Foundation, to examine health and wellbeing outcomes after regeneration.

The discussion explored the social regeneration processes in urban planning across diverse global cities by adopting the “fis - bowl” format. In Brazil, social value was a contentious topic, often dominated by powerful enterprises, leaving local residents with limited access to planning processes. This imbalance demonstrated the need for more inclusive decision-making to ensure that social value reflected the interests of broader communities. In Paris, a transportation resettlement project highlighted similar tensions, with challenges arising from the need to quantify social value—a concept distinct from social capital and difficul to measure. The complexities of political influence also shaped these dynamics, as specific groups maintained control over decision-making processes. In Mumbai, India, the Mumbai Climate Action Plan became the first to include a dedicated gender chapter, highlighting the importance of integrated planning while ensuring active participation of women in urban development processes. Oakland, USA, faced issues related to new housing developments near transit areas, where rising housing costs and the displacement of long-time residents generated fear and resistance, while clear quantitative success metrics were lacking. Eastern European cities dealing with urban regeneration faced mistrust from local populations when initiatives were led by government bodies, signalling a need for community engagement and transparency. In China, the "cold construction" approach involved collaboration between political, planning, and civil society entities, balancing social and economic needs in development. Meanwhile, Doha, Qatar contended with the social needs of both local and transient populations, requiring sensitivity to cultural and religious customs. Governance challenges, such as aligning urban planning with administration across different levels, highlighted the complexity of meeting the needs of an international city. Incorporating disaggregated data on gender and minority groups was essential to understand and address these shifting social dynamics.

Key takeaways from the discussion emphasised that urban regeneration was not ‘one-size-fits-all’ but demanded context-sensitive and inclusive approaches. This meant addressing issues like housing affordability and displacement while fostering community trust. Effective planning had to strike a balance between quantitative and qualitative measures, especially when dealing with societal values that vary across cities. Ultimately, achieving social value in urban planning required involving diverse stakeholders, addressing political biases, and ensuring that community needs were met equitably. Planning had to go beyond mere political motives, and embrace educational and bottom-up initiatives to foster sustainable and resilient communities. Those present concluded that for urban planning to be successful it had to balance quantitative and qualitative data and include diverse stakeholders to achieve inclusive, sustainable development.

Siena © Judith Ryser

The aim of ***"Urban Storytelling for Participatory Exchange: How our Experiences of the City can be Used to Build Inclusive and Resilient Futures"*** was to demonstrate both the power and value of storytelling as an urban participatory process. Samir Amin and Taliah Dommerholt of the ISOCARP Institute presented a complete Urban Storytelling methodology. [allocated mentors/facilitators Ronit Davidovici-Marton, Abimbola Tofowowo, Monica Bonu]. A story is one of the oldest tools for communication between humans. Storytelling is a fundamental process of sharing learning and experiences through the creation of a collective space, be it physical, digital or imagined. Over the years, a variety of tools have been developed enabling the public to participate in planning processes through a story. As a tool, storytelling provides a basis to promote spaces that facilitate the co-exchange of knowledge, ideas, and experiences between stakeholders, acting as meeting points within complex interactions. The premise is that through telling stories, both cognitive and affective domains of learning are engaged, resulting in modes of communication based on lived experiences as productive and intersectional points of co-learning. The significant challenge in such a process is the 'translation' of the story into planning inputs. The session was designed to introduce the participants to a broad and central issue in the world of planning: whether and how AI can be integrated into public participation processes based on storytelling, Drawing on collaborative work from multiple applied research and development projects (e.g. the Horizon Europe projects ***"Democratising Just Sustainability Transitions -DUST"*** and ***"Urban Planning and Design ready for 2030 -UP2030)"*** the researchers demonstrated both the power and value of storytelling as an urban participatory process, in the form of a complete urban storytelling methodology for its deployment in complex settings. Examination of typical pitfalls in participatory processes informed the design of a methodology that dealt with participatory fatigue, complex stakeholder dynamics, and communicative barriers. Demonstrations and discussions on the methodology aimed to explore how inhabitants could be guided through storytelling processes, and how their outputs could be connected to different societal sectors: policymaking, activism, the arts, and academia, to create momentum towards shared goals in urban planning and development. The participants were invited to play with an AI-driven storytelling tool. However, storytelling by participants was constrained by guiding questions, which contradicted the essential spontaneous nature of storytelling based on free speech from memory. All the responses were fed into an AI platform, which generated images and narratives. It was fascinating to see AI translate such thoughts into visual scenes. However, this exercise also showed when AI missed the mark, especially in human imagination. For instance, AI interpreted the idea that a tree could bring life to the community into a tree-shape glowing with stars and colourful lights. The psychedelic images produced by this process highlighting that the visualisation capabilities of AI still have a long way to go. All this illustrated AI's current limitations and its tendency to deviate occasionally from realistic interpretations. These experiences reinforced the belief that, while AI may be able to enhance urban storytelling through visualisation, it should be carefully contextualised to prevent it from creating false impressions.

AI, like any powerful tool, has the potential to reshape urban planning but as a complement, not to replace real-life examples and vigorous analyses. Some organisations using AI-generated images were used to showcase things like green roofs or heritage sites, even when real examples were available. While AI-generated visuals can inspire ideas, real images can communicate achievable outcomes better. The session provoked a lively debate, and raised some key issues about the usual fear of new technologies, the interface between a private story and the 'anonymous' AI; intercultural differences in the use and interpretation of AI; whether from a methodological point of view AI was suitable to replace qualitative interviews; whether AI was able to shorten the participation process in practice and whether this was useful and/or desirable. The session concluded that planners and urban professionals should not let AI replace planning work. AI should be used as a support tool and not for decision making. In storytelling for participatory planning, AI should be used with caution to prevent misinterpretation and unrealistic expectations of the stakeholders. Thus, AI may be more suitable for testing questionnaires and structured processes and less as personal social tools that requires free discourse without structured guidance. An AI image will never replace a field photo, but it can inspire further outside-the-box thinking. When introducing new technologies into planning it is important to develop new management methodologies and new tools to manage and plan with the new technology. This may mean that change would not only affect technology but planners and planning as well, if planners want to ensure that they manage the technology instead of the technology managing them.

Jack Lehane, Many Dhingra and Aphra Kerr presented their research on active travel carried out at the University College Dublin as the ***" 'Trojan Bicycle', a Co-creation Workshop for (Latent) Active Travel Policy Pathways"***. [mentors/facilitators Nasim Iranmanesh, Jonila Prifti]. Multiple international actors such as the World Health Organisation (WHO), United Nations (UN) and the World Economic Forum (WEF) have increasingly recognised the importance of urban planning in population health, inclusive of social, economic, environmental, structural and cultural drivers. However, while challenges may be shared between cities and regions, bureaucratic remit at the local level can often limit the formal engagement of local authorities with interconnected urban health determinants, necessitating different solutions at the local level. This restricts the inclusion of local knowledge and perspectives within tech-driven urbanism, understanding of associated health disparities, and the identification of patterns in city planning and urban governance that could otherwise scale population health impacts. Active travel — whereby citizens make journeys in physically active ways like walking, wheeling and cycling — is an example of a practice that cuts across multiple sectors and bureaucratic jurisdictions such as transport and mobility, climate and environment, community development, enterprise and commerce, and tourism. As a shared urban practice at the local authority level, it can serve as a 'proxy' to enable different organisations to exchange learning outcomes for latent and un(der)represented, yet interdependent, best practices for urban determinants of health.

This inclusive workshop, structured into orientation, co-creation and evaluation, invited also those without prior knowledge or experience in active travel. The workshop adopted established co-creation methodologies to map, mediate and mobilise policy challenges and opportunities for regional and local digital transformation via active travel practices. Guided by the quadruple helix innovation model for digital transformation, the workshop adopted a holistic perspective for healthy urbanism. The aim was to engage a diversity of stakeholders from local, regional and national levels across sectors (public sector, industry, academia, civil society) to learn from alternative approaches to intermediating public sector practice.

The presentation of active travel practices and the public sector landscape in Ireland was based on the research expertise of the ADAPT SFI Research Centre for AI-Driven Digital Content Technology, in partnership with Dublin City Council, Ireland's largest local authority, which provided two industry-embedded researchers to support digital twin and population health ecosystems. Related existing projects included ***"Data Insights for Active Travel"*** of the Partnership for Healthy Cities (PHC), a network supported by Bloomberg Philanthropies, in partnership with the World Health Organisation (WHO) and the global health organisation Vital Strategies.

For the interactive co-creation phase of the workshop the participants self-organised into groups, ensuring a balance, in particular across cities, sectors, active travel experience and, in general, a degree of involvement in policy regulation and mediation. The groups identified and discussed drivers and barriers of approaches to active travel according to different citizen engagement frameworks, governance models, and regulations, and presented them to the other groups. The groups then co-reviewed the existing mechanisms and indicators, assessed the interconnections between them, and synthesised their evaluation to compare and contrast it with international policy and planning expectations of relevance to urban health. The outcome of the workshop was to develop and document core competencies required for diverse approaches to active travel. It comparatively mapped methods through which local and regional actors mediated policy challenges and opportunities. The outcome is expected to support the development of an active travel toolkit. Its aim is to facilitate formal and informal approaches to address health and wellbeing needs of local communities better, as well as to contribute to a wider, healthier urbanism planning for policymakers and practitioners.

Siena © Municipality of Siena

Reflections and Suggestions

The congress team in charge of mentoring and facilitating Urban Conversations and Special Sessions reflected more generally on the content of all these face-to-face events and how such experiments, innovative methods and creative approaches to essentially participatory urban planning could contribute to ISOCARP's avant-garde heritage. Reflections by Ronit Davidovici-Marton and Judith Ryser on the most challenging issues identified at these informal interactive discussions are evoked here, together with suggestions of how to incorporate this body of new knowledge usefully into future ISOCARP activities.

Interface Between Urban Planning and Artificial Intelligence

Artificial Intelligence is on the agenda of every profession at present, including urban planning. It can be conceived as a tool to shift traditional plan making to risk-mitigation planning by integrating AI into planning practice. However, the informal discussions highlighted the difficul of a general open debate about an emerging technology which evokes considerable uncertainty. Illustrated as a novel planning tool applied to real time storytelling and analysis was a promising way to sharing the diverse attitudes of planners towards the role of AI, whether it would provide added value and how it would change the planning profession. This meant a need for urban planners to engage deeply with the ethical implications of AI and to strike a balance between innovation and mitigating potential risks of AI for cities.

Regionalism

Regionalism and its ambiguities have challenged planning for a long time. Technicalities of regional planning were reflected again in the unresolved questions of defining an area, the use of an area as a cluster, the purpose of clusters of cities and villages, the relation between planning at national, local and regional scale, the dichotomy between urban and rural regions, as well as cross-border issues. ISOCARP was a pioneer in addressing regionalism as a planning issue and to relate it to governance. During accelerating urbanisation, regionalism was practically abandoned as planning moved almost entirely to the urban space, with cities becoming the basic planning unit. The changing reality in non-urban areas led to changes in both the urban and the rural systems all over the world. Migration to cities was emptying the countryside, turning agriculture, food security, and open space into a leading planning challenge. This should give rise of a new discussion on how to plan the non-urban, semi-rural and rural space, by learning about contemporary town-village relations and their interface.

Public Participation

Driven by rapid urbanisation the development industry has become the main producer of the built environment and resisted fie ce-ly to community engagement in planning. Nevertheless, the involvement of communities in their built environment and its inevitable transformation increased and gained agency in many planning processes. Many experiments illustrating this evolution were presented at the Siena congress and discussed at the informal urban conversations. Well-rehearsed objections by those who (re-) build the city are the delay to the planning process thereby inhibiting financial reward.

Research showed though that developments which engaged community participation were less contested and more durable than those produced in conflict with the local population. The congress revealed how public participation started to become an integral part of the development process also in China, India, as well as other countries with liberal planning systems, also in the developing world. The informal discussions showed that the planning debate had shifted from combating public participation to developing methodologies to improve the participation process to the benefit of all stakeholders, more recently by adopting and adapting new digital tools including AI. This process includes revisiting values, and in particular the role and obligation of all the stakeholders in a more transparent and open planning process.

Inclusive Cities and Raising Extremism

Inclusion is increasingly presented as a value leader in planning. This raises complex and critical questions about fundamental values of known planning methodologies. Cities tend to develop physical spatial patterns which reflect society as a whole with little input by planners while urbanisation trends seem to produce increasing spatial social segregation and polarisation. This division also reflects the effect of migration, displacement and de facto exclusion. Adding climate change to it means that planning methodologies devised during a more stable and predictable world may no longer by feasible for the current dynamic, uncertain and conflictual situations in rapidly growing urban concentrations. This requires to include values in the debate about the future role of planning in the development, regeneration, maintenance and preservation of cities.

Future Informal Planning Debates

The participants of the Special Sessions and the Urban Conversations at the Siena congress felt that these open discussions among planners were so beneficial that they could be integrated into future congresses. The voluntary team of facilitators and mentors developed a sense of social belonging at these explorations and experimentations in common enabling it to garner useful lessons for future informal, properly resourced and managed events framed by clear guidelines. Distinct from formal presentations but well-coordinated, successful urban conversations are initiated by individual participants or groups on pressing as well as emerging planning challenges. Small in size, seated in the round, without props, these face to face events are bringing together young and mature planners to engage for a short time in mutually enriching exchanges on their planning experiences, projects, ideas, even dreams. Such interaction is conducive for their future cooperation, creation and sharing knowledge.

Judith Ryser, London 23 January 2025

ISOCARP
Knowledge for Better Cities

60th ISOCARP World Planning Congress Proccedings

Siena © Municipality of Siena

Paper Index

Track 1. Cultural Heritage for Sustainable and Climate-Resilient Futures

Lulu CHEN, Jian DAI, Gu SHUYI
Research on Protecting Traditional Villages and Integrating Culture and Tourism
A Case Study of Zhenbei Village, Harbin City from the HUL Perspective

Pooja KUMARI, Rabi Narayn MOHANTY
Unveiling Varanasi's Legacy – A Visual and Historical Analysis of Evolution

Panpan FENG
Research on the protection and renewal of overlapping sites within the context of cultural ecology perspective

Antonella CONTIN
Impacting Sustainability Operations
Integrating Local Knowledge and Nature-Based Solutions through Theoretical Frame-works and Innovative Cartography for Cultu-ral Impact

Jin SHANG
The Influence of Architectural Culture on the Development of Religious Heritage
The Case of Asian Pagodas

Carmen ULISSE, Nasim Sadraei TABATABAEI, Lorena FIORINI, Alessandro MARUCCI
Integrating cultural heritage and protected areas
Case study of Cultural Routes in the Abruzzo Region

Jin DAI, Xiaoxia WANG, Chunqi WANG
The Evolution and Generation of the Concept of Historic Trails: Based on the Comparison of Chinese and American Practices

XIn JIN, Jiayi WEI, Xiang FU
A visibility-based approach to analyze visual and cultural sustainability of Canal heritage
A case of the Grand Canal (Yangzhou Section)

Jiuqi MENG, Qing YUAN, Dongyu ZHANG, Hong LENG
The Role of Intangible Cultural Heritage in Sustainable Development of Small Towns
A Case Study of Heilongjiang Province

Yan ZHOU, Hong JIANG, Xinyi WU
Study on the spatial characteristics and heritage value of the ancient city Mrauk-U, Myanmar

Yu GAO, Yifei XU, Chi LI
Construction of Multi-Factors Ecological Landscape Recreation System Based on the Minimum Cumulative Resistance (MCR) Model

Mengke WANG, Andre BROWN
Main Leveraging Artificial Intelligence for Enhancing Flood Resilience in Urban Villages: A Case Study of Zhengzhou, China
A Comprehensive Framework Applied to Zhengzhou, China

David CALAS, Barbara CALAS-REIBERGER
Textile Heritage | Active Future
About Invisible Vacant Structures of the Waldviertel Textile Industry in Lower Austria, Hidden Potentials, Absent Appreciation as Well as Realisable Perspectives. A Case Study

Anurag Aman KAUSHAL, Prashant ANAND, Bharath H AITHAL
Integrating Traditional Dandaka Planning for Climate-Resilient Urban Housing
A Multi-Method Study on Thermal Comfort in High-Density Residential Buildings

Xueyan MA, Hong LENG, Jingxin QI
The effect of subjective perception of the park environment on mental health among elderly people in cold region
A case study in Northeast China

Xiaochen WU, Rong GUO
Research on the spatial consistency of carbon emissions and economic development in Heilongjiang Province, China

Jingwei JU, Neng ZHANG, Yuanru LI
Planning Heritage for Resilience Enhancement in Historic Cities
The Case of Enshi, China

Dong-Seok KIM, Seok- Ho HONG
A Study on Urban Planning to Protect Cultural Heritage from Air Pollution
Focusing on the protection of Gyeongju's cultural heritage from air pollution

Amit BHATTACHARYA
Inquiries into Historical and Cultural Ecology of Adi Ganga, a Heritage River of Kolkata, India to forging Urban Climate Resilience

Zhuolin TAN, Yuan YUAN, Shuyu HUANG, Wei DONG
Resilience Strategies of Chinese Unit Communities for addressing Climate Change Risks
A case study of Harbin's historical industrial distinct

Xiaodi WANG, Danyun JIN, Yufei SUN, Liang XIONG
The Impact of Impervious Surface Increase on Urban Flood Risk
Case Study in Pearl River Delta (PRD) China

Jintu XU, Xiliu HE
Typhoon-Resilient Spatial Patterns in the Chaoshan Region of Guangdong, China
Leveraging Time-honored Indigenous Knowledge for Future-oriented Heritage Conservation and Resilience Planning

Rabi MOHANTY, Ashaprava MOHANTA
Assessment of the Traditional Design Approaches of the Heritage City of Puri, India

Siwaporn KLINMALAI
Challenges of Urban Regeneration in Cultural Sites: The Creative Economy Policy in Song Wat District, Bangkok, Thailand

Yiqun WANG, Jiayi LI
Reviving Suburbia: Integrating Urban Agriculture for Sustainable Community Development in the Boston Metropolitan Area

Jianqiang YANG, Min WANG, Ya-nan LIN
Sustainable Conservation and Regeneration in the Face of Change: The Case of Ancient City of Suzhou

Melis YILMAZ, Cemile TIFTIK
From Heritage to a Sustainable Solution: Drinking Fountains of Fethiye, Türkiye

Elena BATUNOVA
Urban Shrinkage and the Future of Built Heritage
A Resilience Perspective

Yiting JIANG
The Social Space Reconstruction of Traditional Villages Based on the Driving of Tourism
A Case Study of Fuling, China

Siqi LIU, Longyan HUANG
Embedded Governance and Spatial Response of Traditional Residence Regeneration
A case study of Chenjiapu Village in Songyang County, China

Jingxin QI, Hong LENG
Traditional Ecological Wisdom Inheritance and Resilient Urban Planning
Taking Cold City as an Example

Zihui TIAN, Tianyi ZHANG
Heritage as a Driver for Resilience: A Four-Dimensional HUL Approach to Cultural Heritage in Urban Development

Rui YE
Study on the sustainability of flood control in mountain cities: The Case of Water System Construction in Huizhou Ancient City

Francesco ZULLO, Annamaria FELLI, Chiara CATTANI
Green Infrastructures, Monumental and State-Owned Assets: The Role of Tratturi in the Southern Italian Landscape

Meryem H NALBANT, Gizem ERDOĞAN
Renewal of the City Center Izmir Cankaya Case Study

Ang QU
Relationship between climate change risk perception, mental health, and differences in urban environments

Priyanka KUREEL, Joy SEN, Arkopal K GOSWAMI
Cultural Heritage and Urban Transformation: The Role of Festivals in Enhancing Public Spaces and Driving Development
Case of Durga Puja in Kolkata

Ziqi WU, Xiliu HE, Heping LI
Spatial heterogeneity in the impact of traditional mountainous urban patterns on retail industry location
A case study of Chongqing historic district

Vuyiswa LETSOKO, Mhlalisi MNDZEBELE, Trynos GUMBO
Investigating Past, Present, and Emerging Research Trends on Public Spaces for Cultural Heritage, Social Cohesion, and Safety

Juan GUAN, Jiujiu GUO, Shan WANG
Exploring the Extraction and Innovation Path of "Canal Genes"
Taking the South Canal Section of the Beijing-Hangzhou Grand Canal in China as an Example

Siena © Municipality of Siena

Paper Index

Track 2. Innovation, creativity, legacy: Cities of/for Tomorrow

Erlangga BASKARA, Widasari Yunida PUTRI
Reviving River Corridors for Sustainable Mobility and Urban Regeneration in Bandung, Indonesia with CARE Approach

Süleyman Nurullah Adahi ŞAHIN, Yavuz HALIMERGÜN, Abdulkadir ÖZDEN
Walking Towards Sustainability: Optimizing Public Transit through the 'Walkable Cities' by Time-Oriented Model

Gustavo RIBEIRO, Victor ANDRADE
Walkability Index as a Strategic Planning Instrument for the Historic Centre of Rio de Janeiro

Michela MARCHI, Enrico NOCENTINI, Fabiola TROPEA, Asia TONIELLI, Nadia MARCHETTINI, Federico María PULSELLI
The Sustainable Energy and Climate Action Plan (SECAP) design and development: the case study of the Municipality of Grosseto (Italy)

Janneska SPOELMAN, Anja OVERDIEK
Co-creating eco-cities
Increasing residents' willingness to take action to enhance biodiversity in their neighbourhood

Yiqun WANG, Charles SONG, Em SAWYER, Regina YANG
Envisioning the Rural Metropolis
"Ethanol Urbanism" for Ecological and Social Sustainability in the Near-Collapse Scenario for the Year 2074

Nermeen DALGAMONI, Yasmein OKOUR
Spatial justice education in non-democratic planning spaces: A case study of Jordan

Tianyu ZHANG, Hong LENG, Qing YUAN
Characterizing the spatial and temporal correlation between urban shrinkage and social-ecological system resilience
A case study of Liaoning Province, China

Hao CHEN, Xuanyuan GU
Trend of New Quality Productivity forces of International Biomedical Parks and the Shanghai Spatial Action Plan

Nasreen Kauser Mahdavinejad SHABBIR DUMMI, Afshin MOHAMMADJAVAD GHORBANI
Walking towards tomorrow
Humanizing urban spaces in Nizwa souq, Oman

Chengcheng YIN, Bruno MARQUES, Jaqueline MCINTOSH
Healing Cities: Integrating Virtual Reality Therapeutic Landscapes into Urban Planning for Future Well-being

Tingting YU, Zeliang WEN
Research on Spatial Planning Strategies for Community Integration of Healthcare and Physical Activity
From the Perspective of Proactive Health Interventions

Xingcan ZHOU, Kojiro SHO, Qingya CEN, Hongfei QIU
Assessment and optimization of urban blue-green space services based on multi-source big data
A case study of central Wuhan

Ayush PAWAR, Rajshree KAMAT
Peri-urbanization and infrastructure dynamics strengthening flood resilence with green and grey solutions in developing nations

Chenhui LI
Identification and cause analysis of food deserts in the old town
A case study of the old town of Nanjing

Ockert PRETORIUS
Exploring indicators of economic resilience in South African towns and cities

Burcu SOYGÜZELOĞLU, Selin Aslan ŞENOL, Melis Oğuz ÇEVIK
Transforming Small Anatolian Cities: Insights from Student-Driven Urban Change in Amasya, Türkiye

Barnali CHAKRABORTY, Priyanka DEY
A fuzzy approach for critical quality assessment of neighbourhood risk factors in historic city centres:
Empirical evidence from Kolkata, India

Clotilde HAVARD
Petites villes de demain: revitalizing small cities for a sustainable future

Xiliu HE, Jintu XU, Ziqi WU
Unveiling City Images through Social Media
A Data-Driven Approach for Inclusive Planning and Heritage Conservation in Nanjing

Siqi LIU, Han LI, Chunyang ZHANG
Research on Healthy Street Identification and Evaluation Based on Social Media Data and Street View Imagery

Jiaxuan ZHAO, Hong LENG, Qing YUAN
Inclusive Urban Design: Exploring the Relationship between Neighborhood Environments, Outdoor Activities, and Health in China from Children's Perception

Ulrich GRAUTE
Artificial Intelligence (AI) in urban and territorial development: opportunities and risks decision-makers, planers and citizens

Melis YILMAZ
From Galleries to Screens: The Digitalization of Exhibition Spaces

Piotr ZELAZNOWSKI, Will GARNER, Naomi HÉBERT, Wenchi YANG
Heritage as a leverage for urban innovation. Case study of using AI as a co-designer

Xuanmin DONG, Yu DU
Evaluation and strategy of community belonging based on Multi-agent LLM
A case study of the long-term rental apartments in Beijing

Neha JAISWAL, Abraham GEORGE
Addressing the Impact of Urban Form on Liveability
A Critical Review

Najmeh MOTALAEI, Anssi JOUTSINIEMI, Klas FONTEL, Jarno PELTONEN
From Aesthetics to Functionality: Planning for Public Art in Shaping Helsinki's Inclusive Public Spaces – A Case Study of the Pasila Neighborhood

Purba BISWAS, Priyanka DEY
Spatial Analysis of Urban Growth Patterns and Land Use Dynamics in Industrial Cities along the DMIC Corridor: A Remote Sensing and GIS Approach

Mani DHINGRA, Aphra KERR, Jack R. LEHANE
'Rethinking' digital twins and building alternatives for smart city planning in Dublin

Eleni OIKONOMAKI
Identifying the Determinants of the Innovation Ecosystems
A Geospatial Analysis across New York's and Boston's neighborhoods

Tianheng SHU, Xia LIAO, Shuo YANG, Taofang YU
Modeling the effect of amenity determinants on urban innovation space using geographical random forest models
A Beijing case study

Meenu S NAIR, K.K Anilkumar
Redefining the roles and jurisdictions of civic bodies to provide efficien public service delivery: A case of Bengaluru Metropolitan region

Nitesh SHUKLA, Arup DAS, Tarak Nath MAZUMDER
The people without power: Exploring the governance within informal settlements of Surat city, India

Damla BALCI, Can AYDIN, Murat KILINC, Gizem ERDOĞAN AYDIN
AI-Powered Feature Selection Techniques for Optimizing Urban Heat Island Factors

Balázs CSERPES
Assessing Spatial Impacts of Digitalisation on Labour Markets: Methodological Approaches

Naifu LIU, Xiaoxu LIANG, Yu ZHANG
A Digital-twin Based Conservation of Campus Historic Buildings under Sustainable Development Framework

Zijing WANG, Xiaoyi WEN, Xiaosen WEN
Construction of urban security risk intelligent attack and defense system based on TIM platform under climate change
A case study of Lanxi City, Zhejiang Province, China

Alice JELMINI, Nicolò D'ANDREAS
"Spaziamo": Revitalizing Locarno through Tactical Urbanism

Xiaoxuan DU, Shiliang LU
Leveraging the Olympics for waterfront revitalization: Insights from Tokyo 2020 Olympic Village

Haozheb ZHANG, Qing Luo
Research on demand for public space for residents' daily leisure activities in old communities based on KANO-IPA analysis
A case study of Harbin, China

Ming LU, Ke NING
Research on recreational environment optimization of waterfront parks in winter cities based on IPA-Kano model
Take Daqing as an example

Cheng SHI, Xiaoxiang YI, Lei XIA, Shuai YU
Tourism destination images analysis and tourism development indicators evaluation based on perceived gap
Bridging Online Perceptions and Reality

Xinyi WU
Conceptual Differentiation of City Spatial from the Heritage Conservation Perspective

Xinfang ZHANG, Qing YUAN, Hong LENG
Study on Regional Differences and Configuration Paths of Factors Influencing Population Outflow
Empirical Analysis from 26 Resource-based Shrinking Cities in China

Peiyi FAN
Urban Green Space Planning Based on the Aniene River Heritage Corridor
Biodiversity Conservation and Sustainable Urban Design

Nur Muhammad Gito WIBOWO
Jakarta 2045 – Jakarta after IKN: Towards Restorative Urbanism in Jakarta Urban Future

Qimin XU, Qimin Chen CHEN
Development beyond the edge
Assessing the externalities of the dual-track urban network at township level in Shanghai Metropolitan Areas

Xianze ZHANG, Ying LIU
Exploration of Renewal Paths for Modern Sports Architectural Heritage Based on Intelligent Grading

Ying TAN, Jiarui HU, Yijing LIN
A study on the digital portrayal of user groups of urban park green spaces in the main urban area of Nanjing based on LBS data

Liang HE, Peikui FENG
Traditional Industrial Parks Renewal Practices from the Perspective of Circular Economy
Take the Yangtze River Delta Demonstration Zone as an example

Paper Index

Track 3. Urban Memories and Inclusive Regeneration

Abantika MUKHERJEE, Haimanti BANERJI
Socio-economic contributions of living industrial heritage
A correspondence analysis of industrial community in West Bengal, India

Nandini MUKHOPADHYAY, Shreyas P BHARULE, Joy SEN
Reviving Heritage and Empowering Communities
Inclusive Regeneration Practices in the Temple Towns of Bishnupur and Kalna, India

Zhangna SU, Jianyun ZHOU
Clarifying Existing Land Use Rights in China
Foundation for Urban Redevelopment

Dawei WANG, Wenzhu ZHOU
Conservation and revitalization of port industrial heritage under the historic urban landscape framework
A case study of Great Harbor in Qingdao, China

Shutao LIAO
Heritage, Heart, and Home: A Socio-Cultural and Emotional Approach to Urban Tree Trail Planning

Andrada-Ioana LUPULESCU, Inkeri AULA, Pietro ELISEI, Saturnino LUZ, Masood MASOODIAN, Áurea Rodrigues CIDEHUS, Antti RUOTOISTENMAKI, Ilektra SIMITSI, Elpida TZIKA, Renata Viera CIDEHUS
INT-ACT Intangible Cultural Heritage, bridging the past, present and future
A position paper on INT-ACT project progress

Purbita SAMANTA, Subrata CHATTOPADHYAY, Archiman BISWAS
Preservation of intangible heritage and empowering non-native ethnic communities in the Indian context

Haziel M. BUAM, Shreyas P. BHARULE
Planning of a Community- based festival to empower local communities and their cultural identity
A study of the Behdieñkhlam Festival in Jowai Meghalaya, India

Deniz CAN
Exploring Urban Resilience and Dichotomy of Transformation Projects in İstanbul
A Comparative Study of Gasworks Museum and Galataport İstanbul

Siyuan HAO, Xiliu HE
Spatial Justice in Heritage Communities
Resident Perceptions of Recreational Spaces in Suzhou's Classical Garden Areas

Polina IVANOVA
The Problem of Cultural Heritage: What Is Heritage Value for Residents?

Zhiyong QIU, Xinjian ZHANG, Conghui YIN, Ling YANG
A Study on the Evaluation and Creation of Community Cultural Spaces from the Perspective of Scene Theory
A Case Study of Tianjin Community

Shitao JIN, Yuan DENG, Huijun TU
Reprogramming Urban Communities: Enhancing Children's Well-being through a Value-Based Programming Approach in Inclusive Planning and Design

Jingwei JU, Chengyan XIA
Evolving Socio-Spatial Dynamics in Traditional Chinese Village Dwellings
A typological analysis of Xiwu Village

Yiqun WANG
Planning A "Cultural Center" for Athabasca Oil Sand Mining Region
Establishing A Cultural Ground for Techniques of Reclamation in Fort Mckay First Nation

Kai ZHANG, Yushuang TANG, Xinrou HUANG, Lingran TAO, Yibo LIU
Analysis of the influencing factors of urban street space on the health of people of all ages
Based on partial least squares structural equation model

Xindan CAO, Yidong YU, Lu LIU, Xiji JIANG, Xianglei SHI
The practical study of inclusive waterway renewal planning
A case study of West Hongqiao Business District in Shanghai, China

Israa MAHMOUD, Eugenio MORELLO, Luca LAZZARINI, Asef AYATOLLAHI
Co-creation for Urban Biodiversity
The experience of a public participation process in a living lab in Milan, Italy

Tingting YU, Xu GUO
Health-oriented Resilience Evaluation of Village-amid-the-city in Cold Area: A Case study of Harbin, northeastern China

Danyang JING
Exploration of the Active Aging Renewal Model in Double-Aging Communities
From the Perspective of Sense of Place

Wenqian NIU
Achieving Environmental Justice for Disadvantaged Communities in Industrial Recession Urban Areas

Gargi ROY
Streets For People
Pathways of Change from India's Smart Cities

Stephanie CHEUNG, Sarah MUI, Alan CHEUNG
Rebuilding villages and empowering rural communities through Sai Kung Hoi Arts Festival

Pilisiwe MASIBA, Sandla MASINYANE, Thulisile MPHAMBUKELI
Urban Regeneration and Small Town Revitalisation, Tools for redressing spatial injustices
A case of eMaxesibeni Town, Eastern Cape, South Africa

Siwei PENG, Xingping WANG
Research on Rural Revitalization Planning from the Perspective of Youth Friendship
Taking Nuanshui Town as an Example

Xijia SUN, Xiangfeng LI, Rui HOU
Traditional to Contemporary: Study on Inheritance and Transformation of Chinese Covered Bridge Culture Heritage from a Spatial Connectivity Perspective

Barnali CHAKRABORTY, Priyanka DEY
Revisiting the notion of urban blight in the context of Global South
A discursive approach

Dongxin LIAN, Shifu WANG
An Initial Exploration of Progressive Cultural Industry Cluster Models in Historical Districts from the Perspective of Catalysts
Taking Feng Yuan Street-Liwan Lake District in Liwan District, Guangzhou as an Example

Jin YAN, G RONG, L XIANGJIAN
Spatio-temporal effects of urban rail transport on residential prices around stations
A case study of Harbin Line 1

Kangsheng LIU, Wei DONG, Yu DONG, Tianyi HOU
A Case Study of Singapore HDB Residents on the Formation of Community Attachment in Community Gardens

Zhao ZHAO
Reshaping Citizenship
A Study on Inclusive Regeneration and Governance in Megacities Based on Beijing's Practices

Whenchen GONG, Han GAO
Research on spatial image and cultural identity between new and old cities
A case study of Xiamen, China

Kailun LI
Spatial Contraction Characteristics and Regeneration Pathways in Industrial Areas
A Comparative Study of Venice and Nanjing

P.R. YAAZHINI, Kiranmayi RAPARTHI, Pratheep MOSES
Socio-Economic Spatial Framework for Assessing the character of urban liminal or transition spaces in regulating ecosystem services
Case of Chennai City

Archiman BISWAS, Subrata CHATTOPADHYAY, Purbita SAMANTA
Transforming Urban Landscapes: The Role of Commercial Centres in Shaping Collective Memory in Tier-II Cities
A Case Study from the Developing Country Context

Shuai YU, Xiaoxiang YI, Lei XIA, Cheng SHI
Evaluation and Planning Strategies for Ice-Snow Cultural Tourism Destinations Based on Public Perception
A Case Study of Heilongjiang Province, China

Simone BACK PROCHNOW
Existing in Kinship to Everything
Fourth Nature Patterns and Paths to Regeneration

Kexin LIU, Jianfei CHEN, Yu BAN
Design Strategies for the Regeneration of Existing Hospitals in Cold Cities with the Aim of Sustainability and Regionalism
A Case Study in China

Jahui ZHU, Wei DONG, Yu DONG, Yuelei ZHAO, Xiaohan LIANG
Associations between neighborhood built environment and social health among older adults in Harbin, China

Jahui ZHU, Wei DONG, Yu DONG, Jingwen LIANG
Built environment and social health of the elderly in Harbin: A comparative study of communities built before and after housing reform

Nasim IRANMANESH, Sepideh ETAATI
Iranian Mosques, an icon in identity of Iranian cities

Jian DAI, Xiaokai MI, Zhiqing ZHAO
The Correlation between Loneliness and Community Third Space for Young People Living Alone in Shenzhen
A case study of youth community in Shenzhen

Paper Index

Track 4. Sustainable Urban Density

Yasmein OKUR
Beyond the Buzzwords: Examining perceptions of climate change resilience and adaptation in Jordanian municipal planning

Yi-fei XU, Chi LI
Regional Comprehensive Disaster Prevention System Planning from the Perspective of Resilient Cities
A Case Study of Mentougou District, Beijing Municipality

Yuran ZHAO, Hong LENG, Yan ZHAO
Urban Carbon Emission Prediction and Carbon Neutrality Pathways Based on Urban Spatial Elements

Yan ZHAO, Qing YUAN, Yuran ZHAO
Multi-Scale Analysis of Urban Density and Carbon Emission Dynamics
A Case Study of Harbin, China (2007-2021)

Anneloes Van NOORDT
Climate neighbourhoods in Flanders
Initiating a broad transition process towards a sustainable urban environment

Qi AN, Yu DONG, We DONG
How the urban morphology impact thermal environment in high-density areas
A city-block-scale study in Harbin, China

Debanjali SAHA, Haimanti BANERJI, Umesh KUMAR
Critical Success Criteria for sustainable and affordable housing delivery in high-density urban areas
A case study of Indian megacities

Junbo XIA
Reactivating High-Density Suburbs: From Regional to City-Wide Service
A Case Study of Yishun and Jurong East in Singapore

Xin ZHAO
The Factors and Indicators System That Influences Sustainable Density

Cheng SHI, Xiaoxiang YI, Yibo LIU
Study on the Evolutionary Characteristics of County Town Shrinkage and Planning Response Strategies under Multi-Dimensional Framework
Taking the Three Northeastern Provinces of China as an Example

Daphné ROELS, Guy VLOEBERGH
DNA analysis and research by design as a framework for quality of life
Case study Veurne, Belgium

Gabriela TENORIO, DE SOUZA
Would Brasília be less Brasília if more people lived in the protected area?

Guido CIMADOMO
Urban Density in Portland (USA)
The experience of the Urban Growth Boundary

Chi LI
Landscape Character Assessment and Sustainable Development Strategies Under the Urban-Water Integration Perspective
A Case Study of Dongting Lake Area, Hunan Province, China

Georgies SROUR
Maximizing Urban Vegetalisation
A Comprehensive Data-Driven Strategy for estimating Maximum Vegetation Coefficient

Yizhe WANG
Exploring Urban Spatial Planning Methods from the Perspective of "Renewable Energy" Development
A Case Study of Spatial Planning Practices in Changzhou, China

Cunyan JIANG, Zide LIU
Correlation between Urban Density and Heat Health Risk in Megacities: A Case Study of Shenzhen

Hong LENG, Jiayi LUAN, Qing YUAN
Linking Ecosystem Service Supply and Demand to Resilience of Blue-green Space: A Conceptual Framework

Haoting TANG, Lulu CHEN, Qing YUAN
Bird biodiversity Conservation on Older Urban Residential Areas Renewal
A Case Study of Yu'er Village, Shenzhen

Zihao WANG, Chunyang ZHANG
Research on high-density community renewal and design guidelines based on health promotion
A case study of Guangzhou, China

Hao CHEN, Jing YU, Xuanyuan GU
Research on the Spatial Evolution and Overall Scale of Pudong New Area in China under the Guidance of National Strategy

Yujao WEI, Xu GUO, Hong LENG
The correlation between neighborhood environmental characteristics and travel distance
An analysis using origin-destination data in Harbin, China

XinYi LIU, Yibo LIU, Xiaoxiang YI
The Relationship Between Innovation Districts and the Management of Shrinking Cities

Anindita PRIYADARSINI, Sumana GUPTA
Balancing Urban Densities: Exploring Retail and Population Distribution for Sustainable Indian Cities

Shuai YU, Xiaoxialng YI, Haoping ZHANG
Research on the Coupling Coordination Degree of Land Intensive Use and Sustainable Development in Shrinking Cities
A Case Study of Northeast China

Esra Kut GÖRGÜN
Examining the Land Use and Land Cover Change Using Vegetation Indices in Muğla, Türkiye

Shuo LYU, Rong GUO
Evaluation of ecological environment quality in Harbin based on Remote Sensing Based Ecological Index

Juan GUAN, Jiujiu GUO, Shan WANG
Study on the correlation between pm2.5 and urban vitality in megacities in china over the past 20 years: a case study of beijing

Paper Index

Zhiyong QIU, Mengyao DUAN, Jian DAI, Ling YANG
The impact of spatial density on residents' perception in residence-dominated metro station areas
Taking the Red Line of Harbin metro in China as an example

Track 5. Circular Urbanity

Tianxiao HUANG, Ming LU
Research on Campus Environmental Space Configu ation under the Perspective of Supply and Demand - Taking Harbin Institute of Technology as an Example

Anna RUINI, Fabio SPORCHIA, Alessia Le ROSE, Carmela GIOIA, Nicoletta PATRIZI, Simone BASTIANONI
Timber Buildings and the Environmental Benefits of Cascading: LCA Application to Circular Practices in the Wood Value Chain

Mingyi SHI
Circular Urbanity: Innovations and Insights for Sustainable Urban Development

Yiqun WANG
Floating Futures
Redefining Water Management through Sustainable Landscape Interventions in South Boston

Alfred WILLINGER, Marianne BÜGELMAYER-BLASCHEK, Silja TILLNER, Karl GRIMM, Irene ZLUWA, Elia STEFAN, Rita EBNE, Tanja TÖTZER, Martin JUNG, Martin SCHNEIDER, Romana BERG, Karl BERGER
Transforming public spaces towards user-friendly, climate resilient and energy producing spaces
The Bartlett

Zesen FAN, Yibo LIU, Jun XING, Lei XIA
Response to "Dual-Carbon" Objective in Comprehensive Territorial Spatial Planning of Resource-Based Cities: A Case Study of Fujin city

Siena © Municipality of Siena

Author Index

AITHAL, Bharath H
AL ARIDI, Elissa
AN, Qi
ANAND, Prashant
ANDRADE, Victor
ANILKUMAR, K.K
ANWAR, Ayesha
ASLAN ŞENOL, Selin
AULA, Inkeri
AYATOLLAHI, Asef
AYDIN, Can
BACK PROCHNOW, Simone
BALCI, Damla
BAN, Yu
BANERJI, Haimanti
BASKARA, Erlangga
BATUNOVA, Elena
BHARULE, Shreyas P
BHATTACHARYA, Amit
BISWAS, Archiman
BISWAS, Purba
BROWN, Andre
BUAM, Haziel M.
BÜGELMAYER-BLASCHEK, Marianne
CALAS- REIBERGER, Barbara
CALAS, David
CAN, Deniz
CAO, Xindan
CATTANI, Chiara
CEN, Qingya
CHAKRABORTY, Barnali
CHATTOPADHYAY, Subrata
CHEN, CHEN
CHEN, HAO
CHEN, JIANFEI
CHEN, Lulu
CHEUNG, Alan
CHEUNG, Stephanie
CIMADOMO, Guido
CONTIN, Antonella
CSERPES, Balázs
D'ANDREAS, Nicolò
DAI, Jian
DALGAMONI, Nermeen
DAS, Arup
DE SOUZA TENORIO, Gabriela
DENG, Yuan
DEY, Priyanka
DHINGRA, Mani
DONG, Wei
DONG, Xuanmin
DONG, Yu
DU, Xiaoxuan
DU, Yu
DUAN, Mengyao
DUMMI SHABBIR, Nasreen Kauser
ELISEI, Pietro
ERDOĞAN AYDIN, Gizem
ETAATI, Sepideh
FAN, Peiyi
FAN, Zesen
FANG, Qiumei
FELLI, Annamaria
FENG, Panpan
FENG, Peikui
FIORINI, Lorena
FONTEL, Klas
FU, Xiang
GAO, Han
GAO, Yu

GARNER, Will
GEORGE, Abraham
GHARAT, Piyush Chandrashekhar
GHORBANI, Afshin
GONG, Whenchen
GÖRGÜN, Esra Kut
GOSWAMI, Arkopal K
GRAUTE, Ulrich
GRIMM, Karl
GU, Shuyi
GU, Xuanyuan
GUAN, Juan
GUMBO, Trynos
GUO, Jiujiu
GUO, Ran
GUO, Rong
GUO, Xu
GUPTA, Sumana
HALIMERGÜN, Yavuz
HAO, Siyuan
HAVARD, Clotilde
HE, Liang
HE, Xiliu
HÉBERT, Naomi
HONG, Seok- Ho
HOU, Rui
HOU, Tianyi
HU, Jiarui
HUANG, Longyan
HUANG, Shuyu
HUANG, Tianxiao
HUANG, Xinrou
IRANMANESH, Nasim
IVANOVA, Polina
JAISWAL, Neha
JELMIN, Alice
JI, Shuting
JIANG, Cunyan
JIANG, Hong
JIANG, Xiji
JIANG, Yiting
JIN, Danyun
JIN, Shitao
JIN, Xin
JIN, Y
JING, Danyang
JOUTSINIEMI, Anssi
JU, Jingwei
KAMAT, Rajshree
KAUSHAL, Anurag Aman
KERR, Aphra
KHALIFA, Mostafa
KILINC, Murat
KIM, Dong- Seok
KLINMALAI, Siwaporn
KUMAR, Umesh
KUMARI, Pooja
KUREEL, Priyanka
LAZZARINI, Luca
LE, Liang
LEHANE, Jack R.
LENG, Hong
LETSOKO, Vuyiswa
LI, Chenhui
LI, Chi
LI, Han
LI, Heping
LI, Hongji
LI, Jiayi
LI, Kailun

LI, Xiangfeng
LI, Yuanru
LI, Zhengru
LIAN, Dongxin
LIANG, Jingwen
LIANG, Xiaohan
LIANG, Xiaoxu
LIAO, Shutao
LIAO, Xia
LIN, Ya-nan
LIN, Yijing
LIU, Chang
LIU, Jiayi
LIU, Kangsheng
LIU, Kexin
LIU, Lu
LIU, Naifu
LIU, Siqi
LIU, Taorong
LIU, Xin
LIU, Yibo
LIU, Ying
LIU, Zide
LU, Ming
LU, Shiliang
LUAN, Jiayi
LUO, Qing
LUPULESCU, Andrada-Ioana
LUZ, Saturnino
LYU, Shuo
MA, Xueyan
MAHDAVINEJAD, Mohammadjavad
MAHMOUD, Israa
MARCHETTINI, Nadia
MARCHI, Michela
MARQUES, Bruno
MARUCCI, Alessandro
MASIBA, Pilisiwe
MASINYANE, Sandla
MASOODIAN, Masood
MAZUMDER, Tarak Nath
MCINTOSH, Jaqueline
MENG, Jiuqi
MI, Xiaokai
MNDZEBELE, Mhlalisi
MOHANTA, Ashaprava
MOHANTY, Rabi Narayan
MOHSEN, Hiba
MORELLO, Eugenio
MOSES, Pratheep
MOTALAEI, Najmeh
MPHAMBUKELI, Thulisile
MUI, Sarah
MUKERJI, Arjun
MUKHERJEE, Abantika
MUKHOPADHYAY, Nandini
NAIR, Meenu S
NALBANT, Meryem H
NING, Ke
NIU, Wenqian
NOCENTINI, Enrico
OĞUZ ÇEVIK, Melis
OIKONOMAKI, Eleni
OKOUR, Yasmein
OVERDIEK, Anja
ÖZDEN, Abdulkadir
PALIT, Kasturi
PAWAR, Ayush
PELTONEN, Jarno
PENG, Siwei
PRETORIUS, Ockert
PRIYADARSINI, Anindita

PULSELLI, Federico María
PUTRI, Widasari Yunida
QI, Jingxin
QIU, Hongfei
QIU, Zhiyong
QU, Ang
RAPARTHI, Kiranmayi
RIBEIRO, Gustavo
RIZA, Müge
RODRIGUES CIDEHUS, Áurea
ROELS, Daphné
RONG, G
ROY, Gargi
RUOTOISTENMAKI, Antti
SADRAEI TABATABAEI, Nasim
SAHA, Debanjali
ŞAHIN, Süleyman Nurullah Adahi
SAMANTA, Purbita
SAWYER, Em
SEN, Joy
SHANG, Jin
SHI, Cheng
SHI, Xianglei
SHO, Kojiro
SHU, Tianheng
SHUKLA, Nitesh
SIMITSI, Ilektra
SONG, Charles
SONG, Shiyi
SONG, Zhe
SOYGÜZELOĞLU, Burcu
SPOELMAN, Janneska
STEFAN, Elia
SU, Zhangna
SUN, Xijia
SUN, Yufei
TAN, Ying
TAN, Zhuolin
TANG, Haoting
TANG, Yushuang
TAO, Lingran
TAŞKIRANLAR, Dervis
TIAN, Zihui
TIFTIK, Cemile
TILLNER, Silja
TONIELLI, Asia
TROPEA, Fabiola
TU, Huijun
TZIKA, Elpida
ULISSE, Carmen
VAN NOORDT, Anneloes
VIERA CIDEHUS, Renata
VLOEBERGH, Guy
WANG, Chunqi
WANG, Dawei
WANG, Haoxin
WANG, Mengke
WANG, Min
WANG, Shan
WANG, Shifu
WANG, Xiaodi
WANG, Xiaoxia
WANG, Xingping
WANG, Yiqun
WANG, Yizhe
WANG, Yuqi
WANG, Zihao
WANG, Zijing
WEI, Jiayi
WEI, Yujiao
WEN, Xiaosen
WEN, Xiaoyi

WEN, Zeliang
WIBOWO, Nur Muhammad Gito
WILLINGER, Alfred
WU, Xiaochen
WU, Xinyi
WU, Ziqi
XIA, Chengyan
XIA, Junbo
XIA, Lei
XIANGJIAN, L
XIE, Ruoxi
XING, Jun
XIONG, Liang
XU, Chunyu
XU, Jintu
XU, Qimin
XU, Yifei
YAAZHINI, P.R.
YANG, Jianqiang
YANG, Ling
YANG, Regina
YANG, Shuo
YANG, Wenchi
YE, Rui
YI, Xiaoxiang
YILMAZ, Melis
YIN, Chengcheng
YIN, Conghui
YU, Jing
YU, Shuai
YU, Taofang
YU, Tingting
YU, Yang
YU, Yidong
YU, Ziyi
YUAN, Qing
YUAN, Yuan
ZELAZNOWSKI, Piotr
ZEN, Zesen
ZHANG, Chunyang
ZHANG, Dongyu
ZHANG, Haozhe
ZHANG, Kai
ZHANG, Neng
ZHANG, Tianyi
ZHANG, Tianyu
ZHANG, Xianze
ZHANG, Xinfang
ZHANG, Xinjian
ZHANG, Yu
ZHANG, Yudi
ZHAO, Jiaxuan
ZHAO, Xin
ZHAO, Yan
ZHAO, Yuelei
ZHAO, Yuran
ZHAO, Zhao
ZHAO, Zhiqing
ZHOU, Jianyun
ZHOU, Wenzhu
ZHOU, Xingcan
ZHOU, Yan
ZHU, Jahui
ZHU, Yini
ZLUWA, Irene
ZULLO, Francesco

Siena © Municipality of Siena

Rapporteurs:

*- **Dr.Rajshree Kamat**, Associate Professor, Department of Architecture and Planning, Manit, Bhopal (M.P), India*

*- **Silja Tillner,** Mag.arch. MA (M.ArchII) Architect and Urban Designer, Founder and Director of Architects Tillner & Willinger Vienna, Austria*

*- **XIN YI**, Associate Prof. Dr.Ing., School of Architecture, Southeast University, Nanjing, P.R.China*

1. Introduction

Siena, the 60th ISOCARP World Planning Congress venue with its rich tapestry of history and dedication to heritage preservation, serves as a living embodiment of the theme "Reinventing the (In)Visible Cities: From Heritage to Innovation, Forging Pathways to Resilience". The congress seeked to chart a course towards sustainable urban development, reimagine city planning and design to accommodate innovation, honor Siena's unique historical significance and focus on topics such as urban revitalization, leveraging cultural heritage for sustainable development and combating climate change. The challenge for reinventing cities lies in meeting the needs of the present and future while preserving the essence of the past.

The "Heritage for a Sustainable Future" theme explores how preservation and utilization of cultural heritage can serve as a catalyst and/or a powerful driver for sustainable urban redevelopment of resilient cities and regions. This report synthesizes insights from Track 1 with six sub-themes in which key challenges, findings, and recommendations for the revitalization of protected rural and urban areas and the refurbishment of listed buildings and landmarks were identified. The presented abstracts, research contributions, and global experiences provided a comprehensive overview of present and future rural and urban development strategies while addressing issues of heritage preservation and sustainability.

2. Core Objectives

Track 1 focused on exploring how preservation and utilization of cultural heritage can serve as a catalyst and/or powerful driver for sustainable urban development of resilient

cities and regions, with following broad objectives. These five primary objectives are crucial to increasing the resilience and the safeguarding of heritage sites while still allowing for the future redevelopment of these spaces:

1. **Integrating Traditional Knowledge into Contemporary Planning**, supporting community-driven approaches for resilience and highlighting their stories
2. **Exploring Technological Innovation Solutions for Climate Resilience**
3. **Integrating Cultural Heritage and Tourism**, balancing the goals for revitalization, regeneration with sustainable redevelopment
4. **Fostering the Preservation and Utilization of Cultural Heritage - Preserving Cultural Heritage through Adaptive Reuse** of Historical Structures, while allowing for future development
5. **Energy-Efficient Restoration**

3. Sub-Themes

Track 1 focused on exploring how To better manage these objectives and contextualise research papers and case-studies, five sub-themes have been defined:

1. **Conservation and Development of Cultural Heritage:** This sub-theme emphasizes the importance of preserving endangered sites or listed buildings. The preservation and utilization of Cultural heritage also depends on improving the connectivity for the sites and finding appropriate uses.
2. **Technological Innovations for Climate Resilience:** new methods to chart current situations, connect results of different analytical results help to better forecast risks and develop strategies for protection.
3. **Climate Resiliency / Risks and Future Measures:** Resilience is a key aspect of sustainable urban redevelopment, especially when focusing on heritage sites' adaptability to changing environmental conditions. This sub-theme highlights strategies for resilient urban planning, including adaptive reuse of buildings.
4. **Revitalization, Regeneration & Sustainable Redevelopment:** This sub-theme addresses the balance between redevelopment and heritage preservation, exploring how the areas around cultural and landmark sites can experience redevelopment while retaining their unique identity and historical character. In rural areas heritage sites offer an opportunity to stimulate economic activities, e.g. attract visitors and create attractive work and living environments.
5. **Community-driven Approaches for Resilience:** strengthen the support for heritage appreciation, foster social inclusiveness and community cohesion. The inclusion of the community connects to local knowledge and appropriate urban design strategies for liveable environments for all citizens.

4. Data Summary

Total number of sessions: 11, organized into 6 sub-tracks. From 105 submitted abstracts 100 were accepted—68 research paper, 29 case studies and 6 posters. A total of 57 participants registered, with 40 presenting research contributions and 17 case studies across eleven sessions under six sub-themes. The accepted presentations represented 21 countries, including Australia, Austria, Brazil, China, Cyprus, Egypt,

Germany, India, Indonesia, Iran, Italy, Philippines, Poland, Russia, South Africa, South Korea, Sweden, Switzerland, Thailand, Turkey, United Kingdom, highlighting diverse perspectives on challenges for heritage sites.

5. Key findings (new methods, insights, approaches, etc…)

- Heritage as a contribution to resilience
- Heritage as an identification for revitalization
- Learning from rediscovered traditional knowledge
- Application of up-to-date technologies
- Responsibility & international collaboration
- Governance & Policy: develop heritage policy
- Access to local knowledge from the community through new methods of engagement, e.g. social media
- Fully realizing the multiple challenges that the digital age brings to cultural heritage
- In the process of the evolution of the times, the technical and social conditions that cultural heritage protection relies on are constantly being eroded

6. Identified Challenges

- Climate hazards affecting heritage & health
- Lack of responsibility & coordination between stakeholders, community and government
- Loss of traditional knowledge on resilient urban planning
- Ownership conflicts, fragmentation
- Lack of resilience governance policies
- Development pressures on protected areas due to housing needs
- Lack of awareness & knowledge
- Heritage connotation differences between virtual reality and real life
- The inheritance and utilization of cultural heritage conflict with the maintenance of authenticity

Identified issues include the marginalization of rural areas, population shrinkage, the loss of heritage sites to speculation and overdevelopment and the impacts of climate change particularly endangering heritage. In particular, the following key findings emerged from the presentations:

7. Recommendations (practice and research)

- The leverage of the impact of climate threats is especially important for sensitive environments around heritage sites.
- The development of sound and applicable heritage policy is the basis for preservation.
- The learning from traditional planning knowledge hast o be held in high esteem.
- The application of modern digital technology merged with traditional sustainable methods may lead to innovative and yet proven strategies.
- Tourism interests offer an opportunity to safeguard heritage and create economic stimulus, yet over-tourism has to be prevented.
- The promotion and support of bottom-up initiatives leads to sustainable and long-lasting solutions.
- The use of research shall help to prepare the ground-work for strong legislation on safeguarding heritage and stregthening its resiliency.
- The use of existing vacant structures has to be promoted before new construction and soil sealing are allowed, e.g. through

tax breaks, financial support, etc.

- The value of cultural heritage needs to be deeply integrated with the history and context of the region.
- Urban planning itself is part of the cultural heritage. It is necessary to focus on the mechanism of its evolution and its relationship with the context.
- It is necessary to not only focus on the protection of the heritage itself, but also pay attention to the relationship between heritage clusters and maintain the environment in which the heritage is located.

8. Conclusion

Track 1 outlines a comprehensive framework for the safeguarding of heritage sites, supporting their revitalization and sensitive redevelopment in the future, emphasizing sustainability, inclusivity, and resilience. The use of technological innovations, as the digital transformation, helps to address the challenges of climate change and environmental hazards more effectively. Using cultural heritage as a key attractor and driver for revitalization supports rural areas to address shrinkage and marginalization. Implementing these insights and recommendations can support cities and rural areas in evolving into environments that are equitable, efficient, and responsive to both human and environmental needs.

Research Paper

Research on Protecting Traditional Villages and Integrating Culture and Tourism

A Case Study of Zhenbei Village, Harbin City from the HUL Perspective

Jian Dai, Harbin Institute of Technology, China
Shuyi Gu, Harbin Institute of Technology, China
Lulu Chen, Harbin Institute of Technology, China

Abstract

Zhenbei Village is a traditional village along the Middle East Railway, and it has developed tourism with the help of historical and cultural resources. However, due to the lack of reasonable guidance, the contradiction between its protection and tourism development has become increasingly prominent. Historic urban landscape (HUL) is a protection method for living heritage, which emphasizes that development should be attached importance to in protection, and the significance of historical stratification at the same time. This paper extracts the concept of "historical stratification" in HUL, studies the overall spatial correlation and temporal cultural value cognition of various elements in Zhenbei Village, and analyzes the landscape pattern, street space, architectural clusters, landmark nodes and cultural characteristics of different development stages. On this basis, Five strategies, namely, optimization and display of landscape pattern, optimization and continuation of street space, activation and protection of architectural clusters, repair and maintenance of landmark nodes, and protection and inheritance of intangible cultural heritage, are put forward to integrate the protection of villages with the development of cultural tourism, in order to provide reference for the protection planning of other traditional villages and the integration of cultural tourism.

Keywords

Traditional village protection , Historic urban landscape, historical stratification, Integration of culture and tourism

1. Introduction

With the continuous improvement of the protection concept of traditional villages in China, although the protection of traditional villages has achieved certain results, there are still problems, which are reflected in the sharp decline in the number of villages, the serious destruction of some villages, the lack of inheritance of cultural heritage, and the threat of the environment and pollution. The Blue Book on Traditional Villages in China: Survey Report on the Protection of Traditional Villages in China (2017), released in December 2017, clearly points out that the current protection of traditional villages needs to adhere to the principles of integrity, authenticity, and sustainability. Based on the current state of conservation practices, the report emphasizes that village conservation should not be limited to tangible and static cultural heritage but should also cover intangible and living intangible cultural heritage. In 2011,

UNESCO adopted the Recommendation on Historic Townscapes, which elaborates on the relevant concepts and provides new perspectives and approaches to promote monuments' conservation and sustainable development. There have been successful cases of such practices in the international arena, with a wide range of applications covering ancient villages and towns. Taking Zhenbei Village as an example, conserving its traditional villages suffers from fragmentation and insufficient utilization of tangible and intangible cultural heritage inheritance. The current research on historic townscapes is rich, mainly focusing on the sustainability and systematicity of cultural heritage protection, the cognition of historical layers and overall protection, etc., such as Yang Tao[1]from the "process" and "hierarchy" of history, and the "process" and "hierarchy" of history. The study of the law of stratified accumulation of remains from the "process" and "hierarchy" of history and the construction of a sustainable systematic protection framework including four levels of identification, protection, development, and management, and Gu Xuanyuan[2]through the study of HUL concepts and methods, the study of the law of historical stratification for the significance of shaping the characteristics of the urban space. The significance of historical layering for the shaping of urban spatial characteristics. Therefore, under the guidance of the HUL concept, this paper studies the spatial and temporal dimensions of the cultural heritage of Zhenbei Village and proposes a holistic preservation and display strategy accordingly.

2. Methodology

2.1.Overview of historic urban landscape theory

Historic urban landscape (HUL) is defined in the HUL Recommendation as urban areas that have been formed through the accumulation of history and that combine cultural and natural values and characteristics. This category extends beyond the traditional notion of "core historic district" or "wholeness" to the cultural and geographic context of the city. The broader contextual elements encompass topography, geomorphology, hydrological conditions, natural features, historic buildings, modern elements, above and below-ground infrastructure, open spaces and gardens, land use and spatial layout, and experiential and visual connections. In addition, the concept addresses social practices, cultural values, economic dynamics, and intangible aspects related to diversity and identity.

It can be seen that the historic townscape encompasses both the historical process and the current and future attributes of the object of study, as well as the tangible and intangible cultural heritage. This approach is essential for the conservation and study of villages, as it considers the context of the object of study and the environment in which it is situated and respects local values.

2.2. Recognition of historical layers and holistic conservation

The core concepts of historic townscapes cover two main aspects: firstly, the recognition of layers, and secondly, holistic conservation. The former emphasizes that the city is a multilayered concept dedicated to studying cultural heritage from its inception to its evolution and to discovering the intrinsic value of urban heritage in both its temporal and spatial dimensions. The latter focuses on improving urban heritage conservation strategies and integrating them into a diversified system of goals for the sustainable development of the city as a whole, which is reflected in the way cultural heritage is perceived, valued, and planned.

Traditional villages have unique cultural heritage and landscape deposits. Zhenbei Village, as a traditional village along the Middle East Railway, is a village with both Russian and Chinese styles and modern and contemporary features, so the protection of its cultural heritage must first recognize the mechanism of historical accumulation and understand the process of its accumulation from a dynamic perspective. The

existing studies on historical stratification, the stratification laws of historical landscapes, the interpretation of historical stratification processes, and the study of ephemerality and co-temporality are generally studied. Li Heping (Li, 2020), Xiao Jing (Xiao, 2018), and others have analyzed the landscape elements and characteristic symbols of historical cities in various development periods according to the concept of "accumulation" of urban historical landscapes and then analyzed them in depth. They analyzed the landscape elements and characteristic signs in each period of development of historical cities and then summarized the evolution of urban historical landscape characteristics. Pei Yu (Pei, 2022) and colleagues focused on the "comprehensive combing of resources and value assessment" of the urban historic landscape, analyzed the historical layering of Yulin Ancient City in-depth, and constructed a historical layering value assessment system of Yulin Ancient City accordingly. Cao Yongmaodiscusses the nature of the concept of "urban historic landscape," distinguishes between the temporal and co-temporal dimensions of the landscape, and then proposes a strategy for conserving historic towns that integrates both temporal and co-temporal considerations (Cao, 2019).

Research on the other core concept of holistic conservation is often based on revealing the pattern of historical accumulation, and most of the conservation targets are historic districts and historic towns. Zhao Xia (Zhao, 2014), Shen Yichen (Shen, 2020), and others explored the intrinsic value and comprehensive protection strategy of northern Zhejiang's historical and cultural cities, which are characterized by canal settlements. They explored the overall protection and planning management system proposal for the industrial heritage in the northern port area of Ningbo Ningbo Yongjiang. At the same time, they conducted a study on the overall protection of industrial heritage in Ningbo Yongjiang North Port Area and the proposal for a planning and management system. Yang Tao used the theory of historic cityscape to study the evolution of the conservation method of Barkhor Street's historical and cultural district and explored the possibility of its application in the conservation of historical and cultural districts (Yang, 2014). Tu Li, Zhao Pengjun, and others take the basic principles of historic townscape as an entry point, and based on their in-depth understanding of the spatial layout and value stratification of villages, they explore the basic mechanism of the formation of the historical layers of traditional villages and accordingly put forward a holistic conservation strategy for the implementation of the relevant strategies (Tu, 2021).

2.3. The Suitability of Introducing Historical Stratification Cognition and Holistic Protection into Village Protection

Traditional villages often have a long period of historical remains and value accumulation, and by analyzing their historical layers, it is possible to have a comprehensive understanding of their village values; secondly, traditional villages are often affected by regional factors, and the mechanisms behind the changes of their layers and value characteristics need to be understood; finally, there is a prominent link between the protection of cultural heritage of traditional villages and their sustainable development; based on the above reasons, it is appropriate to integrate holistic conservation concepts and layer recognition methods into the scope of traditional village conservation.

3. Analysis of the Historical Layers of Zhenbei Village

3.1. Overview of the Historical Heritage of Zhenbei Village

The planned village is Zhenbei Village in Harbin City, which is located in the northern part of Yifanpo Town, surrounded by mountains and water, with a good ecological environment, belonging to the traditional villages along the Middle East Railway, and rich in historical and cultural resources. Zhenbei

Village is one of the third batch of traditional villages in China, as announced by the Urban and Rural Affairs Department. At the same time, it is the first village in Shangzhi City that has been included in the list. According to the detailed planning unit of Zhenbei Village defined in the land space plan of Yimianpo Township as the planning scope, the total area of the village is 1981 hectares, and it is a village of suburban integration, with a planning period of 2023-2035 and a near-term period of 2025 (Figure 1).

Figure 1. Distribution of villages in Zhenbei Village. Source: Authors.

3.2. Overview of Historical Heritage of Zhenbei Village

3.2. 1. Composition of the historical heritage of Zhenbei Village

Landscape leisure culture: Mountains and water surround Zhenbei Village, which has a favorable ecological environment. The Ant River is a large tributary on the right bank of the Songhua River, and rice is abundant along its banks. Rich in mountain resources, it is rich in medicinal plants, high-quality timber, fruits, vegetables, mushrooms, etc. Currently, Zhenbei Village utilizes its superior natural landscape layout to create leisure activities such as landscape tours and derive Zhenbei's oil paintings and other artistic cultures.

Street pattern: Zhenbei Village has formed a unique street texture in the development process, and the Middle East Railway is the key factor for its formation. The village's layout is closely centered around the railroad, and the streets and lanes converge to the railroad line or are distributed parallel to the railroad line. The village's layout is closely centered around the railway, with streets converging to the railway line or distributed parallel. Due to the planning in the early stage of construction and the limitation of land resources, the layout of buildings in the village is relatively compact. In addition, the streets and lanes of Zhenbei Village are diversified and have historical continuity. These streets and lanes have witnessed the historical development of Zhenbei Village, carrying rich cultural connotations and historical memories. The streets and lanes close to the Yimianpo Station show a certain radial shape, and most of the streets and lanes in the village show a regular grid layout. Some show a curved and irregular shape due to the impacts of the surrounding topography and geomorphology, the Ant River, and the natural growth factors.

Architectural Clusters: The Russian style characterizes the existing Middle East Railway building clusters in Zhenbei Village. The village's layout extends from the west to the east, from the beginning of the Red Flag Bridge to the east, and the layout of Russian-style buildings in the village is well organized. Within the village, there are 105 Russian-style buildings, of which 46 are state-level protected buildings. Most of these buildings were built between1903and1904, and each is hung with the signboard of "National Key

Cultural Relics Protection Unit-Middle East Railway Complex." The complex's main buildings are well-preserved, but some houses have damaged walls, broken roofs, etc. Some of the courtyards in the complex have preserved traditional Russian customs, such as planting trees and flowers in the front gardens of the houses. The elements of the walls, portals, window panes, roofs, chimneys, etc., contrast with the surrounding flowers, which is particularly conspicuous against the yellow and white tone of the old houses and overflowing with a strong Russian flavor.

Landmark node: There are many landmark nodes in Zhenbei Village, and they can reflect the style of the village in different periods. The former site of the waiting room of the railway station in Bianpanpo and the former site of the Songhua River Branch Command of the Middle East Railway Road Protector Army are the witnesses of the fusion of Chinese and Western cultures with the architecture of the Middle East Road as the carrier. The former site of the locomotive crew apartments of the Middle East Railway in Yimianpo, the "East Building," now the Hayi Rafting Entertainment Park, is a bunker-style building. The "East Building," the former site of the locomotive crew's apartment on the Middle East Railway, is now the Haiyi Rafting Entertainment Park.

Intangible cultural heritage: There are rich intangible cultural heritages in Zhenbei Village, including the Middle East Railway and beer cultures. The Yimianpo Station of the Middle East Railroad was built in September 1898. With the trade, the craft of making "nesting dolls" was introduced to the northern village of Yimianpo. 20century50s, local folk artists successfully produced the first domestic nesting dolls, marking the emergence of the industry in the side slope nesting dolls. In addition, Zhenbei Village is also known for its cultural relics and beer culture, being one of the first areas in China to cultivate hops and black currants (i.e., blackcurrants). However, the Guanghan Biomass Company currently occupies the site. In the early 50s, the state invested in a modern brewery in the area, which was the beginning of the wine industry in the town, but the brewery went bankrupt in the early nineties.

3.2. 2. Stratification of historical layers of historical heritage in Zhenbei Village

The distinction between "tangible cultural heritage" and "intangible cultural heritage" defines, to a certain extent, the framework of the elements of the historic landscape of Zhenbei Village and the content of its conservation and presentation. In practice, these two elements are not isolated from each other but have been organically integrated into the historical process. The construction of the Middle East Railroad contributed to the development of the village and attracted foreign residents to live here during the Sino-Russian trade. After more than a century of evolution, the landscape, folk traditions, natural conditions, the Middle East Railroad construction remains, and the intangible cultural heritage of Zhenbei Village has evolved into an integral part of the village. Landscape, folk traditions, natural conditions, the remains of the Middle East Railroad, and intangible cultural heritage have shaped the current landscape of Zhenbei. The current appearance of Zhenbei Village is not only the product of the interweaving of tangible and intangible systems but also the result of profound historical accumulation (Table 1). According to the historical development process of Zhenbei Village, its historical layers follow the correspondence of "culture-time-space." Zhenbei Village contains rich and diversified historical and cultural resources. However, the protection and utilization of these resources are scattered and fragmented.

	Middle East Railway Culture Layer	Beer culture layer	Folk culture layer
Historical staging	1898-1952	1930-1990	1950-present
Spatial features	Historic buildings, architectural	Individual building	Individual building

	clusters		
Significant Events	Yimianpo Railway Station was built	"Samsung" beer	Matryoshka doll making skills
Representative cultural relics	The former site of the locomotive crew apartment, the former site of the headquarters and the former site of the waiting room of the railway station on one slope of the Middle East Railway	Yimianpo Winery	—

Table 1. Layered Information Table of "Culture-Time-Space" Cultural Heritage in Zhenbei Village. Source: Authors.

4. The integration path of Zhenbei Village protection and cultural tourism from the perspective of HUL

4.1. Overall protection of landscape pattern

Create the brand impact of the characteristic tourism industry chain, deepen the influence of the characteristic leisure tourism industry, combine Shangzhi and Heilongjiang tourism market demand, around the Russian style experience activities, experience and products, combined with the main arteries to create the rural culture and tourism life landscape axes, create service facilities nodes; and relying on the ants to create the riverfront landscape axes, shaping the landscape and historical and cultural nodes (Figures 2-3).

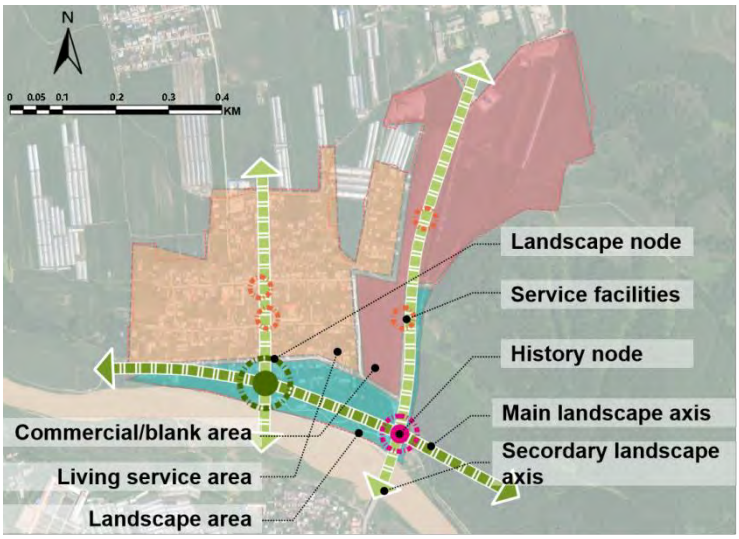


Figure 2.Landscape Pattern of Xinlitun. Source: Authors.

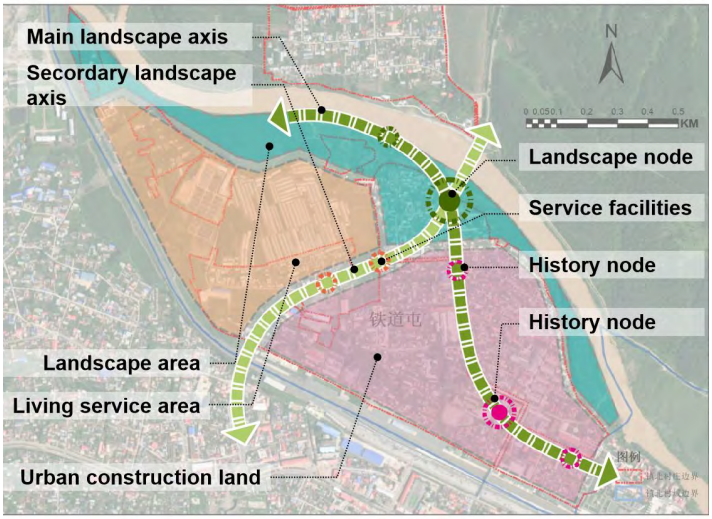


Figure 3. Landscape Pattern of Tiedaotun. Source: Authors.

4.2. Optimize and continue street space

Combine the current road and street grading classification. According to the grade and current road conditions, the improvement of village roads is divided into three categories: road widening, road surface improvement, and road connectivity. The main roads are standardized and delineated, sidewalks, street trees, and cables are sequenced, and the roads are hardened, brightened, and divided into sidewalks; parking spaces or parking lots are set up along the routes according to demand. The streets and lanes in the village will be improved and hardened, the side ditches will be enhanced, the soil along the roads will be removed, and the landscape along the roads will be upgraded. The disconnected roads between the village groups and between the villages and farmlands will be connected to improve the road transportation system of the villages, ensure the passage of agricultural machines, and improve the efficiency of farming operations(Figures 4-5).

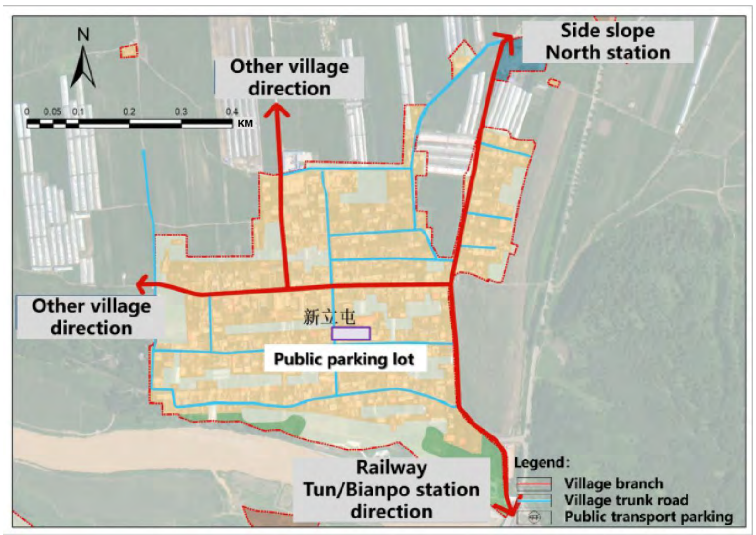


Figure 4. Xinlitun Road Traffic Planning Diagram. Source: Authors.

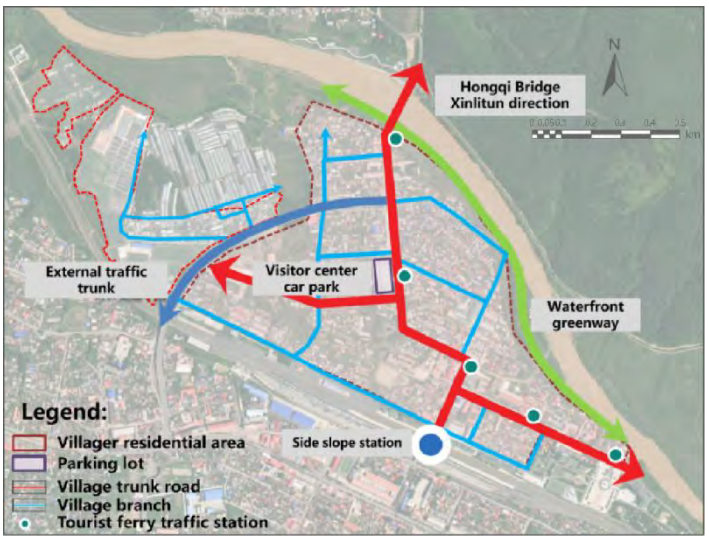


Figure 5. Road Traffic Planning Diagram of Tiedaotun. Source: Authors.

4.3. Activating and displaying building clusters

For the conservation of building clusters, mainly focusing on Tiedao Tun, which has many historical buildings, the first step is to determine the conservation zoning (Figure 6), and based on the upper planning, road and neighborhood division, the types and values of different types of historical and cultural heritage are systematically analyzed, and A-Riverfront Recreation, and B-Township Folklore are delineated, C-historical cultural tourism, D-art and culture four major protection areas. Secondly, on the basis of a comprehensive census of the town's historical architectural resources, all kinds of historical and cultural buildings are graded for protection. According to the age of the buildings, cultural resources, and the degree of importance, the buildings are classified into three grades: cultural relics, historical buildings, and Russian-style houses. Relying on the characteristic resources of the four districts, implanting characteristic functions, and combining the strong culture and history of Tiedaotun, we build a fine tour line for the display of architectural clusters and village styles (Figure 7), with the first line being the greenway cycling picking line, the second one being the rural life experience line, the third one being the Russian style experience line, and the fourth one being the Wukas characteristic sightseeing line.

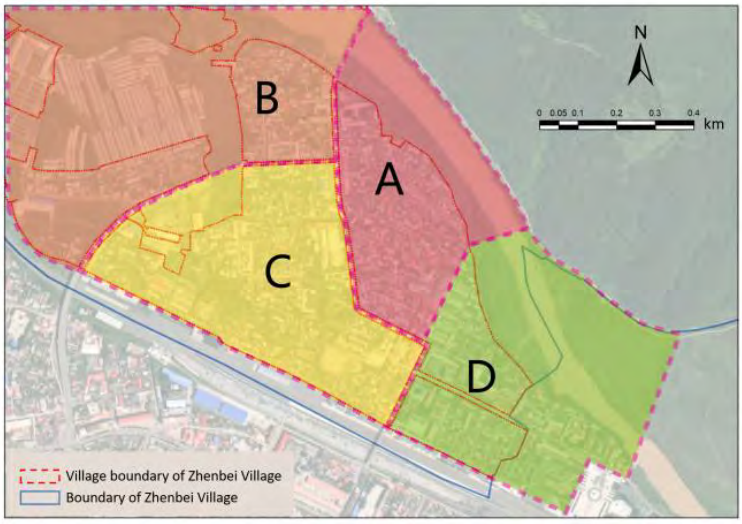


Figure 6. Protection partition. Source: Authors.

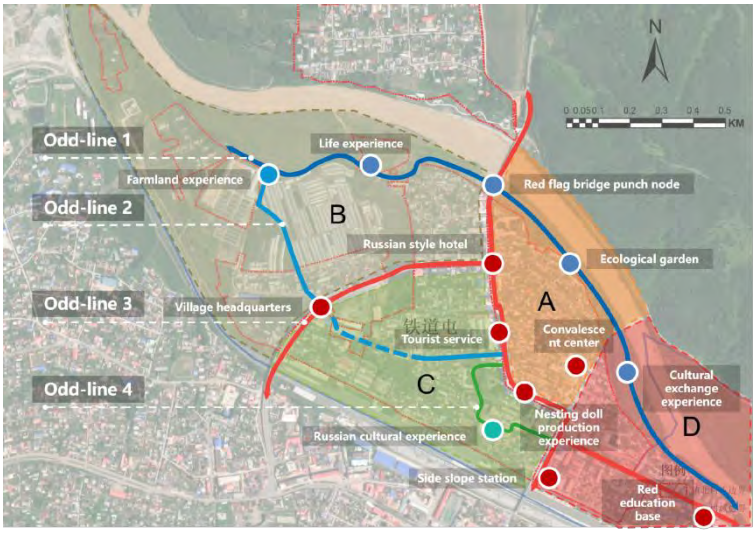


Figure 7. Design of boutique tour line. Source: Authors.

4.4. Repair and maintenance of landmark nodes

The design is mainly for the important nodes of Xinlitun and Tiedaotun. Xinlitun mainly renovates the former site of the brewery, the former site of the elementary school, and the former site of the water tower, and since the historical and cultural value of these three buildings is relatively low, it is mainly renewed by injecting three functions: the village activity center, the tourists' service center, and the village history museum (Figure 8). There are many historical and cultural buildings in Tiedaotun, so the landscape design is optimized for the important historical nodes (Figure 9).

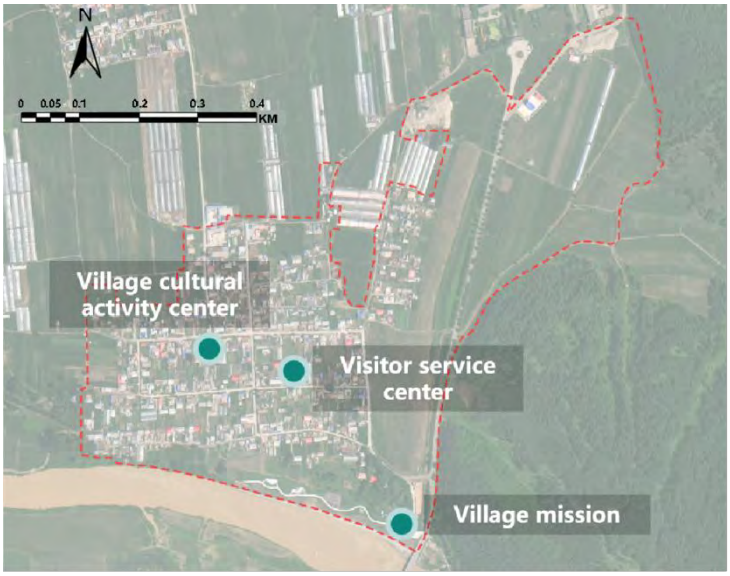


Figure 8. Reconstruction of Xinlitun node. Source: Authors.

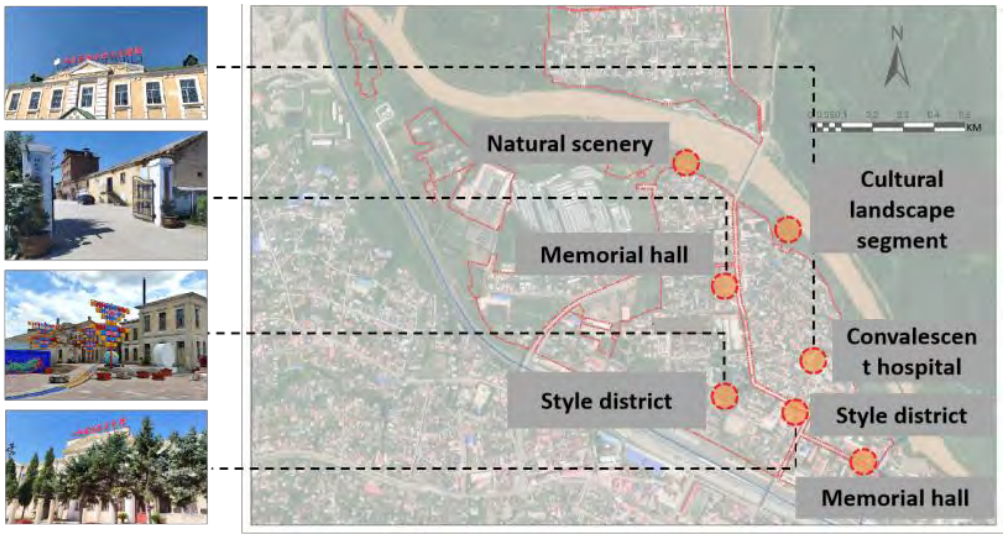


Figure 9. Optimization of railway nodes. Source: Authors.

4.5. Safeguarding and Transmission of Intangible Cultural Heritage

Structuring "1+N" rural characteristic experiential tourism, promoting the integrated development of one, two, and three industries in Zhenbei Village, and carrying forward the beer culture and condor culture of Zhenbei Village, "1" refers to Rural tourism and leisure based on the agglomeration of tourism products, which based on the development of agricultural products, organically attached to the ecological tourism and participation in the experience and other functions; "N"- utilization of the status quo Intelligent greenhouse greenhouses, beer production, condor production base and rich historical and cultural heritage and other advantageous conditions to derive a variety of functional combinations (Figure 10).

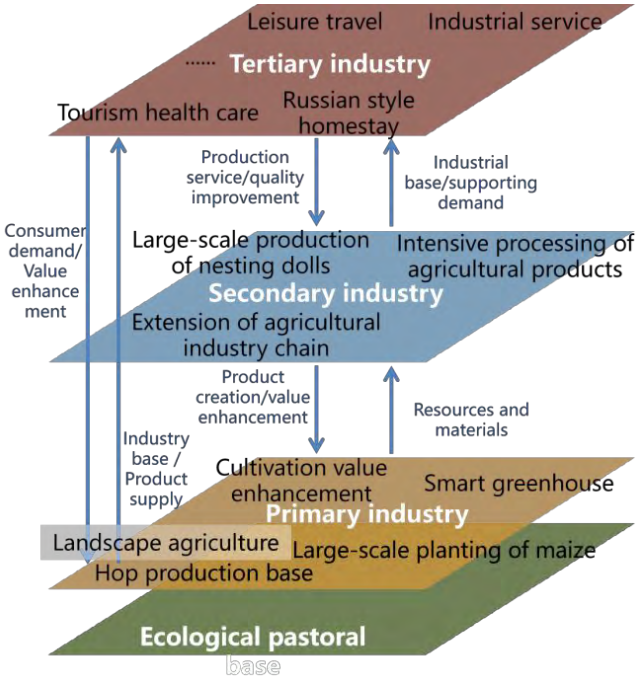


Figure 10. Inheritance Conception of Intangible Cultural Heritage. Source: Authors.

5. Conclusion

Based on the theory of historic townscape (HUL), this paper starts from two key ideas of cognition of its historical layers and holistic protection, studies the law of historical layers of Zhenbei Village in Harbin City, and cognizes the cultural heritage composition of Zhenbei Village from five categories of imagery elements: landscape pattern, street system, architectural clusters, landmarks, nodes, markers, and intangible cultural heritage, and proposes five major development strategies for cultural tourism integration in Zhenbei Village based on this foundation. Based on this, five development strategies for cultural tourism integration in Zhenbei Village are proposed to provide feasible paths for the inheritance and development of traditional villages. However, this paper also has deficiencies in the investigation of cultural heritage. It lacks quantitative data support, so future research can combine withArcGISspatial analysis to study the traditional villages in Zhenbei Village in depth. In the future, we can combine ArcGIS spatial analysis to further study the historical stratification of traditional villages in Zhenbei Village. (Team members: Yiqiu Cai, Jiacheng Pan, Yujun Wang, Hanyu Feng)

This paper is jointly funded by the following two projects: Heilongjiang Province Philosophy and Social Science Research Planning Project (23GLB024), the Protection and Utilization of Northeast Anti-Union Revolutionary Sites and the Design of Theme Trails (24136).

6. References

Yang, T., 2015. Sustainable and systematic: An exploration of neighborhood conservation methods in Barkhor Street conservation practice in Lhasa. *Urban Development Research*, 22(2), pp.13-19.

Gu, X., 2016. Significance of historical stratification research on shaping urban spatial characteristics--Thinking based on the concept and method of historic urban landscape (HUL). *Urban Architecture*, (16), pp.41-44.

Li, H. and Fu, P., 2020. Study on interpretation and protection methods of stratification law of urban historical landscape--A case study of Longxing Ancient Town in Chongqing. *Chinese Gardens*, 36(4), pp.49-54.

Xiao, J., Cao, K. and Li, H., 2018. Evolution law and stratification management of urban historical landscape. *Urban Development Research*, 25(3), pp.59-69.

Pei, Y., Yang, R. and Dang, A., 2022. Interpretation and value evaluation of historical stratification process of Yulin Ancient City based on urban historical landscape method. *Urban Development Research*, 29(7), pp.128-136.

Cao, Y. and Li, H., 2019. Diachronicity and synchronicity in the protection of historic towns--Enlightenment and thinking of "Urban Historical Landscape". *Urban Development Research*, 26(10), pp.13-20.

Zhao, X., 2014. Integral protection method of canal settlement in North Zhejiang Province based on historic urban landscape--Taking Jiaxing famous city protection planning as an example. *Urban Development Research*, 21(8), pp.37-43.

Shen, Y. and Zhang, J., 2020. Protection of industrial heritage integrity from the perspective of historic urban landscape--A case study of Yongjiang Beigang District, Ningbo. *Southern Architecture*, (5), pp.8-15.

Yang, T., 2014. Exploration of sustainable holistic neighborhood protection methods from the perspective of historic urban landscape--A case study of the protection planning of historical and cultural neighborhood in Barkhor Street, Lhasa. *Modern Urban Research*, (6), pp.9-13.

Tu, L., Zhao, P.J., Hu, Y.J., et al., 2021. Discussion on stratified cognition and holistic protection of traditional villages--Introduction of historic urban landscape method. Urban Development Research, 28(11), pp.92-97.

Case Study Report

Unveiling Varanasi's Legacy - A Visual and Historical Analysis of Evolution

Pooja Kumari[1], Research Scholar, Department of Architecture, Planning, and Design,

IIT BHU, Varanasi, 221005, India

Rabi Narayan Mohanty[2], Assistant Professor, Department of Architecture, Planning, and Design,

IIT BHU, Varanasi, 221005, India

poojakumari.rs.apd23@itbhu.ac.in, rnmohanty.apd@iitbhu.ac.in

Abstract

Varanasi, also known as Kashi, holds immense significance in Hinduism, Buddhism, and Jainism, making it one of the world's oldest continuously inhabited cities. The city's ghats (riverfront), temples, havelis (mansions), and narrow lanes are not merely standalone structures; they are testaments to a living legacy, a narrative that speaks volumes about the city's rich history and urban development. Numerous kingdoms and religious movements have influenced the architectural fabric of the city. This research unveils the main factors influencing Varanasi's architectural landscape through close observation and analysis of the city's built environment and examining historical writings and archaeological artefacts. Gaining a deeper understanding of Varanasi's dynamic past and present through its architecture paves the way for its continued preservation and evolution. Data collection required the following steps: mapping, photography, referring old texts, documentation, and interpretation. Tools like AutoCAD, GIS and literature review were used to condust this study. The main of this study to develop an inventory by detailed documentation for various structure and that will a great help for studying architectural evolution, recording history and conservation.

Keywords

Cultural landscape, Urban Development, Architectural evolution, Social fabric, Built environment, preservation

1 Introduction

Varanasi always has been a spritiual and culture center with such significance religious importance and deep historical roots. Its beautiful architectural diversity reflects rich history. But, due to its rapid ueabisation, the city faces danger to its heritage. This study aims to investigate the architectural development of Varanasi, examining its unique designs, building materials, and the influences on its cityscape. Varanasi has different names, from various time periods, Kashi is one of them. This city holds a very significant places for various

religions such as Hinduism, Buddhism, and Jainism. One of the oldest living city, the history goes back to thousand years, which is reflected in its architectural landscapes. Along with its architectural diversity, ghats, temples and narrow streets potrays city's lively and vibrant social life. Studying the architectural evolution of the city will help to take a peek through the infuence of various rulers and religions.

With the passage of time, architectural diversity of the city reflects in mosques, temples, ghats and forts. But rapid urbanization is changing the fabric of the city with the usage of recent materials like- concrete and less detailed features on the buildings are replacing traditional materials. Unique identity and cultural importance of the city faces risks from these changes. The aim of the study to explore or identify the main elements that is affecting original landscape while urbanization by studying archeological documents and studying buildings. This research aims to help preserve Varanasi's valuable heritage for future generations by studying the city's architectural changes, key styles and materials, and factors shaping its urban landscape.

2 Research Methodology

This research is divided into 3 steps methodologies: data collection, data analysis and inventory creation. The main tools utilized in this study was photography for documentation, reconnaissance survey for initial analysis and comprehensive literarture review for the base knowledge. After data collection, it was analysed to identify the problems and by the help of literature, inventory creation took place. This methodical strategy enabled a strong comprehension of the research subject and built a sturdy base for future discoveries and suggestions as shown in figure 1.

3 Site Introduction

Varanasi, also called Kashi, showcases a mixture of historical opulence, spiritual holiness, and cultural liveliness that attracts tourists from various locations. Varanasi is situated at the heart of the Ganges valley in North India, on the eastern side of Uttar Pradesh, along the Ganges' left crescent-shaped bank as shown in figure 2. Varanasi has a population of 1,201,815 (National Institute of Urban Affairs, 2021), with a sex ratio of 887 per 1000 males and a literacy rate of 79%. The urban expansion in the city's surrounding areas is evident as the growth rate dropped from 37% in 1991 to 10% in 2011. It is worth mentioning that Varanasi's population is made up of 53% males, 47% females, and 10.75% children, along with a significant working-age group ranging from 15 to 59 years old. Around 25.20% of the urban population lives in slums, highlighting difficulties during urbanisation. The literacy rate is 79%, with males slightly edging out females regarding literacy levels (Varanasi Development Authority, 2021).

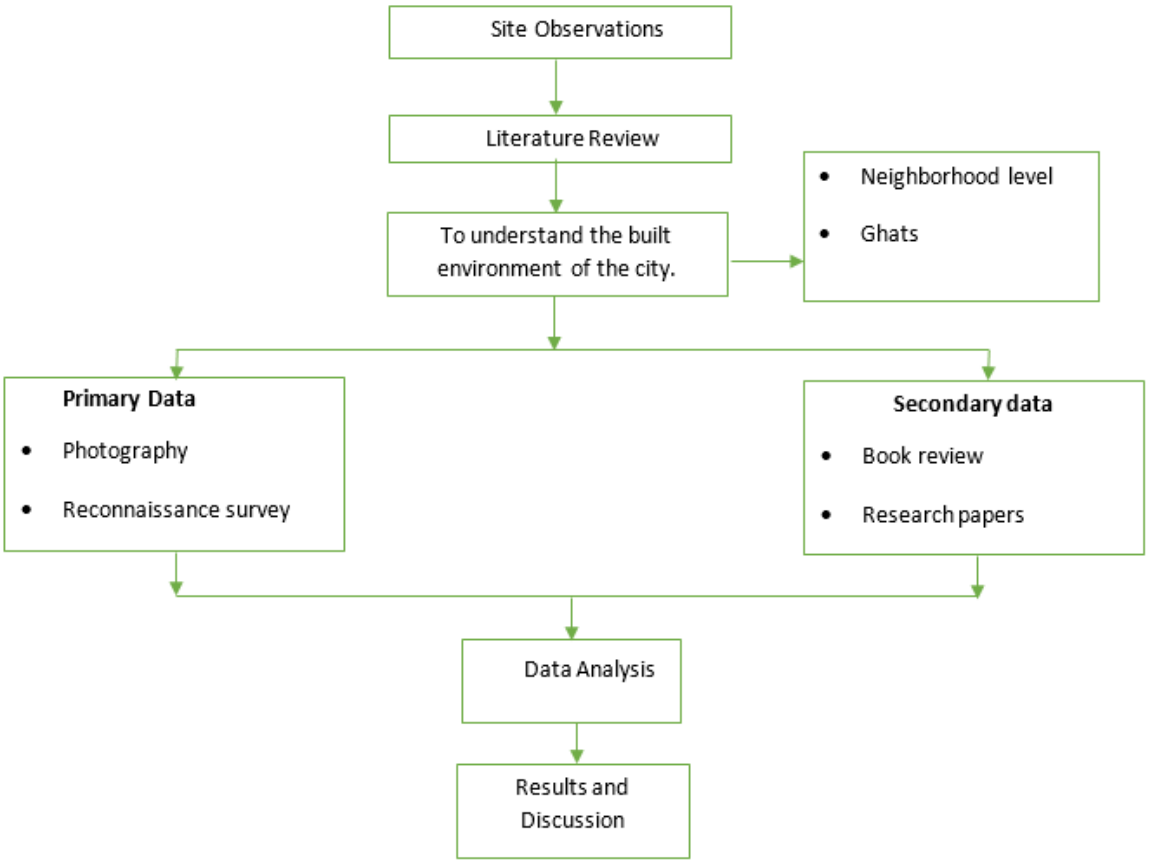


Figure 1 Methodology, Source: Author

3.1 Accessibility and Tourism

Varanasi is easily accessible and has multiple transportation options, such as Lal Bahadur Shastri Airport and important railway junctions like Varanasi Cantt and Mughal Sarai. Varanasi is connected to major destinations by National Highways 2, 7, and 29, improving its accessibility. The appeal of Varanasi goes beyond its easy access, which is evident in the large number of yearly visitors it draws. Varanasi has a total of 129,405,720 visitors, comprised of 129,182,767 domestic travellers and 222,953 foreign tourists (UP Tourism, 2024).

3.2 Economic Landscape

The average annual per capita income of Varanasi city is INR 1,93,616, which is higher than the national average of INR 68,747 (Varanasi Development Authority, 2021). Economically, Varanasi boasts a diverse sectoral presence that contributes to its livelihood. The primary sector sees the cultivation of mangoes and the production of paan, traditional betel leaf preparations that are integral to local customs. In the secondary sector, Varanasi is renowned for its silk industry, producing some of the finest silk fabrics in the country

(Charaipotra *et al.*, 2018). The tertiary sector plays a significant role in the city's economy, driven by pilgrimage tourism that draws days and wide to Varanasi's sacred sites and historic temples.

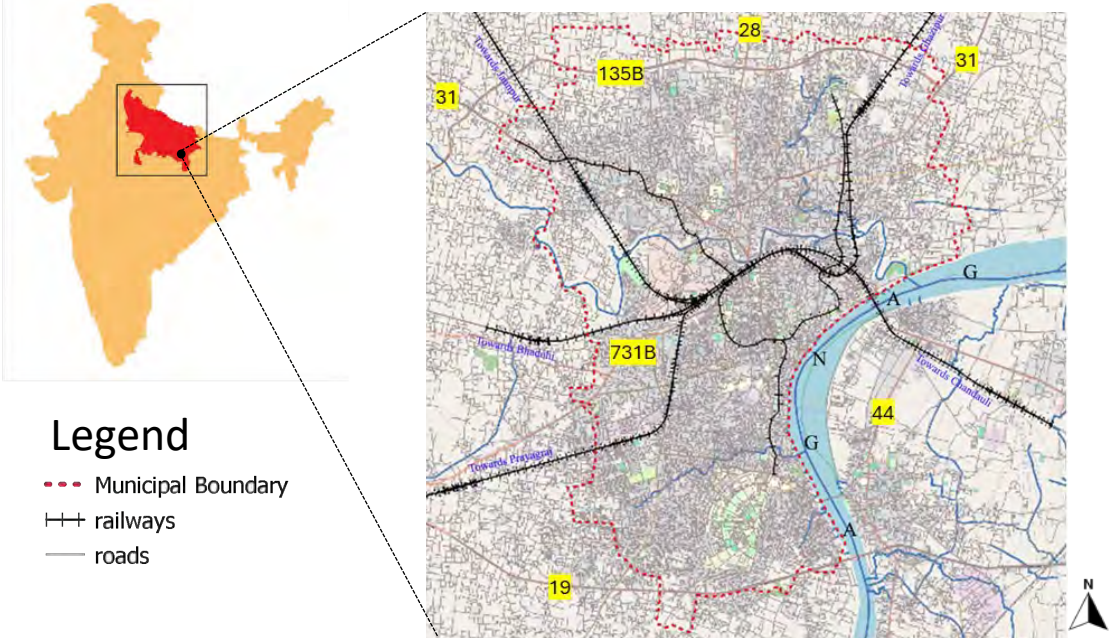


Figure 2 Site Location, Source: Author (r1)

3.3 Transport Network

Varanasi has a highly efficient transport system with good rail, air, and road connections. The Lal Bahadur Shastri Airport, situated about 24 km away from the city centre, is a crucial gateway for air passengers. Three main rail connections linking Varanasi to Lucknow, Bhadoi, and Prayagraj are Enhancing the city's strategic location on the Delhi-Kolkata railway route. Furthermore, Varanasi is connected to important metropolitan cities such as Delhi and Kolkata, as well as significant cities in Uttar Pradesh like Lucknow, Prayagraj, Jaunpur, and Gorakhpur, through its road network (Modak and Sanyal, 2024). Roads cover 11 and 15% of Varanasi's land; less than half of the city can be reached via paved roads. Furthermore, the haphazard growth of the city, along with the residents' lack of awareness and malfunctioning traffic signals, have contributed to the traffic problems in Varanasi (Varanasi Development Authority, 2021).

3.4 Urban Evolution and Planning Challenges

Varanasi, one of the oldest cities still inhabited in the world, has experienced substantial changes influenced by its historical importance, cultural diversity, and religious significance. Yet, the city faces contemporary urban planning difficulties due to fast urban growth, increasing population, and the need to harmonise development and heritage conservation. Responding to these challenges, Varanasi has embraced the necessity of sustainable urban planning. Efforts are being made to tackle infrastructure shortcomings, environmental concerns, and housing requirements, emphasising inclusive growth for all inhabitants (B SINGH, 2007).

In essence, Varanasi is a testament to India's cultural legacy and rich heritage, fusing tradition and modernity to form a city that is both timeless and progressive. Varanasi's spiritual atmosphere, impressive architecture, and lively markets attract visitors to embrace its enchanting allure fully and encounter the heart of India (Singh, 2007).

4 Problem Identification

Varanasi's historic districts and structures encounter numerous difficulties due to incorporating different materials and architectural designs throughout the years. The haphazard construction method has caused a lack of aesthetic unity and visual imbalance (r2) leads to inadequate showcasing of the city's architectural history. Including contemporary electronic devices and technologies in these classic buildings adds to the visual mess and compromises their historical authenticity.

Furthermore, combining different architectural styles without a unified design approach has resulted in a fragmented cityscape, where blending two separate styles lacks harmony and consistency. The combination of various architectural elements reduces the buildings' attractiveness and impairs their historical and cultural importance.

Neglecting and failing to maintain have led to a decline in building conditions, diminishing the city's architectural appeal and cultural significance. The presence of street vendors and vehicles parked in these areas contributes to urban chaos and reduces the walkability of the streets, presenting obstacles for locals and tourists.

Tackling these obstacles in Varanasi's historic neighbourhoods and structures necessitates a comprehensive strategy emphasising conservation, renovation, and environmentally friendly city planning. Varanasi can restore the beauty of its historic buildings by utilising careful design interventions, heritage conservation measures, and urban planning strategies, all while maintaining a balance between tradition and modernity as depicted in figure 3.

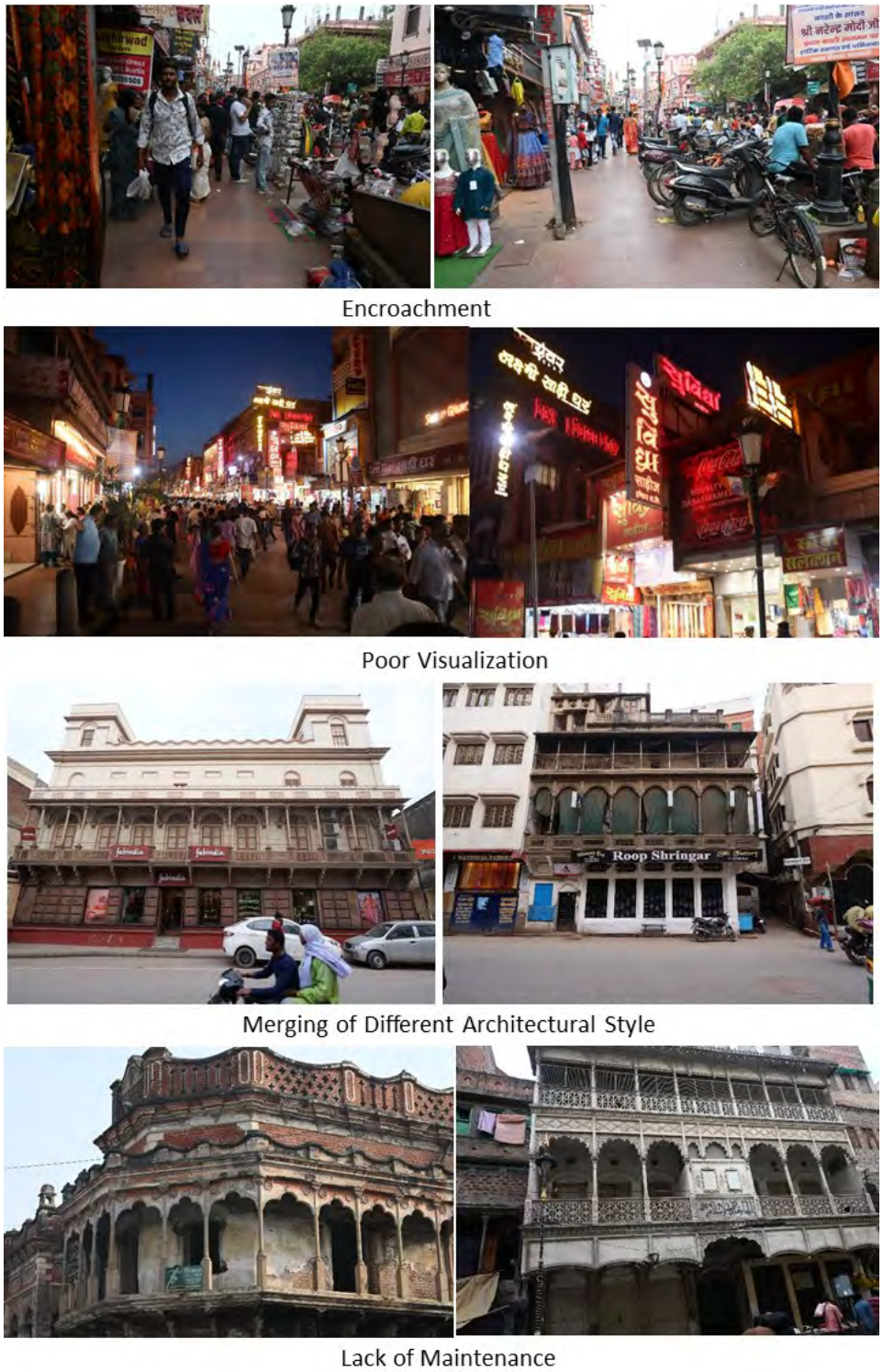


Figure 2 Problem Identification, Source: Author

5 Results

Varanasi ranks as the state of Uttar Pradesh's fifth most densely populated city. A Class II city has a municipal area population of 1,201,815 (Census, 2011) and a total urban agglomeration population of 1,435,113. The Municipal Corporation covers 82.1 square kilometres, while the urban agglomerations cover 793 square kilometres.

Varanasi, also called Banaras or Kashi, is the "spiritual capital of India" and is among the world's most ancient inhabited cities. The city showcases vibrant living traditions of religious faith, rituals, numerous festivals, and traditional ancient forms of worship and belief. Varanasi, located on the banks of the Ganges River, is famous for its temples, ghats, archaeological sites, silk and textile industry, various forms of asceticism, spiritual and meditative practices, education, music, dance, handicrafts, and art forms that have thrived through the generations (The Great Varanasi, 2023a).

The timeline provided outlines significant events in Indian history, starting with the Vedic Civilization in the 8th BCE and culminating in independence in 1947. Key periods include the Buddhist Civilization in the 2nd BCE, the rule of the Nawab of Oudh in the 12th century, and the Mughal Empire's peak under Aurangzeb's rule in the 17th century. The 16th century saw the rise of Man Mahal and Akbar's rule, while the 18th century witnessed the rule of the Marathas, Raja of Banaras, and the beginning of British colonial rule as shown in figure 4 (The Great Varanasi, 2023b).

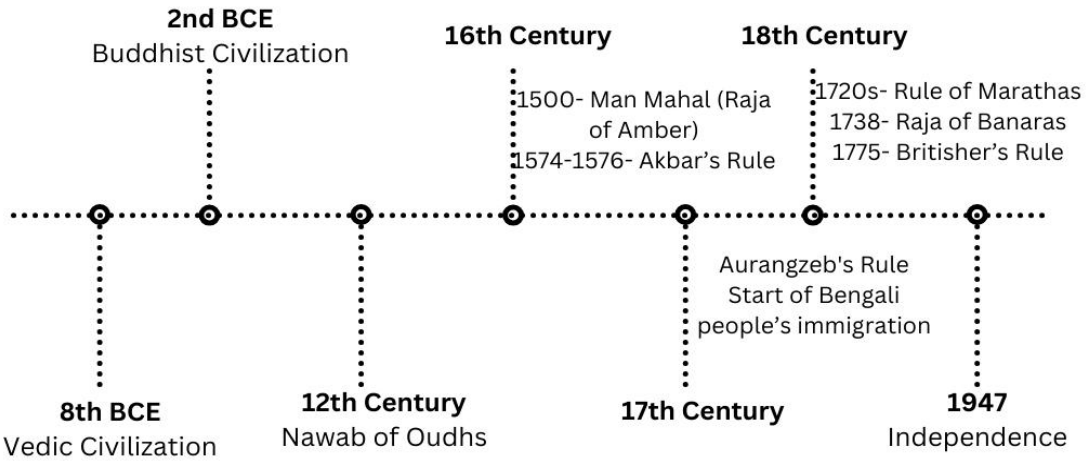


Figure 3 Historical Timeline of Varanasi, Source: Author

Tourist attractions in the city include heritage monuments and temples like Kashi Vishwanath, Sarnath, Ramnagar Fort, and the 84 ghats spanning 6.8 km along the Ganga River banks. Its congested urban areas and narrow streets also shape the city's identity. The transformation into the top sacred spot for Hinduism, along with the rich mix of cultures and impressive combination of natural beauty and architectural wonders, has granted the city its special identity and a one-of-a-kind urban structure. The interconnected maze of small roads in the historic old town links the important cultural landmarks, the ghats, and allows entrance to the river. The fertile alluvial Gangetic plains are where Varanasi is located geologically.

Varanasi, an ancient and highly respected city in India, showcases a diverse blend of historical periods and cultural impacts that have moulded its cityscape. The city's development reflects the various cultures and ruling families which have influenced its architectural history.

The Vedic civilisation, famous for its spiritual and philosophical impact, thrived in the northern region of Varanasi, close to the Varuna plains. This period established Varanasi as a holy hub for education, worship, and intercultural communication. In the era of Buddhism, Sarnath became well-known for its religious teachings and impressive architecture, with structures constructed in the northern-western part of the city. The architectural heritage of Varanasi was enriched by the introduction of Buddhist influence, merging artistic creativity with spiritual beauty.

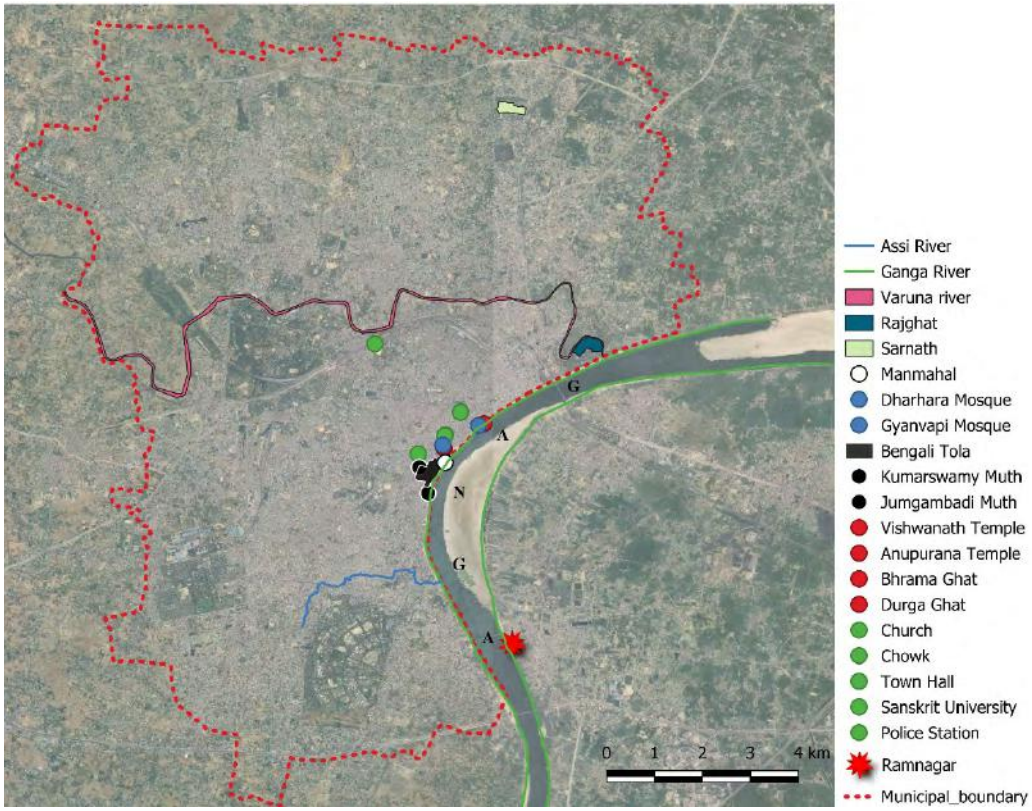


Figure 5 Location of different historical sites, Source: Author (r3)

Bengali settlers transformed the southern area of the Vishwanath Temple into a cultural hub, infusing Varanasi with their distinct traditions and customs and enhancing the city's social dynamics with their lively cultural rituals. The rulers of Banaras strategically placed their Ramnagar fort on the eastern side of the Ganga River, showcasing their dominance over the area. This impressive piece of architecture represented the royal family that once governed Varanasi as demonstrated in figure 5.

Later leaders, like the Marathas, tried to revive the city's old buildings by building new temples and protecting the sacred Panchkoshi Yatra Marg. Their endeavours were focused on respecting Varanasi's legacy and

maintaining its spiritual importance for the coming generations. In the British colonial era, Varanasi experienced growth in the outer areas as the British government aimed to update and reorganise the crowded original city centre. This growth showcased the impact of colonialism on the urban growth and planning of Varanasi (Madhuri Desai, 2017).

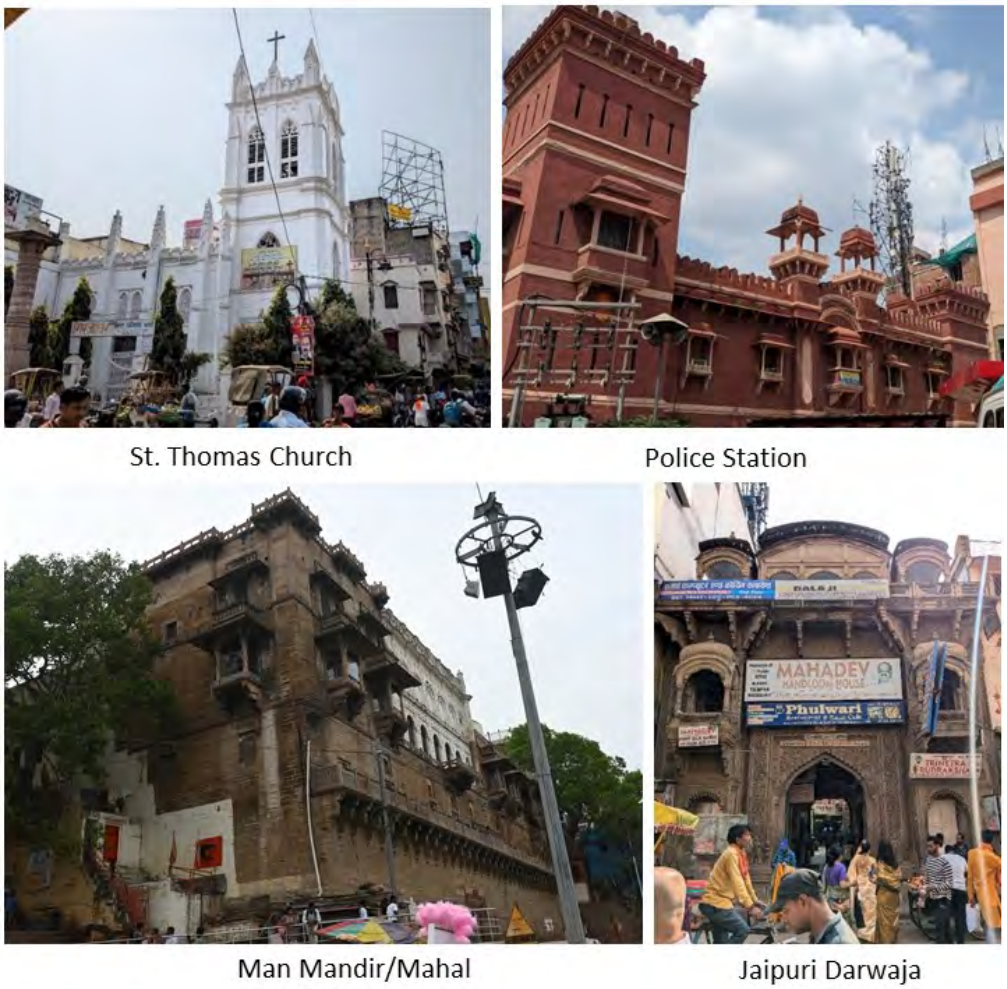


Figure 6 Prominent Buildings of Different Era's, Source: Author

The fortification on the ghats of the Ganga river was a showcase of power from past rulers, who ruled or visited Varanasi. Blend of various architectural style gives Varanasi a unique identiry and royal history through historical sites like Man mahal, Barhma Ghat, Durga Ghat, mosques, temples and forts as shown in figure 6.

5.1 Inventory

Table 1 shows the inventory as a result of this study. This table contains the detail of different architectural style amon various centuries. Along with major buildings and landmarks for that particular time period it contains the details like- building materials and key architectural features.

Table 1 Inventory, Source: Author

Time Period	Type of Architecture	Materials	Architectural Elements	Main Buildings
16th century	Rajasthani Architecture	Stone Baked bricks, Limestone, Marble, Timber, Stucco	Chhatris (cenotaphs) Jharokhas (balconies) Jaalis (intricate latticework)	• Man Mandir • Bindu Mahadev Temple • Kanganwali Haveil • Jaipuri Darwaja
17th century	Mughal Architecture	Bricks Sandstone Marble	Minarets Calligraphy Geometric Patterns bulbous domes large iwans (arched portals) intricate stucco work	• Gyanvapi Mosque • Dharhara Mosque
17th century	Bengali Architecture	Terracotta Tiles Bricks Wood Lime	Terracotta panels depicting mythological scenes Floral motifs	• Jangambadi Muth • Kumarswamy Muth • Bengali Tola • Durga Temple • Panchkroshi Marg Revival
18th century	Maratha Architecture	Stones Granite Limestone	Tapering shikhara (spires) Fortress like structure	• Anpurana Temple • Barhma Ghat • Durga Ghat • Brahmapuris
18th century	Colonial Architecture	Bricks Iron Steel Glass Concrete	Octagonal structures and rectangular wards, pointed arches, elaborate decorations, and spires in the Churches, Neo-Classical elements like columns, symmetry, and pediments	• Urban improvement entailed wider roads, open spaces, and uniform building standards. Construction of Town Hall, • Queen's College (Sanskrit University) • Chowk • Police Station • Prince Wales Station • Alfred Hall

6 Broder Impact of Project

This study provide information on construction techniques and materials from various periods, which is important for the conservation of heritage buildings. This study can help to strengthen the social bonds through common pasts and helps to promotes pride among the community.This can impact the area's economy by renovating the space and historic buildings. Well-maintained heritage sites boost tourism, bringing in visitors, increasing income for local businesses, and opening up job prospects.

7 Conclusion

This study aims to thoroughly investigate Varanasi's architectural legacy, emphasising protecting the city's historic buildings and designs to maintain its true essence. The goals of this research involve pinpointing buildings built in various historical periods, documenting the architecture of heritage structures, and creating a map to show the distribution of these buildings throughout Varanasi. Moreover, the study seeks to evaluate the impact of historic structures on the economy, society, and environment, emphasising their importance in promoting community pride and eco-friendly tourism. Varanasi has evolved drastically over time. As the new rulers came from different regions, cities adopted various elements from those regions. Various buildings can also be seen in the city from different periods, ranging from the Buddhist civilisation to the British Era. The project aims to boost tourism and improve cultural heritage experiences for visitors by renovating the public spaces around these historic buildings.

Moreover, it is essential to educate people about the importance of these buildings to foster a sense of duty towards their upkeep and protection. Creating standards and regulations for preserving and repurposing historical structures is crucial to guarantee their enduring safeguarding and ongoing cultural significance. Finally, the main goal is to find a way to maintain Varanasi's architectural history while also meeting urban growth needs, ensuring that old and new structures blend seamlessly into the city's landscape.

8 Funding

This research is funded to the first author by the Ministry of Education, India, as a part of PhD curriculum.

9 References

B SINGH, R. P. (2007) 'Urban Planning of the Heritage City of Varanasi (India) and its role in Regional Development', 8, pp. 259–268. Available at: www.corp.at.

Charaipotra, Y. *et al.* (2018) 'ScienceDirect Prioritizing Attributes for Pedestrian Facility Improvement in a Historically Significant Tier-II Indian City-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY'. Available at: www.sciencedirect.com.

Madhuri Desai (2017) *BANARAS RECONSTRUCTED Architecture And SAcred SpAce in A hindu holy city*. Seattle and London: univerSity of WAShington preSS.

Modak, S. and Sanyal, S. (2024) 'Road network structure of Varanasi city based on connectivity and spatial pattern', *GeoJournal*, 89(1), pp. 1–17. doi: 10.1007/s10708-024-11003-y.

National Institute of Urban Affairs (2021) *National Institute of Urban Affairs Understanding Varanasi City from the lens of Disability Inclusion*. Varanasi.

Singh (2007) 'Varanasi (India): Perspectives and Visions of Strategic Urban Development of a Heritage City', *43rd ISOCARP Congress Antwerp*, pp. 1–15.

The Great Varanasi (2023a) *The Changing Face of Varanasi: Examining the City's Rapid Development and Urbanization*. Available at: https://varanasipedia.com/history-of-varanasi/the-changing-face-of-varanasi-examining-the-citys-rapid-development-and-urbanization/ (Accessed: 21 October 2024).

The Great Varanasi (2023b) *Varanasi Through the Ages: A Historical Timeline of the City's Evolution*. Available at: https://varanasipedia.com/history-of-varanasi/varanasi-through-the-ages-a-historical-timeline-of-the-citys-evolution/ (Accessed: 21 October 2024).

UP Tourism (2024) *https://uptourism.gov.in/hi/post/Year-wise-Tourist-Statistics*. Available at: https://uptourism.gov.in/hi/post/Year-wise-Tourist-Statistics (Accessed: 18 October 2024).

Varanasi develoment Authority (2021) *Varanasi Master Plan 2031 - Booklet*. Varanasi.

Case Study Report

Research on the protection and renewal of overlapping sites within the context of cultural ecology perspective

Panpan FENG, Chongqing University, China

Abstract

Industrial heritage, as an important part of human cultural heritage, is not well protected and reused in our country at present, and the experience and examples in dealing with overlapping heritage sites are even more limited. Studying its protection alone cannot fundamentally solve the problem. It must be placed in a comprehensive cultural ecosystem including the social environment, natural environment, and human environment, so that various elements can be integrated, intertwined, and coexist with each other. Faced with the complex cultural environment and the decline of its own industrial culture, this study takes the overlapping area of the Cultural Heritage for Wang mang's Nine Temples and the industrial relics for China Steel Plant as an example. Starting from the context of cultural ecology perspective, this study proposes three major implementation strategies for respecting cultural evolution, building cultural levels and strengthening cultural elements. Specific strategies are as follows: To begin, it is important to take a holistic view and comprehensively evaluate the cultural ecological evolution. The second step involves constructing a cultural ecological network based on the Symbiotic relationship. Finally, it is necessary to establish a cultural ecological memory with a coordinated concept.

Keywords

Cultural ecology, Cultural Heritage, Wang Mang's Nine Temples ruins, Industrial relics, Symbiotic protection

1. Project starting problem

1.1. Historical evolution

The ruins of Wang mang's Nine Temples are pivotal ritual architectural sites in Chinese history due to their unprecedented scale and unique structure. With the acceleration of urban construction in Xi'an, the China Steel Plant built on its ruins is the first metallurgical machinery production plant built in Shaanxi Province, leaving a large amount of industrial landscape and spatial resources for the city(Figure 1). Effectively protecting and showing cultural Heritage, as well as preserving and updating industrial relics in this overlapping area, has become an urgent matter given the increasing prominence of cultural heritage.

Figure 1. Historical evolution of Wang Mang's Nine Temples ruins & Steel Plant. Source: By Author.

1.2. Starting problem

One of the conference themes is cultural heritage for sustainable urban development, which harmonizes perfectly with the objectives of this research report. As an important part of human cultural heritage, the current level of protection and reuse of industrial heritage varies internationally, and the experience and examples of dealing with overlapping heritage area are even more limited. Faced with the complex cultural environment and the decline of its own industrial culture, this study takes the overlapping area of the ritual building area of the Wang Mang's Nine Temples ruins and the industrial relics of the old China Steel Plant as an example. Starting from the context of cultural ecology, this study proposes three major implementation strategies for respecting cultural evolution, building cultural levels and strengthening cultural elements. It forms a composite cultural ecosystem with the surrounding cultural environment, providing constructive opinions and feasible strategies for the protection and renewal of dual heritage.

Figure 2. Project starting problem. Source: By Author.

2. Project context

Nowadays, the transformation of industrial sites is stereotyped, such as industrial landscape parks (Beijing ShouGang Industrial Landscape Park), cultural and creative industrial parks (Beijing 798), etc. Therefore, based on the theory of cultural ecology, starting from the core viewpoint of cultural ecology theory "dynamic balance", from the perspective of structure and function, we follow the principles of holistic protection, dynamic balance, and in-situ protection. Combining the viewpoint of system theory to treat culture, we study the relationship between the system interior (factory texture and remaining

buildings), the system and surrounding environment (factory and surrounding plots), and the system and external environment (urban construction in Xi'an) to comprehensively examine cultural issues. In this regard, the renewal and transformation of the overlapping area is a realistic path for the practice of cultural ecology theory. Starting from the micro level, we can better use the methods of cultural ecology to solve the current dilemma of the protection, renewal and reuse of the overlapping area of the ruins. The following is a summary of the current problems in the SITE.

2.1. The cultural heritage lacks protection and display

Due to the urban construction in the central urban area of Xi'an and the lack of awareness of protection among the people, the site of Xi'an China Steel Plant was directly superimposed on it, which damaged the protection of the Wang Mang Nine Temples Site. Its original "U"-shaped building structure consisting of a central building, a wall, four gates and four corners was also destroyed(Figure 3). It was a huge innovation in architectural form, although it was burned down shortly after it was built. Afterwards, the ruins under the rammed earth were superimposed and not fully displayed.

2.2. The industrial relics needs to be protected and renewed

The subsequent shutdown and relocation of the China Steel Plant resulted in many idle factory buildings and a large area of idle space resources in the factory area, and the surrounding residents also lacked public activity venues for leisure and entertainment. In recent years, the abandonment of the factory area has caused serious damage to the appearance of many industrial relics, but its workshops, auxiliary buildings, and office buildings are still there, but they have not played their due value in all aspects(Figure 4). It is imperative to protect and utilize them.

2.3. The contradiction between urban construction and protection of the overlapping area

With the development of Xi'an, the "withdraw from the second and enter the third" industrial policy was issued, and the China Steel Plant stopped relocating. As a result, the original factory building was abandoned and vacant, and the surrounding residents lacked public activity space, and the industrial development of the plot lagged behind. While the Wang Mang's Nine Temples ritual building area under the rammed earth and the China Steel Plant industrial remains on it brought opportunities for the development of the plot, many construction requirements also brought restrictions to the development of the plot. How to balance the contradiction between dual heritage protection and urban development and construction is a contradiction that needs to be solved urgently.

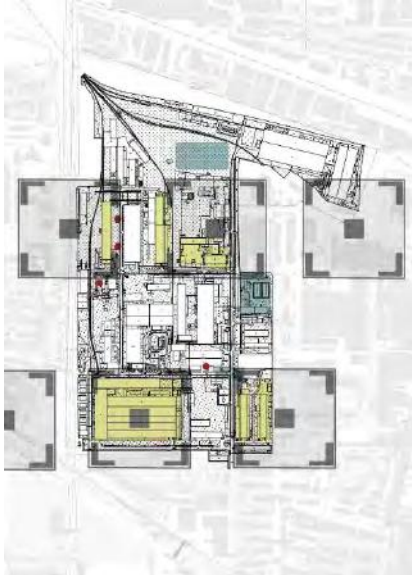


Figure 3. Overlay of Wang Mang Jiu Temple Site and China Steel Plant Site. Source: By Author.

Figure 4. Architectural features of some parts of the China Steel Plant. Source: By Author.

3. Project results AND Broader impact

3.1. Respect cultural evolution

The overlapping area of the double heritage has experienced the evolution from Han culture to industrial culture, from the ruins of the ritual building area of the Wang Mang's Nine Temples to the industrial remains of the China Steel Plant. The inherent cultural value of the ruins area is quite high. The project object of cultural ecology is culture. It respects the cultural evolution process of the overlapping area of urban ruins. While focusing on the present, it also needs to inherit the cultural context and look to the future.

First, inherit the cultural context to enhance the readability of culture. On the basis of continuing the traditional Han culture, industrial culture, and Silk Road culture, implant new creative culture, resort out the cultural context, and realize the symbiosis of multiple cultures on the site. Second, focus on meeting the needs of multiple groups of people in the present. The essential service object of urban space renewal and transformation is people. Understand the needs of multiple groups of people, put forward targeted transformation suggestions, and formulate a reasonable spatial function layout to meet multiple needs. Third, focus on the future to stimulate the vitality of the cultural and creative industry. The vigorous development of a place is inseparable from the support of the economic industry. A reasonable and appropriate layout of the cultural and creative industry will bring new vitality to the land,

thereby promoting the Han culture and industrial civilization in the overlapping area of the double ruins(Figure 5).

Figure 5. Industrial Culture Experience Hall AND Maker Market. Source: By Author.

3.2. Build cultural levels

The protection and reuse of the site cannot exist in isolation, but must coexist and prosper with the surrounding cultural environment, social environment, and natural environment. From the perspective of cultural ecology, urban space is a diverse cultural circle composed of local culture, society, economy, politics, etc. Compared with the Han culture of the site, industrial culture is more like an invasive culture that has entered the cultural ecosystem of the site. Therefore, our protection and renewal strategy should start from the symbiotic view, classify, grade, and hierarchically give it corresponding protection, and place it in the overall cultural ecosystem of the surrounding environment, link it with cultural clusters such as the Han Chang'an City Ruins in the north and the Da Ming Palace Ruins in the east, form a cultural ecological chain, and then construct a cultural ecological network.

First, the revival of cultural clusters. Cultural clusters are like cultural units of different sizes in space. Extract the cultural elements of the cultural clusters, awaken the historical memory of the cultural clusters, revitalize the carrying space of the cultural clusters, and realize the revival of the cultural clusters. Second, the link of cultural chains. The link of cultural chain is the link of urban space. A single cultural cluster cannot exert its maximum vitality. The link between cultural clusters such as the ritual architecture of the Han Chang'an City Ruins, Ming Tang Bi Yong, Silk Road Group Sculpture, Kaiyuan Gate, etc., can make the entire cultural ecosystem more symbiotic and prosperous. Third, the integration of cultural clusters. Diverse cultures are in a comprehensive cultural cluster, forming a cultural circle of double ruins superimposed sites. When the cultural clusters, cultural chains, and cultural clusters in the cultural circle reach a state of dynamic balance, a stable cultural ecosystem will be formed(Figure 6).

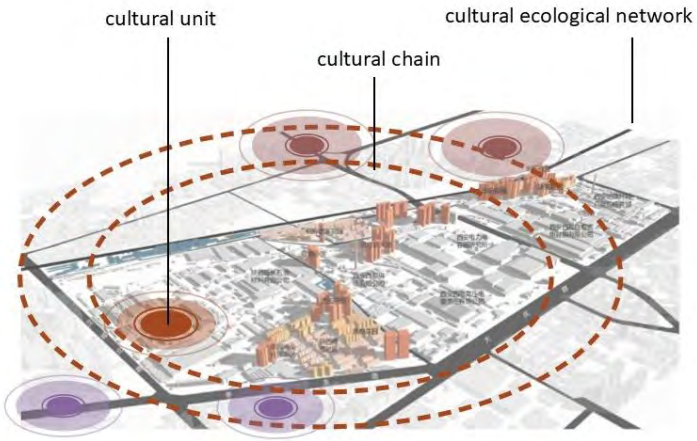


Figure 6. Construct a cultural ecological network. Source: By Author.

3.3. Strengthen cultural elements

The structure of the cultural ecosystem of China Steel Plant has multi-dimensional diversity, the coordination of Han culture and industrial culture, the coordination of tradition and modernity, and the mutual influence and restriction of various cultural elements. Protection and renewal is to coordinate these different cultural elements and strengthen their influence, transforming the original abandoned factory into an industrial heritage museum, artist workshop, cultural and Creative Center, commercial supporting facilities, etc., and coordinating tradition and modernity to shape the cultural ecological atmosphere.

Starting from the view of coordination, it can be regarded as a targeted protection of the classification and block of the site to shape its cultural atmosphere in the details. The main points can be divided into two points: protection and renewal of material cultural elements and protection and renewal of intangible cultural elements. First, create a recognizable space. Identify the spatial cultural elements through specific means such as exposing some old structures, comparing the old and new elements, and abstracting cultural elements(Figure 7). Second, awaken cultural memory. Record the special events that occurred in different periods such as the Han cultural memory and industrial memory of the site, plan cultural activities, immerse in cultural experience, etc., to arouse people's civilization resonance and build the collective memory of the people(Figure 8).

Figure 7. Expose old building structures. Source: By Author.

Figure 8. Application of Silk Road Cultural Elements. Source: By Author.

3.4. Future Development

The overlapping area of the site is the product of the joint action of multiple heritage elements from multiple eras. However, the protection and renewal of the overlapping areas in the city is not a new topic. The isolated study of its protection cannot fundamentally solve the problem. It is necessary to place it in the comprehensive cultural ecosystem of the social environment, natural environment, and human environment, so that all elements can be integrated, interconnected, and coexist and prosper. Faced with the complex cultural environment of the Sinosteel plant area under the overlap of the two sites and the decline of its own industrial culture, from the perspective of cultural ecology, this paper proposes a practical guidance strategy based on respecting cultural evolution, building cultural levels, and strengthening cultural elements, so that it can coexist and prosper with the surrounding cultural environment, thereby forming a complex cultural ecosystem for the site to better protect the two sites.

4. References

Landorf, C. (2009). 'A framework for sustainable heritage management: a study of uk industrial heritage sites'. International Journal of Heritage Studies, volumes(15,6), 494-510.

Zhang, J., Cenci, J., Becue, V., Koutra, S., & Liao, C. (2022). 'Stewardship of industrial heritage protection in typical Western European and Chinese regions: Values and dilemmas'. Land, volumes(11,6), 772.

Wu, X., Yu, L., Fang, H., & Wu, J. (2021). 'Research on the protection and reuse of industrial heritage from the perspective of public participation—a case study of northern mining area of dingshan, China'. Land, volumes(11,1), 16.

Wang, H., Ge, J., Chen, X., Zhou, Q., & Huang, K. (2024). 'Heritage Tourism Development Should Take Care of Industrial Heritage Protection: A Study on the Development Strategy of Industrial Heritage Tourism in Nanjing'. Sustainability, volumes(2071,1050), 16(19).

Yu, J., Safarov, B., Yi, L., Buzrukova, M., & Janzakov, B. (2023). ‘The adaptive evolution of cultural ecosystems along the silk road and cultural tourism heritage: A case study of 22 cultural sites on the Chinese section of the silk road world heritage’. Sustainability, volumes(15,3), 2465.

Cotella, V. A. (2023). ‘From 3D point clouds to HBIM: application of artificial intelligence in cultural heritage’. Automation in Construction, volumes(152), 104936.

Rao, Y., Zou, Y., Yi, C., Luo, F., Song, Y., & Wu, P. (2023).‘Optimization of rural settlements based on rural revitalization elements and rural residents’ social mobility: A case study of a township in western China’. Habitat International, volumes(137), 102851.

Cranmer, E. E., Tom Dieck, M. C., & Jung, T. (2023). ‘The role of augmented reality for sustainable development: Evidence from cultural heritage tourism’. Tourism Management Perspectives,volumes(49), 101196.

Research Paper

Impacting Sustainability Operations.

Integrating Local Knowledge and Nature-Based Solutions through Theoretical Frameworks and Innovative Cartography for Cultural Impact

Antonella CONTIN, Politecnico di Milano, Italy

Abstract

This research explores the integration of local knowledge (CBS) and nature-based solutions (NBS) within metropolitan sustainability frameworks, emphasizing the importance of context-driven approaches in urban planning. Acknowledging the shortcomings of existing policies, particularly in addressing poverty and inequality, the study proposes a transdisciplinary framework that fuses Culture-Based Solutions (CBS) with NBS, creating a unified knowledge ecology termed "Metropolis as Heritage." Utilizing innovative cartographic techniques (Metropolitan Cartography), the research aims to enhance territorial intelligence, enabling policies that reflect local realities and foster inclusive growth. By examining the interplay between human behavior, cultural practices, and ecological systems, the study highlights the potential of metropolitan urban-rural connections (MetroURLs) to serve as sustainability commons. Key findings underscore the need for institutional capacity and community engagement to implement robust policies that promote resilience and social equity. The research advocates for a new antifragile paradigm of metropolitan urbanity, where culture becomes a vital agent of change, facilitating collective agency and a sense of belonging. Ultimately, this work seeks to redefine urban landscapes through a holistic approach, bridging nature and culture to achieve sustainable development aligned with global agendas like the New Urban Agenda and Sustainable Development Goals.

Keywords

Antifragility, Local Knowledge, Metropolis as Heritage

1. Integrating Local Knowledge and Nature-Based Solutions.

1.1. Enhancing Urban Planning and Policy through Territorial Intelligence and Metropolitan Cartography

Current frameworks often overlook ground realities, as evident in SDG 11's insufficient attention to poverty and inequality. To address this, we should integrate local ecological knowledge through Culture-Based Solutions (CBS) and Nature-Based Solutions (NBS); we named this unified *knowledge ecology* (Castells, 1996), Metropolitan Heritage. Using innovative tools like cartography, urban

policies must reflect local contexts, economies, and cultural traditions, combining global insights with local knowledge for impactful outcomes. Developing a *theory of metropolitan culture* and leveraging advanced cartography can enhance urban planning and design.
Effective policies must guide citizens' behaviours towards desired results and challenge norms that neglect the planet's interests. Market-oriented approaches, particularly in tourism, should align with cultural and economic sustainability to promote inclusive growth.

Nevertheless, institutional capacity is vital to implementing robust policies that support urban transformation. However, to face the current climate crisis, integrating *operational culture* with local knowledge is crucial for stimulating *collective intentionality* (Barbera, 2023) to foster coherent urban planning and sustainable development. This approach addresses real-world complexities and benefits all urban residents equitably. This allows for the *symbolic capacity* to construct cultural practices focusing on the *collective agency.*

In Alessandro Balducci's 2023 work, "invisible cities" are the other side of the visible ones and are characterised by inequality, digital influence, and opaque governance that obstructs citizen participation. Balducci recognises urban life's visible and invisible elements, fostering social learning. Additionally, MSLab at Politecnico di Milano emphasises the importance of the physical context in defining sustainable culture. Understanding causal pathways in modern metropolises is essential for exploring how human behaviour impacts urban spaces and contributes to sustainable urban planning. Our research aims to develop and apply innovative local-scale resource management strategies through metropolitan architecture (Contin, 2015) approaches suited for urban areas. The central question focuses on creating a transdisciplinary framework to evaluate policies, management practices, and projects in metropolitan interphase areas by incorporating local ecological knowledge and understanding social mechanisms and practices. The problem addressed is that the physical structure of geographic relationships reflects *territorial intelligence*, encompassing social, economic, ecological, anthropological, and cultural aspects. Territorial intelligence refers to using spatial data and knowledge to improve land management and promote sustainable development, as the 7th Framework Programme for Research and Technological Development (7th FP) outlines. This program, active from 2007 to 2013, supported research and innovation across various fields, including spatial planning and resource management. This intelligence supports inclusion, redistribution, accessibility, and democracy, foundational for resilient urban transformations. According to that approach, subnational governments, with national funding, play a vital role in implementing systemic prevention measures and adapting climate funding to local needs. It could be fundamental, though, to allow the metropolitan governance dimension to have its funds to address modern climate policy better. Moreover, the European Union's emphasis on environmental and social governance (ESG)

highlights the strategic importance of sustainability, aligning with the research's goal of developing resilience frameworks for local and metropolitan governments.

The research employs a transdisciplinary approach focused on anti-fragility (Taleb, 2014) and de-risking, utilising the Metropolitan Cartography (Contin, 2021) tool to represent the metropolitan scale and the dynamic interplay between nature and culture, in line with the New Urban Agenda (NUA) and Sustainable Development Goals (SDGs). Innovative mapping methodologies assist in identifying, understanding, and designing *hybrid metropolitan landscapes*. Metropolitan Connectivity represents the spatial structure's connections, vital for the continuity of green-grey infrastructure. Maps help grasp the morphological structure of Green, Gray, and Blue Infrastructures, transforming urban-rural margins into potential sites for revitalising metropolitan cultural, natural, and anthropic services. This is a key objective of a Metropolis as a Heritage as promoted by the Heritopolis Society initiative.

Data collection methods include:

- Spatial Analysis: Mapping metropolitan landscapes to evaluate connectivity.
- Qualitative Research: Conducting interviews and focus groups with local stakeholders.
- Quantitative Research: Gathering data on energy, material, and land consumption within a metabolic framework.
- Case Studies: Identifying best practices in specific metropolitan areas.

Participatory Workshops: Engaging communities to co-create sustainable development initiatives.

Key findings emphasise integrating nature-based solutions (NBS) to develop culture-based solutions (CBS) that address social needs by merging nature and culture. The hypothesis is that metropolitan urban-rural connections (MetroURLs), incorporating NBS and CBS, can evolve into *new sustainability commons*, addressing various anthropo-ecological challenges.

The MetroURL Framework, designed with NBS and CBS, offers tailored responses to local challenges, leveraging unique local features. It aligns with the One Health strategy, introducing a new paradigm for metropolitan landscapes by emphasising the interconnectedness of human, animal, and ecosystem health.

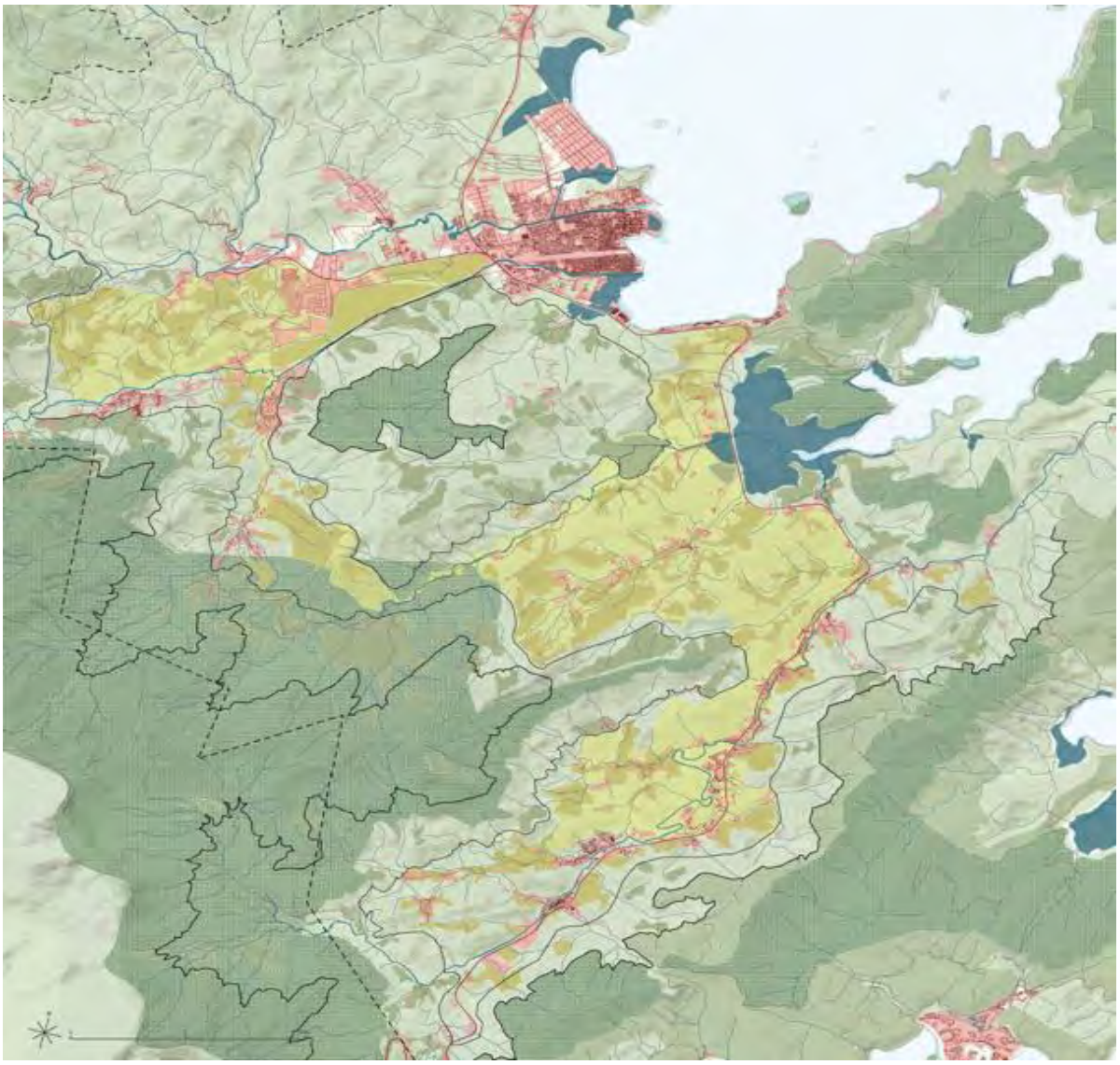


Figure 1: Paraty (Brazil). Definition of the Cairuçu Environmental Protection Area (APA) border following the MC analysis, in Agroforestry as a strategy for biodiversity preservation: directing urban expansion in Paraty's Atlantic Forest. Credit: MSLab, Erika Nataly Amidati, Francesca Cisaria (2024)

2.Metropolis as heritage

2.1 Guidelines for experiencing metropolitan urbanity

We aim to explore whether metropolitan heritage can catalyse the development of an urban culture—envisioned as a "new utopia of reality" (Rogers, 1965) —and formulate a *theory of metropolitan urbanity.* This theory would be supported by a *technological culture* that regulates technological density, enabling contemporary humanity to increase its sustainable care for the world. Achieving this requires a search for meaning, orientation, and direction and a commitment to intentional reading and the art of noticing, as suggested by Anna Tsing (2015).

In an era where relationships—whether among civil and human rights holders or between communities and territories—are often reduced to legal frameworks that bind individuals primarily through force, metropolitan heritage emerges as a source of spiritual meaning (Agamben, 2024). Here, "spiritual" refers to something that transcends individual interests, offering an objective criterion that establishes a canon that regulates ethics, aesthetics, and expressions of human subjectivity. Culture, in this sense, becomes the experience of a spirit not above us but one that envelops us (Tsing, 2015). This culture, understood as "religio" in its etymological sense, binds and connects people to an ideal centre, creating a shared space that transforms a collection of individuals into a society capable of *collective experience*. Our study, therefore, seeks to develop guidelines for experiencing metropolitan urbanity through an integrated, multi-scalar project grounded in an evolving technological culture.

In the Anthropocene, humans often feel alienated and seek environments that allow for experiences of sharing, freedom and quality of life. To achieve this, the antifragile approach (Taleb,2014) emphasises building on what already exists, reinterpreting and re-imagining it in response to unintended designs marked by unpredictability. This approach is context-based, non-scalable, and results from the interplay between human and non-human life. We must, therefore, consider the unintended consequences of human actions, which create an *ecology of disruption* (Tsing, 2015) and, consequently, foster an art of living on a damaged planet—products of the Anthropocene's disruptive forces. Each force may require its *agent of change* (UN-Habitat, Strategic Plan 2020-23). Our Hypothesis is that culture is that agent.This vision could lead to the formation of a metropolitan civilisation, or metropolitan "Humanitas" (Mancuso, 2024), where human and civil rights coexist, creating a *new collective public space*. In this space, citizens can experience a different kind of space-time: local, intimate, collective, and global. Such a collective public space would be characterised by behaviour oriented toward sustainability.

This spiritual sense still exists in some regions of the Global South, where nature has not been secularised and where the relationship between places and communities is mediated by rituals—practices that structure ways of life. This marks the beginning of a metropolitan anthropology that identifies and explains new behaviours and practices within metropolitan spaces. Culture is not just a product of descriptive language but manifests through practices and behaviours representing experience, exploration, invention, and meaning. This brings to light the importance and utility of metropolitan heritage.

	goal	strategy	action	SDGs
inclusivity	Creating a **collective** atmosphere and **constructive relations** among inhabitants, fighting with segregation and discrimination	Finding **commonalities** between cultures, emphasizing similarities, and ensuring a safe atmosphere where people could **create their cultures**	Designing common spaces where people spend time together for a higher purpose and eventually **interact**	5 10
circularity	Financially support the system and the users with a **circular economy** strategy and concretize the project	To ensure that the neighborhood become **self-sufficient** by creating **production-consumption** cycles	Revitalizing local **community gardens**, adding cultural value to the products in the **workshops**, feeding the whole system with **market** sales	8 9
sustainability	Designing sustainable and self-sufficient neighborhoods, in terms of **food, water**, and **energy**	Getting inspired by the methods of the past, following the **heritage** with the new **technology** and innovations	Organizing meetings for products, water, energy and waste management using **information and communication technologies**	11 12

Figure 2: Strategy Table to foster Collective Public Space, in Collective Landscapes of İstanbul: A Tool for Social Integration. Credits: MSLab, İlayda Cömert, Kübra İlayda Turan (2024)

Strategic decision-making at the metropolitan level requires political intervention capable of reshaping the rules and attitudes of metropolitan agents, particularly in real estate, to promote sustainable planning and design. This would address the structural challenges of metropolises by strengthening existing agents of change and creating new ones.

Can metropolitan heritage be an agent of sustainable transformation? Can it enhance quality of life, raise awareness of territorial fragility, and prevent gentrification? As a social project born of collective intelligence, Metropolitan heritage is deeply connected to knowledge of the territory and its practices. The academy's role is to promote integrated pathways across various disciplines, train metropolitan agents to manage the cycle of technological innovation for all and interpret territorial culture as competence, wealth, and heritage.

Finally, metropolitan heritage can become a tool for social equity in climate change, provided we overcome the dichotomies between nature and culture, urbanity and equity, and establish a system of cross-feedback between these elements.

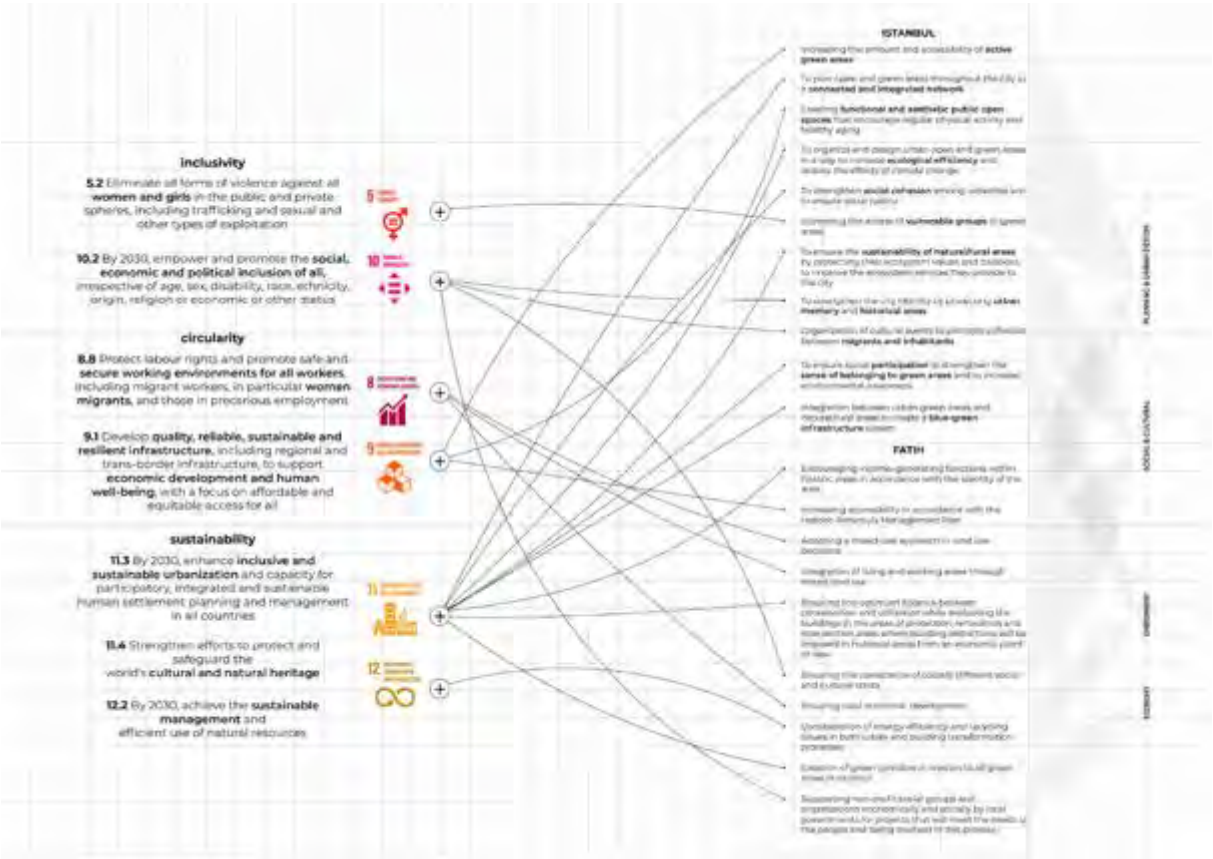


Figure 3: SDGs Targets Map, in Collective Landscapes of İstanbul: A Tool for Social Integration. Credits: MSLab, İlayda Cömert, Kübra İlayda Turan (2024)

Figure 4: Paraty (Brazil).The Agroforest Cultural Practices, in Agroforestry as a strategy for biodiversity preservation: directing urban expansion in Paraty's Atlantic Forest. Credit: MSLab, Erika Nataly Amidati, Francesca Cisaria (2024)

3.Context-Driven Metropolitan Urbanity Sustainability

3.1 The Role of Culture and Cartography

Culture as philosophy or culture impacting sustainability operations? Recognising oneself as a 'seeker' (Mauthner, 2012) means being human. Tracing everything back to past knowledge is to renounce the specificity of humans, as Socrates recalled in his oration to the Athenians (Plato, 2021).

During the 1990s, heritage preservation practices began challenging the dominant Eurocentric approaches, which had previously emphasised universal standards, particularly those derived from the Venice Charter (ICOMOS, 1994). This shift brought attention to previously marginalised aspects of heritage value, recognising that heritage is closely tied to cultural practices and performances rather than solely rooted in material, aesthetic, or historical significance. This change marked an anthropological awakening in heritage studies, acknowledging the legitimacy of different urban and social processes and ritual traditions alongside global and institutional standards (Rico, 2024).

Sustainable culture highlights the critical role of context, where environmental conditions profoundly influence the effectiveness of protection efforts. It aims to close the gap between knowledge and practical application by transforming analysis and interpretation into concrete, impactful actions. Setting clear objectives for sustainable culture is essential, particularly when addressing issues like poverty, inequality, and low productivity in urban settings. Cartography is invaluable in this process, as it can pinpoint areas of survival activities, shed light on local practices, and facilitate targeted interventions.

Policy documents often provide abstract recommendations that need to address specific urban challenges. For example, SDG 11 on urban sustainability overlooks critical issues in metropolises. The term "commitment" in the SDGs lacks a foundation in metropolitan urbanity and its culture theory and omits references to social justice or ethical imperatives. Effective urban planning must relate heritage preservation to its socio-economic context, which varies between regions. Understanding local economies, ecologies, cultural traditions, and institutional hierarchies is essential for a coherent metropolitan culture and space theory. With this understanding, addressing the impacts of human behaviour on urban areas and improving living conditions for most urban residents is possible.

4. Developing a Metropolitan Culture

4.1 Operational Culture for a Metropolitan Urban Space Theory

Developing a *theory for the culture of metropolitan urbanity* and utilising cartography to explore sustainable habitats is crucial. The context in which these theories and tools are applied significantly shapes the choice of

instruments, and these instruments, in turn, redefine the context itself. Historically, urban planning has often neglected areas outside of formal plans, labelling them as illegal and subject to demolition while failing to acknowledge the value of ancestral practices within protected areas. Effective urban policies should, therefore, aim not just at resource allocation but at guiding urban behaviour towards desired outcomes.

Context encompasses spaces, sites, flows, processes, and the interactions among actors that influence supply, demand, and pricing. However, the limited capacity of institutions to effectively implement these policies presents a significant challenge. Market-oriented policies, particularly in tourism, are often designed to influence individual and collective behaviours. This raises important questions about the need for *operational culture* in fostering prosperity and identifying the values generated by the tourism industry.
Experimenting with values and resources linked to operating culture can help combat poverty, inequality, and low productivity, improving quality of life. Cartography can identify these values and convert them into measurable indicators. Metropolitan planning should, therefore, challenge purely anthropocentric approaches and acknowledge the significance of behavioural norms, particularly in the Global South, where local cultures play a pivotal role in shaping urban practices and governance strategies.

5. Metropolitan Landscapes

5.1 Fusing Natural and Human Systems

The metropolis embodies an integral fusion of biosphere, water, and soil, collectively called the critical zone (Latour, 2022), requiring regenerative techniques. Within this framework, the intertwined connection between culture, science, and technology, described as entanglement (Chakrabarty, 2021), reinforces the natural system's anti-fragility (Taleb,2014). The goal is to diminish the susceptibility of nature, with society taking a central role in preserving and promoting this natural heritage to ensure its sustainable perpetuation. The ambition is a collaborative effort between the metropolitan city and technology to minimise loss or exposure to risk and capitalise on opportunities that may arise from difficult or unforeseen situations. By cultivating the ability to protect, adapt and transform through exposure to risk and uncertainty, and with the help of technology that can adjust to natural processes, we must develop opportunities, fostering potentials and advantages to improve systems, organisations and strategies that thrive under conditions of stress and volatility, rather than survive. Technology in the contemporary metropolitan context is fundamental for studying nature through verification tools. This tool, however, must operate in tune with historical knowledge of past sustainability. Metropolitan landscapes embody a complex interaction between natural and human systems, necessitating innovative tools to analyse and comprehend these dynamics. Research should prioritise integrating local ecological knowledge at the metropolitan scale, focusing on fostering environmental stewardship, democratic engagement, and resilience. The concept of geohistorical DNA, which merges geography with collective memory, offers a

foundation for creative approaches to urban design.

Territorial Intelligence (https://cordis.europa.eu/article/id/87501-the-smart-approach-to-territorial-intelligence/it), which addresses social, economic, ecological, and cultural dimensions, is vital for developing inclusive and democratic urban solutions. Engaging subnational metropolitan governments in climate prevention efforts is essential, as they are better positioned to address the specific needs of their communities. The European Union's initiatives in regulating environmental and social governance further underscore the growing importance of sustainability in this context (https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/esg-rating-activities_en).

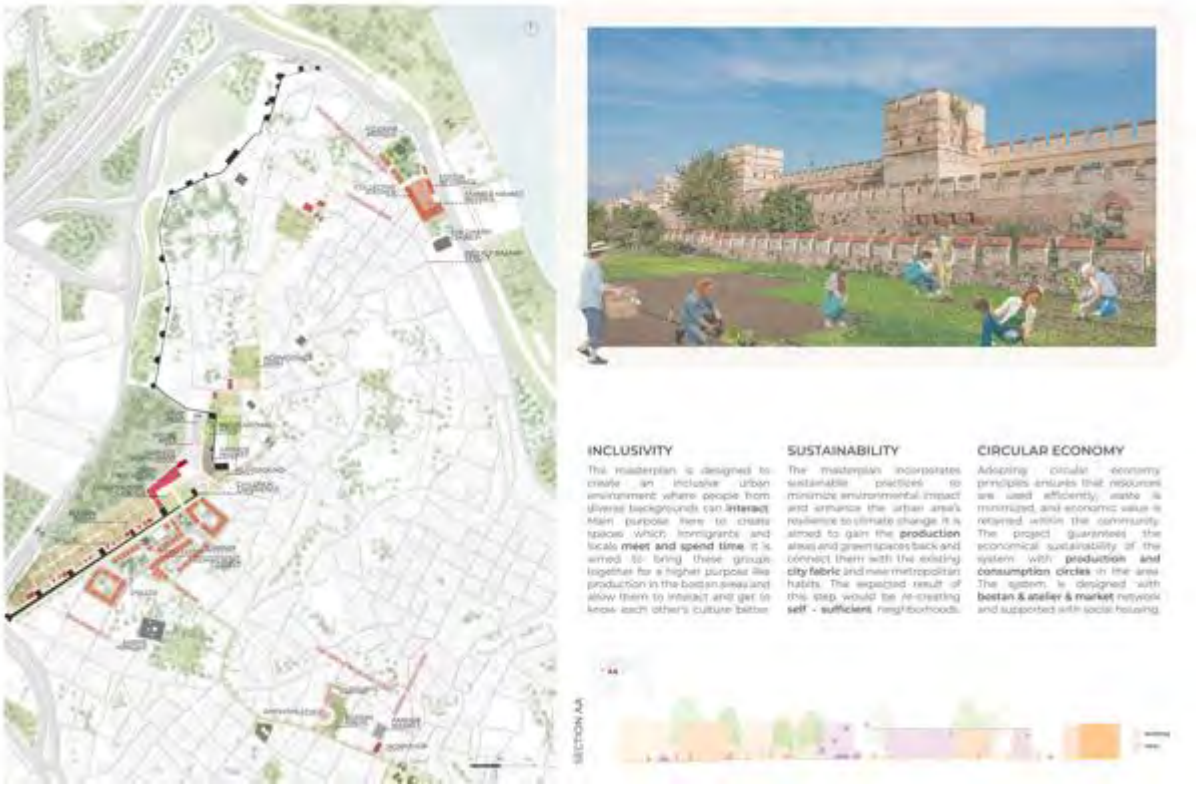


Figure 5: The new Bostan Project, in Collective Landscapes of İstanbul: A Tool for Social Integration. Credits: MSLab, İlayda Cömert, Kübra İlayda Turan (2024)

6. Nature-Based and Culture-Based Solutions for Metropolitan Resilience

6.1 A New Approach to Mapping and Design Hybrid Metropolitan Landscapes

The metropolitan landscapes, particularly through initiatives like the MetroURL project (Contin,2021), aim to achieve a nonlinear understanding of territorial identity by emphasising antifragility and the integration of multiple disciplines. The One Health approach also highlights the interconnectedness of human, animal, and ecosystem health, reinforcing the need for holistic solutions. Introducing nature-based solutions (NBS) offers tailored responses to local challenges crucial for decarbonisation, hydrogeological balance, and climate adaptation. These solutions can redefine urban-rural connections, creating new metropolitan commons of sustainability that address multiple issues simultaneously. However, to truly preserve the heritage of metropolitan areas, it is essential to implement nature- and culture-based solutions (NBS and CBS), transforming these landscapes into collective sustainability assets. By leveraging natural processes and cultural practices, NBS and CBS provide a comprehensive approach to tackling environmental and social challenges in metropolitan settings.

7. Metropolitan Cartography

7.1 Advancing Cartographic Methods for a Culture of Technology

Constructing cartographies that contribute to a pact between the Culture of Technology and the Theory for the Culture of Metropolitan Urbanity evolves map-making through a significant transition. The approach goes beyond mere interdisciplinarity, moving towards a transversal perspective that embraces the diversity of disciplines and focuses on the interactions inherent in architecture and urban studies using a Glossary (Contin, Giordano, Nacke, 2021) that unifies knowledge and underlines shared cultural values. This shift recognises the dynamism and interconnectedness in knowledge creation, incorporating post-disciplinary perspectives and post-human considerations (Braidotti,2014). This perspective extends from a predominantly anthropocentric and social constructionist angle to a broad consideration of the agency and vitality of human and non-human entities at the local scale. The culture of technology assumes a central role as a transitional element between nature and culture in this panorama. Understanding the intertwined relationships between materials, spaces and dynamic local forces is emphasised, shaping contemporary planning and architectural experiences.

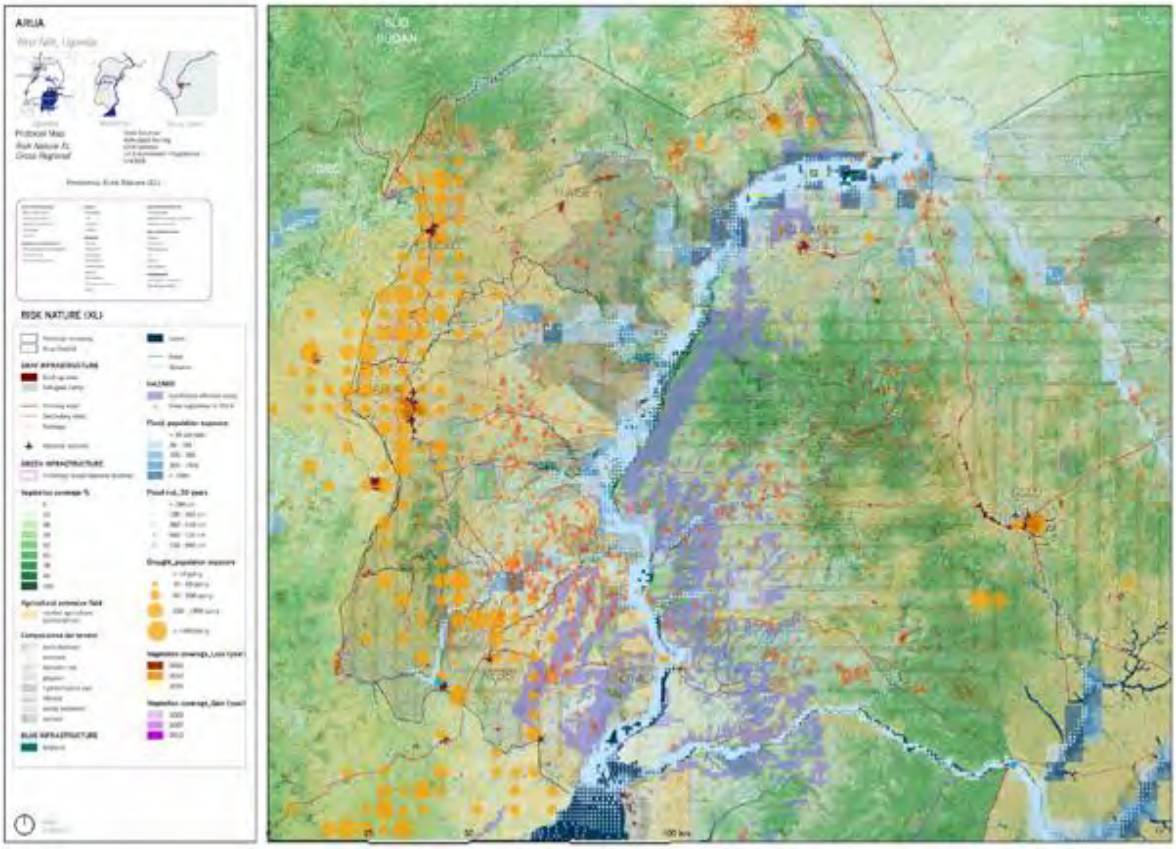


Figure 6: Metropolitan Cartography: Arua (Uganda)Risk Map, in A new periurban centrality for sustainable development in ARUA, Uganda. A multiscale approach for the West Nile region. Credit: MsLab, Bianca Cesarotti

In conclusion, the research provides theoretical insights and practical methods to enhance metropolitan sustainability and resilience. Integrating local knowledge (CBS) and nature-based solutions (NBS) offers transformative strategies for sustainable urban development in alignment with global agendas such as the New Urban Agenda and Sustainable Development Goals. The MetroURL framework illustrates how metropolitan areas can evolve into resilient landscapes that harmonise human activities with ecological systems, fostering inclusive growth and environmental stewardship. Future applications aim to expand these findings across various metropolitan contexts, ensuring that urban planning reflects local realities and promotes equitable and sustainable development.

Hybrid metropolitan landscapes are today's main urban arena, requiring new mapping methodologies to understand and design them effectively. Metropolitan Urbanity, described through cartography (Contin, Galiulo, 2021), can convert urban-rural margins into vibrant sites for cultural, natural, and anthropic services, advancing the goals of the Heritopolis Society initiative for a living landscape supported by a cultural vision of territories.

References

Agamben, G., (2024), Lo Spirito e la Lettera. Sull'interpretazione delle Scritture, Milano: Neri Pozza

Barbera, F., (2023), Le piazze vuote. Ritrovare gli spazi della politica , Bari: Laterza

Braidotti,R., (2014), Il postumano: la vita oltre l'individuo, oltre la specie, oltre la morte, trad.it. A. Balzano, Roma, DeriveApprodi

Castells, Manuel (1996). The Rise of the Network Society, The Information Age: Economy, Society and Culture Vol. I. Cambridge, MA; Oxford, UK: Blackwell

Chakrabarty, D. (2021). The Climate of History in a Planetary Age. Chicago: The University of Chicago Press.

Contin, A., (2015), Questo. Metropolitan Architecture, Santarcangelo di Romagna (RN): Maggioli Editore

Contin, A., Giordano, P., Nacke, M., (2021), Training for education, learning and leadership towards a new metropolitan discipline. Inaugural book, Buenos Aires, Cippec

Contin, A., Galiulo, V., 2021, Methodological Guidelines for Metropolitan Cartography Projects, in Ardeth N.9, Race

Contin, A.,2021. The Metropolitan Structure for a Set of Metropolitan Landscapes. In: (a cura di): Contin, A., Metropolitan Landscapes. Towards a Shared Construction of the Resilient City of the Future. p. 3-39, Springer

ICOMOS, Venice Chart, 1994, Scientific Journal, No.4,(July-Dec 1994)

Latour, B, Aït-Touati, F., (2022), Trilogie Terrestre, Paris, Editions B42

Mancuso, V., Conoscere il divino rende forti le società. Se manca la religione, manca l'umanità, in La Stampa 15 agosto 2024

Mauthner, F.,2012, L'ateismo e la sua storia in Occidente (Vol. 1), Roma: Nessun dogma

Plato, 2021, Apologia di Socrate: discorso a difesa, Kindle Scribe

Rico, T., 2024, Practices and performances, in King, R., and Rico, T., Methods and Methodologies in Heritage Studies, London: UCL Press University College London

Rogers, E.N.,(1965), L'Utopia della Realtà, Roma: Leonardo da Vinci ed.

Taleb, N. (2014). Antifragile: Things That Gain from Disorder. Global Penguin Random House.

Tsing, A., 2015, AURA's Openings. More-than-Human. AURA Working Papers Volume 1

http://anthropocene.au.dk/working-papers-series/

https://unhabitat.org/sites/default/files/documents/2019-09/strategic_plan_2020-2023.pdf

7th FP, https://ec.europa.eu/commission/presscorner/detail/en/MEMO_16_146

ESG, https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en

One Health, https://www.who.int/health-topics/one-health#tab=tab_1

Heritopolis Society, http://heritopolis.org/

Acknowledgement

AI contributed to this text by responding to these prompts: "Improve the writing".

Research Paper

The Influence of Architectural Culture on The Development of Religious Heritage

-The Case of Asian Pagodas

Jin Shang, University of Sheffield, United Kingdom

Abstract

Asian pagoda is a type of religious heritage architecture that developed because of the introduction of Buddhism from ancient India. The original architectural features of the pagoda are not the same as those of the current Asian pagodas. In order to spread Buddhism, Buddhist architecture, especially pagodas, acquired the architectural and cultural identity of the local population by integrating with the local architectural culture. It led directly to the evolution of pagodas in Asia with different architectural appearance in these countries. This study takes pagodas in two typical countries in Asia as cases to analyse the influence factors of architectural culture, which may affect the development of the appearance of ancient pagodas by case study. This research will provide the influences affecting the development of religious architecture from the perspectives of architectural culture. In addition, this study presents a distribution pattern of pagoda differences based on Buddhism's transmission routes and analyses the reasons for this pattern based on the results of the case study. It will be applied for the sustainable protection of religious heritage architecture.

Keywords

Asian pagoda, Architectural appearance, Architectural culture, Distribution pattern

1. Introduction

1.1. Asian pagoda

Pagoda originated from the stupa in India (Zhang, 2000; Xu, 1986). Stupa (Figure. 1) means tomb in Indian Buddhism (Shen, 2005). It is a kind of religious architecture. Asian pagoda is generated from the spread of Buddhism in Asia. At the start of Buddhism, Sakyamuni assigned many missions to spread Buddhism in different directions. Buddhism was divergent in the process of its spread and development. This divergence is primarily reflected in the Mahayana and the Theravada. The Mahayana is mainly distributed in Bhutan, Nepal, Sikkim, China, Turkistan, Central Asia, Korea, Mongolia, and Japan; The Theravada is mostly found in Burma, Ceylon, Cambodia, and Siam (Rost, 1930). This divergence has also led to changes in religious architecture, like pagodas, in different countries.

Figure 1. The model of an Indian stupa. Source: Photo by author at Xuchang Tower Culture Museum

1.2. Architectural culture

Naghizadeh (2000) defined culture as consisting of the knowledge, beliefs, education, values, and customs, which is generated from the development of society. Culture has a great influence on the architecture (Madadpoor, 2000). Architecture is the activity of creating and organizing space (Ettehad *et al.,* 2014). Architecture is not just building; it also includes the methods of building. The aim of architecture is to meet the demand of non-material of local people (Ettehad *et al.,* 2014; Parhizgar, 2003). The cultural factors that can affect the creation of architectural space mainly include culture, beauty, and so on (Ettehad *et al.,* 2014). Religious culture is part of the culture. The beauty of architecture also has many different definitions (Lavdas and Salingaros, 2022). So humans from different countries may also have different perceptions of architectural beauty. This paper focuses on the influence of architectural culture on the development of pagoda morphology in Asia from two perspectives: religious culture and the perception of architectural beauty. In addition, this study examines the influence of transmission paths on the difference in the morphology of pagodas by comparing the pagoda morphology in two different countries.

2. Methodology

At first, this research compared the morphological characteristics of pagodas from different countries in Asia to select the typical cases. Secondly, this research investigated the difference between the case pagoda and the original stupa through the case study. At last, this study explored the factors that affect morphological changes in the development of pagodas and how these factors affect morphological changes in pagodas through historical and literature research. It is found that there are a great number of types of pagodas in China, and some types of pagodas have similar morphological features to some Asian pagodas, but the difference between Chinese pagoda and Indian stupa is large; while the morphology of Thailand's pagodas have many similar features with Indian stupa but is more different from pagodas in China. Therefore, this study mainly chooses pagodas in China and pagodas in Thailand as study cases.

3. Results

3.1. Perception of architectural beauty

In approximately the 1st Century B.C., Buddhism was introduced to Xinjiang. The western region of China became the center of Buddhism at that period. Until the Eastern Han Dynasty, Buddhism was introduced to the central region of China, and eventually evolved into 'Han Buddhism'. (He, 2023). The appearance and structure of the pagoda changed significantly during this period. The changes in the appearance of the pagoda had three main periods. The first period was from the end of the Eastern Han Dynasty to the Tang Dynasty. In the beginning, it was difficult for the Buddhist culture to be accepted by the locals in a short time. The structure of the stupa can not meet the aesthetic preferences of the local people. In order to spread Buddhism, the structure of the Indian stupa began to combine with the structure of the Chinese traditional architecture to generate a new structure. Multi-story pavilion is very popular in ancient China. So this structure was introduced into the evolution of pagoda structure (Zhang, 2009). The multi-story pavilion-style pagoda is one of the typical Chinese pagodas. Figure 2 is one multi-story pavilion-style pagoda, which was built in the Ming Dynasty. It can be seen that the appearance of this architecture has no similarity to the Indian stupa. The structure and façade are different with changed dramatically. The second period of the development of Chinese pagodas was from the Tang Dynasty through the Song Dynasty to the Liao and Jin Dynasties. This period was the highest point in the development of pagodas in China. The number of pagodas increased sharply during this period. Because of the progress of technology, the construction materials of ancient pagodas became more abundant. The construction materials include timber, brick, stone, copper, iron, glaze and so on. Timber pagodas were gradually replaced by masonry pagodas during this period. As the construction materials and technology were changed, the structure and appearance of the pagoda became more varied. In addition to four-sided pagodas, six-sided and eight-sided pagodas began to appear. The internal structure of the pagoda has also become complicated at this period (Zhang, 2009). Most early Chinese pagodas have a four-sided structure, which is largely influenced by ancient Chinese pavilion-style architecture. But six-sided and eight-sided pagodas became the mainstream of ancient pagodas during the Northern Song Dynasty. One of the most important reasons is the change in the aesthetic orientation of the local people at that period (Zhang, 2009). The difference between the pagodas in the Tang Dynasty and Song Dynasty is evidence of the influence of the perception of architectural beauty on the changes in the appearance of pagodas. The appearance of pagodas in the Tang Dynasty is more focused on the overall structure, but the façades have less decoration. The design of the pagodas in the Song Dynasty was more concentrated on the decoration. This change is consistent with the transformation of human aesthetics between these two dynasties (Zhang, 2009). The Yuan Dynasty to the Qing Dynasty is the third period of the development of ancient pagodas in China (Liang, 2004). The construction technology of the pagodas did not develop further during this period, but the types of pagodas began to become more diverse, such as Lama Pagoda, Vajra Throne Pagoda, and Wenfeng Pagoda (Zhang, 2009).

Figure 2. Xuchang Wenfeng Pagoda. Source: Photo by author.

Thailand is also a famous country that has a large number of Buddhists. Buddhism has had a deep impact on the lives of the local people over the centuries of its development in Thailand. The question of when Buddhism was introduced to Thailand has many different answers. Some researchers claim that the reign of Asoka was the period when Buddhism was first brought to Thailand. Other scholars believe that Buddhism was introduced into India later than this period (Kusalasaya, 2024). Based on a review of current archaeological and historical evidence, Kusalasaya (2024) concluded that Buddhism was introduced to Thailand in four different religious forms at four different periods. These four different forms include Theravada, Mahayana, Burma Buddhism, and Ceylon Buddhism (Kusalasaya, 2024). Although the development of Buddhism in Thailand is complex, many of Thailand's pagodas have a similar structure. Figure 3 shows the profile structure of a pagoda in Thailand. It can be demonstrated that the pagoda in Thailand remained similar structures to the Indian stupa through comparison. It evolved unique architectural features based on this similarity. The top structure of the pagoda in Thailand is higher than that of the Indian stupa, and its overall structure is more spectacular.

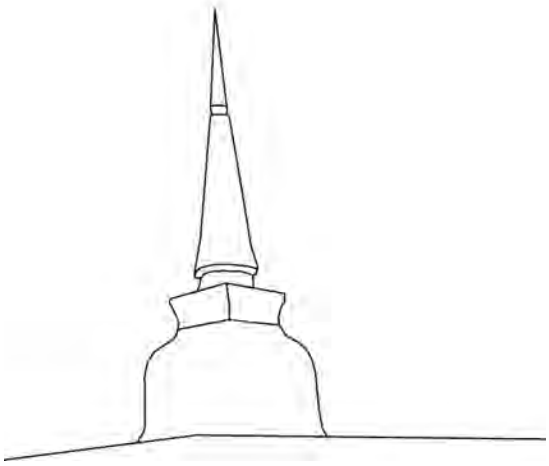


Figure 3. The profile structure of a pagoda in Thailand. Source: This figure was adapted from (Wasriwiwat, 2022) and redrawn by author.

It can be concluded that the perception of architectural beauty played a crucial role in the development of the appearance of Chinese Han Buddhism pagodas. Among these three historical periods, the changes in the appearance of Chinese pagodas mainly occurred in the first and second periods. The greatest changes in ancient Chinese pagodas happened during the first period. The structural features of the pagodas are entirely different from those of Indian stupas. The reason for this significant change is that people in different countries have different aesthetics. The changes in the Chinese pagodas in the second period are mainly reflected in the change from four-sided to six-sided and eight-sided as well as the change in façade decoration. The differences in this period are not as noticeable as those in the first period. It is the result of the evolution of local aesthetics. Compared with the Chinese pagoda, the pagoda in Thailand is more similar to the Indian stupa. The reason is that some structures of the pagoda in Thailand are generated based on the combination of Thai aesthetics and Indian architectural art (Kusalasaya, 2024).

3.2. Religious culture

There is another type of pagoda in China, and the morphological features of this type are widely variable compared to the pagoda of Han Buddhism. An important reason for this difference is related to the religious culture. Buddhism was introduced to Xizang in the 7th century AD. Before Buddhism was introduced to Xizang, the native religion of Xizang was the Bon religion. After Buddhism was introduced into Xizang, it absorbed the information of Bon culture and eventually evolved into Tibetan Buddhism (He, 2023). Tibetan Buddhism is also called Lamaism. It is another typical Buddhism in China. Although Buddhism was introduced to Xizang later than it was introduced to the Central Plains, Tibetan Buddhism is closer to Indian Buddhism than Han Buddhism since it is geographically located closer to India. There is evidence that the appearance of the Lama Pagoda in Tibetan Buddhism has a similar structure to the Indian pagoda (Liu, 2019). Figure 4 is a typical Lama Pagoda. It can be seen that this pagoda has the same circular cross-section as the Indian pagoda (Figure 1) through comparison.

Figure 4. Pagoda of Duke of Bin. Source: Photo by author.

In summary, the difference between the pagoda of Tibetan Buddhism and the pagoda of Han Buddhism is mainly because of the difference in religious culture. Compared to Han Buddhism, Tibetan Buddhism is a

new form of Buddhism that combines the local religion of Xizang. Therefore, the religious content of Tibetan Buddhism is different from that of Han Buddhism. From a geographical perspective, Tibetan Buddhism has been influenced by Indian Buddhism more directly because Xizang is located close to India (Liu, 2019). As a result, Tibetan Buddhism has many similarities with Indian Buddhism. It means the appearance of the pagoda of Tibetan Buddhism is more similar to that of the pagoda of Han Buddhism to the Indian stupa.

3.3. Transmission route

Figure 5 is the map of the spread of Buddhism in Asia. There are four main routes of transmission of Buddhism in Asia. These routes include the northern route, the southern route, the Tibetan route, and the sea route. It can be found that different degrees of difference of pagodas from different transmission routes. The transmission route (the southern route) of Buddhism in Thailand and the transmission route (the Tibetan route) of Tibetan Buddhism are shorter than the transmission route (the northern route) of Han Buddhism. The degree of difference between the Thai pagoda and the pagoda of Tibetan Buddhism is lower than the pagoda of Han Buddhism. The findings about the distribution pattern of the pagodas' difference can be concluded that the degree of difference in the appearance of pagodas is positively correlated with the distance of the transmission route.

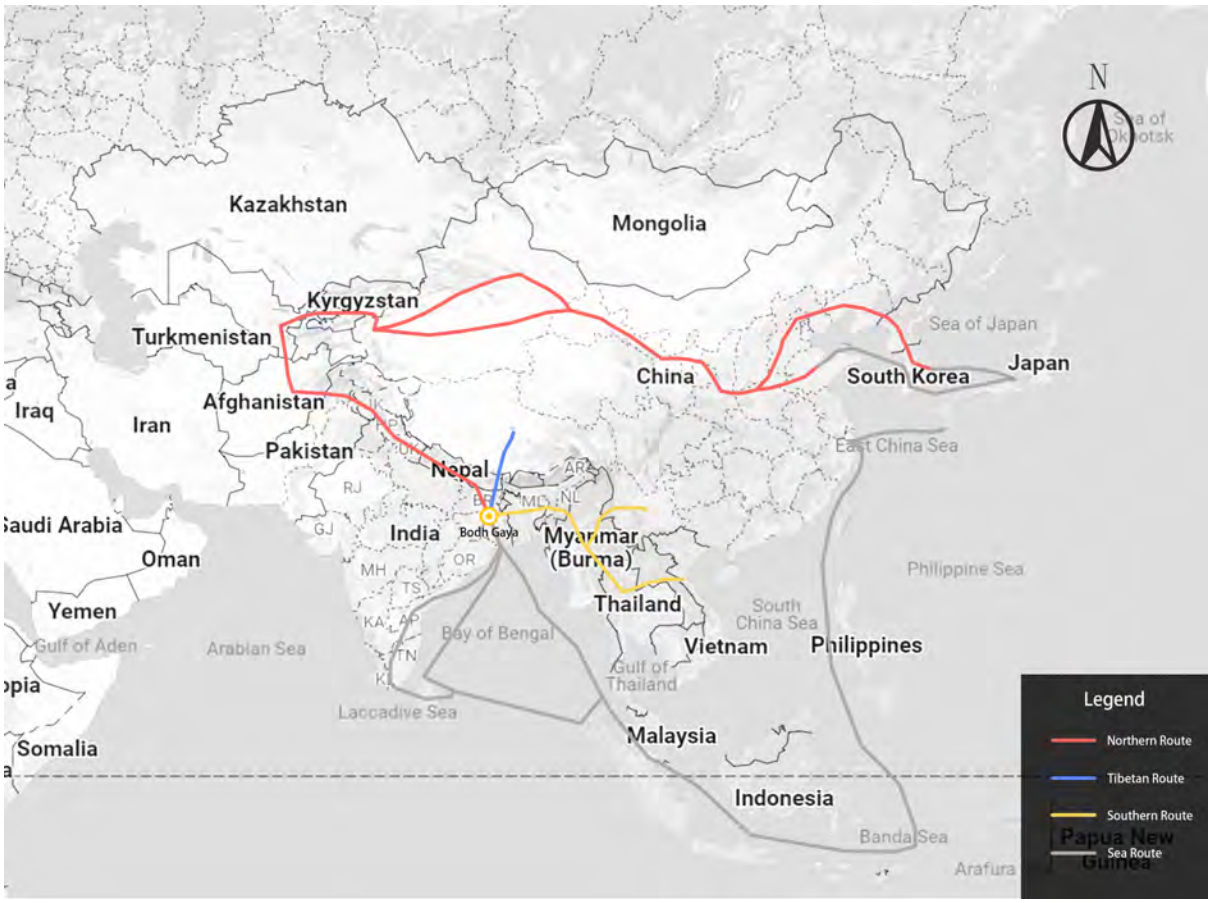


Figure 5. The map of the transmission routes of Buddhism in Asia. Source: This figure is drawn by author and data is from (Xuchang Tower Culture Museum, 2024).

Through the case study, it can be found that the development of the appearance and structure of the pagoda is related to the evolution of its religion. When a religion is transmitted from one country to another, its religious content may change. The reason is that when a religion is introduced to a country or place, this

religion always has a low level of cultural identity with local people. It can generate obstacles to the spread of the religion. The case study above revealed two main methods for Buddhism to increase the cultural identity of the local people. The first method is to combine religious architecture with local traditional architecture. This will increase the local people's acceptance of the religious architecture in terms of the architectural aesthetics. Religion raises the cultural identity through the fulfillment of the aesthetic needs of the local people for religious architecture. Another method is to combine with local religion. It is obvious that the local people have a deeper understanding and a higher level of cultural identity of the local religion. So religion can enhance the understanding and cultural identity of the local population through the combination with local religion. The religious content also changed in this process. The transmission distance refers to the number of countries and regions that a religion passes through during its spread. When the transmission distance of a religion is shorter, it indicates that it has experienced fewer countries and regions. Religious architecture will suffer less from this kind of change.

There is another finding that the appearance of a pagoda may be affected by the pagoda in around country or region. The appearance of the pagoda of Tibetan Buddhism is the evidence of this conclusion. Another piece of evidence is the Japanese pagoda. Japanese pagoda has a similar structure to the pagoda of Chinese Han Buddhism. The reason is that Japan is located close to China. Buddhism in Japan was also deeply influenced by Chinese Buddhism (He, 2023).

4. Conclusion and discussion

Currently, the sustainable development of heritage architecture is an important topic in society. Heritage architecture carries the memory and culture of nations. This research selected the Asian pagoda as a case and mainly explored the factors that may affect the development of the appearance of religious architecture from the perspective of architectural culture. The study finds that religious culture and the perception of architectural beauty are two important factors of architectural culture that have influenced the development of the appearance of religious architecture. This research also concluded the patterns of change in the degree of differentiation in the appearance of religious architecture from the map of transmission routes of Buddhism. It found that differences in the same religious architecture are not only related to architectural culture but also to geographical factors.

The main limitation of this research is that the number of cases is limited. This study just selected Chinese pagoda and Thai pagoda as the study case. It considers less the comparison of the select cases with other countries in Asia. It may ignore some important influence factors and some special situations. Another limitation is that the selection of study literature is insufficient. Most of the selected study literature explains the reasons for the changes in the appearance of the architecture from the perspective of historical development. It lacks the literature on the architectural background. The third limitation is that it lacks a study of the origin and development of Indian stupa. The Indian stupa as the origin of the Chinese pagoda and the Thai pagoda as well as the object of comparison should be studied for its development process.

In the future, this research will explore the influence factors of the development of morphological features in religious architecture from other perspectives, such as the development of construction technology. The findings of this research will mainly contribute to the study of the development of religious architecture.

5. References

Ettehad, S., Karimi Azeri, A.R. and Kari, G. (2015) 'The role of culture in promoting architectural identity', *European Online Journal of Natural and Social Sciences: Proceedings*, 3(4 (s)), pp.pp-410.

He, Y.Y. (2023) 'A Short History of Buddhism in the East', *Xinmin Weekly Journal,* (16), pp.46-49. (In Chinese)

Kusalasaya, K., (2024) *Buddhism in Thailand*. Fivestar.

Lavdas, A.A. and Salingaros, N.A. (2022) 'Architectural beauty: Developing a measurable and objective scale', *Challenges*, 13(2), p.56.

Liang, S.C., (2004) *The Complete Works of Liang Sicheng - Volume 8*, Beijing: China Architecture & Building Press. (In Chinese)

Liu, M.M. (2019) 'A study on the decorative patterns of Tibetan Buddhist monastery architecture', *Open Journal of Social Sciences*, 7(04), p.355.

Madadpoor, M. (2000) *Wisdom and spiritual aspects of arts*, Tehran: The Office of the Arts and Religious Studies.

Naghizadeh, M. (2000) 'The relationship (tradition of Iranian architecture) between identity and modernism and modernity', *Journal of fine arts*, 7.

Parhizgar, G.H. (2003) 'Culture, architecture , and traditions', *Journal of Life Story*, 11.

Rost, E.R. (1930) 'The spread and influence of Buddhism in Asia', *Journal of the Central Asian Society*, 17(4), pp.417-426.

Shen, Z.G. (2005) *Studies on Mechanics Performance, Appraisal and Reinforcing Technique of Bricky & Masonry Ancient Pagodas*. Master's thesis. Xi'an University of Architecture and Technology. Available at: https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD0506&filename=2005087310.nh (Accessed: 01 April 2005). (In Chinese)

Wasriwiwat, P. (2022) 'Myths of Phra Borommathat Chedi, Nakhon Si Thammarat Province: The Tale Types and Cultural Significance along the Thai Peninsula', *Rian Thai International Journal of Thai Studies*.

Xu, H.D., (1986) *Chinese ancient pagoda,* Beijing: China Light Industry Press. (In Chinese)

Xuchang Tower Culture Museum, (2024) Map of the Eastern Transmission of Buddhism. [unpublished] Xuchang, China.

Zhang, M.Q. (2009) *The Architectural Features Research of Bashu Ancient Pagodas.* Master's thesis. Chongqing University. Available at: https://kns.cnki.net/KCMS/detail/detail.aspx?dbname=CMFD2009&filename=2009149019.nh (Accessed: 01 May 2009). (In Chinese)

Zhang, Y.H., (2000) *Chinese pagoda*, Shanxi: Shanxi People's Press. (In Chinese)

Case Study Report

Integrating cultural heritage and protected areas:
case study of Cultural Routes in the Abruzzo Region

Carmen ULISSE
Nasim SADRAEI TABATABAEI
Lorena FIORINI
Alessandro MARUCCI
University of L'Aquila, Italy

Abstract

This case study revolves around exploring the "Cammini degli Altipiani" project in the Abruzzo Region (Italy), affected by the 2009 earthquake. Encompassing the four Cultural Routes (CRs) across 42 municipalities, the CRs are located within Protected Areas (PAs), comprising two National Parks and one Regional Park. Aiming to increase the area's attractiveness and economic growth, these CRs promote historical, cultural, and natural heritage. The research adopts a GIS-based methodology to identify points of interest, focusing on historical, architectural, and natural sites within a 2 km buffer around the cultural routes. The CRs can be a bridge between cultural heritage and PAs, prioritizing the importance of preserving, understanding, and disseminating practices that support sustainable development and resilience while playing an important role in public awareness regarding biodiversity and habitat conservation.
We aim to show that CRs contribute to the preservation of Cultural Ecosystem Services (CES), raising local economic development and enhancing environmental education, ecotourism, and cultural heritage conservation within PAs.

Keywords

Cultural heritage, cultural routes, protected areas, conservation

1. Introduction

In recent years, with intensified global events such as the COVID-19 pandemic, tourism has been increasingly recognized as a potential tool for territorial development. Its positive effects can be harnessed through sustainable planning of strategies and concrete actions to prevent negative impacts on the environment and the quality of life in society (Weaver, 2007; Lu and Nepal, 2009). Despite the increasing spread and promotion of mass tourism today, there are still areas that enjoy a slower perception of the territory (Moira, Mylonopoulos and Kondoudaki, 2017). Over the past decade, there has been growing awareness around the topic of "slow mobility" as an opportunity to preserve the environmental value and attractiveness of regions, enabling more sustainable land enjoyment and tourism (Fullagar, Markwell and Wilson, 2012; Bergantino, Buongiorno and Intini, 2021).

Over time, Cultural Routes (CRs) have evolved and specialized beyond simple itineraries. Initially considered as infrastructure enabling sustainable movement, CRs have now become the content of the infrastructure itself, telling the story of the land and the communities they cross (Majdoub, 2010). In addition, through the exploration of territories by walking, they become examples of territorial planning aimed at safeguarding, enhancing, and promoting local resources (Fistola and La Rocca, 2018).Cultural and touristic valorization thus becomes a trigger for widespread development in inner areas if it generates local-level benefits by integrating with other resources, particularly economic ones, incentivized by various policy actions aimed at combating the abandonment and depopulation of the Central Apennine regions.

This work, therefore, focuses on the theme of CRs as an opportunity to promote slow mobility and sustainable tourism and it describes the case study of 42 municipalities in the Abruzzo Region involved in the "Cammini degli Altipiani" project implemented by the Special Office for the Reconstruction of the Crater Municipalities (USRC). In general, this office manages the reconstruction efforts in 56 municipalities within the Crater area (since 2012) and more than 100 municipalities outside the Crater area (since 2013), and it was established, following the earthquake that struck L'Aquila and surrounding areas in April 6, 2009, by Law No. 134/2012 which defined the end of the state of emergency (***Figure 1***).

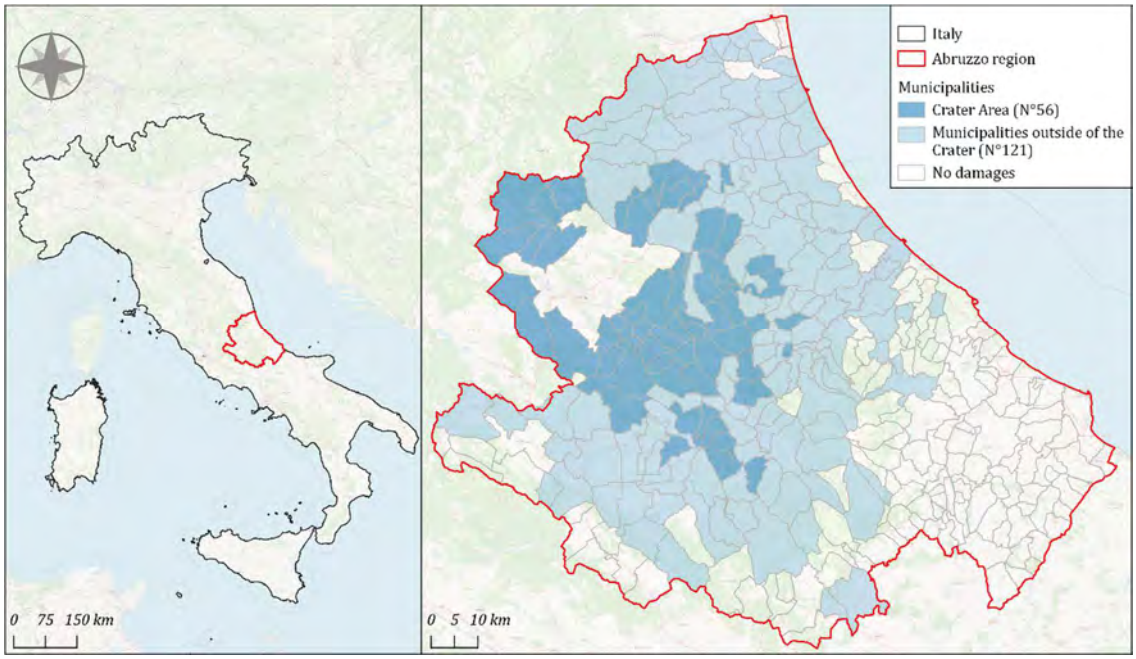


Figure 1. Location of the Abruzzo region and identification of the Crater area

1.1 "Cammini degli altipiani" project

The "Cammini degli Altipiani" project was initiated by the mayors of the municipalities involved and is being implemented by the USRC. This project does not want to replace the current tourist driver but wants to rediscover and highlight the historical, cultural, and natural part of the territory. The aim is to revitalize inner areas and local heritage using scientific approaches and innovative methods.

The project involves four CRs with a total length of 340 km (Cammino della Baronia, Cammino tra i Vestini, Cammino Grande di Celestino, and Cammino dei Francescani) within 42 municipalities, both inside and outside the Crater area. Figure 2 also illustrates that the CRs are included in a triangle of Protected Areas (PAs) (National Law No. 394/91), whose vertices are of the Gran Sasso and Monti della Laga National Park,

Sirente-Velino Regional Park, and Majella National Park. Figure 3 shows specific details for each CR (total length, number of stages, and the number of municipalities they cross).

Figure 2. Study area and localization of the CRs

Cultural Routes	Length (km)	N° of Stages	N° of Municipalities
Cammino della Baronia	77,79	11	9
Cammino dei Francescani	88,85	11	9
Cammino Grande di Celestino	93,17	4 + 2 alternative routes	19
Cammino tra i Vestini	82,41	8	11

Figure 3. Detailed information on the CRs included in the "Cammini degli altipiani" project

These CRs are set in areas of high natural value, recognized for national and international protection. They offer the opportunity to explore historic villages, archaeological sites, and local traditions. Unlike simple trails, what distinguishes these CRs is their rich cultural heritage, encompassing not only monumental and historical but also the ecological heritage of the protected areas, considered in terms of Ecosystem Services (ES) and inner area development.

1.2 Protected Areas and Cultural Ecosystem Services

The framework legislation for parks (National Law 394/1991) for the management and development of Italian parks and nature reserves (Di Pietro, 2019) was initiated in 1991 and provided the basis for preserving PAs. Later in 1997, Italy started to implement the Natura 2000 network established and managed by EU member states (Portaccio, Campagnaro and Sitzia, 2023) governed by two directives namely Habitat Directive (92/43/EEC), with Special Areas of Conservation (SACs) and Sites of Community Importance (SCIs) (Apostolopoulou and Pantis, 2009), and Birds Directive (79/409/EEC), classified into Special Protection Areas (SPAs) (Friedrichs , 2018). They cover 17% of the world's terrestrial regions and they are important in preserving biodiversity and natural habitats. Moreover, without these protected areas, the ecosystem could be at stake (Mwasaga, 2022). At both international and national levels, the interaction between protected areas and ecosystem services is well-documented in the literature (Chan, 2006; Costanza, 2007; Mace, Norris and Fitter, 2012). The establishment of PAs ensures the conservation and enhancement of natural heritage in terms of biodiversity and habitats, while also highlighting the crucial role of these areas in regulating, supporting, and provisioning Ecosystem Services (Xu, 2017).

However, in terms of overall territorial resilience, focusing solely on these categories of ecosystem services would be counterproductive, as it would overlook the intangible aspects of ecosystem services (Brand and Jax, 2007). Protected areas consist of different values namely: social, cultural, environmental, and scientific for both local and global communities (Sharmin, 2020). CRs allow the promotion of these values and the Cultural Ecosystem Services (CES), offering walkers the opportunity to connect with nature, environmental education (Fonseca, 2014), cultural heritage enhancement (Wang, Dane and Arentze, 2023), and ecotourism. In this way, the concept of a protected area expands beyond merely conserving biodiversity and becomes an incubator of “expert knowledge,” transformed into “common knowledge” through the experience of the CRs (Angelini and Santarelli, 2020).

2. Methodology

From its initial stages, the project is structured around a technical framework based on a GIS (Geographic Information Systems) approach. This study uses Volunteered Geographic Information (VGI) data, from OpenStreetMap (OSM) downloaded on February 14, 2024, due to its updated frequency and ease of integration with GIS software. The analysis area is identified based on the guidelines of the “Disciplinare attuativo del Registro regionale dei Cammini,” defined by Abruzzo Regional Law No. 10/2023 (Art. 20-21) and Regional Council Resolution No. 903/2023. This law introduces the Regional Register of Cultural Routes in Abruzzo, delineating the requirements for cultural paths and establishing a 2 km radius for essential services (such as accommodations and dining) around the CR. This same radius was used to get points of interest using OSM data.

In the methodology, historical, archaeological, and natural sites were included based on tourism information available on OSM (https://wiki.openstreetmap.org/wiki/Key:tourism). However, initial data was limited. To expand the dataset, the analysis was extended by including other OSM data layers to create

a wider range of cultural and natural points of interest across the region. ***Figure 4*** provides an overview of the categories and elements incorporated.

Points of interest	Description
Archeological sites	A place in which evidence of past activity is preserved
Castles and fortifications	Ancient structures and defensive buildings of historical significance
Churches, hermitages, and religious sites	Sacred buildings and places of worship
Civil architectures	Elements of architectural interest (buildings, palaces, squares, towers, and fountains). The type of access of the buildings (public/private) is not differentiated
Museums, monuments, and artistic sites	Elements of artistic interest (museums, memorial sites, monuments, theatres, artworks)
Naturalistic sites	Wide variety of physical geography, geological, and landcover features of natural interest (peaks, lakes, springs, caves, parks)
Viewpoints	A location with a good view of the surrounding countryside or notable buildings

Figure 4. Description of the Category of the Points of Interest

The resulting dataset is 760 elements across historical, architectural, religious, artistic, and natural sectors. Also, the dataset was reviewed to remove duplicates and unnecessary data to obtain an exhaustive database reflecting Cultural Ecosystem Services (CES). This objective approach provided a foundation for anthropologists engaged in researching and creating cultural content for the "Cammini degli Altipiani".

When it comes to expressing the educational values and aesthetic experiences provided by protected areas, it's challenging to identify specific locations (Plieninger *et al.*, 2013). Instead, we need to consider the whole protected area. For this reason, we intersected the CRs with the boundaries of PAs. These analyses considered the boundaries of Natura 2000 sites (https://www.mase.gov.it/pagina/liste-dei-sic) and Italy's protected area network (http://geoportale.regione.abruzzo.it/Cartanet). The results were expressed in terms of the percentage of CRs that fall within Protected Areas because there is an overlap between National and Regional Parks and their corresponding SCAs.

3. Results

The initial results focus on the cultural heritage identification in a 2 km buffer around the CRs. ***Figure 5*** shows the location of various points of interest, and the graph in ***Figure 6*** shows that this area is characterized by religious and architectural heritage.

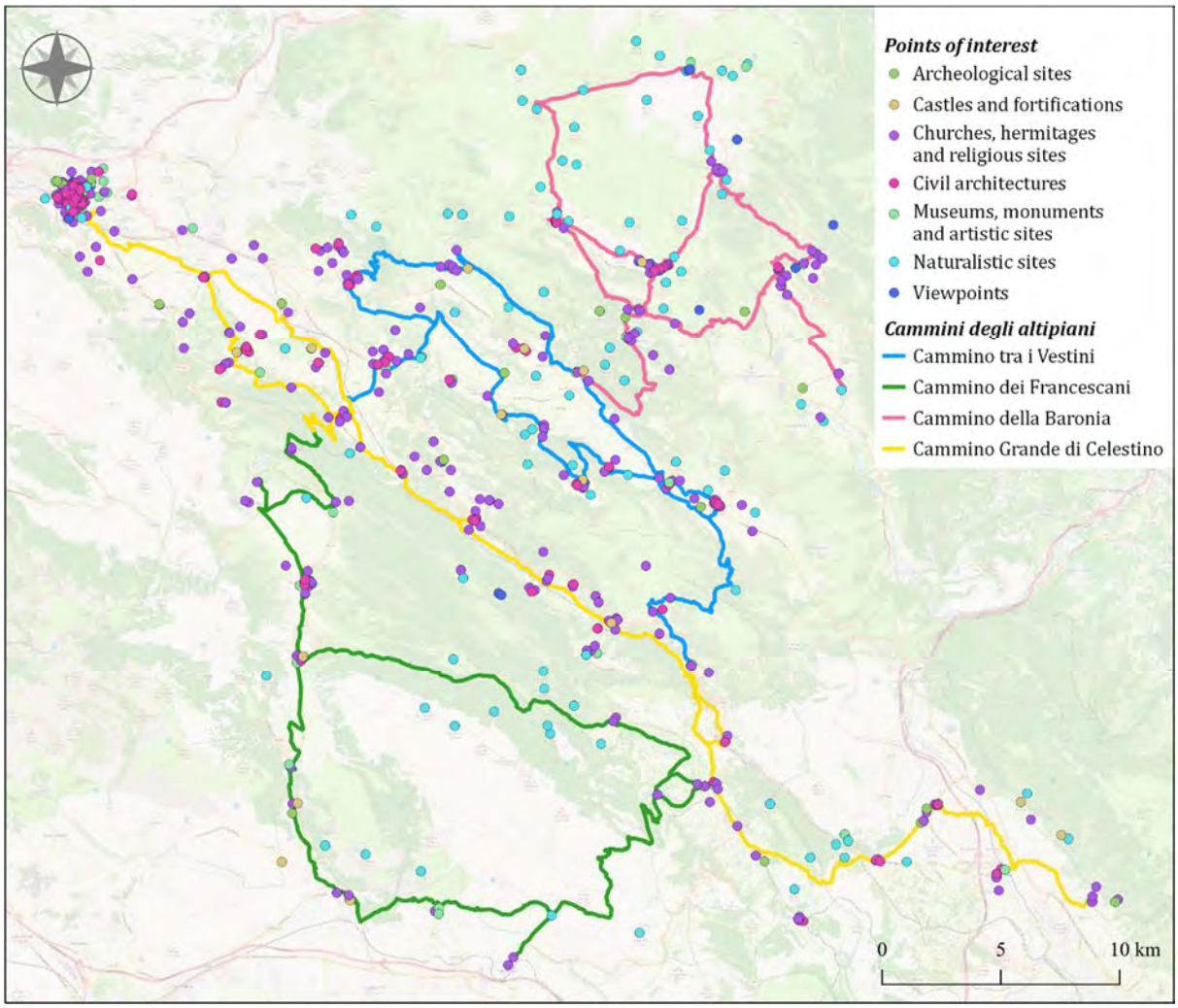


Figure 5. Qualitative characterization of the points of interest

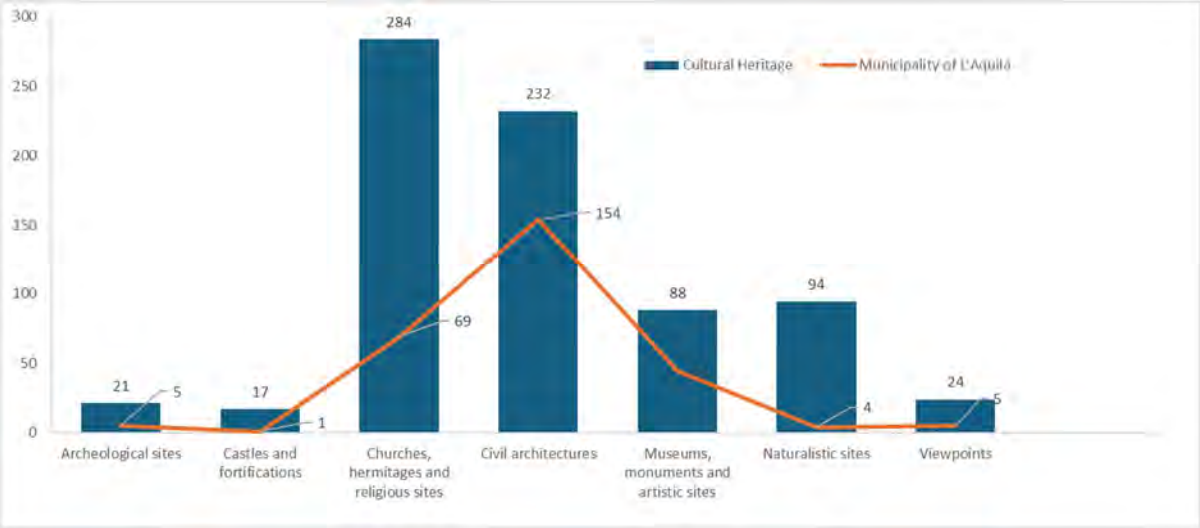


Figure 6. Quantitative characterization of the points of interest

These play an important role in the cultural identity and history of the area and the CRs. To better understand the results, according to the National Strategy for Inner Areas (Strategia Nazionale Aree Interne - SNAI), L'Aquila is a "hub" for essential services but also the city is distinguished by its cultural and historical richness (Di Stefano *et al.*, 2011). Indeed, around 66% of civil architectural heritage in the surrounding buffer zone is in L'Aquila but the accessibility of these structures remains crucial. Public buildings can support cultural tourism and local development, while those privately owned may limit such opportunities. Therefore, more analysis are needed to evaluate the public accessibility to these properties and whether they are architecturally significant.

A 2 km buffer was used to evaluate the points of interest along the CRs, but this analysis overlooks the areas' morphology. Although some locations appear close to CRs in aerial views, the actual walking distances might be longer due to highland topography and the real paths. This may impact the visitor experience, since reaching some locations could be more difficult than expected, suggesting a need for further evaluation of the points of interest and their accessibility (***Figure 7***).

Figure 7. Example of the 2 km buffer limitation

According to the Ministry for the Environment and Energy Security (MASE), the Abruzzo region has the highest percentage of areas under ecological protection compared to the number of sites and the regional surface area. Based on the observations from our case study, 21% of Italy, 36% of the Abruzzo region, and 59% of the municipalities involved in the study fall within PAs similarly, 19% of Italy, 31% of the Abruzzo region, and 61% of the engaged municipalities are classified as Natura 2000 sites. ***Figure 8*** shows the complete and partial overlapping between them in the Abruzzo region.

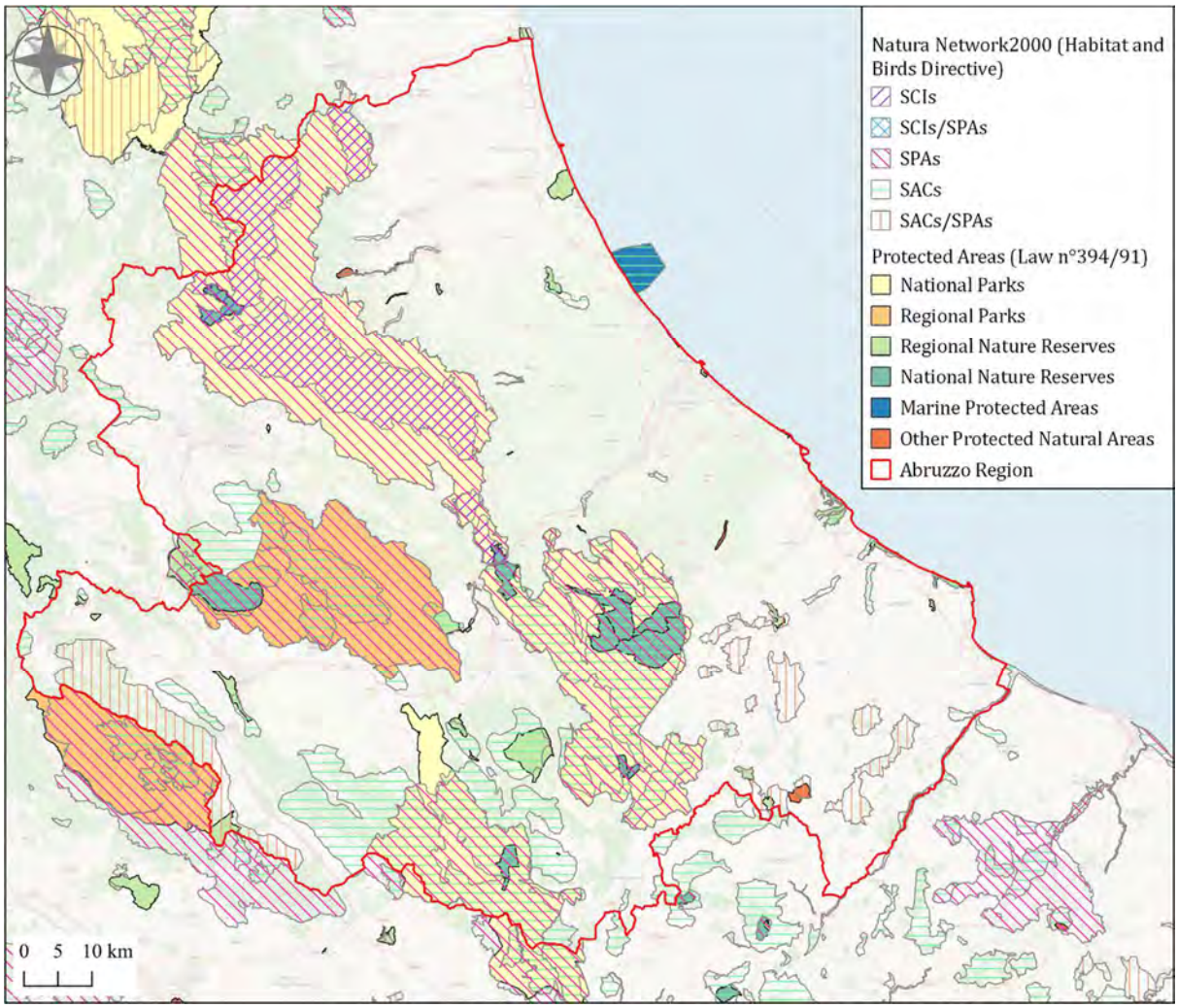


Figure 8. National and international level of protection in the Abruzzo Region

As for the PAs and the CRs, ***Figure 2*** and ***Figure 9*** show that not all the CRs pass through these zones.

Cultural Routes	Length (km)	Length in Natura 2000 (km)	Length in PAs (km)	Percentage of Cultural Routes in Protected Areas
Cammino tra i Vestini	82,41	7,79	7,79	9%
Cammino Grande di Celestino	93,17	38,44	36,17	41%
Cammino della Baronia	77,79	56,26	55,78	72%
Cammino dei Francescani	88,85	79,40	79,40	89%
Total	342,22	181,90	179,13	53%

Figure 9. Percentage of CRs in Protected Areas

As represented the situation is rather diverse. Less than 10 percent of Cammino tra i Vestini is embedded in PAs. However, more than half of the Cammino della Baronia lies within the Gran Sasso and Monti della Laga National Park. In addition, the Cammino dei Francescani is almost entirely located in the Sirente-Velino Regional Park. Lastly, The Cammino Grande di Celestino is the only one that passes through the regional park and intersects with one of the entrances to the Maiella National Park.

Beyond the specific details, it is important to evaluate the overall context of these CRs and PAs. The CRs are interconnected, and as a result, they also link the three PAs. In this way, sustainable mobility and use of the PAs can be achieved, while also connecting the intangible cultural heritage of these environmental attractions.

4. Conclusion

This case study explores how Cultural Routes (CRs) can serve as multidisciplinary laboratories for studying and promoting Cultural Ecosystem Services (CES). Using open data and tools like QGIS enhances spatial visualization and data management, allowing for an objective approach to study Cultural Ecosystem Services (CES) through the spatialization of hotspots and indicators—whether physical, biophysical, or biological, such as protected areas and habitats. However, while this spatial approach facilitates data retrieval, it may overlook CES's intangible qualities (Chan *et al.*, 2006). To address this, subjective methods like social media data (Martí, Serrano-Estrada and Nolasco-Cirugeda, 2019; Prete *et al.*, 2020) or interviews with local communities (Maraja, Barkmann and Tscharntke, 2016) can provide additional insights. This inclusive, bottom-up approach strengthens community engagement and fosters local stewardship (Ulisse, Fico and Marucci, 2024).

In contrast with typical trails, CRs enhance knowledge about cultural heritage and promote biodiversity conservation, especially within protected areas. Future work could include an isochrone analysis for proximity assessment of the points of interest, considering real travel times and terrain features (Khodnenko, Kudinov and Smirnov, 2018). Many CRs pass through protected areas, so it is crucial to balance tourism growth with conservation using sustainable management strategies (Stronza, Hunt and Fitzgerald, 2019; Maksanova *et al.*, 2023).

Acknowledgments. The project was implemented through funding from Measure A, objective 3.a of the National Plan for Complementary Investments to the National Recovery and Resilience Plan (PNRR), under the initiative titled "Creation, implementation, and consolidation of cultural, thematic, and historical routes and pathways."

Ph.D. studentship has been provided by the PNRR found "D.M. 351/2022 M4C1 – Investment 4.1 – Ph.D. program for Public Administration" in collaboration with the Special Office for the Reconstruction of the Crater Municipalities (USRC).

5. References

Angelini, R. and Santarelli, P. (2020) 'Nuove forme di accessibilità fisica e virtuale per la valorizzazione del patrimonio naturale e culturale delle aree interne', *URBANISTICA INFORMAZIONI*, special issue n.(289).

Apostolopoulou, E. and Pantis, J.D. (2009) 'Conceptual gaps in the national strategy for the implementation of the European Natura 2000 conservation policy in Greece', *Biological conservation*, 142(1), pp. 221–237.

Brand, F.S. and Jax, K. (2007) 'Resilience as a Descriptive Concept and a Boundary Object', *Ecology and Society*, 12(1). Available at: http://www.jstor.org/stable/26267855.

Chan, K.M.A. *et al.* (2006) 'Conservation Planning for Ecosystem Services', *PLoS Biology*. Edited by W. Reid, 4(11), p. e379. Available at: https://doi.org/10.1371/journal.pbio.0040379.

Costanza, R. *et al.* (2007) 'Biodiversity and ecosystem services: A multi-scale empirical study of the relationship between species richness and net primary production', *Ecological Economics*, 61(2), pp. 478–491. Available at: https://doi.org/https://doi.org/10.1016/j.ecolecon.2006.03.021.

Fistola, R. and La Rocca, R.A. (2018) 'Slow Mobility and Cultural Tourism. Walking on Historical Paths', in R. Papa, R. Fistola, and C. Gargiulo (eds) *Smart Planning: Sustainability and Mobility in the Age of Change*. Cham: Springer International Publishing, pp. 301–322. Available at: https://doi.org/10.1007/978-3-319-77682-8_18.

Fonseca, C. *et al.* (2014) 'Coastal and marine protected areas as key elements for tourism in small islands', *Journal of Coastal Research*, (70), pp. 461–466.

Friedrichs, M. *et al.* (2018) 'Evaluation of habitat protection under the European Natura 2000 conservation network–The example for Germany', *PLoS One*, 13(12), p. e0208264.

Khodnenko, I., Kudinov, S. and Smirnov, E. (2018) 'Walking distance estimation using multi-agent simulation of pedestrian flows', *Procedia Computer Science*, 136, pp. 489–498. Available at: https://doi.org/10.1016/J.PROCS.2018.08.256.

Mace, G.M., Norris, K. and Fitter, A.H. (2012) 'Biodiversity and ecosystem services: a multilayered relationship', *Trends in Ecology & Evolution*, 27(1), pp. 19–26. Available at: https://doi.org/https://doi.org/10.1016/j.tree.2011.08.006.

Majdoub, W. (2010) 'Analyzing cultural routes from a multidimensional perspective', *Almatourism - Journal of Tourism, Culture and Territorial Development*, 1(2), pp. 29–37. Available at: https://doi.org/10.6092/ISSN.2036-5195/2029.

Maksanova, L. *et al.* (2023) 'Ecotourism Development in the Russian Areas under Nature Protection', *Sustainability 2023, Vol. 15, Page 13661*, 15(18), p. 13661. Available at: https://doi.org/10.3390/SU151813661.

Maraja, R., Barkmann, J. and Tscharntke, T. (2016) 'Perceptions of cultural ecosystem services from urban green', *Ecosystem Services*, 17, pp. 33–39. Available at: https://doi.org/10.1016/J.ECOSER.2015.11.007.

Martí, P., Serrano-Estrada, L. and Nolasco-Cirugeda, A. (2019) 'Social Media data: Challenges, opportunities and limitations in urban studies', *Computers, Environment and Urban Systems*, 74, pp. 161–174. Available at: https://doi.org/10.1016/J.COMPENVURBSYS.2018.11.001.

Mwasaga, R.U. *et al.* (2022) 'Awareness of urban communities on biodiversity conservation in Tanzania's protected areas'.

Di Pietro, R. *et al.* (2019) 'A survey of landscape planning in Italy, where application is utopia. An updated proposal for a shared landscape analysis model', *PLANT SOCIOLOGY*, 56(2), pp. 113–128.

Plieninger, T. *et al.* (2013) 'Assessing, mapping, and quantifying cultural ecosystem services at community level', *Land Use Policy*, 33, pp. 118–129. Available at: https://doi.org/10.1016/J.LANDUSEPOL.2012.12.013.

Portaccio, A., Campagnaro, T. and Sitzia, T. (2023) 'Birds and Natura 2000: a review of the scientific literature', *Bird Conservation International*, 33, p. e20.

Prete, C. *et al.* (2020) 'Foreste e servizi ecosistemici culturali: mappatura su larga scala utilizzando un approccio partecipativo', *L Italia Forestale e Montana*, 75, pp. 119–136. Available at: https://doi.org/10.4129/ifm.2020.3.01.

Sharmin, F. *et al.* (2020) 'Millennial tourists' environmentally sustainable behavior towards a natural protected area: An integrative framework', *Sustainability*, 12(20), p. 8545.

Di Stefano, P. *et al.* (2011) 'SISMA ABRUZZO 2009: La "ricostruzione" del Comune di L'Aquila-Percorso e metodologia', *Anidis 2011* [Preprint].

Stronza, A.L., Hunt, C.A. and Fitzgerald, L.A. (2019) 'Ecotourism for Conservation?', *Annual Review of Environment and Resources*, 44(Volume 44, 2019), pp. 229–253. Available at: https://doi.org/10.1146/ANNUREV-ENVIRON-101718-033046/CITE/REFWORKS.

Ulisse, C., Fico, R. and Marucci, A. (2024) 'Territorial Regeneration in the Crater Municipalities After the Earthquake of L'Aquila: Social Challenges and Innovative Approaches', in O. Gervasi et al. (eds) *Computational Science and Its Applications – ICCSA 2024 Workshops*. Cham: Springer Nature Switzerland, pp. 302–314.

Wang, B., Dane, G. and Arentze, T. (2023) 'A structural equation model to analyze the use of a new multi media platform for increasing awareness of cultural heritage', *Frontiers of Architectural Research*, 12(3), pp. 509–522.

Xu, W. *et al.* (2017) 'Strengthening protected areas for biodiversity and ecosystem services in China', *Proceedings of the National Academy of Sciences*, 114(7), pp. 1601–1606. Available at: https://doi.org/10.1073/pnas.1620503114.

Research Paper

The Evolution and Generation of the Concept of Historic Trails: Based on the Comparison of Chinese and American Practices

Jian Dai, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Xiaoxia Wang, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Chunqi Wang, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

With the increasing demand for spiritual consumption, people's emphasis on the protection and rational use of cultural heritage is also increasing. Starting from theoretical research, this paper traces the concept and evolution of historic trails, and analyzes the classification and construction characteristics of historic trails in China and America. Based on Oregon National Historic Trail and Guangdong-Hong Kong-Macau Greater Bay Area Cultural Heritage Trail, the similarities and differences of historic trail practices between the two countries are compared. The article holds that there are conceptual differences between the historic trails between the two countries: 1. America aims to restore the real trail in history, while China focuses on connecting scattered historical heritages in series; 2. In terms of construction characteristics, the two have unified constituent elements and similar connotation characteristics; 3. According to the practice of historic trails, it is found that America has the standardized historic trail management and interpretation system, while China has the complete sign system, which pays attention to theme and visualization. Through the comparison and summary of historic trails between China and America, the development direction of historic trails is clarified, to promote the planning and construction of Chinese historic trails.

Keywords

Evolution and Generation, Historic Trails, Comparison, Chinese Practices, American Practices

1. Introduction

With the increasing demand for spiritual consumption of the people of various countries, the sense of cultural identity and self-confidence of their own nation are constantly increasing, and the degree of attention to the protection, inheritance and rational utilization of cultural heritage is also constantly increasing (Wang and Wang, 2016). Depending on the source and destination of tourists, some 35 to 80 percent of tourists today travel specifically to gain a deeper understanding of the culture or heritage of a particular destination (Hilary and Bob, 2017). Based on this, the protection of historical and cultural heritage should take historical and cultural heritage as a kind of economic resources and property that

can be exploited, and carry out cultural tourism and cultural commodity development, so as to achieve the sustainable development of cultural heritage. According to the current research, linear cultural heritage can be divided into cultural routes (Wang et al, 2022), heritage corridors (Tao and Wang, 2013), historic trails (Liu, 2013) and other forms with different protection and utilization emphases. With the development of cultural tourism, historic trails have gradually attracted the attention of scholars and urban builders from all over the world.

At present, most of the studies on historic trails take the American National Trail System as the research object to carry out case analysis, mainly because the National Historic Trail System originated in America, and focuses on two aspects: First, the historic trail construction case reference, and many studies take the American Trail System as the research object, such as LeeK. Cerveny (2017) conducted 17 interviews with National Scenic Trail administrators and partners and collected data on governance based on 11 National Scenic Trails in America to propose four governance elements for National Scenic Trail management. Chinese scholar (He et al, 2023) used the case of the American National Trail System to analyze the development status of Chinese national parks by drawing lessons from the experience and lessons of its system mechanism. Second, the development mode of historic trails from the perspective of heritage tourism, using geographical methods to quantitatively analyze the best routes of historic trails, such as applying minimum cost path analysis (LCPA) in GIS to determine cost-effective routes, to form heritage trails and determine the best routes for developing Megalithic Stone Heritage Trails. Chinese scholars (Zhang et al, 2023) mainly use the theory of spatial syntax to sort out the data of tour routes and spatial data, and quantitatively analyze the accessibility of tour routes and the regional linkage effect of tour routes. Some scholars analyze the characteristics of cultural routes from the perspective of sociology, mainly using grounded theory, obtaining open sentence text data, analyzing and discussing the characteristics of cultural heritage routes, and constructing literary thematic tourism routes (Yang et al, 2020; Yue and Li, 2023).

Therefore, this paper mainly discusses the concept of evolution and generation of historic trails, taking America, the origin country of historic trails, and China, which has rich historical and cultural resources, as the research objects, aiming to achieve the following goals: (1) Trace the concept and evolution of historic trails, and analyze the theoretical basis of historic trails; (2) Analyze the classification and characteristics of historic trails in China and America from the construction of historic trails in the two countries; (3) Based on the case practice of Oregon Historic Trail in America and Guangdong-Hong Kong-Macau Greater Bay Area Cultural Heritage Trail(Guangdong) in China, this paper compares the similarities and differences between the concepts of historic trails in the two countries from two aspects: heritage investigation and route selection, management and publicity.

2. Evolution and Generation of Concept of American Historic Trails

2.1. Origin of Concept of American Historic Trail

The concept of historic trails originated in America at the earliest. It was originally built in America to meet the needs of recreation. America defined "trail" as a passage for leisure and recreational activities such as walking, cycling, skiing, and cross-country (Lin and Yu, 2010). Later, based on the National Trail System, the National Trail System Act of America was revised in 1978. The National Historic Trails is officially part of the National Trail System (Figure 1).

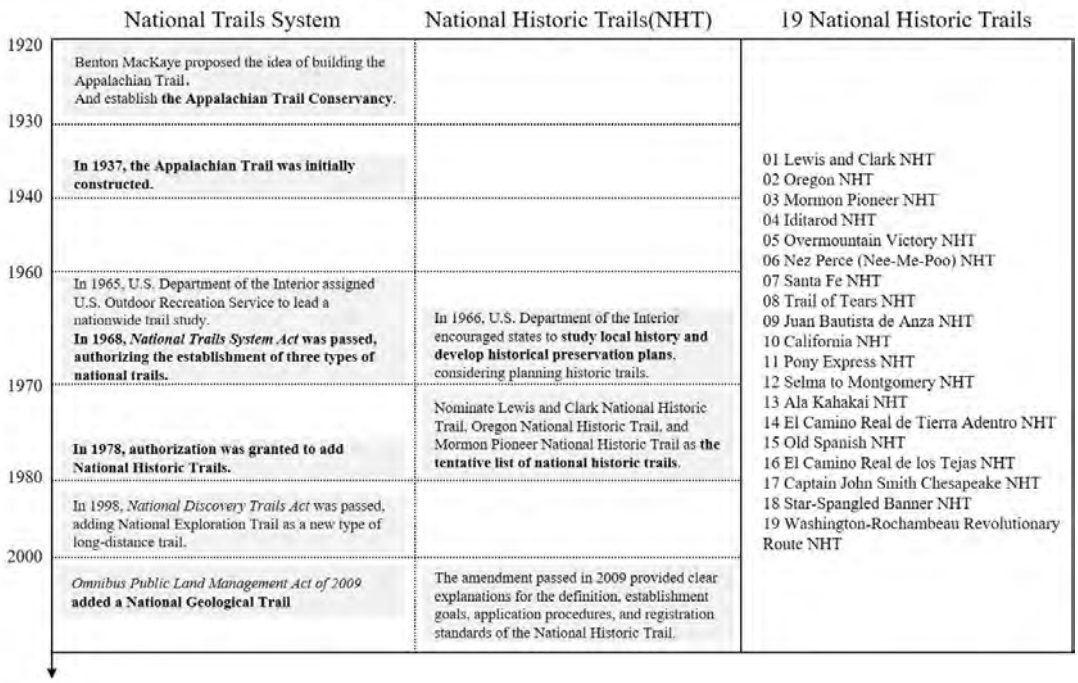


Figure 1. The Development of American Historic Trails. Source: drawn by authors, 2024.

The National Trail System Act of America points out that the National Historical Trail refers to the recreational passage that extends along the original road or route with national historical significance as much as possible and connects real and important historical and cultural resource points in series to achieve the purpose of protecting and spreading history and culture (Du et al, 2015). Up to now, 19 National Historical Trails (He et al, 2022) have been established in America (Figure 1).

2.2. Classification of American Historic Trails

2.2.1. Level of American Historic Trails

The identification of historic trails in America is based on the standards determined by the National Trail System Act and is divided into National and State Trails according to the landing level. According to the status of the Historical Trail, it is divided into six levels (Figure 2), and the base site, the authenticity of the line, and the reconstruction and reconstruction of the line are accurately divided.

The classification of historic trails varies from state to state. Minnesota is divided into State Trails, Regional Trails, County Trails, Local Trails, and Private Trails according to the service scope that the historic trail can carry (Zhang and Wei, 2014).

The condition of trail	Trail Level
The base location can be confirmed, trail is obvious, and the position remains unchanged.	Historic Trail 1
After verification of the location, there have been significant minor changes to trail.	Historic Trail 2
After verification of the location, there is almost no evidence of trail.	Historic Trail 3
After verification of the location, trail will be permanently changed	Historic Trail 4
Approximate or unconfirmed location	Historic Trail 5
The confirmed location has been reconstructed.	Historic Trail 6

Figure 2. Classification according to the status of historic trails in America Source: drawn by authors, 2024.

2.2.2. Classification of American Historic Trails

There is no official statement on the classification of American historic trails. Different states have detailed regulations. For example, Minnesota officials propose that trails should be divided into four categories: Shared-Use Pave Trails, Natural Surface Trails, Bikeways, and Winter-Use Trails according to their usage functions, pavement paving, location, and seasonal changes (Zhang and Wei, 2014). For example, the shared-use paved trail system is mainly composed of multi-level purpose trails (Figure 3).

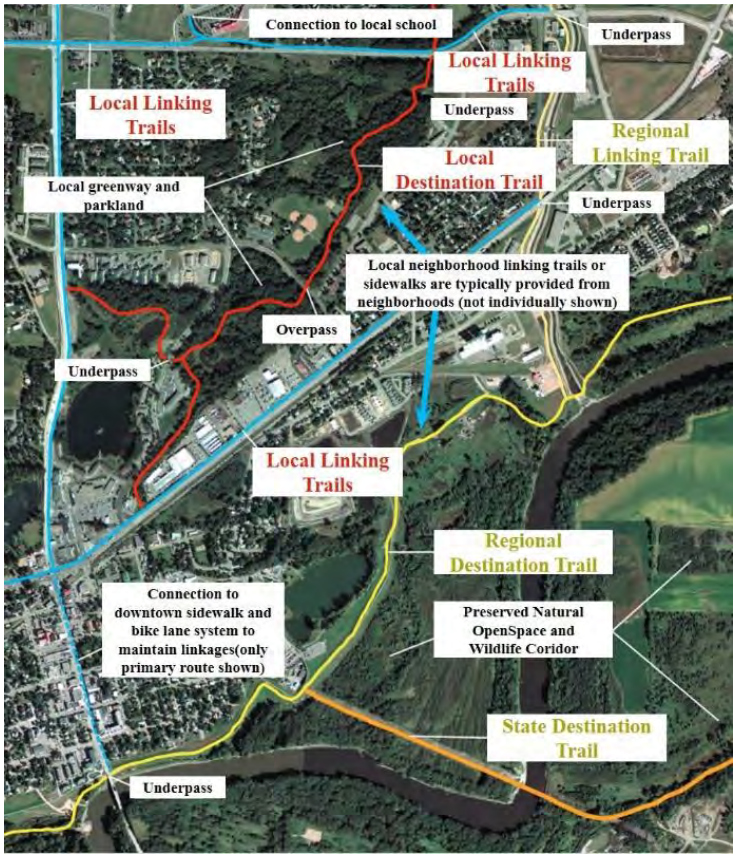


Figure 3. Minnesota Shared-Use Pave Trails System Source: References [18], 2018.

2.3. Practice of Oregon National Historic Trail in American

In 1978, the Oregon National Historic Trail was authorized by Congress. The Oregon Historic Trail began on the banks of the Missouri River in Missouri during the Revolutionary War and crossed plains, mountains, and deserts to Portland (Figure 4). Immigrants came to Oregon during the westward movement of America is an important chapter in the national history of America. The purpose of the Oregon National Historic Trail is to certify, protect, and explain the venues, routes, and history of the Oregon Trail. Let people know their best and understand history (U.S. National Park Service).

Figure 4. Oregon National Historic Trail Distribution Map Source: U.S. National Park Service, 2024.

2.3.1. Investigation and Route Selection of Historic Trail

The Oregon National Historic Trail makes up the trail resource from estuaries and springs to graves and also consists of numerous trail ruts, graves, landmarks, and markings. Combining the natural and cultural elements of each state, including routes, segments, and many different types of historical landscapes, the America *Integrated Management and Use Plan* makes detailed statistics on the number of high-potential areas in each state and the areas that need to be updated (Figure 5). At the same time, the resources of high-potential areas and lots are listed in detail by state.

State	Sites	Segments	Example of Sites
MISSOURI	7	0	National Frontier Trails Museum, Harry S. Truman sites and so on
KANSAS	14	1	Lewis and Clark Park, Hillsdale State Park and so on
NEBRASKA	17	0	Omaha, Fort Calhoun and so on
WYOMING	32	5	Fort Laramie National Historic Site, Cheyenne and so on
IDAHO	32	3	Montrose , Villages of Van Buren and so on
OREGON	27	6	Interstate 84 to Oregon City
WASHINGTON	2	0	——
TOTAL	131	15	——

Figure 5. Oregon National Historic Trail Resource Distribution Map Source: U.S. National Park Service,2024.

The route selection of historic trails should be identified and determined by official institutions according to historical facts. The route should follow the original route in history as much as possible, and the road sections that cannot be restored should be explained by signs or signs. Historic trails can include not only walking trails but also roads and water routes along or parallel to historic trails (Table 1). To raise public awareness of historic trails, the state established Auto Tour Route along existing county, state, and federal highways, allowing two-wheeled driving equipment to pass throughout the year.

Table 1. Oregon Historic Trail Transit Types. Source: U.S. National Park Service.

Traffic type	Function
Motorized section	Mainly for tourists using motorcycles
Non motorized section	For tourists who hike, ride bicycles, and ride horses to pass through
Off road section	The original trail away from highways and roads
Auto Tour Route	Part of it overlaps with the Historic Trail; The other part relies on explanatory facilities to guide the actual travel route

2.3.2. Historic Trail Management and Publicity

In terms of trail image design, due to the large scale of National Historic Trails, the National Park Service of America improves the cultural readability of National Historical Trails and provides tour guidance by developing interactive maps, and unified signs, and designing tourist guides and interpretation systems

(Figure 6). Each state will design according to its trail characteristics and transportation system to provide tourists with the best route. A series of signposts and voice explanation signs will be placed at important nodes so that the public can trace back the background of historic sites, and skillfully use the display function of historic site space to turn historic sites into "museums along the line" for display to the public (Figure 7).

Figure 6. Oregon Historic Trail Travel Guide Source: U.S. National Park Service, 2024.

Figure 7. Signs along Oregon Historic Trail Source: U.S. National Park Service,2024.

3. Evolution and Generation of Concept of Chinese Historic Trails

3.1. Origin of Concept of Chinese Historic Trail

The Chinese Historic Trail was the first one that Hong Kong paid attention to and established a relatively small-scale "Heritage Trail" to strengthen the protection and resource utilization of cultural heritage and provide the public with a deeper understanding of Hong Kong's cultural heritage. At present, there are six heritage trails in Hong Kong (Zhang and Guo, 2016). The construction of Mainland Historic Trails is developed based on the Hong Kong Heritage Trail System and Mainland Greenway Network.

In 2023, China officially proposed to build a "Cultural Heritage Trail", and pointed out that the clear concept is a cultural heritage tourism route with immovable cultural relics as the backbone, specific

themes as the main line, organically related, beaded into a chain, and focused on displaying thematic history and culture (the People's Government of Guangdong Province, 2023).

3.2. Classification of Chinese Historic Trails

3.2.1. Level of Chinese Historic Trails

Similar to the classification of American historic trails, Chinese historic trails are divided into three categories: National Cultural Heritage Trail, Regional Cultural Heritage Trail and County Cultural Heritage Trail (Table 2), emphasizing the integration and development of cultural heritage protection and tourism. Hong Kong Heritage Trail System and Cultural Heritage Trail do not clearly distinguish the grades of trails, and are mainly constructed based on the theme of trails.

Table 2. Level table of Cultural Heritage Trail in China Source: National Cultural Heritage Administration.

Grade	Characteristic	Theme
National Cultural Heritage Trail	Link the construction of National Cultural Parks and major national strategies.	Have national significance and ethnic representativeness, enhance the centripetal force of Chinese culture and expand the international influence of Chinese culture.
Regional Cultural Heritage Trail	Rely on important regional strategies, major projects, or cross provincial important mountains, rivers, and roads.	Highlight the historic and cultural characteristics of the region, condense the tourism logo brand of regional cultural heritage.
County Cultural Heritage Trail	Based on the county as the basic unit, associate various levels and types of cultural relics and cultural heritage resources.	Activate low-level immovable cultural relics to meet the spiritual, cultural, and tourism needs of the people.

3.2.2. Classification of Chinese Historic Trails

The theme of Guangdong-Hong Kong-Macau Greater Bay Area Cultural Heritage Trail (Hereinafter referred to as the Greater Bay Area Trail) is divided into eight major themes (the People's Government of Guangdong Province, 2023). For example, the seven themes of the Hong Kong Heritage Trail (Figure 8). The "National Cultural Heritage Trail" determined by the state also clearly indicates that the theme is the main line of the tour trail, and puts forward the concise angle of the theme of "road time, things and people" (Table 3).

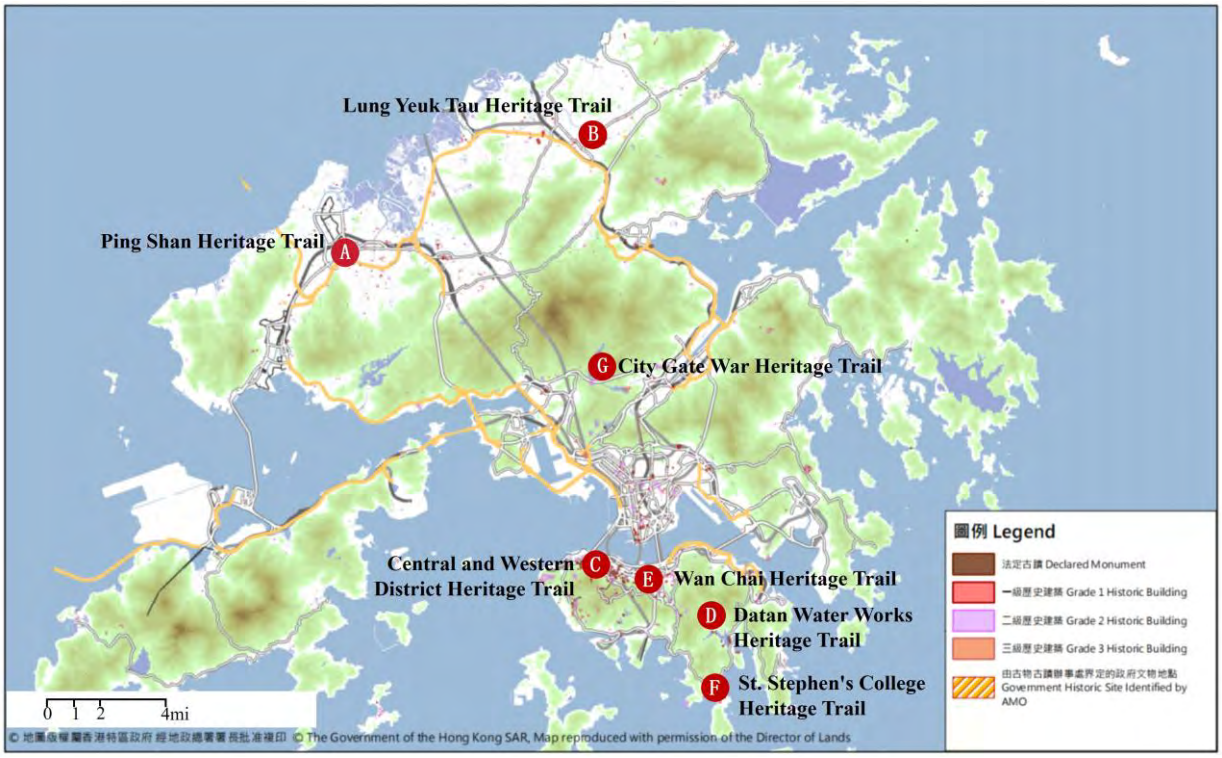


Figure 8. Distribution map of heritage trails in Hong Kong Source: Antiquities and Monuments Office, 2024.

Table 3. National Cultural Heritage Trail Determined by Cultural Relics Theme Trails Source: National Cultural Heritage Administration.

Topic types	Connotation	Case Study of Historic Trail (Taking Guangdong Province as an Example)
Due to historical road becoming trails	Based on historical road networks, water and land corridors, etc., connect water towns, ancient towns, post stations, and associations, recreate the charm of ancient roads.	Guangfu Ancient Post Road Cultural Heritage Trail
Due to historical period becoming trails	Perceive specific stages of civilization progress based on cultural relics, and revolutionary sites from the same period.	Shenzhen Shekou Reform and Open Cultural Heritage Trail
Due to historical events becoming trails	Take historical events and memorial venues as a guide to feel the pulse of history.	Shaoguan Renhua Red Army Long March Cultural Heritage Trail
Due to historical figures becoming trails	Based on celebrity residences, cliff carvings, etc., present the life stories of historical figures and promote patriotism.	Zhuhai Modern celebrities Cultural Heritage Trail

3.3. Practice of Guangdong-Hong Kong-Macau Greater Bay Area Cultural Heritage Trail

3.3.1. Investigation and Route Selection of Historic Trail

Since Guangdong Province put forward the concept of "cultural heritage trails" in 2018, there are currently more than 25,000 immovable cultural relics in Guangdong Province, and nearly 8,000 are expected in the Greater Bay Area Trail announced now include eight major themes and a total of 44 physical trails (Huang).

In terms of the construction of tour trails, the Greater Bay Area Trail are divided into two types: Original Route and Connecting Route. Original Route should be long-distance and suitable for recreation. They mainly rely on greenways, ancient post roads in Nanyue, historical districts, and other walking and cycling quality. Good urban road selection. The Connecting Route is long distance and has poor accessibility, which plays the role of connecting the sites of the trails. It is generally distributed in the peripheral countryside areas, mainly relying on scenic roads, regional roads, country greenways, ancient post roads, and cultural routes .

3.3.2. Historic Trail Management and Publicity

The Greater Bay Area Trail was jointly launched by the Guangdong Provincial Department of Culture and Tourism and other government departments. While announcing the first batch of trails, the Greater Bay Area Trail Sign System of Guangdong Province was also released, which clarified the common visual norms of the three places and formed the theme trail sign (Figure 9).

Figure 9. The Greater Bay Area Trail Sign Source: Guangdong provincial department of culture and tourism, 2024

For the earlier Hong Kong Heritage Trail (now part of the Greater Bay Area Trail system), its interpretation system is more perfect. For example, the interpretation system of the Sun Yat-sen Historic Trail is introduced. The explanation system mainly consists of maps and explanation signs to show tourists carefully planned heritage trails to attract tourists to visit and promote local education (Figure 10). To better explain the history and culture of the trail, there is also an exhibition related to Dr. Sun Yat-sen's life in the Sun Yat-sen Memorial Hall to conduct comprehensive publicity and display to the public.

Figure 10. Schematic Diagram of Interpretation System of Sun Yat-sen's Historic Trail Source: Antiquities and Monuments Office, 2024.

4. Comparative Analysis of Concept Evolution and Practice of Historic Trail between China and America

4.1. Comparison of Concepts of Historic Trails between China and America

Based on the above interpretation, this paper concludes that the biggest difference between the concepts of historic trails in America and China lies in the authenticity of historic trails. American historic trails put more emphasis on the real existence of historic trails, while the connotation of Chinese historic trails has been expanded, which not only protects the authenticity but also emphasizes the role of classification by different themes and connecting many historical and cultural heritages in series (Table 5).

Table 5. Analysis of the Definition of Historic Trails in China and America Source: drawn by authors.

Country	interpretation	Similarity	Difference
America	National Historic Trails	Emphasizing historical significance and recreational value, it can be developed into a tourist route	Emphasize closely following the original historical path as much as possible.
China	Guangdong-Hongkong-Macao Greater Bay Area Cultural Heritage Trail(Guangdong)		Emphasize the specific themes, with connections and string like structures, to showcase thematic historical heritage.

4.2. Comparison of Characteristics of Historic Trails between China and America

According to the classification analysis of the historic trials of the two countries, it is basically based on the scope from the whole country to the local level, and refined to different states or provinces; In terms of classification, American historic trails emphasize the function of trails, while Chinese historic trails emphasize clear themes, and divide resource points with historical figures, historical events, historical routes, etc. as themes. Therefore, this paper summarizes two common characteristics of historic trails between China and America.

4.2.1 The Constituent Elements of Unified Historic Trail

Historic trails at home and abroad are composed of trail sites and routes. The sites in America are areas with high heritage protection value. A considerable number of them have been listed in The National Register of Historic Places simultaneously (Al-Hagla K S, 2010). The sites determined by Guangdong Province refer to the cultural relics and resources related to the trail, including museums, and cultural centers along the way, which are similar to the sites in America and integrate cultural heritages and cultural facilities.

The historic trails in America are formed according to the original routes in history and maintain their authenticity. Historic trails are also classified according to bicycles, walking, and other transportation modes. The Greater Bay Area Trail does not indicate the characteristic of historical authenticity, which refers to the creation of physical trails with moderate length and suitable for recreation in areas or sections with dense resource points. Urban areas rely on greenways and other urban roads with good walking and cycling quality, so that resource points can be reached and it is convenient for sightseeing and experiencing (Figure 11).

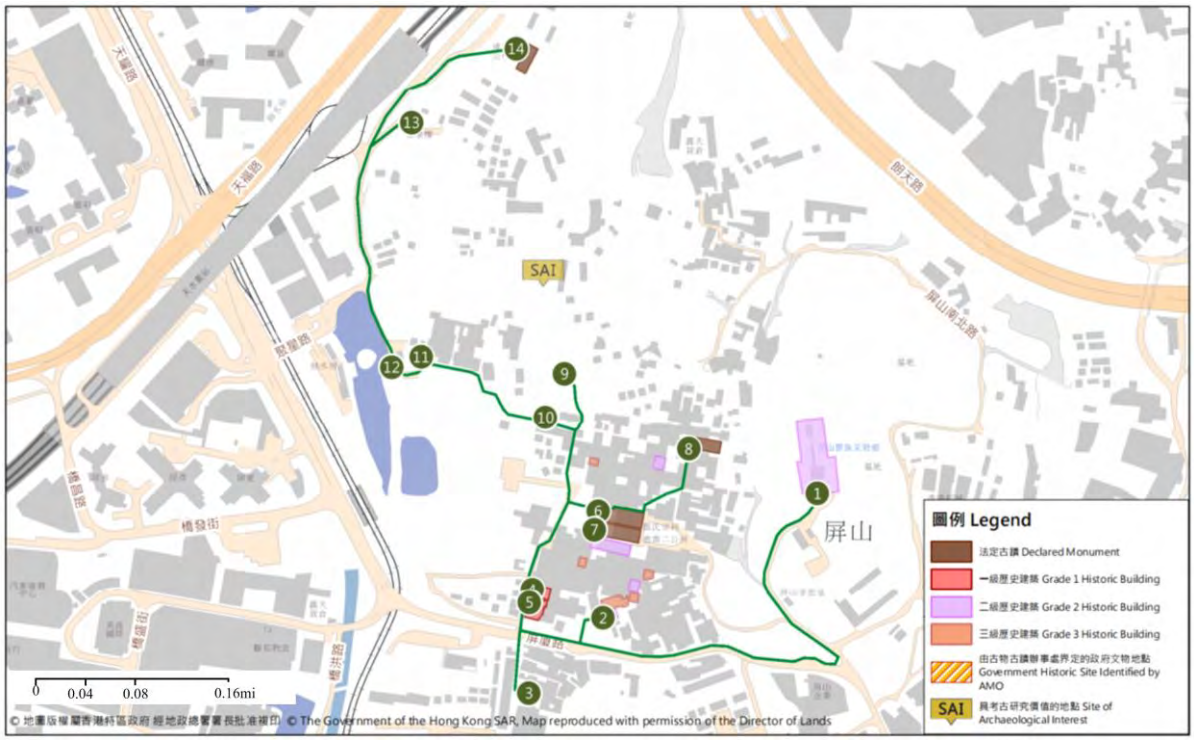


Figure 11. Trail Route Map: Taking Hong Kong and Guangdong as Examples Source: Antiquities and Monuments Office, 2024.

4.2.2 Similar Connotation Characteristics of Historic Trails

Historic trails in both China and America have the connotation characteristics of overall historical significance and recreational value. The American Historic Trail emphasizes that the historical scenic spots along the route should have important national significance and show rich American history. So that the public can learn about American history and culture while relaxing. Chinese historic trails also emphasize the centralized protection and use of historical and cultural resources, to enhance the relevance of historical and cultural resources, so the trail can put historical and cultural resources into the original environment that affects their generation and evolution, and endow the tourist trail with a complete value core (Liu et al,2024).

However, the slight difference is that America has a more institutionalized management system, while China mainly focuses on the theme and visualization of historic trails. From the establishment to the management of historic trails in America, the standardization and legalization of historic trails are guaranteed from a legal height based on the National Trail System Act (Figure 12). China's historic trail emphasizes that the theme is the soul of the trail, and the theme of the trail can reflect the unique historical and cultural heritage. The concise theme can pay attention to the internal relationship between heritage, heritage, and environment in the historical development context. By excavating the theme of heritage elements, the image of the trail will be branded, and the readability of historic trails will be improved.

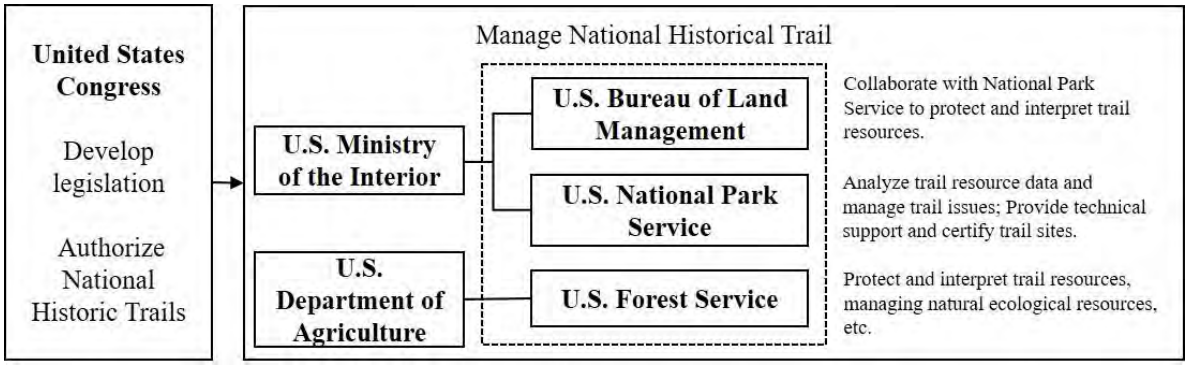


Figure 12. Historic Trails are mainly managed by state agencies Source: drawn by authors, 2024.

4.3. Comparative Analysis of Practice of Historic Trails between China and America

Based on the above analysis and research, this paper compares and analyzes the Oregon National Historic Trail and the Guangdong-Hong Kong-Macau Greater Bay Area Cultural Heritage Trail. In practice, the common point between them is that they have a relatively complete system in route selection, management, and publicity of historic trails, and have formed a historic trail construction and management system. There are some differences at the more detailed level, mainly as follows:

First, at the level of resource survey, when the Oregon National Historic Trail is planned, the number of middle and high potential areas in each state that need to be updated are counted in detail, and the distribution of resources is listed in detail to provide a basis for the selection of national trails. China does not emphasize the detailed sorting out of historical resources but uses the resource list of cultural heritage protection systems to emphasize the theme of historic trails to provide a basis for route selection. Second, in the selection of routes, America puts more emphasis on maintaining the authenticity of the routes, using signs or signs to explain the unrecoverable road sections, and setting up Auto Tour Route to meet the needs of different tourists, while China puts more emphasis on the

accessibility of sites, and some routes will use the existing transportation network to create new ones that are convenient for traffic between sites. Third, in terms of management and publicity, America relies on the National Trail System and has a systematic publicity management system, including management organizational structure and explanation system; However, China has unified regulations on the identification system, and the interpretation and management system is relatively complete in Hong Kong.

5. Conclusion

This paper compares the construction of historic trails between China and America, draws lessons from the experience of American historic trail construction, and explores how to manage groups of historical and cultural heritages in a more centralized way, so as to promote the integration of culture and tourism. The main conclusions are as follows:

First, the concept of historic trails originated from the American National Trail System, and America already has a complete theoretical system. China's historic trails started from the construction of heritage trails in Hong Kong, relying on the construction of greenway network and recreation network, and turned to the protection of historical and cultural heritage. Theoretical research and construction are late, but the concepts of the two are basically the same, and their main purpose is to protect and display cultural heritage.

Secondly, by analyzing the classification of historic trails in the construction of two countries, this paper summarizes the characteristics of historic trails. Their common feature is that they have a unified constituent element-composed of resource points and trail routes, and similar attribute characteristics-overall historical and recreational value. However, the slight difference is that American historic trails are more institutionalized, while Chinese historic trails pay more attention to theme and visual.

Thirdly, by comparing and analyzing Oregon National Historic Trail with Guangdong-Hong Kong-Macau Greater Bay Area Cultural Heritage Trail, it is concluded that America will conduct extensive resource surveys in sites, while China will conduct extensive theme sorting; In terms of route selection, America emphasizes maintaining the authenticity of routes, while China emphasizes the accessibility of sites; In terms of management and publicity, America has a systematic publicity management system. Since China's construction has just started, only the publicity and management of tourist trails in Hong Kong are perfect at present, and the overall management and publicity need to be followed up.

Funding

This work was supported by the Fundamental Research Funds for Heilongjiang Philosophy and Social Sciences Research Planning Project under Grant 23GLB024.

5. References

Wang Chen, Wang Yuan. (2016) 'Introduction to cultural heritage Beijing', *Tsinghua University Press*.

Hilary Du Cros and Bob McKercher. (2017) *Cultural tourism*. Translated from the Chinese by luping Zhu. Beijing: The Commercial Press.

Wang Yingxue et al. (2022) 'Research trends of linear heritage at home and abroad', *Journal of Southwest Forestry University (Social Sciences)*, 6 (1): 8-15.

Tao Li and Wang Liguo. (2013) 'Review on the development history and research progress of linear cultural heritage abroad', *Ideological Front*, 39 (3): 108-114.

Liu, Qingyu. (2013) 'Experience on the protection and utilization of linear cultural heritage abroad', *Southeast Culture*, (2): 29-35.

He Shuyue et al. (2023) 'Spatial representation of national parks from a trail perspective-A case study of US national parks', *Chinese Gardens*, 39 (3): 53-59.

Sieng K T et al. (2023) 'Megalithic Stone Heritage Trail Mapping Using GIS as Tourism Product for Cultural Sustainability in Tambunan', *Sustainability*, 15(4): 3714.

Zhang Bing et al. (2023) 'Accessibility analysis and optimization of zoo trails from the perspective of pathfinding', *Journal of Zhejiang Sci-Tech University (Natural Science Edition)*, 49 (1): 148-156.

Yang Shan et al. (2020) 'Picking up flowers in Shanghai School: A thematic tourist route design with Zhang Ailing's literature as an example', *Library Forum*, 40 (10): 32-41.

Yue Na and Li Jun. (2023) 'Cultural heritage protection path along Huangdukou in Shanxi from the perspective of cultural routes--An exploratory study based on grounded theory', *Arid Region Resources and Environment*, 37 (7): 102-110.

Lin Shenglan and Yu Qing. (2010) 'Act-based U.S. National Trail System', *Urban Planning International*, 25 (3): 81-85.

Du Yan, Lu Xiao and Xue Xiaofei. (2015) 'A review of the management and planning of national historic trails in the United States', *Chinese Gardens*, 31 (8): 40-44.

He Shuyue, Zhao Xinyu and Cheng Min. (2022) 'Research on the Construction of Scenic Trail System in the United States and Its Enlightenment to the Development of Nature Reserve System in China', *Landscape*, 39 (2): 69-76.

Zhang Jingya and Wei Min. (2014) 'Classification and classification of state trails in the United States: a case study of Minnesota', *Chinese Gardens*, 30 (10): 116-119.

He Shuyue et al. (2021) 'Exploring the conservation and development strategies of large linear heritage spaces--Based on the planning and management of the National Historic Trail in California, USA', *Decoration,* (8): 92-97.

Zhang Yujia and Guo Xuan. (2016) 'Fragment and coupling--An exploration of the construction of cultural heritage trails and the integration of historical environment in metropolitan cities', *Modern Urban Research*.

People's government of Guangdong Province (2023) The portal website of Guangdong Provincial People's Government. Available at: https://www.gd.gov.cn/gdywdt/bmdt/content/post_4151112.html. (Accessed: 30 May 2023)

Office of Antiquities and Monuments-Heritage (2021) Office of Antiquities and Monuments-Heritage. Available at: https://www.amo.gov.hk/en/heritage-trails/index.html. (Accessed: 13 June 2024)

People's government of Guangdong Province (2020) The portal website of Guangdong Provincial People's Government. Available at: https://www.mct.gov.cn/whzx/qgwhxxlb/gd/202006/t20200612_854403.htm. (Accessed: 30 May 2023)

Huang Huizi. (2023) 'Study on the revitalization design of historical and cultural blocks in Changzhou Island from the perspective of cultural heritage trails' , *Guangzhou Academy of Fine Arts*.

Qiu Weiping and Lei Linzi. (2022) 'Research on the Development and Protection of Cultural Heritage Trails from the Perspective of Symbiosis Theory--A Case Study of Guangdong-Hong Kong-Macau Greater Bay Area', *Journal of Taiyuan City Vocational and Technical College,* (4): 29-32.

Al-Hagla K S. (2010) 'Sustainable urban development in historical areas using the tourist trail approach: A case study of the Cultural Heritage and Urban Development (CHUD) project in Saida, Lebanon', *Cities*, 27 (4): 234-248.

Liu Junmin, Song Ruiqi and Liu Huihui. (2024) 'Research on cultural relics thematic trails from the perspective of relevance theory', *Journal of Northwestern University (Philosophy and Social Sciences Edition)*, 54 (3): 84-91.

Research Paper

A visibility-based approach to analyze visual and cultural sustainability of Canal heritage

A case of the Grand Canal（Yangzhou Section）

Xin Jin, Southeast University, China
Jiayi Wei, Southeast University, China
Xiang Fu, Southeast University, China

Abstract

Canal heritage plays a crucial role in enhancing urban cultural sustainability through its historical significance and public participation. This study proposes a visibility-based approach to quantitatively assess the visual manifestation of canal heritage, in order to analyze visual and cultural sustainability of the canal heritage.

Keywords

Canal Heritage, Cultural Sustainability, Visual Analysis

1.Introduction

Cultural heritage, which is shaped by environmental, cultural and social factors, is also recognized as a driver and enabler of sustainable urban development, as an important part of the well-being of cities and communities(Tweed and Sutherland, 2007; Alves, 2017). In recent years, governments and institutions have increasingly realized the value and role of cultural heritage in building sustainable cities, and this is becoming a hot topic for scholars(UNESCO, 2021). Articles 2 and 13 of the Convention on the Protection and Promotion of the Diversity of Cultural Expressions emphasize the role of culture in sustainable development. The value of cultural heritage is not only in economic, social and environmental terms, but also in cultural terms due to the importance people attach to the sense of belonging(Liu, Zhang and Wu, 2022), collective memory(Pourbahador and Brinkhuijsen, 2023), spirit of place and cultural identity(Marta de la Torre, 2002) in urban spaces(Hribar, Bole and Pipan, 2015). Cultural heritage in cities contains historical information from different times, and while defining the historical uniqueness of the city, it also provides a blueprint for cultural sustainability(Guzmán, Roders and Colenbrander, 2017; Bohnet *et al.*, 2022). Cultural sustainability is thus precisely the continuation of the city's cultural lineage, where heritage enhances the city's image by shaping people's material perception of the city and improving it even more on a spiritual level(Ziyaee, 2018). For this reason, cultural heritage is also recognized as an important part of the vital fabric of place. From this perspective, the preservation of cultural heritage contributes to the creation of a more historically rich and culturally vibrant city, which in turn promotes the cultural sustainability of the city.

Canal heritage is a typical cultural heritage, and historically important cities are often born and flourished because of rivers(Wuijts *et al.*, 2022), for example, the Rideau Canal in Canada promoted the economic development of Ottawa and Kingston(Jordanna N. Bergman *et al.*, 2021); the Amsterdam Canal in the Netherlands relieved the pressure of transport in the city of Amsterdam and influenced the growth of the city(Pourmohammad-Zia and van Koningsveld, 2024). Canal heritage, on the other hand, as an agglomeration of cultural heritage in a linear geographic space, includes not only the canal waterways, which are regarded as the body of the heritage, but also the associated tangible cultural heritage in space, such as historical sites, important artefacts, and groups of historical buildings(Tang *et al.*, 2022a). By the end of the 20th century, there were more than 63,000 kilometers of canals used as navigation routes worldwide(Bergman *et al.*, 2022). Among them, the Grand Canal of China is considered to be the longest linear cultural heritage in the world, running through 35 cities in China, connecting the country's northern and southern economic zones, and playing an important role as a hub(Fouad, Heggy and Weilacher, 2023). The main purpose of the canal in its early years was to support a wide range of socioeconomic activities such as irrigation, transport and hydroelectric power generation, and the canal continues to fulfil its shipping function to this day. As a living heritage, although the shipping function of canals has gradually diminished with the development of transport in modern cities, due to their rich historical resources and their influence on the evolution of urban spatial patterns, canals have gradually become part of important public spaces in cities today, serving the daily lives of local residents and providing recreational spaces for foreign tourists. The preservation of canal heritage plays a crucial role in enhancing the cultural sustainability of cities by providing public recreational opportunities and aesthetic value through its historical significance and public participation, as well as enhancing the urban landscape and the well-being of its inhabitants(Fouad, Heggy and Weilacher, 2023). In past heritage studies, the cultural sustainability of traditional heritage was often presented through accessibility(Baldarelli and Cardillo, 2022; Dumitrascu, Teodorescu and Cioclu, 2023; Xu *et al.*, 2023). In the case of canal heritage, because of its large cross-regional scale and the large number of heritage units with varying conservation values, visual sustainability is a better way to highlight its cultural sustainability(Guanting Zhang, Shi Cheng, and Yuan Gao, 2023). On the other hand, the heritage value of the canal heritage is not only embodied by a single individual heritage site, but also as the overall image of the heritage resource cluster along the canal. In contrast to the conservation of traditional heritage characterized by a single point and high quality, the conservation of the canal heritage as a whole image from a visual point of view is more likely to highlight the city's cultural identity and enhance its cultural sustainability.

As an important factor to be assessed in the protection of cultural heritage, the visibility of heritage resources is one of the most important indicators to judge the degree of their perception and one of the measures of the integrity of heritage resources(Ashrafi, Kloos and Neugebauer, 2021). By improving the daily visibility of urban dwellers, the canal heritage will be better perceived, which in turn will prevent the occlusion of the canal heritage by buildings in the buffer zone caused by the growth of vertical space due to rapid urban development. Therefore, by realizing the visual sustainability of the canal heritage, the cultural sustainability of the canal heritage can be more significantly reflected. Currently, the development of canal heritage conservation research in different dimensions, such as ecological restoration(Tang *et al.*, 2022; Zhang *et al.*, 2024) and socio-economic benefits(Li, Zhang and Sun, 2020), can be seen from the existing research results, but the number of specialized researches in the direction of visual conservation is relatively small, and there is a lack of researches that propose conservation strategies through quantitative evaluation. On the other hand, the existing visual studies are usually limited to single viewpoints, which cannot be applied to the study of large-scale, linear canal heritage with a large number of viewpoints(Guanting Zhang, Shi Cheng, and Yuan Gao, 2023). Therefore, a quantitative assessment of the visual performance of canal heritage from a visual perspective is necessary and irreplaceable. This study proposes a methodology based on the visibility of a large number of viewpoints to quantitatively assess

the visual performance of canal heritage in order to analyse the visual cultural sustainability of canal heritage.

2. Methodology

2.1.Framework

This paper proposes a practical approach to quantitatively assessing the visual performance of canal heritage by establishing a multi-factorial analytical framework. The goal of visual assessment should be to quantify observers' visual perception of canal heritage and to analyse the visual cultural sustainability of canal heritage. As part of the proposed methodology, this paper is based on the ArcGisPro 3.0 platform for quantitatively analyzing the visual perception of canal heritage. Figure 1 illustrates the framework of the proposed methodology and the study consists of three main phases:

(1) Hierarchical processing of heritage resource points. Canal heritage resource points are important objects for demonstrating cultural sustainability. The canal heritage as an observed point is characterized by a large number of heritage units with varying values, of which the degree of manifestation is not the same for heritage resource points of different high and low values. Generally speaking, resource sites with high heritage value tend to have greater influence in the visual perception of the canal, thus this paper employs the Analytic Hierarchy Process (AHP) to assess and categorize canal-related heritage sites for further analysis.

(2) Quantitative visual processing analysis of multiple types and a large number of viewpoints. As urban corridors, canals provide large-scale public spaces for residents and tourists, and at the same time, they are characterized by a rich variety of barge types and long shorelines. This also results in a large number of viewpoints and viewpoint types during observation in people's daily behavioral areas. This paper extracts process data such as visibility, number of visibility, and area of visibility of cultural heritage units to cope with the situation of multiple types and large-scale continuous viewpoints coexisting with observation points.

(3) Data Analysis and Statistics. Using Python modelling, the calculation results of the previous stage are stratified according to the category criteria, classified according to the attribute information, and batch statistical analysis is carried out to obtain the two indicators of the visibility degree of the number of heritage resource points and the visibility degree of the area of heritage resource points. Meanwhile, to better present the quantification results of each indicator, the Kriging interpolation method (KRG) is used to visualize the results of the visual manifestation indicators, thereby analyzing the visual sustainability status of the canal heritage.

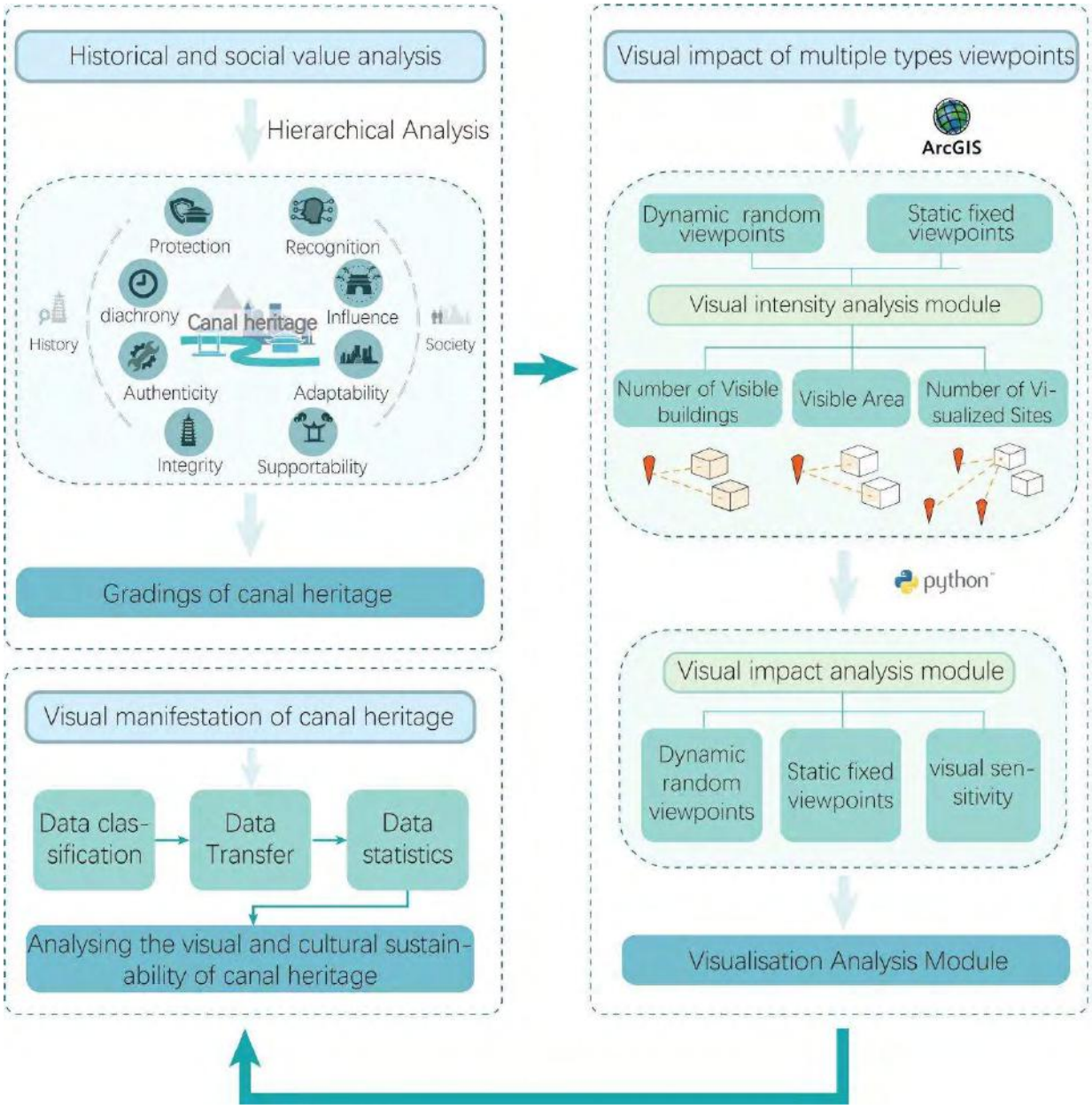


Figure 1. Framework. Source: Authors.

2.2. Classification of Observed Points

This study calculates weights using the Analytic Hierarchy Process (AHP) and the quartile method, with the weights reflecting the relative ranking of value factors.In the topic of cultural sustainable development, the selection of evaluation factors for each material part of the canal heritage fully reflects the multifaceted composition of value, and 8 factors are selected to characterize the conservation value of the heritage site from the 2 aspects of the heritage's historical and social dimensions: the factors of the historical value dimension include protection Level, diachrony, authenticity and Integrity, which describes the inherent historical value of the heritage resource site itself, and it is an evaluation of the heritage's status quo The factors of social value dimension include recognition degree, influence, adaptability and supportability, which describe the degree of influence of the heritage resource site on the city at the cultural level and the coordination and compatibility of the heritage resource site with the city functions, and it is the evaluation of the social influence attribute. In terms of factor assignment, the Rickert 5-point scale is usually used for

grading assignment in previous heritage value evaluation, and to make up for the shortcomings of single-method quantitative assessment, this study uses explicit assignment criteria for scoring. It is worth mentioning that the evaluation index system of this study is an open, flexible and general model, in which the index criteria are relative and can be modified according to the specific needs and assumptions of different cities, and the evaluation indexes under consideration can be expanded when necessary. On this basis, by constructing a two-by-two importance matrix, a comprehensive judgement was obtained, so as to calculate the final weight value of each indicator as shown in Figure 2. Finally, the comprehensive value assessment results of each heritage resource point were calculated. In order to better reveal the differences between the observed points, the calculation results are divided into three Levels: above 6 points, between 4 and 6 points, and below 4 points.

	Type	Weights	Grading criteria						
			10	8	7	6	5	4	2
Heritage Value	Protection	0.292	World Cultural Heritage	National level	Historic Towns of China	Provincial level	City level	County level	Industrial heritage
	Diachrony	0.189	Before 581 AD	581AD-1127AD	-	1127AD-1911AD	-	1911AD-1949AD	After 1949AD
	Authenticity	0.12	Legacy integrity	-	With few traces of present-day tinkering		With some present-day repairs		Incomplete legacy
	Integrity	0.12	With no missing or damaged parts	-	-	With a few missing parts	-	With some missing pieces	With many missing parts
Social Value	Recognition	0.094	Worldwide	National	-	Provincial	-	City	City Area
	Influence	0.073	Carrier of local cultural origins		Representing non-mainstream culture		Representing a certain culture		No involvement
	Adaptability	0.061	Positive to urban sustainability		Neutral to urban sustainability	-	Positive to morden city	Neutral to morden city	Poor integration
	Supportability	0.051	Landscape spatial pattern	-	-	Landscape structure system	-	-	Landscape nodes

Figure 2. Indicators for evaluating the value of heritage resources. Source: Authors.

2.3.Quantitative Processing and Analysis of Visibility of Observed Viewpoints

This study independently developed and designed the visibility analysis module of heritage resource points to solve the problem of large number and types of viewpoints. After grading the heritage resource points, the ArcGIS platform was used to start generating the Urban Digital Elevation Model (UDEM). The heritage resource points divided into three independent layers were imported into the model and set as the observed point layer. In order to facilitate the calculation of the visual field and total field of view of the heritage resource points in different layers, the vector building outline data with elevation information corresponding to the heritage resource points in different layers are converted into DEM data with raster data structure. At the same time, the urban terrain model and urban building model are fused and raster data, i.e., obstacle surface data, are constructed to generate the urban digital elevation model (UDEM).

After setting and defining the viewpoint data and target point data, an iterator is used to loop over all viewpoints.

Next, the viewpoint visibility is calculated for all viewpoints. The visibility analysis module was designed independently for different types of viewpoints to extract process data such as the visibility of heritage resource points, the visibility of heritage resource points based on the number statistics and the visibility of heritage resource points based on the area statistics, in order to cope with the co-existence of multiple types of large-scale consecutive viewpoints and observation points.

2.4. Data analysis and statistics

Data statistics and processing mainly include the processing of the resultant data after modelling and analysis, as well as the output of the resultant data for subsequent quantification and visualization of the indicators. The data processing models such as vector overlay analysis, raster overlay analysis, neighbourhood analysis, partition statistics, summary statistics, spatial connectivity and spatial filtering, attribute filtering, etc. are mainly used in ArcGIS tools. Python modelling was used to count the number of resource points in each Level visible at viewpoint Vi (visual field), to calculate the surface area S of each resource point that can be visible by viewpoint Vi, and to count the area of resource points in each Level visible at viewpoint Vi (total field of view), so as to further count the number of videos of the heritage resource monoliths. The calculation results of the previous stage are stratified according to the category criteria, classified and analyzed according to the attribute information, and statistically analysed by transferring the attributes according to the spatial relationship, and then finally the analysis results are presented through visualization.

3. Case study：the Grand Canal（Yangzhou Section）

3.1. Study site

The 1,794-kilometre-long Grand Canal, listed as a UNESCO World Heritage Site in 2014, dates back to the 5th century BC and is the longest canal in the world. Yangzhou, on the other hand, is the birthplace of the Grand Canal, and the Yangzhou section of the Grand Canal is the earliest and most important section of the canal for canal and salt transport in history, and its shipping function has never been interrupted. In the historical development of more than 2,500 years, there is a close connection between the development of Yangzhou city and the canal water system. Meanwhile, the canal heritage of Yangzhou section is the richest among the regions along the Grand Canal in the country, containing 58 resource sites such as hydraulic heritage, historical and cultural neighbourhoods, gardens and former residences, and industrial heritage.

In the paper, the ancient canal section of Yangzhou of the Grand Canal is taken as the research scope, specifically from the north to Juwan Bay, folding to the southwest through the Golden Dam, and then entering the urban area of Yangzhou from the south until the Gaomin Temple, with a total length of about 18 kilometers. At the same time, the hinterland area of about 1km on both sides of the river (within two

blocks), which has the best pedestrian perception, will be selected for the visibility-based study.

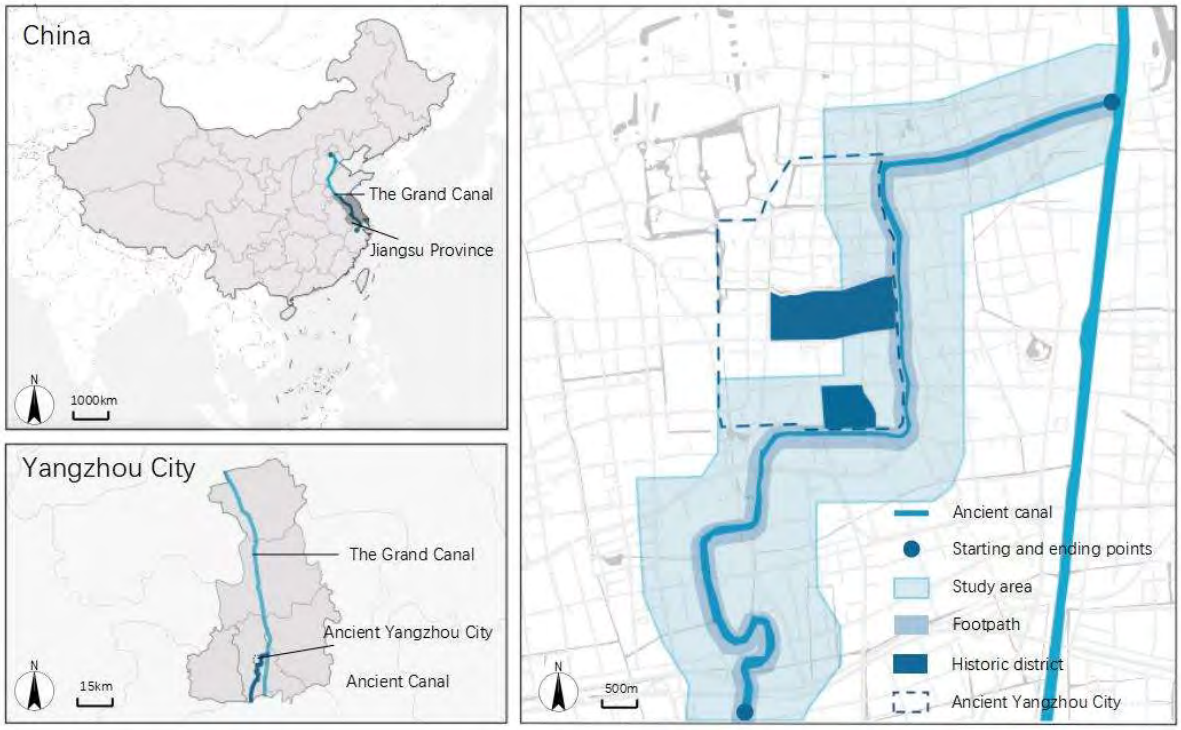


Figure 3.Location of study area.Source: Authors.

In terms of spatial morphology, the canal does not pass through the ancient city of Yangzhou, but joins with other waterways to form a channel and network on the periphery of Yangzhou. In ancient times, the canal flowed through the edge of the city to meet the needs of transit traffic and also to undertake certain defence functions, thus creating a complex shoreline pattern. The rich morphology of the canal system creates a complex visual relationship, and this complexity poses a challenge for the subsequent visibility study.

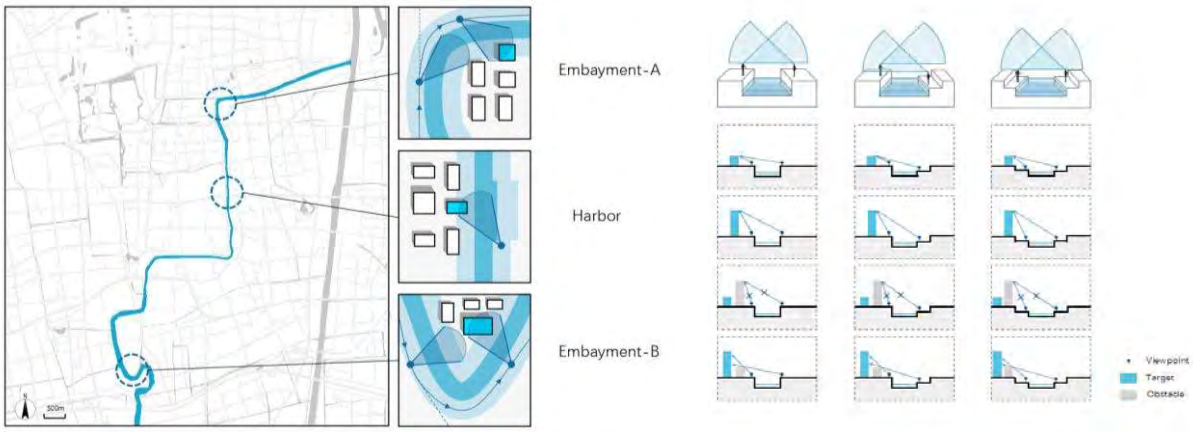


Figure 4.The Complexity of Canal Spatial Patterns.Source: ISOCARP.

3.2. Data Preprocessing

In this paper, the Yangzhou section of the Grand Canal is selected as the research sample, both of which are derived from the BIGEMAP database and the Baidu map database, and are organized and summarized

using the ArcGis tool on the basis of the original data. Considering the calculation time and efficiency, a 2m*2m grid is used to generate elevation raster data in this study. In the environmental modelling, the shoreline is abstracted into three types according to the actual situation of the river cross section of the ancient canal: the height difference between both sides of the river bank and the water surface is 2.5m; the height difference between one side of the river bank and the water surface is 2.5m, and the other side is 0.5m; and the height difference between both sides of the river bank and the water surface is 0.5m. In order to ensure that there are at least two or more viewpoints at the narrowest position of the river, a grid sampling of 10 m * 10 m was used, with a raster accuracy of 1 m * 1 m. The total number of observation points within the study area was about 16,817, of which 10,478 viewpoints at the river surface. Another part that needs to be considered is the setting and definition of viewpoint data. The viewpoints are sampled with a homogeneous grid or extracted as 3D point elements according to a certain pattern, and the height is set as the terrain height plus the average human eye height of 1.7m, so as to construct a 3D viewpoint collection with absolute height.

The study area encompasses a total of 2 resource point clusters and 2,245 individual entities, including architectural structures, infrastructure, ruins, as well as commemorative green spaces and squares. Based on the historical building heritage value assessment criteria, the heritage within the study area of Yangzhou was evaluated for its value, with comprehensive scores calculated and sorted according to their values for ranking and classification. The resource point classification results indicate: Level 1 includes 1 resource point cluster with 422 entities; Level 2 includes 1 resource point cluster with 1,819 entities; Level 3 consists of 4 individual entities, primarily comprising modern industrial heritage and warehouses.

After the setup and definition of the viewpoints (observation points) and target points, an iterator is used to loop over all viewpoints. Next, the visibility of all viewpoints is calculated. Finally, the visual field and total field of view of all viewpoints are calculated. Finally, Python modelling is used to stratify the analysis results according to the category criteria, classify the statistics based on the attribute information, and transfer the attributes based on the spatial relationship to achieve the statistical analysis of the results.

Taking the Yangzhou section of the Grand Canal as an example, we implement the methods of quantification of indicators and visibility analysis to quantitatively assess its visibility and its visual performance as an overall image, so as to analyse its visual and cultural sustainability status, and to help planners and city managers to formulate improvement strategies.

4. Results

This study analyses the key data and important indicators in the process of quantitative visual manifestation treatment of the Yangzhou section of the Grand Canal through system analysis and data processing.The process data generated in the operation of the module are analyzed and the indicators are quantitatively calculated through Python programming, and the results of the visual manifestation indicators are presented with data visualization effects using Kriging interpolation (KRG).

4.1.Visibility analysis of historical resources

The degree of visibility of heritage resource sites varies considerably by Level as shown in the figure: Level 1 resource sites consist mainly of the river itself and the historic buildings along it. In particular, the significant visibility of the river itself makes it the central strength of this Level of resource sites. In addition, other Level 1 heritage resource monoliths tend to be clustered near the canal channel, which has better visibility due to its prominent geographical location and surrounding open space; Level 2 heritage resource sites have reduced visibility compared to Level 1, but their heritage resource sites can still be seen to be

distributed along the canal; and Level 3 heritage resource sites are fewer in number and more dispersed, and their degree of visibility is significantly lower.

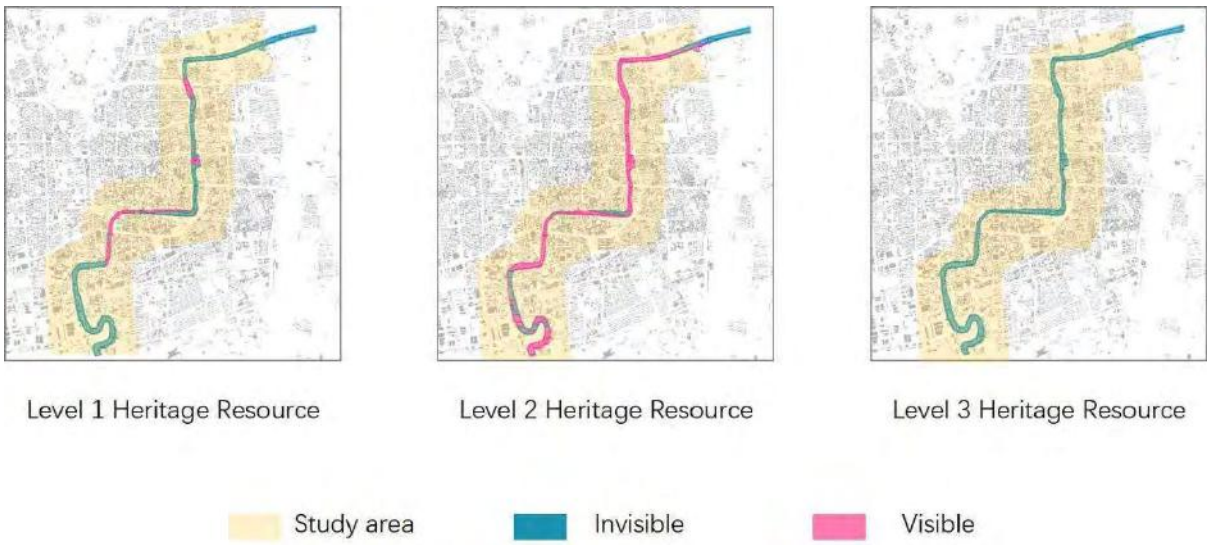


Figure 5.Visibility analysis of historical resources.Source: Authors.

4.2.Spatial distribution of visual manifestation indicators

In this study, in order to more accurately analyse the visibility of the canal heritage, this paper adopts a spatial segmentation method based on Geographic Information Systems (GIS). Specifically, we adopted a 2:1 box format for segmentation, dividing the parcels within the study area into three parts, ABC. This method was chosen to ensure uniform coverage of the study area, while facilitating subsequent data collection and analysis. As shown in the figure, the viewpoints with greater visual impact on the landscape corridor from the primary resource point monoliths are mainly distributed in the B section. The visual degree of each viewpoint based on the number of statistics is lower than that based on the area statistics, mainly due to the fact that the heritage resource monoliths are densely distributed near the street and the river. In addition, the degree of visibility of heritage resource sites from the viewpoints is closely related to the spatial pattern of the river and the height of the surrounding buildings. However, the degree of visibility based on area is similar for all three areas, and is even lower in the Lot B area. For the Level 2 resource sites, the lower degree of visibility based on both counts and area statistics for each viewpoint is primarily due to the fact that most of the heritage resource units in the area are part of the Dongguan Street Historic-Cultural Neighbourhood, with lower average building heights and smaller volumes. The Level 3 resource sites, although they have a greater impact on the Lot C viewpoints with a very high degree of visibility, are of a lower value Level and therefore have less impact on the subsequent composite results.

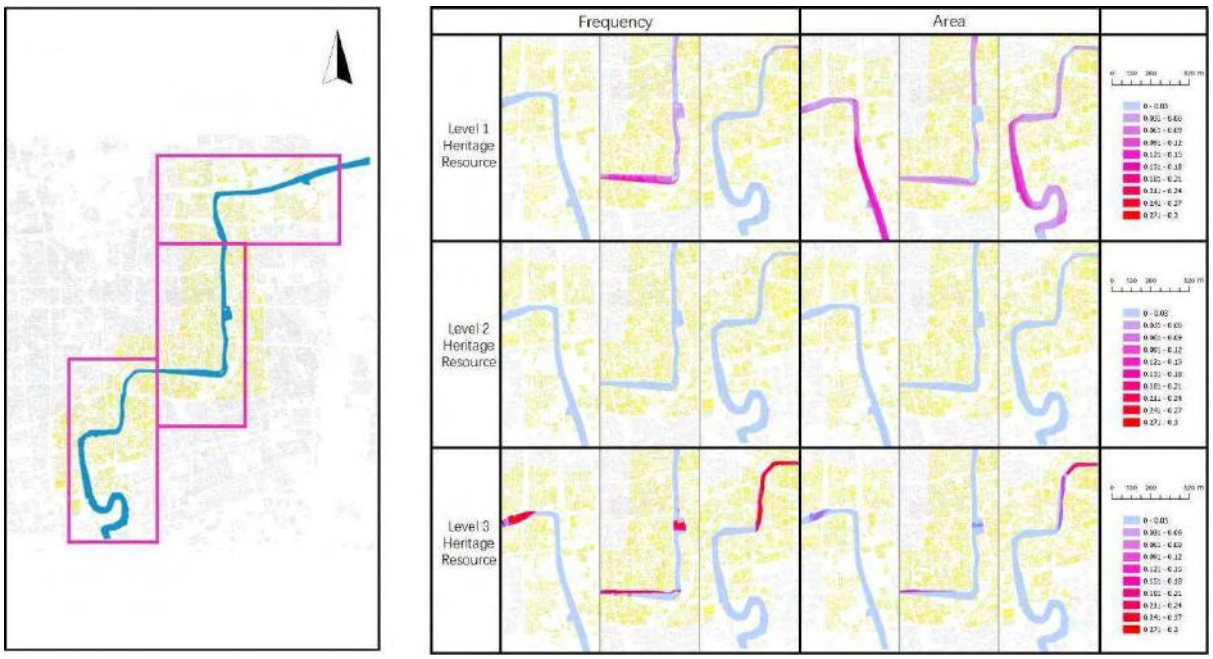


Figure 6.Spatial distribution of visual manifestation indicators.Source: Authors.

4.3.Spatial pattern visual and cultural sustainability

Visual and cultural sustainability is not just a numerical calculation of objective visibility and visibility levels, but a comprehensive analysis of the individual visibility levels of heritage resource sites for each viewpoint based on counts of numbers and based on the same area. It is not only necessary to consider the calculated value of the degree of visibility of each level of heritage resource point, but also need to superimpose the weight of each level of resource point. The weight of the Level 1 resource points is -0.527, the weight of the second-level resource points is -0.333, and the weight of the third-level resource points is -0.140.

On this basis, the calculation results based on the number statistics and based on the area statistics are superimposed without weights, so as to comprehensively demonstrate the spatial pattern of visual and cultural sustainability of the canal heritage. It can be seen that the visual and cultural sustainability of canal heritage not only depends on the number of resources, but also is closely related to the level of its resource sites. The higher grade resource sites are often distributed along the canals, so their visual sustainability is relatively better.

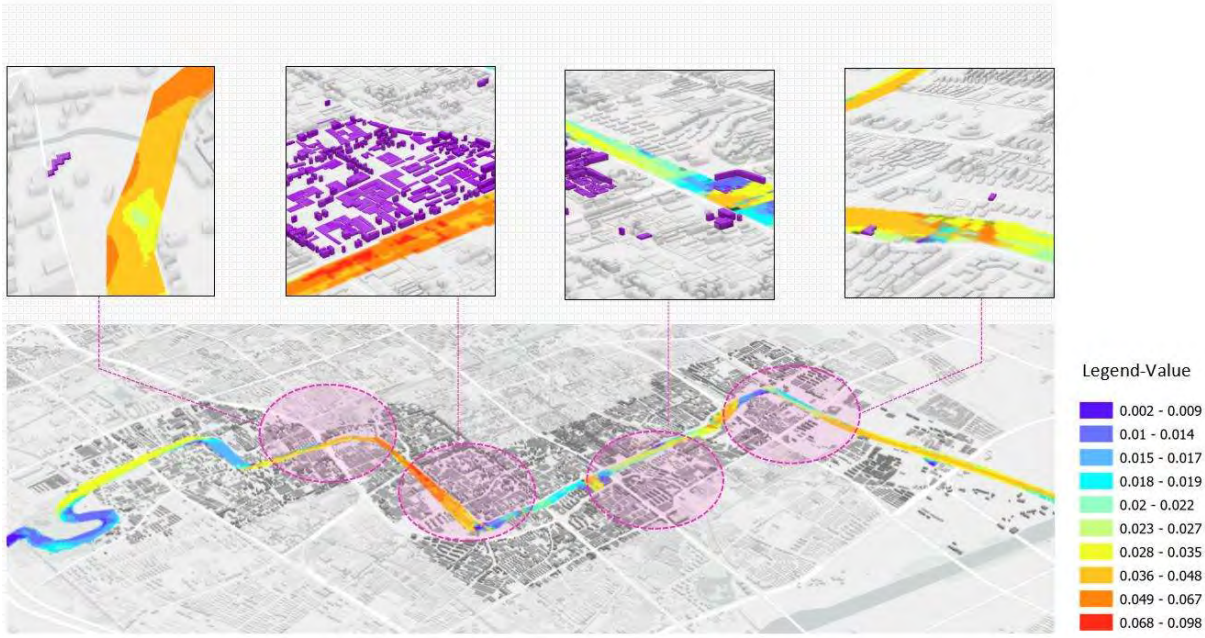


Figure 7.Spatial pattern visual and cultural sustainability.Source: Authors.

5. Conclusion

Canal heritage is recognized as a driver of cultural sustainability(Li *et al.*, 2024), and its visual representation is crucial for enhancing the cultural sustainability of cities. Quantitative assessment studies on its visual performance are still scarce, and this study adopts a large number of viewpoint visibility analyses to explore the visual cultural sustainability of canal heritage in depth. In the process, we constructed a set of scientific assessment methods and selected the Yangzhou section of the Grand Canal as a case study for application, which provides a reference for future planning and decision-making.

Firstly, the hierarchical analysis method and the nine-point method were applied to calculate the weights of the heritage resource points, so as to achieve a hierarchical treatment of these points. Immediately after that, we launched the quantitative processing analysis of visibility of multiple types and a large number of viewpoints. Subsequently, based on the completion of data analysis and statistics, we obtained two important indicators: the degree of visibility of heritage resource sites based on the number statistics and the degree of visibility of heritage resource sites based on the area statistics, which provide us with a quantitative understanding of the visibility of heritage resource sites. In order to further enhance the intuitiveness of the data, we used the Kriging interpolation method to visualize the results. This method not only effectively presents the spatial distribution of canal heritage, but also provides an important basis for the spatial distribution of visual representation.

In summary, this study provides a systematic research template and a feasible technical road map for the visual and cultural sustainability of canal heritage. In the future, this methodology can be widely applied to heritage management and research in other canal cities, helping relevant decision-makers to formulate policies more effectively and promote heritage conservation and sustainable use. Through the establishment of a scientific assessment system, the value of canal heritage will be better reflected, contributing to the sustainable development of culture.

6. Funding

This research was funded by the National Natural Science Foundation of China (grant number 6551240003), the General Project of Social Science Foundation of Jiangsu Province (grant number 22YSC004) and the Fundamental Research Funds for the Central Universities"(grant number 2242023R321).

7. References

Alves, S. (2017) 'The sustainable heritage of vernacular architecture: the historic center of oporto', *Procedia Environmental Sciences*, 38, pp. 187–195. Available at: https://doi.org/10.1016/j.proenv.2017.03.105.

Ashrafi, B., Kloos, M. and Neugebauer, C. (2021) 'Heritage impact assessment, beyond an assessment tool: a comparative analysis of urban development impact on visual integrity in four UNESCO world heritage properties', *Journal of Cultural Heritage*, 47, pp. 199–207. Available at: https://doi.org/10.1016/j.culher.2020.08.002.

Baldarelli, M.-G. and Cardillo, E. (2022) 'Managerial paths, social inclusion, and NBS in tactile cultural products: theory and practice', *Journal of Hospitality & Tourism Research*, 46(3), pp. 544–582. Available at: https://doi.org/10.1177/1096348020944440.

Bergman, J.N. *et al.* (2022) 'Historical, contemporary, and future perspectives on a coupled social–ecological system in a changing world: Canada's historic Rideau Canal', *Environmental Reviews*, 30(1), pp. 72–87. Available at: https://doi.org/10.1139/er-2021-0026.

Bohnet, I.C. *et al.* (2022) 'How cultural heritage can support sustainable landscape development: the case of třeboň basin, czech republic', *Landscape and Urban Planning*, 226, p. 104492. Available at: https://doi.org/10.1016/j.landurbplan.2022.104492.

Dumitrascu, A., Teodorescu, C. and Cioclu, A. (2023) 'Accessibility and tourist satisfaction—influencing factors for tourism in dobrogea, romania', *Sustainability*, 15, p. 7525. Available at: https://doi.org/10.3390/su15097525.

Fouad, S.S., Heggy, E. and Weilacher, U. (2023) 'Waterways transformation in the vulnerable port city of alexandria', *Cities*, 141, p. 104426. Available at: https://doi.org/10.1016/j.cities.2023.104426.

Guanting Zhang, Shi Cheng, and Yuan Gao (2023) 'A visibility-based approach to manage the vertical urban development and maintain visual sustainability of urban mountain landscapes: A case of Mufu Mountain in Nanjing, China'.

Guzmán, P.C., Roders, A.R.P. and Colenbrander, B.J.F. (2017) 'Measuring links between cultural heritage management and sustainable urban development: an overview of global monitoring tools', *Cities*, 60, pp. 192–201. Available at: https://doi.org/10.1016/j.cities.2016.09.005.

Hribar, M.Š., Bole, D. and Pipan, P. (2015) 'Sustainable heritage management: social, economic and other potentials of culture in local development', *Procedia Social and Behavioral Sciences*, 188, pp. 103–110. Available at: https://doi.org/10.1016/j.sbspro.2015.03.344.

Jordanna N. Bergman等 (2021) 'Historical, contemporary, and future perspectives on a coupled social–ecological system in a changing world: canada's historic rideau canal', *Environmental Reviews*, 30(1), pp. 72–87. Available at: https://doi.org/10.1139/er-2021-0026.

Li, H. *et al.* (2024) 'How heritage promotes social cohesion: an urban survey from nara city, japan', *Cities*, 149, p. 104985. Available at: https://doi.org/10.1016/j.cities.2024.104985.

Li, J., Zhang, H. and Sun, Z. (2020) 'Spatiotemporal variations of land urbanization and socioeconomic benefits in a typical sample zone: a case study of the beijing-hangzhou grand canal', *Applied Geography*, 117, p. 102187. Available at: https://doi.org/10.1016/j.apgeog.2020.102187.

Liu, S., Zhang, F. and Wu, F. (2022) 'Contrasting migrants' sense of belonging to the city in selected peri-urban neighbourhoods in beijing', *Cities*, 120, p. 103499. Available at: https://doi.org/10.1016/j.cities.2021.103499.

Pourbahador, P. and Brinkhuijsen, M. (2023) 'Municipal strategies for protecting the sense of place through public space management in historic cities: a case study of Amsterdam', *Cities*, 136, p. 104242. Available at: https://doi.org/10.1016/j.cities.2023.104242.

Pourmohammad-Zia, N. and van Koningsveld, M. (2024) 'Sustainable urban logistics: a case study of waterway integration in Amsterdam', *Sustainable Cities and Society*, 105, p. 105334. Available at: https://doi.org/10.1016/j.scs.2024.105334.

Tang, F. *et al.* (2022a) 'Spatio-temporal variation and coupling coordination relationship between urbanisation and habitat quality in the grand canal, china', *Land Use Policy*, 117, p. 106119. Available at: https://doi.org/10.1016/j.landusepol.2022.106119.

Tang, F. *et al.* (2022b) 'Spatio-temporal variation and coupling coordination relationship between urbanisation and habitat quality in the grand canal, china', *Land Use Policy*, 117, p. 106119. Available at: https://doi.org/10.1016/j.landusepol.2022.106119.

Tweed, C. and Sutherland, M. (2007) 'Built cultural heritage and sustainable urban development', *Landscape and Urban Planning*, 83(1), pp. 62–69. Available at: https://doi.org/10.1016/j.landurbplan.2007.05.008.

UNESCO (2021) 'Culture: 2030 indicators', UNESCO World Heritage Centre. Available at: https://whc.unesco.org/en/culture2030indicators/.

Wuijts, S. *et al.* (2022) 'The health potential of urban water: future scenarios on local risks and opportunities', *Cities*, 125, p. 103639. Available at: https://doi.org/10.1016/j.cities.2022.103639.

Xu, Y. *et al.* (2023) 'Examining the urban regeneration of public cultural space using multi-scale geospatial data: a case study of the historic district in jinan, china', *FronLevels in Built Environment*, 9, p. 1328157. Available at: https://doi.org/10.3389/fbuil.2023.1328157.

Zhang, X. *et al.* (2024) 'Neonicotinoid insecticides in waters of the northern jiangsu segment of the beijing-hangzhou grand canal: environmental and health implications', *Science of the Total Environment*, 923, p. 171455. Available at: https://doi.org/10.1016/j.scitotenv.2024.171455.

Ziyaee, M. (2018) 'Assessment of urban identity through a matrix of cultural landscapes', *Cities*, 74, pp. 21–31. Available at: https://doi.org/10.1016/j.cities.2017.10.021.

Research Paper

The Role of Intangible Cultural Heritage in Sustainable Development of Small Towns

A Case Study of Heilongjiang Province

Jiuqi MENG, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources; School of Architecture and Design, Harbin Institute of Technology, China

Qing YUAN, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources; School of Architecture and Design, Harbin Institute of Technology, China

Dongyu Zhang, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources; School of Architecture and Design, Harbin Institute of Technology, China

Hong Leng, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources; School of Architecture and Design, Harbin Institute of Technology, China

Abstract

The northeastern region of China has a long history and unique folk culture that has bred a rich intangible cultural heritage, especially in small towns characterized by an urban-rural dichotomy. However, with population decline, small towns in Northeast China face a range of economic and ecological risks. Intangible cultural heritage is a potential tool for economic growth and conservation. Therefore, this study takes Heilongjiang, the most northeastern province of China, as an example, and uses data from 2010 and 2020, from 61 county-level administrative units. Firstly, hierarchical clustering is used to categorize the samples into five categories based on intangible cultural heritage, and then examines the relationship between intangible cultural heritage and the level of the economy and ecological environment. The results of the study show that towns with better intangible cultural heritage have better results in terms of economic and ecological aspects, but the rapid growth of intangible cultural heritage may pressure the environment.. This study suggests that intangible cultural heritage may be a tonic for small towns that are losing population, which not only protects and preserves the excellent Chinese culture, but also promotes economic growth and ecological conservation to a certain extent.

Keywords

Intangible Cultural Heritage, Heilongjiang, Balanced Development, Small Towns

1. Introduction

Intangible Cultural Heritage (ICH) is the core of human civilization, something does not manifest in materiality. ICH speaks to local history and collective memory; it also relates strongly to local economic development and environmental protection, thereby being important to sustainable development (Wang, Wen and Fang, 2019). The amount of ICH is often regarded as a key indicator of cultural diversity, especially

in small towns. The UNESCO (United Nations Educational, Scientific and Cultural Organisation) Convention for the Safeguarding of the Intangible Cultural Heritage asserts that cultural diversity has immense value for social, economic and environmental matters (UNESCO, 2022).

Located in the north-east of China, Heilongjiang Province has rich natural resources and a unique industrial historical background. In the early years of the People's Republic of China, lots of agricultural, forestry, mining and industrial small towns were established in Heilongjiang Province. These towns have rich folk culture, and many of them have ICH items certified by the government, such as the Hezhe ethnic group's Imakan rap, the Manchu shaman ritual, and other various traditional handicrafts, songs, dances, and festival activities (Wang, 2020). However, after the reform and opening up, these small towns face risks and challenges such as population loss, economic decline, and ecological damage in the process of industrialisation and urbanisation.

Culture is a more fundamental, profound and enduring force in the development of a people. ICH can enhance the sense of belonging of local residents; it helps to promote tourism and drive economic growth. Therefore, it is important to research on the impact of ICH on the sustainable development of small towns in Heilongjiang Province (Zhang and Zheng, 2023).This study analyzes the changes in ICH from 2010 to 2020 and explores its relationship with economic and environmental indicators, aiming to speculate on the role of ICH in simulating economic development and environmental protection in small towns in Heilongjiang Province. It provides theoretical support for planners and policy makers to formulate strategies for the protection and development of local cultural heritage, as well as a reference for the formulation of planning policies for the balanced development of small towns in Heilongjiang Province.

2. Literature Review

2.1. The State and Challenges of Intangible Cultural Heritage in Heilongjiang's Small Towns

According to UNESCO, intangible cultural heritage (ICH) includes oral traditions and expressions, performing arts, social customs, rituals and festivals, knowledge and practices concerning nature and the universe, and traditional craftsmanship (UNESCO, 2004). The Chinese Government has always attached great importance to the safeguarding of ICH. China's approach to safeguarding ICH has been recognised by the international community. Heilongjiang Province has accumulated rich ICH resources due to its unique cold climatic conditions, frontier geographical location and diverse ethnic cultures (Jiang, 2021). The ICH categories in Heilongjiang include folk traditions, traditional medicine, handicrafts, drama, dance, music, folk literature, as well as traditional sports, games, and acrobatics. At present, the Heilongjiang government has released six batches of provincial ICH lists, of which a large number are declared by counties, such as the Oroqen bear fighting dance in Jiayin County, the traditional brewing technology of Fuyu Laojiao wine in Fuyu County, and Kedong fermented bean curd in Kedong County. This reflects that with the gradual increase in public awareness of cultural heritage protection, small towns in Heilongjiang Province have actively promoted the exploration and protection of intangible cultural heritage, creating a lively situation of extensive social participation and protection and transmission for all (Ping and Li, 2011). Most notably, the Hezhen Imakan storytelling tradition, an important part of the Hezhen fishing and hunting culture, has been inscribed on UNESCO's List of Intangible Cultural Heritage in Need of Urgent Safeguarding (Intangible Heritage Home, 2023).

The ICH of small towns integrates rural culture and also has certain urban civilization characteristics, and residents have a strong sense of cultural identity towards it. Although small towns in Heilongjiang have abundant ICH, they still face challenges of protection and inheritance. In the ten years from 2010 to 2020, the population of Heilongjiang Province has decreased by more than 6.46 million, making it the largest

population loss in China. In severe provinces, many small towns have suffered from significant population decline (Tong et al., 2020). Well-educated young people are choosing to go to other regions for employment, resulting in a decline in cultural identity, a shortage of cultural bearers, and a lack of protection of the ICH (Khakzad, 2017). At the same time, good cultural resources have not been well developed, making it difficult to transform them into economic and social value. Against the backdrop of the economic recession in the Northeast, the lack of funding for small towns has limited the preservation and development of ICH, creating a vicious circle. Population loss has stymied the development of ICH-related endeavours in small towns in Heilongjiang Province, creating the need for a more systematic cultural strategy.

2.2. The Role of Intangible Cultural Heritage in Small Towns' Sustainable Development

Numerous studies have shown that ICH plays an important driving role in the economy, society, and ecology of small towns. Firstly, in terms of economy, ICH is conducive to drive local economic growth by promoting the development of industrial production and cultural tourism (Wang, Wen and Fang, 2019). Cultural tourism is an important component of the tertiary industry in small towns. On the one hand, cultural tourism can provide a large number of job opportunities, alleviate the crisis of population loss, and increase population vitality. On the other hand, cultural tourism can attract tourists and stimulate consumption, increase local fiscal revenue, and provide capital for the development of various undertakings. As a major growth driver for many small towns, cultural tourism attracts tourists, stimulates local consumption, and creates employment opportunities. For example, Ning'an County has attracted many young tourists interested in Qing Dynasty costume dramas by developing the theme tourism of Ninggu Pagoda, which has stimulated the local economic development. However, the impact of the tourism industry on the economy exhibits seasonal fluctuations (Corpo et al., 2008). ICH has a relatively stable economic impact on small towns due to industrial production. For example, Kedong County has the famous traditional food "Kedong fermented bean curd" in China. The industrial production makes this ICH continue to drive local economic growth.

Socially, ICH reflects the history of small towns and the collective memory of their inhabitants. Inheriting and developing ICH helps to enhance residents' sense of belonging and cohesion. Residents of small towns promote social interaction by organising cultural activities related to ICH (Xia, Chen and Hou, 2020). For example, events such as the Monkey Stone Mountain Temple Festival in Bin County and the Russian Basque Festival in Xunke County promote cultural transmission and enhance young people's sense of identity with traditional culture, thereby strengthening their sense of belonging to their hometowns and easing population loss (Su et al., 2020). However, to maximise economic benefits, some local governments have over-commercialised the ICH, which causes it to lose its original cultural essence and may lead to misunderstandings among residents, making it difficult to enhance social cohesion.

In terms of the environment, many traditional lifestyles reflected in ICH are closely related to natural ecology. ICH related to primary industries such as agriculture, forestry, and fisheries often emphasize the sustainable use of natural resources (Tani, Hashimoto, and Ochiai, 2016) to achieve the traditional Chinese ecological concept of "harmony between man and nature, and coexistence of all things". For example, the River Opening Ritual in Raohe County, the agricultural customs in Lanxi County, and the Northeast black bee farming techniques in Raohe County all emphasize the continuous acquisition of natural resources through respect for nature. The concept of harmonious coexistence between humans and nature is valuable for contemporary environmental protection. However, excessive development of cultural tourism to promote local ICH may put pressure on the ecological environment, increasing waste and energy consumption (Lin et al., 2021). Therefore, how to protect and inherit ICH while achieving environmental sustainability remains an urgent challenge to be addressed.

In summary, although ICH has significant value for the economic, social, and ecological sustainable development of small towns, its practical application still faces risks. How to further research and formulate policies to balance the relationship between development and protection is still an area that needs attention.

3. Methodology

3.1. Research Area and Data

The research scope includes all county-level administrative units in Heilongjiang Province that are not under the jurisdiction of the city. A few units have been omitted due to administrative division adjustments. Ultimately, the study area includes 61 county-level units, including 41 counties and 20 county-level cities (Figure 1). Among these 61 county-level unit samples, only two counties have experienced population growth in the past decade, while the rest of the county-level units have experienced population decline.

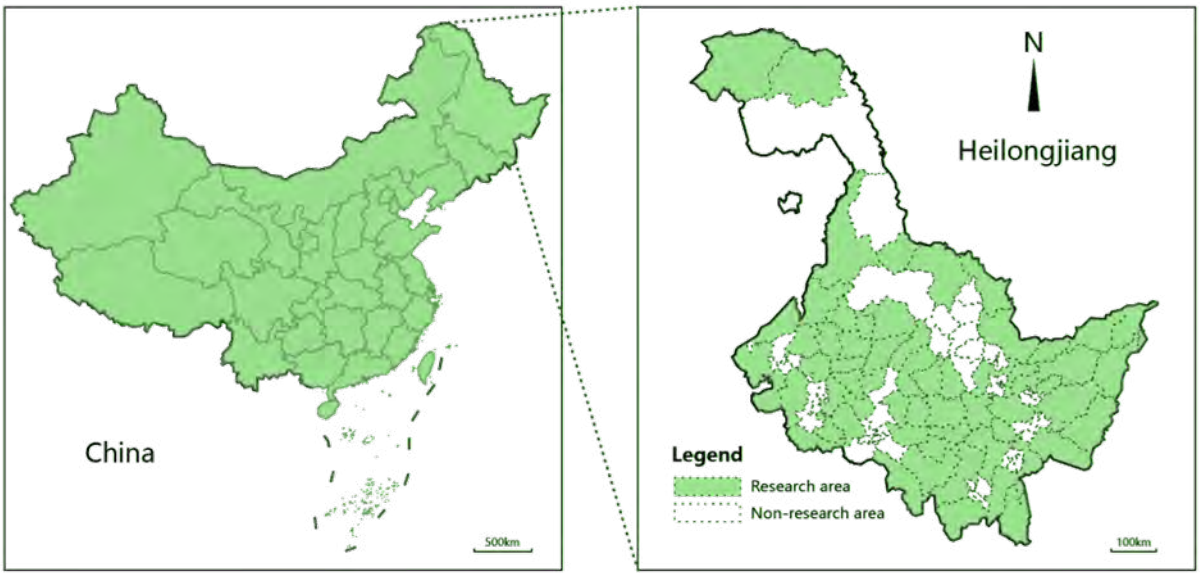


Figure 1. Research Area. Map Source: Amap Open Platform.

The data on the number of ICH projects comes from six batches of the Heilongjiang Provincial Intangible Cultural Heritage List on the website of the Heilongjiang Provincial Government. Date of per capita disposable income for both urban and rural residents was gathered from statistical yearbooks. They are economic indicators. NDVI data was obtained from NASA's MOD13A3 dataset, with annual NDVI values calculated using the maximum synthesis method, processed in alignment with the study area's administrative boundaries. PM2.5 data came from the high-resolution Surface PM2.5 dataset by the Atmospheric Composition Analysis Group at Washington University in St. Louis (Hammer et al., 2020), with yearly averages calculated per county based on administrative boundaries. NDVI and PM concentration are ecological indicators.

3.2. Research Methodology

This study uses hierarchical clustering method to classify small towns in Heilongjiang Province based on the changes in the number of ICH between 2010 and 2020. Hierarchical clustering divides the dataset into different levels to form a tree-like clustering structure. This method can reflect the hierarchical relationship of classes without the need to predetermine the number of clusters effectively.

The specific steps of this study are as follows: (1) Calculate the distance matrix between categories: Based on the data of ICH quantity changes from 2010 to 2020, use Euclidean distance to calculate the distance matrix between each small town. (2) Perform hierarchical clustering: Based on the calculated distance matrix, Ward D method is used for hierarchical clustering of small towns. This method gradually combines the two combinations with the highest similarity to form a new group and calculates the intra-group differences of the new group to minimize intra-group differences during each merge, ensuring that the new grouping structure remains compact. Repeat this process to gradually merge all samples into a hierarchical structure, namely a tree diagram, providing grouping criteria for the final clustering results clearly. (3) Determine the number of clusters: By observing the tree diagram and combining it with actual research needs, select the optimal number of clusters. This study ultimately classified small towns into five categories. The red line in Figure 2 marks the segmentation points of the hierarchy.

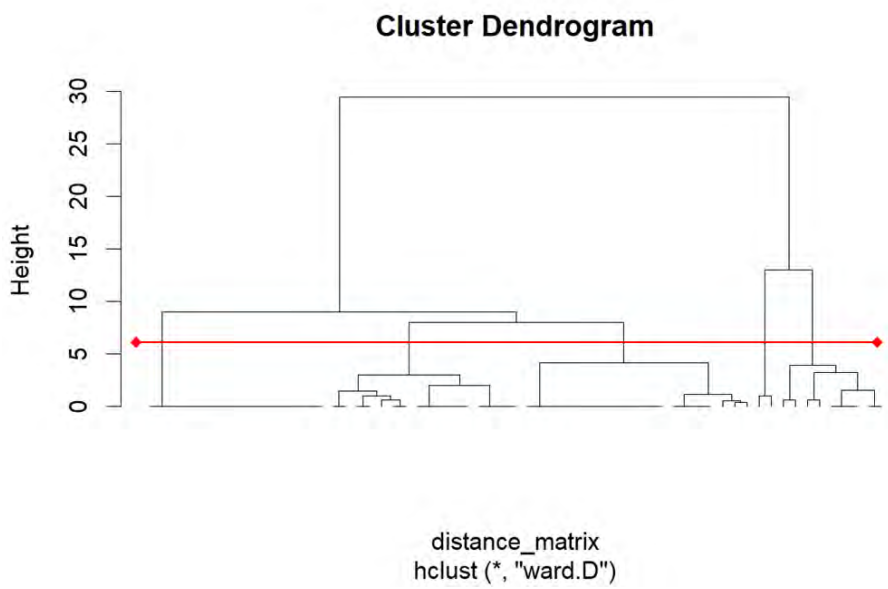


Figure 2. Dendrogram of Clustering. Source: author.

After clustering, further analyze the characteristics of each category and compare the similarities and differences between different categories to explore the relationship between changes in ICH quantity and economic and ecological indicators.

4. Result

4.1. Result of Clustering

The scatter plot and spatial distribution map of the small town classification results are shown as Figure3 and 4.

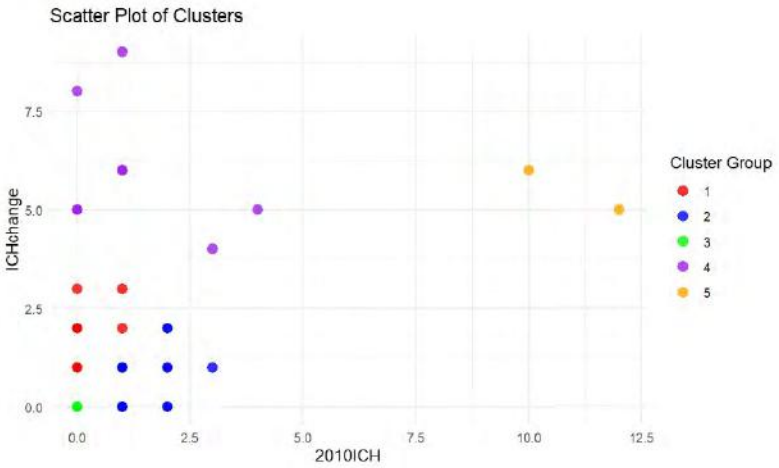


Figure 3. Scatter Plot of The Small Town Classification Results. Source: author.

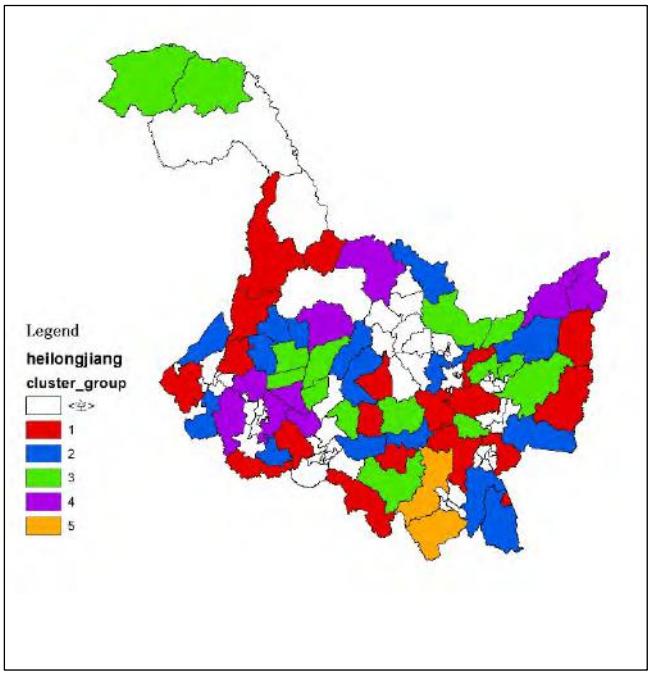


Figure 4. Spatial Distribution of The Small Town Classification Results. Source: author.

(1) Category 1 (Red): Weak foundation, slow development

In 2010, the number of ICH in these small towns was almost zero; from 2010 to 2020, the growth in the number of ICH remained minimal, with most towns not exceeding 2, indicating slow development of their ICH.

(2) Category 2 (Blue): Moderate foundation, stagnant development

In 2010, the number of ICH in small towns in this category ranged from 0 to 2, indicating a relatively weak foundation. But until 2020, the number of their ICH remained almost unchanged, suggesting that the development of their ICH has almost stagnated.

(3) Category 3 (Green): No ICH foundation

In 2010, small towns in this category had zero ICH, and this number did not change from 2010 to 2020, implying that they had no effect on the excavation of ICH..

(4) Category 4 (Purple): Moderate foundation, rapid development

In 2010, the number of ICH in these small towns ranged from 2 to 5. It is worth noting that the number of their ICHs has significantly increased in 2020, with each increasing by more than 5. This indicates that small towns of this type have achieved good results in developing ICH.

(5) Category 5 (Yellow): Good foundation, stable development

The only small towns belonging to this category are Hailin City and Ning'an City, two county-level cities. In 2010, the ICH number of these small towns was significantly higher than other categories, at over 10. From 2010 to 2020, their ICH numbers further increased, indicating a strong foundation in the protection and development of ICH.

4.2. Differences between Different Cluster Groups

After clustering, the study conducted an in-depth analysis for each category to reveal the relationship between ICH development and the economic and ecological indicators of small towns. The study uses the boxplots diagram in Figure 5 to show the distribution of these indicators in the different categories.

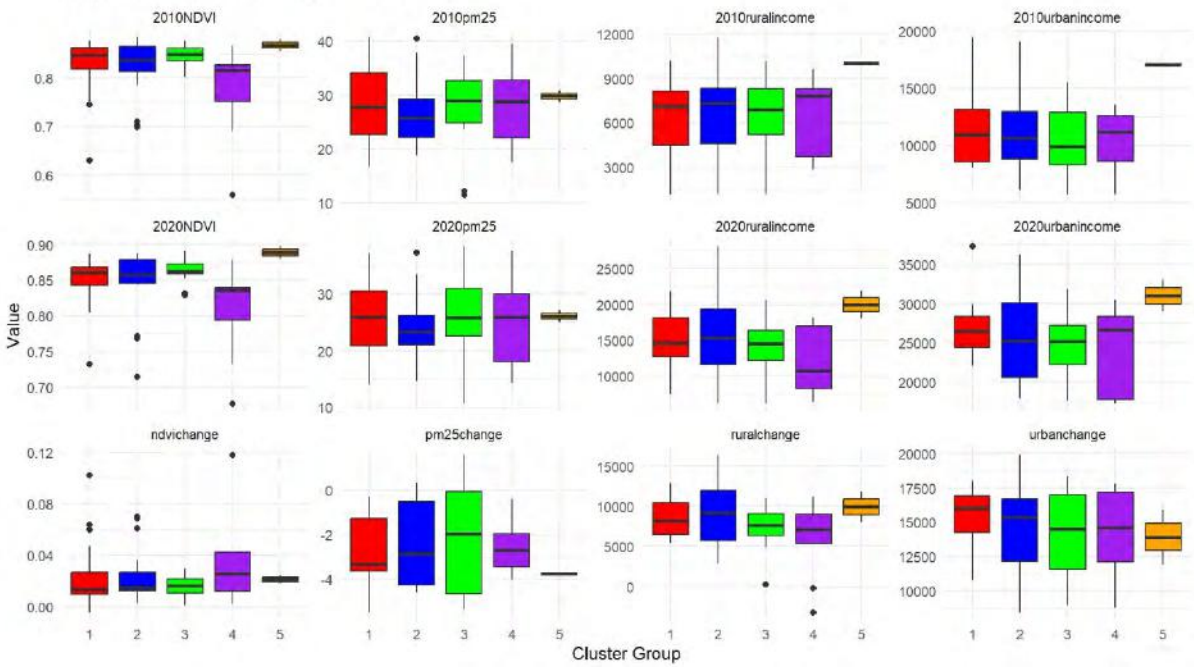


Figure 5. Boxplots of Various Fields by Cluster Group. Source: author.

(1) Ecological Indicators

NDVI: Boxplots from 2010 and 2020 showed that the NDVI levels and changes in the first three categories of small towns were similar and consistently remained at a relatively high level, showing that the vegetation coverage in these small towns was good and stable. The NDVI of the fifth category of small towns has always been the highest, implying that the ecological environment quality of these small towns is good. However, compared to other categories, the vegetation coverage of small towns in category 4 is significantly lower.

PM2.5 Concentrations: Overall, the PM2.5 concentrations in various small towns have decreased, indicating that the overall air quality in Heilongjiang Province has improved in the past decade. The

category 2 small towns have the best air quality among all categories. Although Category 5 small towns had the worst air quality in 2010, they also showed the most significant improvement.

(2) Economic Indicators

Per Capita Disposable Income of Rural Residents: From 2010 to 2020, rural incomes in small towns in category 5 have been significantly higher than other categories and have shown substantial growth, reflecting the more developed rural economies of these small towns. Small towns in category 4 show the least growth in rural incomes over the decade, resulting in their levels of rural incomes being significantly lower than those of small towns in the other categories in 2020. Small towns in category 2, which would have been average, had more growth over the decade, resulting in better overall rural income levels in 2020.

Per Capita Disposable Income of Urban Residents: In 2010, category 5 small towns show a fairly clear advantage in urban income over other small towns, and despite lower growth rates, they also continue to lead the way in urban income in 2020, reflecting the fact that these small towns have very prosperous urban economies. Meanwhile, small towns in categories 1 and 4 had relatively high town incomes in 2010 and show noticeable growth over the decade, especially in category 1. Thus, these small towns show relatively high town incomes in 2020.

5. Discussion

(1) Development strategy for category 1 small towns

The ICH foundation of small towns in category 1 is very weak, and their economic development is relatively average. Despite growth in urban income, the overall economic level remains at a moderate level. In terms of ecology, they have good vegetation coverage and improved air quality. However, due to the lack of ICH resources, these small towns find it difficult to promote ecotourism or environmental protection through the activation and utilization of cultural resources. The lack of ICH may hinder its innovative policies in managing natural resources.

These small towns should prioritize the excavation and promotion of ICH, and enhance residents' cultural identity through the development of cultural resources. Ecotourism can be developed with appropriate policy support. The government should provide economic incentives and educational training for projects with cultural potential to help these areas establish cultural industries. For example, Wuchang City has one of the best rice in China, Wuchang rice, but there is no ICH related to it. The local government can try to collect folk stories and legends related to the planting and cultivation of Wuchang rice, declare the ICH, and rely on it to develop farming theme tourism.

(2) Development strategy for category 2 small towns

The ICH foundation of small towns in category 2 is slightly better than that of category 1, but these towns have stagnated in ICH development. These small towns have the best ecological environment indicators among all categories, showing effective local ecological governance. However, the poor development of ICH limits the potential for achieving economic benefits through cultural tourism or ecological economy.

With a good ecological environment, category 2 small towns should pay attention to future prospects in developing cultural tourism and ecological economy. These towns can develop cultural and ecological tourism industries to promote economic growth. For example, Mishan City has Xingkai Lake, the boundary lake between China and Russia, which is the largest freshwater lake in East Asia. But there are only two ICH items about Xingkai Lake: Xingkai Lake legend and Xingkai Lake winter fishing, which leads to a lack of anchor points for the development of tourism in the local area. The government can fully leverage the rich

ecological resources and beautiful landscapes of Xingkai Lake to vigorously promote ecotourism, integrate cultural, ecological, and economic activities, and gradually improve residents' income levels.

(3) Development strategy for category 3 small towns

The small towns in category 3 do not have any ICH base. Despite their high environmental quality, their economic development is more mediocre, implying a lack of economic motivation. These small towns are unable to utilise ICH resources to convert them into economic value, and their eco-environmental protection efforts are under greater pressure.

The main task for Category 3 small towns is to identify cultural resources and initiate cultural industry support programmes. The government can encourage local cultural experts and scholars to participate in documenting potential ICH projects and formulating development and promotion plans. These towns can raise their profile by organising festivals and exhibitions. For example, the city of Mohe is the only place in China where the Northern Lights can be viewed and the polar day and night can be experienced, and the Northern Lights and Winter Solstice Festivals are regularly held, but there are no provincial ICH programmes. The local government should grasp this unique resource condition and support cultural industries related to festivals, aurora borealis, ice and snow, etc., so as to further enhance the cultural attractiveness of Mohe City.

(4) Development strategy for category 4 small towns

Small towns in category 4 are making rapid progress in ICH development. The economic growth of these small towns is slow, particularly in rural areas, highlighting a serious urban-rural gap; meanwhile, the rapid development of ICH may have triggered a conflict between tradition and modernization and promoted industrial development, though it has also increased environmental pressure.

These small towns need to balance economic, ecological and cultural objectives. Greater attention needs to be paid to environmental protection when expanding the cultural tourism industry. Government support policies should focus on sustainable strategies to ensure that the development of the cultural industry and environmental protection go hand in hand, and attention also needs to be paid to encouraging rural residents to participate in the cultural industry and to narrowing the income gap between urban and rural areas.

(5) Development strategy for category 5 small towns

Small towns in category 5 have a strong ICH foundation and are steadily developing. They demonstrate the balanced progress between cultural preservation, economic growth, and environmental governance. The government should encourage the two small towns in the category to serve as models for other towns, share successful experiences, and promote regional coordinated development. Other small towns should learn from their model of government led and socially engaged.

6. Conclusion

This research showed that there was a relationship between the ICH base and growth rate and the economic and ecological performance of these small towns. However, it could not directly prove that the growth of ICH had impact on economic growth or ecological improvement. Rather, the observations indicate that small towns with better ICH resources generally performed better in those two areas. ICH can thus be very instrumental to the sustainable development of small towns. Next-step studies should investigate best practices for ICH development and how cultural resources operate in varying social, economic, and ecological settings. Massive participation from all sectors, especially those dealing with

cultural identity and the involvement of residents, will be central in driving efforts toward protecting ICH and sustaining small town development.

Ackownledgement: National Natural Science Foundation of China. *Research on the Coupling Coordination of Small Towns' Shrinkage and Resilience of Social-Ecological Systems and Differential Planning Response——Take Northeast China as An Example* (52278056)

7. References

Corpo, D, B. et al. (2008) "Effects of Tourism Upon the Economy of Small and Medium-Sized European Cities: Cultural Tourists and 'The Others'," RELX Group (Netherlands). Available at: https://doi.org/10.2139/ssrn.1140611.

Hammer, S, M. et al. (2020) "Global Estimates and Long-Term Trends of Fine Particulate Matter Concentrations (1998–2018)," Environmental Science & Technology, 54(13),p. 7879-7890. Available at: https://doi.org/10.1021/acs.est.0c01764.

Intangible Heritage Home (2023). Available at: https://ich.unesco.org/en/home.

Jiang, X. (2021) "Research on the Path of Inheriting Intangible Cultural Heritage in Northeast China through College Art Education," IOP Publishing, 693(1),p. 012121-012121. Available at: https://doi.org/10.1088/1755-1315/693/1/012121.

Khakzad, S. (2017) "Promoting coastal communities through cultural tourism: the case of fishing communities in Brunswick County, North Carolina," Taylor & Francis, 13(5),p. 455-471. Available at: https://doi.org/10.1080/1743873x.2017.1391272.

Lin, H. et al. (2021) "Research on the Development of Religious Tourism and the Sustainable Development of Rural Environment and Health," Multidisciplinary Digital Publishing Institute, 18(5),p. 2731-2731. Available at: https://doi.org/10.3390/ijerph18052731.

Ping, T. and Li, W. (2011) "Improving strategies for Heilongjiang provincial culture industry and international culture trade," , 4,p. 1020-1024. Available at: https://doi.org/10.1109/msie.2011.5707589.

Su, X. et al. (2020) "How is Intangible Cultural Heritage Valued in the Eyes of Inheritors? Scale Development and Validation," SAGE Publishing, 44(5),p. 806-834. Available at: https://doi.org/10.1177/1096348020914691.

Tani, Y., Hashimoto, S. and Ochiai, M. (2016) "What makes rural, traditional, cultures more sustainable? Implications from conservation efforts in mountainous rural communities of Japan," Taylor & Francis, 41(8),p. 892-905. Available at: https://doi.org/10.1080/01426397.2016.1184631.

Tong, Y. et al. (2020) "Small towns shrinkage in the Jilin Province: A comparison between China and developed countries," Public Library of Science, 15(4),p. e0231159-e0231159. Available at: https://doi.org/10.1371/journal.pone.0231159.

UNESCO. (2004) What is Intangible Cultural Heritage?. Available at: https://ich.unesco.org/en/what-is-intangible-heritage-00003 (Accessed: 25 October 2024).

UNESCO. (2022) Convention for the Safeguarding of the Intangible Cultural Heritage. Available at: https://ich.unesco.org/en/convention (Accessed: 25 October 2024).

Wang, J., Wen, F. and Fang, D. (2019) "Intangible Cultural Heritage Tourism and the Improvement of Rural Environment in China: Value Cocreation Perspective," IOP Publishing, 237,p. 052079-052079. Available at: https://doi.org/10.1088/1755-1315/237/5/052079.

Wang, R. (2020) "Inheritance of Intangible Cultural Heritage of Oroqen Ethnic Group Based on Computer Network Culture," IOP Publishing, 1574(1),p. 012003-012003. Available at: https://doi.org/10.1088/1742-6596/1574/1/012003.

Xia, H., Chen, T. and Hou, G. (2020) "Study on Collaboration Intentions and Behaviors of Public Participation in the Inheritance of ICH Based on an Extended Theory of Planned Behavior," Multidisciplinary Digital Publishing Institute, 12(11),p. 4349-4349. Available at: https://doi.org/10.3390/su12114349.

Zhang, N. and Zheng, X. (2023) "A visual analytics approach for national intangible cultural heritage in Heilongjiang province," Journal of Computational Methods in Sciences and Engineering, 23(3),p. 1625-1633. Available at: https://doi.org/10.3233/jcm-226679.

DeepL (2024) DeepL Translator. Available at: https://www.deepl.com/translator (Accessed: [2025-01-20])

Research Paper

Study on the spatial characteristics and heritage value of the ancient city of Mrauk-U, Myanmar

Yan ZHOU, Southeast university, China

Hong JIANG, Southeast university, China

Xinyi WU, Southeast university, China

Abstract

Mrauk-U is a historical city in the Rakhine state of Myanmar. It has an important historical position, distinct regional environment, and unique spatial features. Nourished by agricultural civilisation, maritime civilisation and religious culture, its urban space presents unique characteristics. This study analyses the site location, spatial form and layout the Mrauk-U city in order to examine how the agricultural, maritime and religious factors influenced the urban space of Mrauk-U. It is reveals that the people of Mrauk-U adapted and utilised the natural environment through appropriate planning ideas and methods driven by social needs such as agricultural irrigation, military defence, maritime trade and symbolism significance. They integrate the artificial with the natural and create urban spaces with distinctive characteristics. Therefore, it is concluded that Mrauk-U has shown an outstanding planning achievement in shaping cultural landscape, and has even become a model for the skilful integration of urban space and natural environment in Southeast Asia.

Keywords

Historical city, Spatial characteristics, Mrauk-U, Urban space

1. Introduction

The ancient city of Mrauk-U in the present-day Rakhine State of Myanmar was one of the most important historical capitals of the Arakan Kingdom in ancient Southeast Asia. The Arakan Kingdom was located in the western part of the Indochina Peninsula in the Bay Area, with the Rakhine Mountains to the east and the Bay of Bengal to the west. Existed from the 15th to 18th centuries, the Mrauk-U Kingdom was not only the most powerful kingdom in Arakanese ancient history but also became a maritime military power, a trading hub, and a religious centre in ancient Southeast Asia. Its capital city, Mrauk-U, became an important center of international trade and cultural routes in ancient times. As an outcome where humans rely on nature to create their living environments, the construction of human settlements is driven by social needs and shaped by human activities. The study of the spatial characteristics and value features of this historical city is an important way to understand the local history and culture and is of great academic and practical significance.

The historical urban spaces are important vehicles for reflecting the concepts and methods that ancient peoples employed in planning their living space. The capital city Mrauk-U ruled the coastal area west of the Rakhine Mountains for a long time, flourishing through the influences of agricultural, maritime and religious culture. This city presented a landscape quality closely combined with the natural environment in its urban spaces. Existing studies on Mrauk-U have mostly focused on its Buddhist architecture (Li, 2019),

urban forms (Wang, 2019), and religious landscapes (Zhou et al., 2024). However, there is insufficient research on how the overall urban spatial characteristics of Mrauk-U were formed. How did the ancient people of Mrauk-U harmonize and interact with the local natural environment and cultural factors in urban construction? The internal mechanisms and ideological influences have not yet been fully explained. In this context, this study aims to explore the urban spatial characteristics of the ancient city of Mrauk-U to foster a more in-depth understanding of its construction logic.

In recent years, our research team has conducted large-scale field studies on the ancient city of Mrauk-U, obtaining first-hand data such as three-dimensional topography and orthophotos of the city, which facilitates in-depth analysis of this historical city. The team utilized these original spatial data and referenced historical remains in combination with archaeological literature, historical maps, documented records, paintings, and artworks to speculate and reconstruct the spatial urban elements of ancient Mrauk-U. Based on the ArcGIS platform, a historical spatial information database and a digitized three-dimensional model of the city's urban space were created. Based on this, this paper examines the natural and regional environment of Mrauk-U and sorts out the main social factors influencing its urban development. Furthermore, it identifies the relationship between natural and artificial elements within the urban space, analyses the spatial characteristics of the ancient city under the influence of various social factors, explores the city-building ideas and wisdom of Mrauk-U that have been developed during the process of getting along with the nature, and summarizes the distinct values of this historical city.

2. Formation background of Mrauk-U

2.1. Natural environment

The Rakhine State has a tropical monsoon climate, resulting in a region rich in rainfall resources—conditions favorable for rice cultivation. The terrain around Mrauk-U rises in the northeast and descends toward the southwest, with the Rakhine mountain range extending in a "finger-like" pattern towards the plains. The valley plains of the Kaladan and Lemro rivers provide rare flatland in Arakan, with fertile land along their banks(Figure 1). The early capital names, Dhanyawadi and Vesali, mean "grain-rich region" and "land of abundant grains," respectively. Since ancient times, this area has been the center of power and home to Arakan's most important cities.

Figure 1. The geographical environment of Mrauk-U. Source: the author.

2.2. Social features

Mrauk-U served as the political, economic, and cultural center of Arakan Kingdom for over 350 years, spanning from 1430, when King Min Saw Mon ordered the construction of the capital, to 1784, when it was conquered by the Konbaung Dynasty. The city bore witness to the golden age of the Arakan Kingdom from the mid-16th to the mid-17th century.

The society of Mrauk-U was characterized by its agricultural, maritime, and religious culture. Firstly, Mrauk-U develops based on the agriculture civilisation. The rice civilisation was the essential material base for the formation of early Southeast Asian societies (Li, 2020). Abundant rainfall provided natural advantages for the agricultural production , which leads to the development of rice cultivation in Mrauk-U, and the total capacity of its rice warehouses far exceeded local consumption (U Shwe Zan, 1997).

Secondly, Mrauk-U has prospered under the nourishment of maritime civilisation. Proximity to the Bay of Bengal provided the natural basis for maritime trade in the Arakan region, where the rulers accumulated wealth for the country by engaging in international trade. Surplus rice was the main export product, shipped to the Indian subcontinent (Collis, 1973) and other regions. With its important access to the sea, Mrauk-U grew into a thriving trading hub on the east coast of the Bay of Bengal. A Dutch traveller, Schouten, came to Mrauk-U in 1660 (Tun Shwe Khine, 1992). He described it as the richest port city in Asia. All these indicate that Mrauk-U was an international city in its heyday.

Thirdly, Mrauk-U was deeply influenced by religious culture. The Arakan region became one of the earliest areas in Southeast Asia to receive the introduction of Indian religions in the process of external exchanges. The Kingdom of Mrauk-U was founded on Theravada Buddhism, with Buddhist thought deeply integrated into local social values. Pagodas and monasteries became essential spaces for the cultural activities in local

society (Li, 2011). Concurrently, the Rakhine people also revered guardian spirits believed to inhabit mountains, rivers, and lakes (Zhong & Yin, 2014). Religious beliefs, such as Buddhism and natural worship, became principal sources of cosmological ideas for the ancient people. Within this cultural framework, social needs for agricultural irrigation, military defense, maritime trade, and symbolic meanings were influential in the construction of the urban space of Mrauk-U.

3. The city's spatial characteristics driven by different demands

3.1. The urban space influenced by the need for agricultural irrigation

Driven by the fundamental needs of agricultural production, the ancient people of Mrauk-U emphasized assessing the topography and hydrology when choosing a city location. They made full use of natural resources to ensure an agricultural hinterland and abundant water supply.

The site of Mrauk-U was flat and openand was located in the largest plain area of the Arakan region. Mrauk-U and earlier Arakan capitals (e.g., Dhanyawadi, Vesali, Launggyet) were all situated in the plains of the Kaladan and Lemro river valleys in Arakan. This area is the largest plain in Arakan and the water is relatively plentiful. Ancient Arakanese people utilized this relatively open expanse, positioned between the sea and mountains, as an early power center as far back as the beginning of the Common Era. Mrauk-U leveraged the agricultural foundations cultivated over generations to establish its capital, optimizing the limited resources available in the plains.

Moreover, Mrauk-U was strategically located within a region with an abundant water system. Hydrological analysis shows that Mrauk-U sits at the watershed junction of the Kaladan and Lemro Rivers. This location not only provides higher terrain but also enables the city to utilize the rivers both to the east and west. This arrangement ensures a relatively stable water supply. Enclosed by rivers and fertile lands, Mrauk-U has an ideal natural base for irrigation. Additionally, large artificial lakes at the city's borders serve as reservoirs, securing water for urban needs. Together with numerous smaller tanks throughout the city, they irrigate crops during the dry season, thereby extending the irrigation period.

3.2. The urban space influenced by the need for military defense

Driven by the need for military security, the ancient people of Mrauk-U emphasized the organisation of the urban spatial pattern when selecting and designing the city's layout and made full use of natural defenses to enhance its security.

Firstly, the city was constructed in a location suited for both offense and defense. On one hand, Mrauk-U was situated at the juncture between foothills and plains, bordered by the Rakhine Mountains to the east and north and distant mountains to the west, creating a relatively enclosed spatial environment that facilitated the establishment of a secure spatial structure. Additionally, the wide, deep creeks to the west served as natural barriers, providing more effective protection than moats (Collis 1973, p. 174). On the other hand, the city was set back approximately 60 kilometers from the coast, creating a buffer zone that could reduce the risk of sudden attacks.

Secondly, the city layout was designed to be highly defensible, creating a defensive barrier that integrated man-made and nature. Mrauk-U lies at the southern tip of the Sin-taung mountain range, with hills to the north and south that are challenging to traverse, providing advantageous conditions for military defense. To strengthen capital defenses, the natural mountains were supplemented with artificial fortifications tailored to specific defense needs in different directions. For example, the western lowlands, guarded by numerous deep tidal streams, posed a challenge for enemy crossing; thus, no additional artificial moat was

required. On the contrary, the eastern section was more exposed and served as the primary entry point for invaders. This area became a key defensive focus, reinforced with walls, lakes, and forts to offset its natural vulnerabilities. The eastern walls and the artificial lakes ran parallel to each other in an east-west direction. The artificial lakes were built with false entrances, to confuse and defeat the enemy (Collis, 1973, p. 174). The walls extended into the mountains, with forts such as Myataung and Laythartaung located in the southeastern hills. Additionally, where rivers intersected fortifications, water gates and batteries were often installed (Collis, 1973, p. 179).

In Mrauk-U, the hills, water systems, and city walls formed a cohesive defensive structure. The natural barriers of hills and rivers surrounding the palace were closely integrated with the city's artificial outer walls and lakes, creating a fortified boundary approximately 19 kilometers in circumference. As described in the Glass Palace Chronicle of the Kings of Burma: "Situated on the top of a hill, the city was strongly fortified."

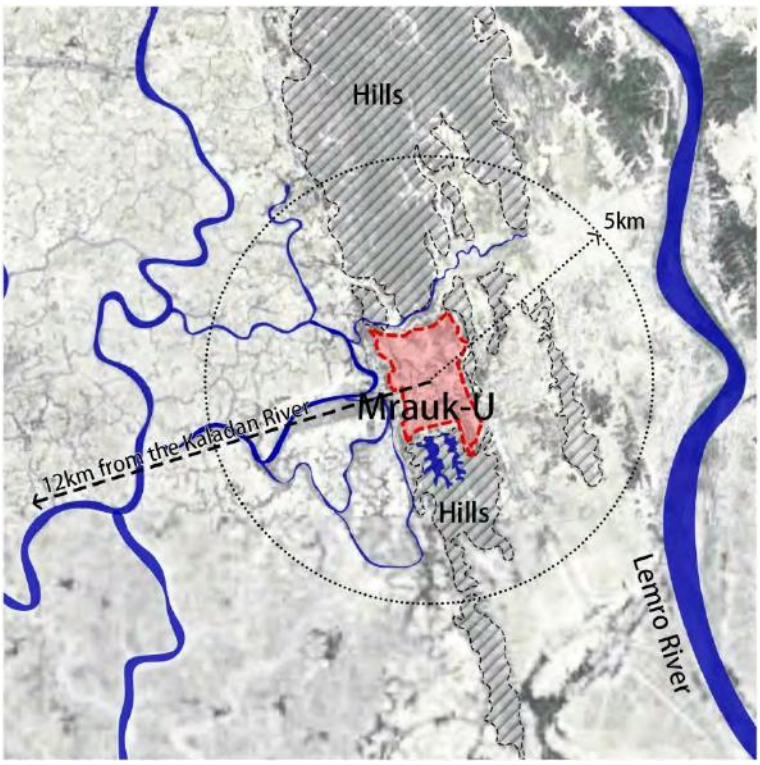


Figure 2. The natural defence barriers of Mrauk-U. Source: the author.

3.3. The urban space influenced by the need for maritime trade

Driven by the economic demand for foreign trade, the ancient people of Mrauk-U focused on shaping an open business environment when laying out the city and developed a comprehensive water transportation network and corresponding supporting facilities.

The city utilized its geographical location to construct a network of rivers and lakes connected to the sea. On one hand, Mrauk-U is located along a major waterway, forming the basic layout connecting the river and the sea. The city site is situated 12km from the Kaladan River on the west side and 5km from the Lemmer River on the east side, allowing simultaneous access to both rivers and providing waterway access for distant ships. Although the city was not built directly by the sea, the rivers on the east and west provided direct access to the sea, establishing a close connection with it. On the other hand, the construction of the

city further enhanced water transportation links with the surrounding areas. Some Jesuits compared Mrauk-U to Venice, recognizing similarities between the two. Father Manrique described Mrauk-U as follows: “A considerable river traverses the city, dividing it into many branches, so that most of the streets are waterways, navigable even by large vessels”(Collis, 1973, p. 179). By utilizing the Alezi and Aungdat rivers as the backbone, canals were dug throughout the city (Figure 3), which strengthened control over the Kaladan and Lemro valleys, allowing agricultural products and handicrafts from the Lemro River to enter Mrauk-U's central market (U Shwe Zan, 1997).

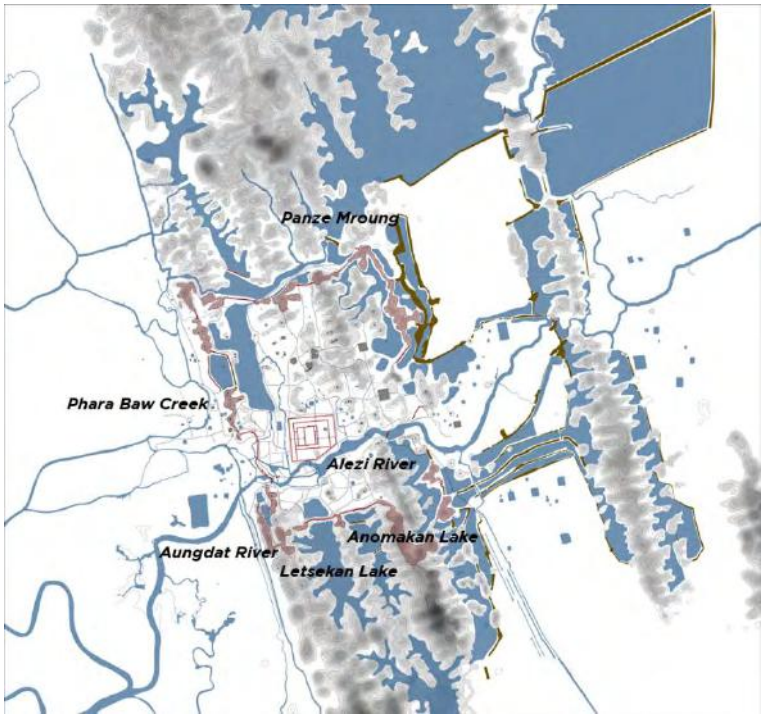


Figure 3. The water system of Mrauk-U. Source: the author.

Moreover, foreign trade support institutions and spaces, such as foreigner communities, port towns, and customs offices, were established based on the features of different positions. The western side of Mrauk-U, adjacent to the sea, served as the primary direction open to Western European traders. In the western part of the city, there were Portuguese community (referred to as Daingri-pet) and Dutch community (referred to as Bandel) along the main river route. The port of Aungdat was the main harbor on the western side serving foreign merchant ships. Leveraging the strong tides of the Kaladan River, the harbor was sufficiently large to accommodate foreign vessels (Raymond, 2002, p. 183). To the south, along the Lemro River, the port towns of Paungdok and Minbya were established, facilitating access to the southern provinces and eastern kingdoms (Tun Shwe Khine, 1992). Additionally, Buting Island**,** located at the mouth of the river, served as the custom for the Arakan kingdom, acting as a gateway linking the outer sea with the Mrauk-U region. According to the 17th-century Dutchman Schouten, merchant ships from the outer sea could only navigate into the Kaladan River to engage in trade with the assistance of a pilot after obtaining permission from the king through a treaty and hoisting a specific flag as a sign of goodwill (Raymond, 2002, p. 183).

3.4. The urban space influenced by the need for symbolic meanings

Driven by the psychological need for symbolic representation, the ancient Mrauk-U people devoted themselves to imbuing urban spaces with sacred meanings when laying out the city.

Firstly, they emphasized the positive significance of the city's location by invoking legends of auspicious omens that had occurred at the site. By using natural elements to convey divine meanings or omens, the location of the city was depicted as one marked by divine intervention and positive visions. The natural environment surrounding the Mrauk-U city site was endowed with symbolic significance, becoming a crucial basis for the location of ancient cities. Legend has it that the king, seers, astrologers and ministers were guided and supported by certain divine providences and omens while searching for a new site for the capital city. Initially, they encountered a strange well-dressed old man standing on the top of the Golden Mountain on the western tributary of the Lemro River, who called out to the king and pointed towards the Galon Mountain which is situated in the north-west of Mrauk-U. Subsequently, they witnessed a series of extraordinary sights where the weak creatures overcome the creatures seemingly more powerful than themselves, leading them to agree that this place was a providential land (Tun Shwe Khine 1992). These legends symbolized for the people the image of a robust capital city, reinforcing the rationale for the choice of this site.

Secondly, influenced by sun worship, the significant buildings exhibit an eastward-facing orientation. It is assumed that this was influenced by the natural worship. In nature, the east represents the direction of the rising sun, symbolizing positivity and sacredness in people's minds. Thus, orienting the buildings to the east establishes a connection between the material world and the natural order, enhancing their sacredness. This is evident in the layout of palaces and Buddhism buildings in Mrauk-U, such as the Shittaung Temple, Ratanabon Temple, and Zina Manaung Pagoda (Figure 4).

Figure 4. The typical temples or pagodas facing the east. Source: the author.

Moreover, the extensive construction of pagodas and temples contributed to the creation of a sacred urban landscape. In the Rakhine region, where Buddhist culture thrived, the establishment of pagodas and monasteries was viewed as a vital means of expressing religious devotion and demonstrating the king's power. Consequently, pagodas were widely constructed in Mrauk-U and were closely integrated with the elements of the natural landscape (Figure 5). A large number of pagodas were erected atop mountain ranges, enhancing their visibility by occupying elevated positions, thus forming sacred skylines for the city alongside the mountain ranges. Additionally, the pagodas atop the mountains are visible from the palaces

and other urban nodes. At the same time, many pagodas are situated near rivers and lakes, producing diverse waterfront landscapes. The pagodas, which symbolize the connection between the human and divine realms, are combined with the natural elements, which is also endowed with sacred meanings. As a whole, they constitute a cultural landscape imbued with strong religious significance, where human and nature are harmoniously blended.

Figure 5. The pagodas in Mrauk-U. Source: the author.

4. Conclusions

The study shows that agricultural, maritime and religious cultures and the natural environment have been skilfully combined in Mrauk-U, forming a historical urban cultural landscape with distinctive characteristics. Driven by the demand for agricultural production, the ancient people of Miaowu made comprehensive use of natural resources to ensure agricultural cultivation; driven by the demand for military defence, they made ingenious use of natural forces to strengthen their defence performance; driven by the demand for foreign trade, they made full use of natural water sources to enhance the convenience of waterway transportation; and driven by the demand for the shaping of symbolic significance, they imbued the city with sacred meaning by closely integrating the natural elements. Mrauk-U people realize or enhance the practical needs of the city in a way that is highly integrated with nature. Mrauk-U old city has made outstanding planning achievements in shaping cultural landscape and can be regarded as a model of the ingenious integration of urban artificial space and natural environment.

By analysing the urban space of the ancient city of Mrauk-U, we realise the influence of the local natural environment and social culture on the construction of the city and the unique spatial form it presents. Through this urban space highly integrated with nature, it can be seen that Mrauk-U 's urban construction not only follows the general principle of utilising local resources, but also makes good use of natural elements, showing remarkable construction methods in water management, military defense and cultural landscape shaping, which is a typical microcosm reflecting the characteristics of urban construction in the Southeast Asian.

5. Acknowledgements

This research is supported by the National Natural Science Foundation of China, grant number [52078116] and the Postgraduate Research & Practice Innovation Program of Jiangsu Province, China, grant number [KYCX23_0314]. The authors express sincere gratitude to the members of the SEU-ARCH team for their hard work during the field survey in Mrauk-U and thank Prof. Dong Wei for his advice on this study.

6. References

Aung Aung Hlaing (2011) 'The Coexistence of Orthogenetic and Heterogenetic City Cultures at Ancient Mrauk-U', *SRDJ*, 2(1), pp. 119-139.

Collis, M. (1973) *The Land of the Great Image*. New York: New Directions Publishing Corporation, pp.174-256.

Li, J. (2019) *The Primary Study on Buddhist Architecture of Mrauk-U, Rakhine, Myanmar*. Master's Thesis. Southeast University, Nanjing, Jiangsu, China, 16 May.

Li, M. (2020) *Myanmar and Southeast Asia*. Guangzhou: World Publishing Corporation, p. 93.

Li, X. (2011) 'Analysis of Temple Culture in Myanmar', *Journal of Baoshan College*, 30(06), pp. 99-103.

Manrique, S. (1927) *Travels of Fray Sebastien Manrique 1629-1643 (Itinerario De Las Missiones Orientales)*. Edited and translated by Lt. Col. Ekford and Father Hosten. London: Hakluyt Society, pp. 217-218.

Raymond, C. (2002) 'An Arakanese Perspective from the Dutch Sources: Images of the Kingdom of Arakan in the Seventeenth Century', in Gommans, J. and Leide, J. (eds.) *The Maritime Frontier of Burma*. Amsterdam: Koninklijke Nederlandse Akademie van Wetenschappen; Leiden: KITLV Press, pp. 177-197.

The Glass Palace Chronicle of the Kings of Burma (2009). [Translated by Li Mou et al.]. Beijing: Commercial Press.

Tun Shwe Khine, M.A. (1992) *A Guide to Mrauk-U: An Ancient City of Rakhine, Myanmar*. Yangon: Nine Nines Press.

U Shwe Zan. (1997) *The Golden Mrauk U: An Ancient Capital of Rakhine*. Yangon: Nines Nine Press, p. 128.

Wang, B. 2019. *Study on the Spatial Form and Development of Ancient City of Mrauk-U, Myanmar* (1-18A.D.). Master Thesis, Southeast University, Nanjing, Jiangsu, China, 1 April.

Zhong, Z. and Yin, X. (2014) *Introduction to Myanmar's Culture*. Guangzhou: World Publishing Corporation, p. 69.

Zhou, Y., Jiang, H., Lu, T. and Shen, X. (2024) 'Formation of a Sacred Urban Landscape: Study on the Spatial Distribution of Pagodas in Mrauk-U, Myanmar', *Religions*, 15(6), p. 719.

Research Paper

Construction of Multi-Factor Landscape Recreation System Based on the Minimum Cumulative Resistance (MCR) Model

Yu GAO, Beijing Forestry University, China
Yifei XU, Beijing Forestry University, China
Chi LI*, Beijing Forestry University, China

Abstract

The establishment of a multi-factors ecological landscape recreation system is of great significance in promoting cultural and tourism integration and transforming and developing suburban areas of the city. The Mentougou district of Beijing is rich in natural and historical-cultural resources, with numerous mining areas needing ecological restoration and industrial transformation. Therefore, this study took the Mentougou district of Beijing as the research object, analyzed its historical, cultural, natural reserve, and mining resources, selects typical representatives for three source areas, namely, historical and cultural source areas, natural ecological source areas, and mining source areas, and applies Minimum cumulative resistance(MCR) model to identify and aid in constructing sustainable recreation corridors, thereby forming a multi-factor coupled ecological landscape recreation system. For each element, the following strategies were proposed: the historical and cultural elements should focus on improving accessibility, enhancing the transportation system, and increasing tourability along the route; the natural recreation elements should prioritize protection, establish diverse habitat communities, enhance biodiversity, and limit gray infrastructure development; the mining recreation elements should emphasize cultural and tourism development transformation, and strengthen peripheral supporting facilities construction while ensuring accessibility. Using a quantitative evaluation method, considering the current situation of Mentougou District, this paper constructed a multi-factors recreation system and proposed suggestions for territorial spatial planning tailored to local conditions, aiming to provide a reference for the sustainable transformation and development of Mentougou District and similar regions.

Keywords

Mentougou District; Landscape Recreation System; Minimum Cumulative Resistance Model; Territorial Spatial Planning; Sustainable Transformative Development

1. Introduction

With the acceleration of urbanization and the transformation of economic structure, the integration of culture and tourism and the transformation and development of urban peri-urban areas have become an important way to promote the sustainable development of the region(Lin et al., 2016, Yu and Song, 2017). Especially in areas rich in natural resources and historical and cultural resources(Li et al., 2021), how to effectively integrate these resources and build an ecological landscape recreation system is not only related to the ecological protection and cultural inheritance of the region, but also the key to realizing economic transformation and social development. Mentougou District in Beijing, as a treasure trove of natural resources and historical and cultural resources(Chen et al., 2020), as well as a concentration of mining areas with urgent needs for ecological restoration and industrial transformation, provides an ideal case for the study(Li et al., 2011).

Mentougou District's natural resources and historical and cultural resources are its unique advantages, but at the same time it faces the dual challenges of ecological restoration and industrial transformation(Yi et al., 2016, Jin et al., 2011, Liu et al., 2009). The establishment of an ecological landscape recreation system aims to promote the integrated development of culture and tourism in the region through the integration of resources such as history and culture, nature reserves and mining areas, and to realize a multi-win situation for economy, society and ecology(Yi et al., 2018). In this study, Mentougou District is selected as the research object, and through an in-depth analysis of the historical and cultural resources, nature reserve resources and mining resources in the region, typical representatives are selected as the three types of source areas, i.e., historical and cultural source areas, natural ecological source areas, and mining source areas, and the Minimum Resistance Model (MCR) is applied to identify and assist in the construction of sustainable recreation corridors to form a multi-factor coupled ecological landscape recreation system. Through the quantitative evaluation method, combined with the current situation of Mentougou District, this paper constructs a multi-factor recreation system and puts forward suggestions for territorial spatial planning according to local conditions. These suggestions are not only applicable to Mentougou District, but also provide a reference for other areas with similar characteristics for sustainable transformation and development. The research in this paper not only helps to promote the integration and transformation development of culture and tourism in Mentougou District, but also provides new perspectives and practical paths for the sustainable development of urban suburban areas.

2. Research framework

First, the Minimum Cumulative Resistance surface for scenic byway construction is obtained by weighted superposition of land use, NDVI, slope, and distance from the road. Then, representative historical and cultural, natural ecological, and mining transformation resource were selected as three types of ecological source sites, and a multilevel scenic recreational path system was constructed on the basis of the minimum resistance surface through the MCR model.

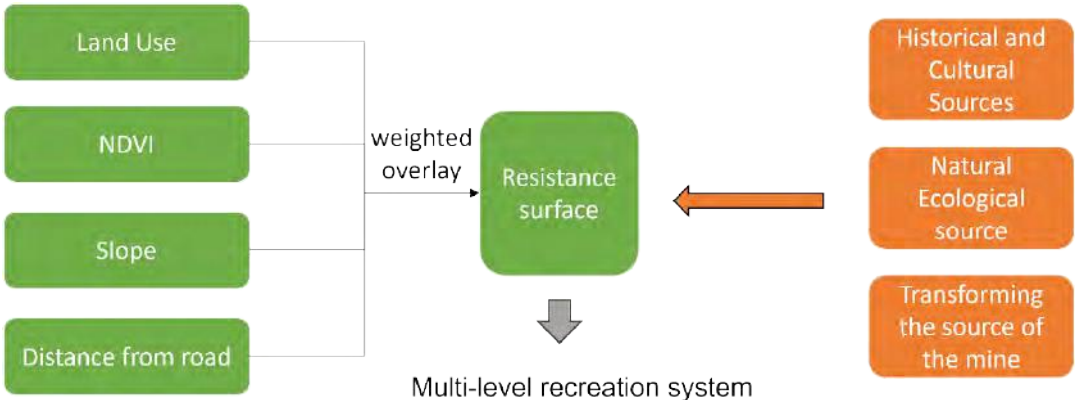


Figure 1. Research framework (source: Author's own drawing)

3. Overview of the study area

3.1. Geographic and Environmental Characteristics of Mentougou District

Mentougou District is located in the southwest part of Beijing, between longitude 115°25 ´ 00“ ~ 116°10 ´ 07” ~ north latitude 39°48 ´ 34“ ~ 40°10 ´ 37” ~ about 62 kilometers from east to west and 34 kilometers from north to south, with a total area of 1447.85 square kilometers. The total area is 1447.85 square kilometers.

Mentougou District is located in the transition zone from the North China Plain to the Mongolian Plateau, with the terrain high in the northwest and low in the southeast. The terrain skeleton was formed during the Yanshan Movement of the Mesozoic Era, and 98.5% of the total area of Mentougou District is mountainous, with the plain area accounting for only 1.5%. The western part of the mountains is the core part of Beijing's western mountains, which are tall and mountainous, with more than 160 peaks about 1,500 meters above sea level. In the northwestern part, there is the “No.1 Peak in Kyoto”, Lingshan, with an altitude of 2,303 meters, and there are also Hundred Flowers Mountain, Dressing the hair in a bun, and Miaofeng Mountain and other peaks(Chen et al., 2014).

Mentougou District has a mid-latitude continental monsoon climate, with a dry and windy spring, a hot and rainy summer, a cool and wet fall, and a cold and dry winter. The climates of the western mountains and the eastern plains are obviously different, with an average annual temperature of 11.7℃ in the eastern plains and 10.2℃ in the western Jaitang area(Li et al., 2023).

3.2. Overview of Historical and Cultural Resources

Mentougou District is an area in Beijing with a deep historical and cultural heritage, known for its rich red history(Shengjie and Minglv, 2023), folk customs, ancient roads and villages(Ma et al., 2015, Xi and Zhang, 2013), religious temples, the coal industry in western Beijing, geological resources, prehistoric culture, the Great Wall culture(He et al., 2023), farming culture, and glazed culture. These cultural resources not only cover a wide range of historical periods from prehistoric civilization to modern industry, but also include natural landscapes, folk beliefs, traditional handicrafts, and many other aspects, which together constitute the rich and colorful cultural landscape of Mentougou District, making it a typical representative of Beijing's vernacular culture and an important cultural heritage area(Gao, 2020, Yang and Fu, 2017).

3.2. Overview of Ecological Resources

Mentougou District of Beijing is rich in nature reserve resources(Tian et al., 2022), and the following is an overview of the major nature reserve resources in the region(Li, 2023):

a. Beijing Hundred Flowers Mountain National Nature Reserve: Located in the western part of Mentougou District, with a total area of 21,743.1 hectares, the reserve is the largest nature reserve in Beijing, and one of only two national nature reserves in the city. The main protection objects of the reserve are the ecosystems of secondary deciduous broad-leaved forests and rare and endangered species and their habitats in the stony mountains of North China in the warm temperate zone.

b. Beijing Xiaolongmen National Forest Park: located in Qingshui Town, Mentougou District, with a total area of 1,595 hectares, it is dominated by natural broad-leaved forests, deciduous broad-leaved mixed forests, temperate coniferous forests, larch forests and deciduous broad-leaved scrubs, with a forest coverage rate of 91%, and with the highest peak of the main peak, Dongling Mountain, standing at an altitude of 2,303 meters.

c. Tianmen Mountain National Forest Park: located in Mentougou District, covering an area of 669.41 hectares, with the main peak at an altitude of 550 meters, the park has majestic mountains, strange peaks and rocks, and deep forests and valleys, and belongs to the Taihang Mountains.

d. Geological Park: Mentougou District has many geological relics, and most of the representative strata in North China are exposed in the territory of Mentougou, and many stratigraphic units were firstly researched in the territory of Mentougou and named in accordance with the geographical name of Mentougou. Geological relics in Mentougou District include seven categories, including geological (body and layer) sections, geological structures, paleontological fossils, mineral rocks and deposits, geomorphological landscapes, water body landscapes and environmental geological relic landscapes.

e. Other Nature Reserves: Mentougou District has several other levels of nature reserves, including municipal and district-level nature reserves, forest parks and wetland parks.

With its unique geographic location and rich natural resources, Mentougou District has become an important ecological conservation area and an important area for biodiversity protection in Beijing. These nature reserves not only provide habitats for wildlife, but also valuable resources for scientific research, education and ecotourism(Jian et al., 2009).

3.3. Overview of mine resources

The mining resources of Mentougou District in Beijing have a long history of exploitation and rich mineral resources. Mentougou District is located in the western mountains of Beijing, and is known as the “cradle of China's geological work”, where geological research was carried out earlier, and since the founding of the State, the mining departments of various regions have systematically carried out regional geological surveys and mineral census and exploration work in Mentougou District(Yu-Xin et al., 2016).

In recent years, Mentougou District has made active efforts to promote ecological protection and green transformation in the ecological conservation area, and to promote synergistic development in the region, including the closure of mines and sand and gravel factories, etc., the promotion of ecological restoration and treatment of abandoned mines, as well as the development of green industries and cultural tourism

brands.

With the changes in urban development and positioning, Mentougou District has begun to transform into a green ecological conservation area, ending its long history of mining.In 2019, Mentougou completely ended its thousands of years of coal-mining history with the shipment of the last load of coal from the Qianjuntai mine(Xu-sheng et al., 2009). This transformation marks an important step in ecological protection and sustainable development in Mentougou District.

West Beijing, “a line of four mines” and the surrounding area by the Men-Da line railroad strung Wangping mine, Datai mine, Muchengjian mine and Qianjuntai mine, four coal mines shut down and withdrawn from production and the rural areas along the composition of the regional tourism resources, the railroad mining heritage is prominent features. Wangping Mine, as the first station of the “four mines”, is the pilot project for the synergistic development of the “four mines in one line” and the surrounding areas.

4. Ecological source area identification

The scope of my study is the Mentougou District of Beijing.Mentougou District has a long history ,with a large number of historical and cultural resources, including historical and cultural villages, Great Wall ruins and so on. The district is also rich in natural resources, including several scenic spots and nature reserves. At the same time, Mentougou District is rich in coal mining resources, leaving behind many coal mining sites that are undergoing transformation and upgrading. How to integrate these resources to create a multi-level scenic recreational path system is the focus of our study.

Mentougou has 3 Chinese Famous Historical and Cultural Villages, 12 Chinese Traditional Villages and 14 Beijing Traditional Villages. Famous ancient villages include Cuanji Village, Lingshui Village, Sanjiadian Village, Liulichu Village and Yanhecheng Village, etc. These ancient villages show the unique beauty of Beijing's ancient towns and villages with their long history and unique cultural heritage. Meanwhile, Mentougou is the place where religion is concentrated in Beijing, with hundreds of Buddhist temples, the most famous of which are Tanzhe Temple and Jingtai Temple. Taoism has also left a deep mark in Mentougou, such as Tongxian Guan and Jade Emperor Temple. Mentougou also has prehistoric cultural relics such as the “Donghulin Man” site, and rich resources of the Great Wall, which is an important part of the Great Wall culture. Therefore, this paper selects traditional villages, prehistoric cultural sites, Ming Great Wall sites and religious and Buddhist temples as the historical and cultural sources of this paper, totaling 33 sites.

Mentougou District is rich in nature reserves, including the Beijing Hundred Flowers Mountain National Nature Reserve, the Beijing Xiaolongmen National Forest Park and the Beijing Tianmenshan National Forest Park. These nature reserves not only provide important habitats for wild animals and plants, but also valuable resources for scientific research, education and eco-tourism, and are important nature reserve resources in Mentougou District and even in Beijing. In this paper, a total of nine natural ecological sources, such as scenic areas and nature reserves, were selected in the Mentougou area according to ecosystem types.

The closure and restoration of abandoned mines is an important step in Mentougou District's transition from traditional coal mining to green ecology. Mentougou District has successively closed all 270 township coal mines and more than 500 non-coal mines and sand and gravel factories in the district. Ecological restoration and management of abandoned mines is also ongoing to restore the natural environment and ecological functions of these areas. Therefore, 11 abandoned mines were selected as source sites in this paper.

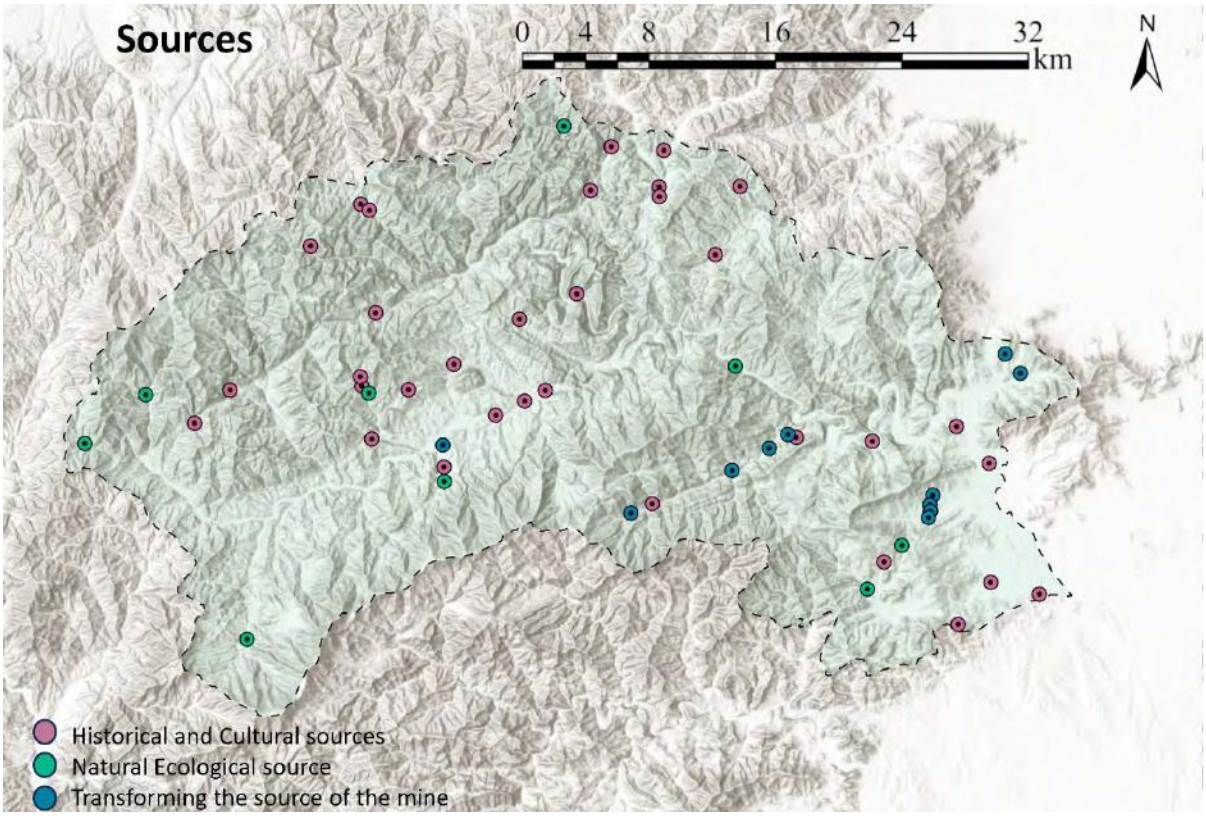


Figure 2. Three source landings (source: Author's own drawing)

5. Construction of Ecological Landscape Recreation Corridor Based on Minimum Resistance Model (MCR)

Referring to the results of previous research, and using AHP analysis, each type of indicator was assigned(Figure 3) and weighted to arrive at the final resistance surface for the construction of the Scenic Byway.

Table 1 Resistance surface construction weighting table

Type	1	2	3	4	5	Weight
Land Use	Water	Forest	Grassland	Farmland	Construction land Unused land	0.423
NDVI	0.85~1	0.78~0.85	0.65~0.78	0.5~0.65	0~0.5	0.332
Slope	≥25	15~25	8~15	3~8	0~3	0.115
Distance from road	≥160	120~160	80~120	40~80	0~40	0.13

Finally, the resistance surface was generated(Figure 4), and the smaller the value in the graph, the smaller the resistance value here, proving that it is easier to generate recreational paths; conversely, the larger the value, the larger the resistance value here, proving that it is more difficult to generate recreational paths.

6. Recreation system planning

6.1 Recreation System

Using the cost connectivity tool inside ArcGIS, the resistance surfaces were calculated with the three source land categories to arrive at the final recreation system(Figure 4).

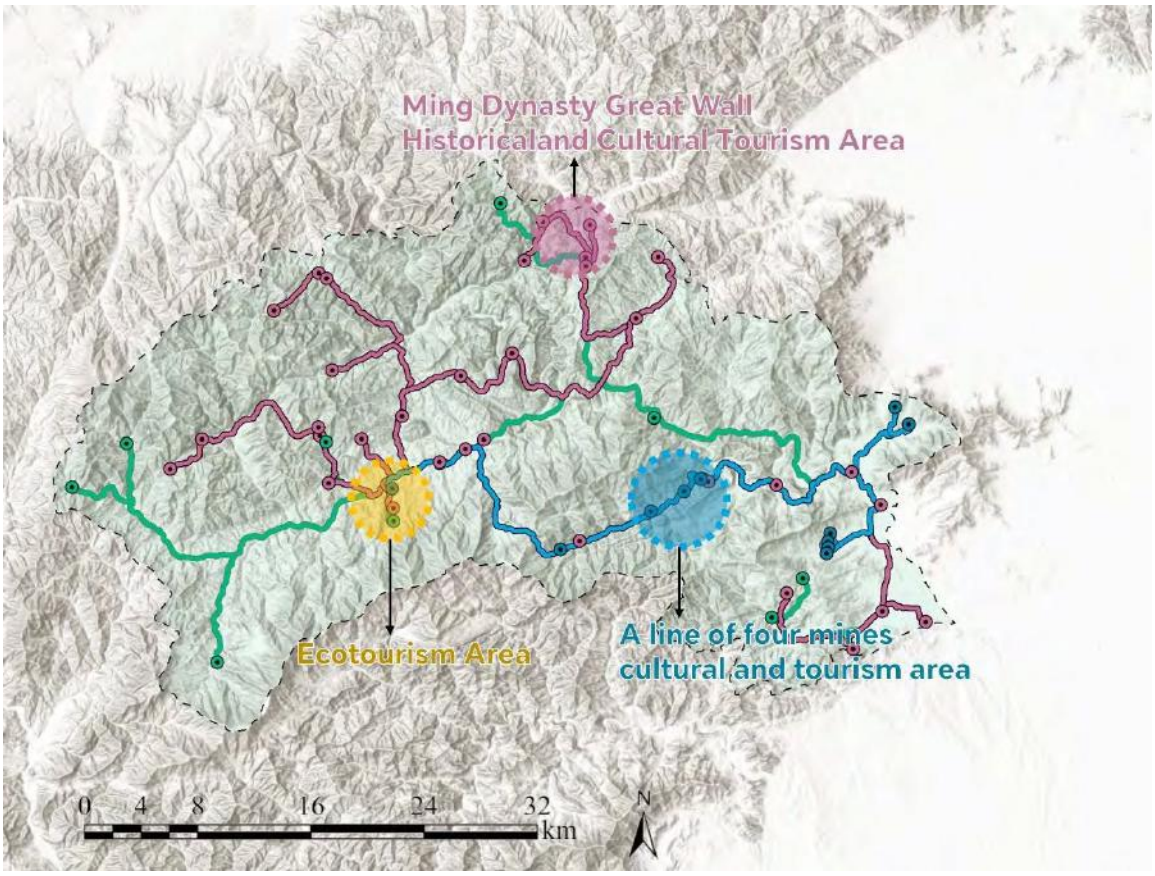


Figure 5. Recreation System Planning (source: Author's own drawing)

A three-tiered system of scenic byways was eventually derived. Based on the distribution institutions of the scenic byways and source areas, we have selected three areas as transportation hubs and service scenic areas for the multi-level recreation system. Including (1) Ming Dynasty Great Wall Historical and Cultural Tourism Area: Establishment of historical and cultural excursion scenic spots centered on the ruins of the Ming Dynasty Great Wall. (2) Ecotourism Area: Establishment of leisure and excursion scenic spots centered on historical and cultural villages and natural ecological areas. (3) A line of four mines cultural and tourism area :Establishment of “one line, four mines” cultural tourism tour area with Wangping Coal Mine as the core.

6.2 Planning Strategies

For the historical and cultural tourism system, we constructed the Ming Dynasty Great Wall Historicaland Cultural Tourism Area in the north. The following planning strategies are also proposed for this recreation system:

- Enhance infrastructure such as public transit, bus systems, and slow-moving trails such as cycling.
- Preservation and utilization of various historical and cultural villages.
- Establishment of a hub of historical and cultural scenic spots centered on the Ming Dynasty Great Wall.

Besides,the following strategies are proposed for the natural ecological recreation system:

- Establish a red line for ecological protection and strictly limit development.
- Establishment of diverse habitats and ecological landscapes.
- Build a system of natural science signage.

The strategies for targeting the transformation of mining areas are:

- Strengthen the construction of hotels and other supporting facilities to form a complete service system.
- Through planning and design, the abandoned mining area is transformed and upgraded, which can be changed into a cultural and creative park.
- Treatment of abandoned mine sites through ecological restoration.

7. Conclusion and outlook

In this paper, a multi-factor coupled ecological landscape recreation system was successfully constructed by comprehensively analyzing the historical and cultural resources, natural reserve resources and mining resources in Mentougou District, Beijing. By applying the Minimum Resistance Model (MCR), this study identifies and assists in the construction of sustainable recreation corridors, effectively connecting historical and cultural sources, natural ecological sources and mining sources to form a comprehensive recreation network. Specific strategies are proposed for different elements: for the historical and cultural elements, accessibility is enhanced and the transportation system is improved; for the natural recreation elements, protection is the main focus and the development of grey infrastructure is restricted; and for the mining recreation elements, the transformational development of culture and tourism and the construction of peripheral supporting facilities are emphasized. Through the quantitative evaluation method, combined with the actual situation of Mentougou District, this paper not only constructs a multi-factor recreation system, but also puts forward suggestions for territorial spatial planning in line with the local reality.

These results provide a scientific basis and practical guidance for the integration and transformation of culture and tourism in Mentougou District, and help promote the sustainable development of the regional economy. The implementation of this study not only protects and utilizes the natural resources and historical and cultural resources of Mentougou District, but also promotes ecological restoration and industrial transformation, and provides a new path for the sustainable development of suburban areas.

Future research can explore and expand on the following aspects: community participation and benefit sharing: strengthen community participation, ensure that local residents can obtain practical benefits from the recreation system, realize benefit sharing, and enhance the sense of access and satisfaction of the community.

Innovative application of ecological restoration technologies: Explore and apply new ecological restoration technologies, especially in the ecological restoration of mining areas, in order to improve the restoration efficiency and effectiveness. Development of cultural tourism products: Combine the history, culture and natural resources of Mentougou District to develop more attractive cultural tourism products and enhance the tourism experience. Improvement of policies and regulations: Research and propose relevant policies and regulations to provide legal support for the construction and management of the ecological landscape recreation system. Cross-regional cooperation: Explore the mode of cooperation with other regions, share resources and jointly build a regional ecological landscape recreation system. Climate Change Adaptation: To study the impacts of climate change on the ecological landscape recreation system and formulate corresponding adaptive management measures. The depth of these studies can further promote the sustainable development of Mentougou District and similar areas, and provide more references and lessons for the transformation and development of urban suburban areas.

Reference

CHEN, X., LI, J. & XU, L. 2020. ECOLOGICAL EXTENSION OF REGULATORY PLANNING IN CHINA'S TERRITORIAL SPATIAL PLANNING SYSTEM: A CASE STUDY ON MENTOUGOU DISTRICT, BEIJING. *Landscape Architecture Frontiers,* 8**,** 42-56.

CHEN, Z. H., QI, J., SHI, S., WANG, J. X. & LIU, Y. 2014. Investigation and Development of Eco-Tourism Resources after Ecological Restoration in Mentougou District of Beijing. *Applied Mechanics and Materials,* 692**,** 103-108.

GAO, C. Study on the Development of Settlement Spatial Form of Famous Historical and Cultural Villages in Mentougou District of Beijing. Journal of Physics: Conference Series, 2020. IOP Publishing, 012085.

HE, D., HU, J. & ZHANG, J. 2023. Assessment of Sustainable Development Suitability in Linear Cultural Heritage—A Case of Beijing Great Wall Cultural Belt. *Land,* 12**,** 1761.

JIAN, S., CHUN-YAN, H. & HUI-FEN, W. 2009. ACCORDANCE BETWEEN UTILIZATION AND PROTECTION OF GEOHERITAGES IN MENTOUGOU, BEIJING. *Resources & Industries,* 11**,** 37.

JIN, J., WANG, R., LI, F., HUANG, J., ZHOU, C., ZHANG, H. & YANG, W. 2011. Conjugate ecological restoration approach with a case study in Mentougou district, Beijing. *Ecological complexity,* 8**,** 161-170.

LI, F., LIU, X., ZHAO, D., WANG, B., JIN, J. & HU, D. 2011. Evaluating and modeling ecosystem service loss of coal mining: a case study of Mentougou district of Beijing, China. *Ecological Complexity,* 8**,** 139-143.

LI, J. 2023. Analysis of the Current Situation and Future Prospects of Tourism Development in the Mentougou Mountainous Area. *Highlights in Business, Economics and Management,* 16**,** 300-304.

LI, M., CAO, Y. & LI, G. 2023. An approach to developing and protecting linear heritage tourism: The construction of cultural heritage corridor of traditional villages in Mentougou District using GIS. *International Journal of Geoheritage and Parks*.

LI, Z., CHEN, J., TAN, C., ZHOU, X., LI, Y. & HAN, M. 2021. Debris flow susceptibility assessment based on topo-hydrological factors at different unit scales: a case study of Mentougou district, Beijing. *Environmental Earth Sciences,* 80**,** 1-19.

LIN, J., CAI, J., HAN, F., HAN, Y. & LIU, J. 2016. Underperformance of planning for peri-urban rural sustainable development: The case of Mentougou District in Beijing. *Sustainability,* 8**,** 858.

LIU, L., JING, X., WANG, J. & ZHAO, C. 2009. Analysis of the changes of vegetation coverage of western Beijing mountainous areas using remote sensing and GIS. *Environmental monitoring and assessment,* 153**,** 339-349.

MA, Y., LIM, J.-K. & KIM, D.-C. 2015. A Study on the traditional color analysis of Chinese historic village-focus on Cuandixia Village of Mentougou District in Beijing. *Journal of the Korean Institute of Traditional Landscape Architecture,* 33**,** 112-128.

SHENGJIE, L. & MINGLV, P. 2023. Quantitative Research on the Value Evaluation of Red Cultural Heritage in Mentougou District of Beijing Based on GIS-AHP. *Journal of Landscape Research,* 15.

TIAN, C., CHENG, L.-L. & YIN, T.-T. 2022. Impacts of anthropogenic and biophysical factors on ecological land using logistic regression and random forest: A case study in Mentougou District, Beijing, China. *Journal of Mountain Science,* 19**,** 433-445.

XI, L. S. & ZHANG, C. X. 2013. Research on the Settlement Causes and Tourism Development of Ancient Village in Western Beijing. *Applied Mechanics and Materials,* 357**,** 1767-1771.

XU-SHENG, L., FENG, L., DAN, Z. & BEI-BEI, W. 2009. Evaluation of resource exploitation value and ecosystem service loss in Mentougou District of Beijing City. *Yingyong Shengtai Xuebao,* 20.

YANG, C. & FU, M. 2017. Protection and tourism development of ancient villages in resource-exhausted mining areas—a case study of Mentougou district. *Land Reclamation in Ecological Fragile Areas.* CRC Press.

YI, Y., SHI, M., LIU, C., WANG, B., KANG, H. & HU, X. 2018. Changes of ecosystem services and landscape patterns in mountainous areas: a case study in the Mentougou district in Beijing. *Sustainability,* 10**,** 3689.

YI, Y., ZHAO, Y., DING, G., GAO, G., SHI, M. & CAO, Y. 2016. Effects of urbanization on landscape patterns in a mountainous area: A Case Study in the Mentougou District, Beijing, China. *Sustainability,* 8**,** 1190.

YU-XIN, X., GUANG-XIN, Y., QIU-LI, H., SUN, N. & XUE-TING, P. 2016. Spatial distribution and pollution characteristics of heavy metals in soil of Mentougou mining area of Beijing City, China. *Journal of Agriculture Resources and Environment,* 33**,** 499.

YU, L. & SONG, Z. A multi-angle analysis on development of modern peri-urban agricultural areas in China: A case study of Beijing. 2017 IEEE International Geoscience and Remote Sensing Symposium (IGARSS), 2017. IEEE, 75-78.

Research Paper

Main Leveraging Artificial Intelligence for Enhancing Flood Resilience in Urban Villages: A Case Study of Zhengzhou, China

A Comprehensive Framework Applied to Zhengzhou, China

Mengke WANG, Victoria University of Wellington, New Zealand

Andre BROWN, Victoria University of Wellington, New Zealand

Abstract

In this paper, we present a conceptual framework for improving flood resilience in urban villages using saof Synthetic Aperture Radar (SAR) imagery and artificial intelligence. This theoretical exploration draws insights from the 2021 Zhengzhou flood event and proposes a methodological approach that combines the all weather imaging capabilities of SAR with deep learning models for flood detection and mapping. The framework addresses the special challenges of urban villages, where high density development is combined with inadequate infrastructure. This study is theoretical but lays the foundation for future empirical research and practical implementation in flood prone urban environments. The proposed framework adds to the growing discourse on urban resilience by providing a systematic approach to integrating advanced technology into disaster preparedness in vulnerable communities.

Keywords

Flood Resilience, Urban Villages, SAR Imagery

1. Introduction

1.1 Research Context

Anthropogenic climate change is driving increasing frequency and intensity of extreme precipitation events that present unprecedented challenges to urban flood management systems worldwide (He and Silliman, 2019). In particular, in informal settlements like the urban villages, where insufficient infrastructure and higher population density work as aggravating factors, this vulnerability is even pronounced (Mwalwimba, Manda and Ngongondo, 2024). In light of the catastrophic July 2021 Zhengzhou flood, with 302 fatalities and CNY 53.2 billion in economic losses, our results emphasize the need for improving flood monitoring and response functions now at these vulnerable urban areas.

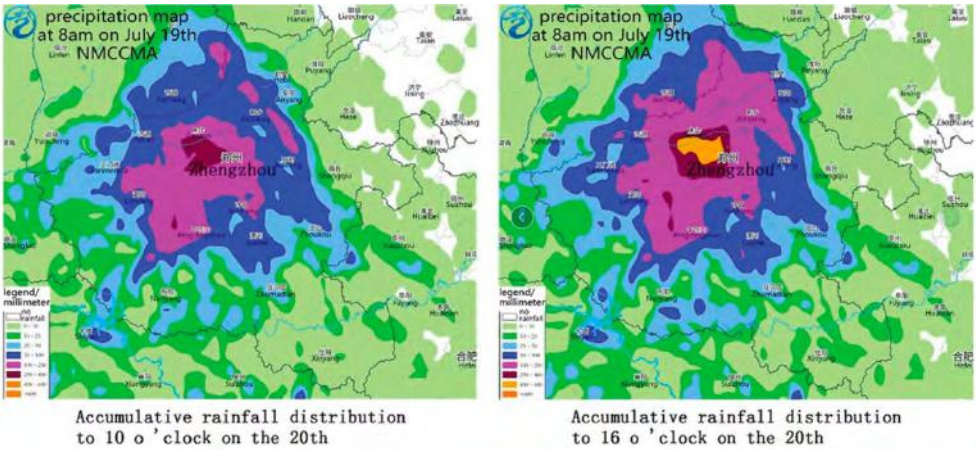


Image 1: Zhengzhou real-time rainfall map. Image source: China Meteorological Administration

However, contemporary flood monitoring approaches are found to lack capabilities to resolve the challenging aspects of urban villages. Traditional methodologies, mostly developed for formal urban areas, generally fail to incorporate the specific spatial and social attributes of informal settlements (Abbott, 2002). However, existing systems often lack sufficient temporal resolution and accuracy in densely populated urban areas, where rapid flood dynamics require near real time monitoring. To bridge these gaps, this research develops an integrated framework that combines Synthetic Aperture Radar (SAR) technology with deep learning methods tailored to the unique requirements of urban villages in Zhengzhou.

Image 2: Zhengzhou after the flood. Image source: Henan News Network

1.2 Research Objectives

This study addresses three primary research objectives:

1. To develop a comprehensive theoretical framework integrating SAR technology and deep learning methodologies for urban flood monitoring, with specific attention to:
    - Data acquisition optimization strategies
    - Processing algorithm adaptation requirements
    - Implementation pathway identification
2. To establish methodological approaches addressing urban village-specific challenges:
    - Morphological complexity considerations
    - Temporal resolution requirements
    - Spatial accuracy optimization
    - System integration protocols
3. To provide a theoretical foundation for future empirical research through:
    - Clear methodological guidelines
    - Testable hypotheses development
    - Validation criteria establishment
    - Implementation pathway identification

The significance of this research lies in its potential to:

- Advance theoretical understanding of technology integration in disaster management
- Establish methodological frameworks for future empirical studies
- Guide practical implementation strategies
- Contribute to urban resilience enhancement

2. Literature Review

Understanding that combines multiple theoretical perspectives and advanced technological solutions is essential for effective flood monitoring and management in urban villages (Jamshed *et al.*, 2020). However, current literature stresses the intricate interplay between urban morphological qualities, socio-technical systems, and adaptive flood dynamics that define a good monitoring approach (He and Silliman, 2019)(Evans, 2012). While technological solutions have been developed to a significant degree, the specific challenges of urban villages, with their high-density development, complex spatial arrangements, and limited infrastructure, require more sophisticated and integrated approaches to flood monitoring and management. Most of the existing research has been in conventional urban areas, and has paid very little attention to the particular context of urban villages (Cohen, 2004). (Fernández and Lutz, 2010) states that most flood monitoring studies focus on planned urban development, which leaves a big gap in the understanding of how monitoring systems can be adapted to the peculiarities of informal settlements. The limitations are particularly acute in the context of Chinese urban villages, where urbanization and informal development patterns result in unique challenges for flood management systems.

Urban form theory provides a theoretical foundation for understanding urban flood monitoring. This theoretical framework, pioneered by (Conzen, 1960), and offers fundamental insights into how urban form influences flood vulnerability. provides fundamental insights into how urban form affects flood vulnerability. He noted that the physical layout and structural characteristics of urban areas play an important role in determining their environmental risk profile. This theoretical framework was subsequently extended (Kropf, 2009) to explicitly link patterns of urban organization to flood risk, focusing on how complex morphology affects water flow dynamics, drainage patterns, flood propagation pathways, and accessibility for emergency response. These morphological considerations are particularly relevant to the case of urban villages, where high building densities, intricate spatial layouts, and limited permeable surfaces make it difficult to monitor and manage flood events.

In addition to physical characteristics, the socio-technical systems perspective provides important insights into the implementation of flood monitoring. This theoretical approach stems from the research of (Trist and Bamforth, 1951) which emphasized the important relationship between technological solutions and their social context. Applying this theory to recent flood monitoring applications emphasizes the need to integrate technical capabilities with local social structures and institutional frameworks. (Yue Zhang *et al.*, 2023) show that the success of flood monitoring systems depends on coordination with local infrastructure capacity, integration with community social networks, adaptation to institutional governance structures, and the ability of communities to use the system. This realization is important in urban villages where social networks may be more important than formal institutional structures.

Complex Adaptive Systems (CAS) theory illuminates further the dynamic nature of urban flood processes. Further developed by (Batty2007) from(Holland, 1996) foundational work, further developed by (Batty2007), it is also adapted that urban flood systems show non-linear behavior patterns that necessitate adaptive monitoring approaches. Emergent properties of these systems require real time analysis capabilities, multi scale interactions requiring integrated monitoring solutions and self-organizing characteristics affecting response strategies. This theoretical perspective emphasizes the necessity for monitoring systems that can adapt to and capture the complexities of urban flood events in the urban village environment.

The recent technological improvements in remote sensing and computational methods have greatly improved flood monitoring capabilities. (A. Refice *et al.*, 2014) highlight the advantages of SAR technology in flood monitoring, particularly its ability to operate effectively in adverse weather conditions and provide

high-resolution imagery through cloud cover. Using large volumes of SAR data, extracting spatial features, analyzing temporal flood patterns, and predicting flood propagation, hybrid CNN-RNN architectures (Islam *et al.*, 2022) show their effectiveness in processing large volumes of SAR data. However, these technological advances provide promising solutions to the complex monitoring needs of urban village environments. However, there are still many significant gaps in current research. The current literature is insufficient in terms of integration between theoretical frameworks and practical monitoring solutions, especially in the context of urban villages.

While individual theories provide useful insights, there is still a need for integrated frameworks that combine multiple theoretical perspectives with technical solutions. In addition, current research has not adequately addressed the challenges of deploying flood monitoring systems in urban village environments, which have unique morphological and socio-technical characteristics. Current algorithms, while effective in traditional urban environments, may not be optimally adapted to the complexity and dynamics of flooding systems in urban villages, and thus optimizing deep learning algorithms for flooding systems in urban villages is an ongoing challenge.

3: Methodology

The objective of this study is to create a comprehensive theoretical framework that combines Synthetic Aperture Radar (SAR) technology with deep learning methods for flood monitoring in urban villages of Zhengzhou. The methodology section provides data acquisition optimization strategies, algorithm adaptation requirements, implementation pathway identification and a complete methodological framework construction. The scientific rigor and systemic coherence of the research design is ensured by the close alignment of each methodological component with Urban Morphological Theory, Socio-Technical Systems Theory, Complex Adaptive Systems (CAS) Theory, and the multi-level perspective on technological transitions.

3.1 Data Acquisition Optimization Strategies

Optimized data acquisition strategies are crucial to accurate and real time flood monitoring. With the complex spatial structures and diverse socio-economic characteristics of Zhengzhou's urban villages, this study employs a dual approach of SAR data acquisition and urban morphology analysis to formulate the detailed data acquisition optimization strategies.

The first step is to choose good SAR satellite data sources for data acquisition. For the flood monitoring needs of Zhengzhou's urban villages, this study uses high resolution SAR data from Sentinel-1, RADARSAT-2 and TerraSAR-X, from which high frequency coverage (every 12 days) and spatial resolution of up to 5 meters in C band is provided for large scale dynamic monitoring. The Canadian Space Agency (CSA) operated RADARSAT-2 which provides high resolution data (ranging from 1 meter to 100 meters) and multi polarization modes that are suitable for fine grained flood monitoring, such as delineating water boundaries and assessing variations in flood depth (Ramsay *et al.*, 2004). The 1 meter spatial resolution and high temporal resolution (Lobo and Garcia, 2014)of TerraSAR-X, operated by the German Aerospace Center (DLR), is ideal for real time detailed flood monitoring and data analysis.

A frequency of data acquisition is chosen based on the dynamic characteristics of floods in urban villages. To capture the rapid flood evolution and expansion paths, the data acquisition frequency is increased to at least once a week, or during the rainy season or flood prone periods. On the other hand, the frequency is changed to once a month during non-flood seasons to monitor long-term flood risk trends and changes. In

addition, high SNR SAR images are selected to maintain stringent control on the SNR and to ensure clear visibility of flood features (Gersman *et al.*, 2008). Polarization modes (e.g., VV/VH) are selected to improve the discrimination of water bodies from the surrounding land surface. Geometric correction, radiometric calibration, and speckle noise reduction using Gaussian and median filters are performed during data preprocessing to improve SAR image quality and consistency and generate high quality data inputs for subsequent deep learning models.

Vector data on building footprints, road networks and land use types were collected through Geographic Information System (GIS) software (e.g., ArcGIS and QGIS) for spatial distribution analysis, mapping of urban villages and identification of flood-prone areas. In addition, the study developed quantitative indicators of morphological complexity including Land Use Diversity Index (LUDI), Building Height Variance (BHV) and Road Network Density (RND). These metrics are calculated using the Shannon Diversity Index of Land Use Diversity (LUDI), Building Height Variance (BHV), and Road Length per Unit Area (RND), which reflect land use complexity, building height variance, and road network density. The spatial data collection strategy is guided by these morphological complexity metrics to increase the density and resolution of data collection in areas of high morphological complexity to accurately capture the dynamics of flooding.

3.2 Algorithm Adaptation Requirements

To adapt deep learning algorithms to complex SAR data, we must understand how to carefully optimize for the multi-level and multi scale flood propagation patterns. This study approaches algorithm adaptation from two perspectives: It covers data preprocessing and feature extraction, deep learning model selection and optimization.

Deep learning algorithms must address the specific needs of flood monitoring, which is why model selection is critical. Based on Holland and Batty complex systems theories, this study chooses and optimizes suitable deep learning models, such as Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and their hybrid models (e.g., CNN–RNN hybrids). SAR images are adept at extracting spatial features (water body boundaries and expansion characteristics) (Wang, Zhang and Hao, 2019), while RNNs are good at dealing with time series data and capturing temporal dynamics of flood spread (B. Nagendra and G. Singh, 2023). The hybrid models combine the strength of CNNs and RNNs to process spatial features and temporal dynamics simultaneously, which improves the capability of dynamic flood monitoring.

Ongoing study optimizes model architecture for better model adaptability and predictive accuracy guided by complex systems theory. For instance, the flood features can be extracted at various spatial scales using introduction of multi scale convolutional layers in CNN component. Adding Long Short-term Memory (LSTM) units into the RNN component will help the model capture long term dependencies better and finally better predict flood expansion path. In addition, a multi level feature extraction mechanism is employed to combine different levels of features to improve the model's ability to adapt to the complex flood propagation patterns.

Deep learning models are good at what they do because data preprocessing and feature extraction are so important. A systematic preprocessing of SAR data is performed including noise filtering, data augmentation and normalization of the images. Then, to improve quality of the SAR images, Gaussian and median filters are used to filter speckle noise from them. Data augmentation is applied to the training data to increase the diversity of the training data and thereby, to improve the model’s generalization capability such as rotation, flipping, scaling etc. For image normalization, we scale SAR image pixel values to the range [0, 1] to stabilize and keep the model training consistent.

Finally, to extract important features for flood monitoring, the study makes use of the urban morphology analysis results. The areas covered are flood depth variations, and water body expansion speed and surface change detection. Water body expansion speed is calculated as flood propagation speed from time series SAR images. SAR images' scattering characteristics are used to estimate dynamic information on flood intensity through estimate of flood depth variations. Surface change detection compares pre and post flood SAR images to identify surface morphology changes (e.g. submergence of buildings and damaged roads). By extracting these features and using them to define input to the deep learning models, accuracy and real time capability of flood monitoring are increased.

3.3 Implementation Pathway Identification

The implementation pathways need to be identified to translate theoretical frameworks into practical applications. Through technical integration and system design, this study ensures the effective application of SAR technology and deep learning methods in flood monitoring of urban villages, and recognizing technology transition pathways.

Practical application is based on technical integration and system design. The study designs technical solutions based on socio technical systems theory, Trist and Bamforth, which accommodate the social structure and flood prevention needs of urban villages. It involves many rounds of communication with community residents, local governments and other stakeholders to understand their flood prevention requirements as well as their level of acceptance of technology, so that the technical solutions meet actual needs. The study collects community expectations and suggestions through surveys and in depth interviews and adapts the technical solutions to increase user satisfaction. In addition, the study provides protocols for system integration that support seamless interoperability between SAR technology and deep learning systems. It includes standardization of SAR data formats, design of real time data transmission protocols, and standardization of system interfaces to facilitate compatibility and scalability of the different technical components.

For the sustainable implementation, it is important to identify technology transition pathways. The study identifies macro, meso and micro level pathways to align the technology transition process with the social and environmental characteristics of urban villages, drawing on (Geels, 2004) multi level perspective on technological transitions. To achieve this at the macro level, collaboration with local governments is pursued to enhance policy support and funding for flood monitoring technologies, and to apply for government research project grants to secure policy incentives and resource allocation for flood management. On the meso level, the study collaborates with SAR data providers and deep learning technology suppliers to build stable technical support and data supply chains to ensure the successful deployment of SAR technology and deep learning systems. In addition, long term partnerships with technology suppliers are also established to ensure a continuous supply of technical resources and support. The study designs and implements training programs for technical operators and community residents to improve their operational capabilities and technology acceptance at the micro level. This would include organizing training workshops, developing operation manuals and establishing technical support teams to enable technical personnel and community members to operate and maintain the flood monitoring system, thus securing its operation and acceptance among the community.

Specific implementation steps include working with local governments to draft technical application proposals and secure policy and funding support, organizing technical training and education through training sessions, operation manuals and technical support teams to ensure that technical staff and

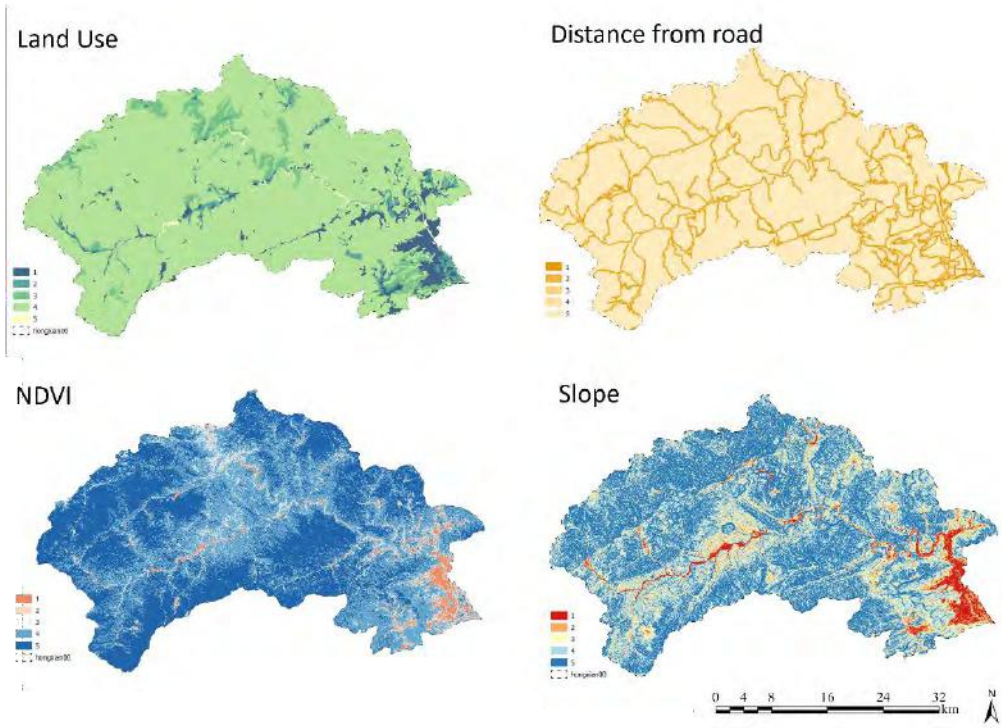


Figure 3. Basic geographic data (source: Author's own drawing)

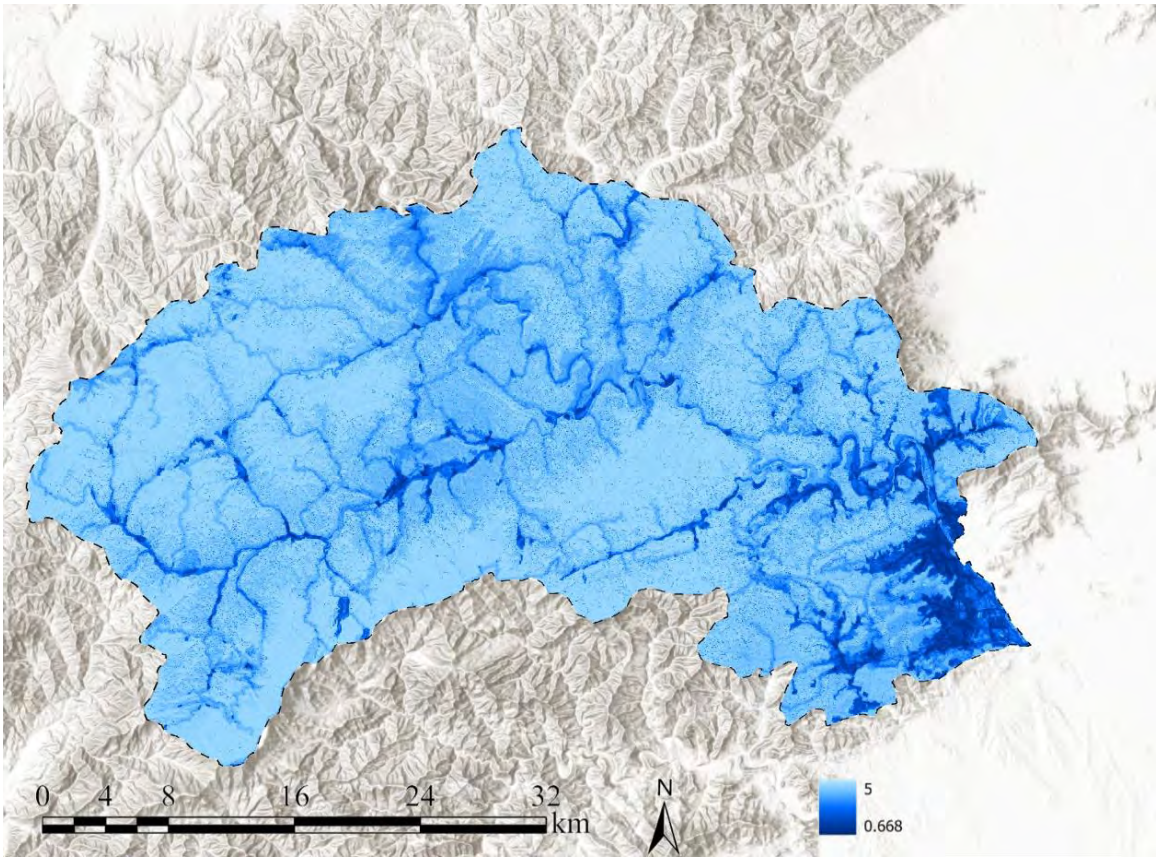


Figure 4. Resistance surface generation results (source: Author's own drawing)

community residents have the necessary operational skills, conducting pilot projects by selecting a number of urban villages in Zhengzhou to deploy the flood monitoring system, performing field tests and optimizing the system according to pilot feedback, and optimizing and scaling the system through refining the system's performance and user experience based on pilot project

3.4 Construction of the Methodological Framework

The systematic and scientific nature of the research requires the building of a robust methodological framework. This study combines quantitative and qualitative research methods, with statistical analysis and deep learning techniques for quantitative assessment of SAR data, and interviews and surveys for qualitative assessment of the social adaptability of the technical solutions from the community resident and local government perspectives. In detail, the construction of the methodological framework is outlined below.

Flood monitoring is assessed for the accuracy and reliability through quantitative analysis. The relationship between SAR data and flood monitoring outcomes is evaluated using statistical methods, such as regression analysis and time series analysis. The study trains deep learning based flood monitoring models using collected SAR data and assesses their predictive performance using metrics such as cross validation, confusion matrices, accuracy, recall and F1 scores. Furthermore, historical flood event data are used to validate the models, to validate the models applicability and effectiveness for different flood scenarios.

The social adaptability of the technical solutions is assessed using qualitative research methods. The needs, expectations, and experiences of community residents, local government officials, and technical operators with the flood monitoring system are gleaned from in-depth interviews. The broader feedback from community residents about their perceptions and willingness to adopt the technology is gathered through surveys. Qualitative research findings are used to optimize the systems so that the technological advancements do not only come with technological advancements but also with the social needs of the communities resulting in a harmonious integration of technology and society.

In the data analysis phase, the study designs flood monitoring models using selected deep learning architectures (such as CNN-RNN hybrid models). The model architecture consists of input layers for processing multi-scale SAR data, hidden layers with multiple convolutional and recurrent units, output layers for predicting flood expansion paths and depths. The preprocessed SAR data is used to train the models with the help of hyperparameters (e.g. learning rate, batch size, and network depth) adjusted to optimize performance. We apply regularisation techniques such as Dropout and L2 to prevent overfitting and improve generalisation performance of the models.

Validation and evaluation of the model are critical to reliability. The models are validated using actual flood event data, using cross validation and confusion matrices to assess accuracy, recall and F1 scores, so that the models are reliable and effective in real world applications. The study further refines the model design based on validation results to improve the predictive capabilities and the adaptability.

The system integration and optimization aims at the effective operation of technical solutions in practical applications. A real time monitoring system is developed by integrating SAR data acquisition, deep learning analysis and flood early warning functionalities. To achieve efficient data flow and processing, the system architecture includes data reception modules, data processing modules, prediction modules and warning modules. It is a real time monitoring system with the capacity to transmit real time data, perform automated analysis and give instant flood warnings to enable quick responses during flood events. Pilot projects are continuously used to improve system performance and user experience by means of user

testing, performance evaluation and feedback mechanisms to ensure the effectiveness and user satisfaction of the system in practical applications. In addition, the system functionality is progressively expanded in the study to meet actual needs, e.g., multi-source data fusion capabilities and higher diversity and accuracy of warning information to ensure the system's adaptability to the changing flood monitoring requirements.

3.5 Research Outputs and Future Research

3.5.1 Research Outputs

This study is expected to achieve the following key outcomes:

1. Methodological Guide: This study will offer a detailed methodological guide of SAR data acquisition, deep learning model construction and optimization, system integration and implementation pathway design. This guide will provide future related research with specific data acquisition strategies, model selection and optimization methods, system design and implementation steps, which will help facilitate the advancement and application of future related research as a reference and replicable research method for subsequent researchers.

2. Testable Hypotheses: It will build a hypothesis framework for flood monitoring, e.g. 'There is a positive correlation between the spatial resolution of SAR data and the accuracy of flood monitoring,' and will validate these hypotheses through empirical research. These hypotheses will furnish a theoretical basis for future empirical studies on flood monitoring technologies and will contribute to the development and application of such technologies.

3. Validation Standards: The system will be validated to establish standards for accuracy, reliability and real time capability of the flood monitoring system. The accuracy of data processing, the reliability of model predictions, and the timeliness of system responses will be these standards, so that the scientific and practical validity of the research findings will be ensured. These standards will produce clear guidelines for the evaluation and optimization of flood monitoring systems.

4. Implementation Pathway Identification: This study will then define the implementation pathways for technological transitions, which will inform the application and dissemination of SAR technology and deep learning to different urban villages. The study will help identify macro, meso and micro level transition pathways for the effective use of technology in practical flood management, enabling widespread adoption and continuous improvement of flood monitoring systems.

3.5.2 Impact and Application Prospects

This study not only develops a systematic theoretical framework for application of SAR technology and deep learning in urban flood monitoring, but also provides innovative solutions for urban flood management in urban villages. The specific impacts and application prospects are as follows:

1. Enhanced Flood Monitoring Capability: This study optimizes data acquisition strategies and algorithm adaptation to significantly increase precision and real time capability of flood monitoring, thus improving urban village's response to flood risk in Zhengzhou. Real time dynamic flood changes are captured with high resolution and high frequency SAR data, and efficient deep learning processing is used to predict flood expansion paths and depths.

2. Increased Community Resilience: An efficient flood monitoring system gives timely warning information to communities to prepare for floods in advance, thereby reducing flood related losses and improving overall community resilience. Flood monitoring and warnings that are timely and accurate help communities execute emergency responses more effectively, minimizing casualties and property damage.

3. Facilitated Integration of Technology and Society: The study applies socio-technical systems theory to guarantee that the technical solutions have technological developments and social needs of the community, which results in a harmonious integration of technology and society. This integration increases the social acceptance and sustainability of the technical solutions, which is important for their effective and long-term application in real settings.

4. Promotion of Scientific and Intelligent Urban Flood Management: This study provides the theoretical framework and implementation pathways to transition urban flood management from traditional empirical approaches to scientific and intelligent approaches for the overall improvement of flood prevention and management in cities. Urban flood management becomes more precise, efficient and intelligent, and the city's capacity for flood risk management improved by using advanced SAR technology and deep learning methods.

3.5.3 Future Research Directions

Despite the construction of a complete theoretical framework, further exploration and validation in practical applications is necessary. Future research can expand in the following areas:

1. Conducting Empirical Studies: Based on the theoretical framework, future research should conduct empirical studies on flood monitoring in certain urban villages to verify the effectiveness and applicability of the framework. Evaluation of the framework's suitability and impact across different environmental and socio-economic contexts can be achieved through the application and testing of the framework in different types of urban villages. Theoretical framework will be refined and optimized with the empirical studies that will provide valuable data support.

2. Technological Optimization and Innovation: The intelligent level of flood monitoring can be continuously optimized and more technological innovations can be explored that are appropriate for complex urban environments, based on deep learning algorithms. For instance, by studying more complex neural network architectures, or through the combination of transfer learning and reinforcement learning, the model's predictive power and flexibility can be enhanced. Further, the precision and comprehensiveness of flood monitoring can be improved by exploring multi source data fusion techniques (as combining SAR data with other remote sensing data, for example, optical imagery and LiDAR data).

3. Interdisciplinary Collaboration: The theoretical framework will be further enriched by strengthening interdisciplinary collaboration with urban planning, sociology, and environmental science, which will further improve the study's comprehensiveness and applicability. Theoretical robustness and completeness of the theoretical framework can be advanced by adopting interdisciplinary perspectives and researchers can deeply investigate the complex relationships between urban morphology, social structures, and flood risks. For example, collaborating with urban planning experts allows us to integrate city development planning data to examine the effects of urban expansion on flood risks, and collaborating with sociology experts can explore the relationship between community flood awareness and behavior and the acceptance of flood monitoring systems.

4. Integration of Policy and Practice: The integration of research findings with local government flood prevention policies will promote the dissemination and application of technology in practical flood

management. The study collaborates with policy makers and practitioners to ensure that research outcomes can be translated to practical flood management strategies that improve the flood prevention capabilities of urban villages. Furthermore, policy recommendations and technical guidance can help local governments develop scientific and effective flood prevention policies and promote systematization and standardization of urban flood management.

4. Conclusion

Based on this work, we successfully develop a comprehensive theoretical framework that integrates Synthetic Aperture Radar (SAR) technology with deep learning methodologies to improve flood monitoring in Zhengzhou's urban villages. The research addressed the challenges of capturing accurate flood dynamics in high density, complex spatial environments by optimizing data acquisition through the selection of high-resolution SAR sources and detailed urban morphology analyses.

Yet, the implementation of the practical version was hindered by technical and resource related challenges, including the high costs and licensing restrictions of SAR data, the need for large computational power to train deep learning models, and the complexities of integration of new systems with existing urban infrastructure. The study then proposed to address these obstacles by using cloud based computing resources to handle computational demands, partnering with satellite data providers to gain access to low cost data, and using transfer learning techniques to reduce the amount of training data required. Furthermore, phased pilot projects were suggested to iteratively test and refine the system, and to guarantee scalability and adaptability. By solving these particular challenges with targeted solutions and comprehensive resource planning, this framework not only advances the theoretical understanding of technology integration in disaster management, but also makes it practically feasible and sustainable, thereby enhancing the resilience and safety of vulnerable urban communities.

4. References

A. Refice *et al.* (2014) 'SAR and InSAR for Flood Monitoring: Examples With COSMO-SkyMed Data', *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 7(7), pp. 2711–2722. Available at: https://doi.org/10.1109/JSTARS.2014.2305165.

Abbott, J. (2002) 'An analysis of informal settlement upgrading and critique of existing methodological approaches', *Habitat International*, 26(3), pp. 303–315. Available at: https://doi.org/10.1016/S0197-3975(01)00049-2.

B. Nagendra and G. Singh (2023) 'Comparing ARIMA, Linear Regression, Random Forest, and LSTM for Time Series Forecasting: A Study on Item Stock Predictions', in *2023 4th IEEE Global Conference for Advancement in Technology (GCAT). 2023 4th IEEE Global Conference for Advancement in Technology (GCAT)*, pp. 1–8. Available at: https://doi.org/10.1109/GCAT59970.2023.10353372.

Birtles, D. and Lee, J. (2021) 'Identifying Distinct Structural Features of the SARS-CoV-2 Spike Protein Fusion Domain Essential for Membrane Interaction', *Biochemistry*, 60(40), pp. 2978–2986. Available at: https://doi.org/10.1021/acs.biochem.1c00543.

C. Gisinger *et al.* (2021) 'In-Depth Verification of Sentinel-1 and TerraSAR-X Geolocation Accuracy Using the Australian Corner Reflector Array', *IEEE Transactions on Geoscience and Remote Sensing*, 59(2), pp. 1154–1181. Available at: https://doi.org/10.1109/TGRS.2019.2961248.

Cohen, B. (2004) 'Urban Growth in Developing Countries: A Review of Current Trends and a Caution Regarding Existing Forecasts', *World Development*, 32(1), pp. 23–51. Available at: https://doi.org/10.1016/j.worlddev.2003.04.008.

Conzen, M.R.G. (1960) 'Alnwick, Northumberland: A Study in Town-Plan Analysis', *Transactions and Papers (Institute of British Geographers)*, (27), pp. iii–122. Available at: https://doi.org/10.2307/621094.

Evans, D. (2012) 'Beyond the Throwaway Society: Ordinary Domestic Practice and a Sociological Approach to Household Food Waste', *Sociology*, 46(1), pp. 41–56. Available at: https://doi.org/10.1177/0038038511416150.

Fernández, D.S. and Lutz, M.A. (2010) 'Urban flood hazard zoning in Tucumán Province, Argentina, using GIS and multicriteria decision analysis', *Engineering Geology*, 111(1), pp. 90–98. Available at: https://doi.org/10.1016/j.enggeo.2009.12.006.

Geels, F.W. (2004) 'From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory', *Research Policy*, 33(6), pp. 897–920. Available at: https://doi.org/10.1016/j.respol.2004.01.015.

Gersman, R. *et al.* (2008) 'Mapping of hydrothermally altered rocks by the EO-1 Hyperion sensor, Northern Danakil Depression, Eritrea', *International Journal of Remote Sensing*, 29(13), pp. 3911–3936. Available at: https://doi.org/10.1080/01431160701874587.

He, Q. and Silliman, B.R. (2019) 'Climate Change, Human Impacts, and Coastal Ecosystems in the Anthropocene', *Current Biology*, 29(19), pp. R1021–R1035. Available at: https://doi.org/10.1016/j.cub.2019.08.042.

Holland, J.L. (1996) 'Exploring careers with a typology: What we have learned and some new directions.', *American Psychologist*, 51(4), pp. 397–406. Available at: https://doi.org/10.1037/0003-066X.51.4.397.

Islam, Md.M. *et al.* (2022) 'Diagnosis of COVID-19 from X-rays using combined CNN-RNN architecture with transfer learning', *BenchCouncil Transactions on Benchmarks, Standards and Evaluations*, 2(4), p. 100088. Available at: https://doi.org/10.1016/j.tbench.2023.100088.

Jamshed, A. *et al.* (2020) 'A Conceptual Framework to Understand the Dynamics of Rural–Urban Linkages for Rural Flood Vulnerability', *Sustainability*, 12(7). Available at: https://doi.org/10.3390/su12072894.

Lobo, J. and Garcia, Y. (2014) 'Global Geoglyph?s Steganography : Uncovering Hidden Earth Art using Space-Based X-Band Synthetic Aperture Radar', in *52nd Aerospace Sciences Meeting*. American Institute of Aeronautics and Astronautics (AIAA SciTech Forum). Available at: https://doi.org/10.2514/6.2014-0489.

Mwalwimba, I.K., Manda, M. and Ngongondo, C. (2024) 'Flood vulnerability assessment in rural and urban informal settlements: case study of Karonga District and Lilongwe City in Malawi', *Natural Hazards*, 120(11), pp. 10141–10184. Available at: https://doi.org/10.1007/s11069-024-06601-5.

Ramsay, B. *et al.* (2004) 'Preparation for the operational use of RADARSAT-2 for ice monitoring', *Canadian Journal of Remote Sensing*, 30(3), pp. 415–423. Available at: https://doi.org/10.5589/m03-076.

Trist, E.L. and Bamforth, K.W. (1951) 'Some Social and Psychological Consequences of the Longwall Method of Coal-Getting: An Examination of the Psychological Situation and Defences of a Work Group in Relation to the Social Structure and Technological Content of the Work System', *Human Relations*, 4(1), pp. 3–38. Available at: https://doi.org/10.1177/001872675100400101.

Wang, P., Zhang, X. and Hao, Y. (2019) 'A Method Combining CNN and ELM for Feature Extraction and Classification of SAR Image', *Journal of Sensors*, 2019(1), p. 6134610. Available at: https://doi.org/10.1155/2019/6134610.

Yue Zhang *et al.* (2023) 'Intelligent flood forecasting and warning: a survey', *Intelligence & Robotics*, 3(2), pp. 190–212. Available at: https://doi.org/10.20517/ir.2023.12.

Case Study Report

Textile Heritage | Active Future

About Invisible Vacant Structures of the Waldviertel Textile Industry in Lower Austria, Hidden Potentials, Absent Appreciation as Well as Realisable Perspectives. A Case Study

Figure 1. Flax Fiber in the Textile Factory Hirschbach. Source: dieTextilfabrik, Sven Wuttej. (2021)

David CALAS, GIU Berlin, Studio Calas, Austria

Barbara CALAS-REIBERGER, Studio Calas, Austria

Abstract

This applied research project investigates the potential for repurposing large-scale, vacant buildings from the textile era in the northern Waldviertel region of Lower Austria, with a focus on the former knitwear factory in Hirschbach. The historic building in Hirschbach, which was vacant for over 50 years, shows good structural conditions, offering meaningful opportunities for reuse. Aiming to develop a place for affordable housing, spaces for co-working and cultural activities, this project offers a pilot for the region. By capitalizing on the building's strong public transport connections via train, the initiative seeks to attract young creatives and promote a sustainable socio-cultural revitalization of the village. This approach not only minimizes land consumption but also strengthens the local community and brings renewed attention to the region's rich textile heritage. At the moment the spaces are used for interim purposes, opening up to local residents, creatives, students and initiatives. These key participatory efforts aim to create a vision for multifunctional uses, combining work and culture through community engagement. The textile factory in Hirschbach acts as living lab and case study, showing how reuse of large-scale vacant buildings can foster holistic sustainable innovation along with the preservation of local identity and inspiring similar initiatives.

Keywords

Vacant Buildings, Regional Development, Heritage, Affordable Housing, Participation, Soil-consumption

1. Introduction

1.1. Invisible Textile Heritage in the Northern Waldviertel Region

The northern Waldviertel region in Lower Austria is a landscape embedded in rich textile history, once home to a thriving industry that contributed significantly to the region's economy. However, in today's context, much of this textile infrastructure has become invisible due to vacancy, neglect and stigmatization. With only a few museums and small factories left to preserve this industrial heritage, many of the buildings that since Austro-Hungarian Monarchy times symbolized progress and prosperity, are now abandoned.

Figure 2-5. Vacancy in Northern Waldviertel Region/Lower Austria, Fig.2 Anderlfabrik, Fig.3 Anderlfabrik Inside, Fig.4 Adensamer Fabrik 1, Fig.4 Adensamer Fabrik 2. Source: dieTextilfabrik, Sven Wuttej. (2022)

Among these structures the Hirschbach knitwear factory (textile factory), located in the small village of Hirschbach, just minutes from the local train station, can be found. This imposing building, disproportionately large compared to the surrounding village structure, served as a cooperative for home-weavers in its initial period, providing stability and a means of competition in a growing and challenging textile market. The building's importance to the local community, as both an industrial and residential hub, has slowly faded over the decades. Despite its rich history and potential, the factory has remained largely invisible since its closure in 1966.

This case study explores the efforts to reactivate the vacant Hirschbach textile factory and the lessons learned from transforming this once-forgotten textile infrastructure into a multipurpose space concept. The project serves as a living lab to test innovative approaches in repurposing vacant buildings while respecting the cultural heritage they represent.

Figure 6. Hirschbach Knitwear Factory (Textile Factory). Source: dieTextilfabrik, Jakob Obkircher. (2022)

2. Context

2.1. The Torn Textile Industry

The Waldviertel region was once a major player in Austria's textile industry, particularly during the era of the Austro-Hungarian Empire. Textile production flourished in the 19th and early 20th centuries, with factories like the Hirschbach textile factory acting as production hubs. The factory, constructed in the second half of the 19th century (approx. 1865) and expanded before World War I, initially functioned as a union space for home weavers specializing in linen and cotton. The cooperative aimed to protect local weavers from the pressures of industrial competition by providing them with shared infrastructure.

The Hirschbach factory was not only a site for knitwear production but also a multifunctional space, with housing units and small agriculture with aggregated stables. Over the one and a half century lifetime, the factory adapted to various needs, from producing everyday textiles to manufacturing socks and gloves for the Austrian army in its final years of operation. However, the combined forces of globalization, technological disruption, and historical events subsequently diminished the need of local textile production, leading to the factory's closure in 1966.

Today, the heritage of the Waldviertel textile industry is mostly invisible. The once active factories are vacant, decaying symbols of a bygone era, and the rich cultural history they represent is almost forgotten. In this context, the Hirschbach factory offers a unique opportunity: a chance to reconnect with this heritage while addressing modern regional challenges, such as alternative housing concepts and sustainable development.

Figure 7-8. Historical Aerial View of the Textile Factory Hirschbach ~1960. Fig. 8. Labourers from the Textile Factory, ~1956. Source: Topothek Niederösterreich.

3. Problem Statement

3.1. The Challenge of Vacant Textile Buildings

The torn and afterwards declined textile industry in the Waldviertel region left behind a cultural void creating additionally large structural vacancy. Factories, like the one in Hirschbach, were abandoned without hand over to future uses. Mostly located in the village cores, their potential has long gone unnoticed due to lack of appreciation. This situation presents a dual challenge today. First, the building substance is constantly deteriorating due to lack of use. Secondly, rural regions in the Waldviertel are grappling with issues of depopulation, particularly among younger generations who migrate to urban centres. The unused status of these buildings, which could serve as social anchors of village life, leaves communities fragmented and subsequently isolated. Thirdly, the widely sprawled single-family housing situation are commonly created by sealing valuable agricultural land on the outskirts of villages, increasing land consumption and occupying important resources for biodiversity.

Therefore, these vacancies hold immense potential in regard of soil preservation, retention of building materials and reuse of already existing spaces for other uses. Especially because the location of these buildings in village centres, close to infrastructure like schools, shops, and public means of transport, makes them prime candidates for revitalization. The challenge lies in developing sustainable, attractive housing and communal spaces that will not only preserve the architectural heritage but also create viable, long-term solutions to rural depopulation.

Figure 9-10. Vacancy in the Anderl and Adensamer Factory. Source: dieTextilfabrik, Sven Wuttej. (2022)

4. Approach and Strategy

3.1. Reactivating the Hirschbach Textile Factory

Recognizing and channelling the hidden potential of Hirschbach's textile factory, a well-rounded strategy was developed to revive the building and correlated socio-cultural relations. Therefore, following measures are taken:

- Forms of Alternative Housing: One of the most pressuring issues in the region in specific and in rural areas generally is the availability of affordable housing for young people. The factory's large multifunctional spaces create an ideal and adaptable floor plan outline, where several opportunities for communal living are offered. An intertwining of interior and exterior spaces, temporary event and adjoint rooms present several options for different living changing living purposes.
- Co-Working and Learning Spaces: The factory's flexible structure, which historically accommodated both production and residential activities, presents an adaptable framing for mixed-uses. Participatory developed plans are already in place to create co-working spaces for locals and guests through workshops and cultural encounters.
- Public Accessibility and Events: To reconnect the textile factory with the social fabric of the village, public access is key. The strategic orientation, which is currently tested with interims uses, includes spaces for cultural events, exhibitions, education and performance. These diverse events attract mixed visitors but creates also a sense of belonging.
- Participatory Planning: Engaging the local community and beyond, has been a crucial component of the strategy. By involving diverse stakeholders in the reactivation process, the process ensures a matching of the building's functions with the community's demands.
- Holistic Sustainability: Repurposing the textile factory serves the dual purpose of preventing further decay of the building while also promoting social inclusive reactivation. Reusing and

refurbishing existing structures avoids the environmental costs of new construction. Additionally, reusing vacant buildings help prevent soil consumption, which would otherwise result in developing new (mostly single-family houses) housing on agricultural or green spaces on the outskirt of the villages.

5. Current and Future Implementation Process

5.1. Step-by-Step Process

The revitalization of the Hirschbach textile factory is part of a step-by-step process, focusing first on interims uses for awareness raising and then on structural holistic renovation. This, to ensure a process which sees the creation of spaces for the community a prime aim. An aim, where initial steps provided the stabilizing of the building's deteriorated conditions, making selected areas safe and accessible for public use. Generally, restoration efforts aimed to respect the building's historical significance, retaining its architectural elements while updating certain aspects for contemporary use.

Figure 11. Point Cloud Survey to Identify Structural Problems. Source: dieTextilfabrik. (2023)

Public involvement was implemented early in the project, through participatory planning workshops, online questionnaires and cultural events hosted in the village. These efforts helped to create community interest and gain attention from local stakeholders, including educational institutions and public institutions. One important step was the creation of a participatory based vision, including future steps of development, which was communicated back to the local community.

Figure 12-13. Idea Workshop "Future of the Textile Factory". Source: dieTextilfabrik. (2021)

5.1. Challenges

Challenges are part of such a process and were embraced stepwise. The financing in regard of the renovation works is a persistent concern, with the project relying on a combination of public grants, private donations, and partnerships with local stakeholders. There has also been an intense exchange with the public department for preservation, particularly in regard of the monument protection status, which is partly essential for ensuring the building's long-term preservation. Also, since such spaces in village cores are often targeted with demolition threats'.

Despite these challenges, the project has already seen significant progress. The factory has become a central point for local creativity and social innovation, offering temporary residents and visitors a space for experiment and ideas.

6. Current and Future Implementation Process

Although the Hirschbach textile factory is still in the early stage of its aimed eco-social transformation, several key outcomes have already emerged:

- Community Engagement: Local residents have expressed increased interest in the project, participating in idea workshops and events. This engagement shows commitment and is proof of valuing such endeavours. Involving the community repetitively is part of the the long-term success of the initiative, as it creates a sense of ownership and identification in the village's cultural environment.

- Cultural Revitalization: The textile factory is a small but visible cultural hub for the village of Hirschbach. The cultural program with plans for working spaces and event areas are key to draw artists, creatives, entrepreneurs, and visitors to the area and subsequently invite them into the building. These new visitors to the village are potential ambassadors of the cause and diversify with their presence the local demographic structure.

- Preservation of Textile Heritage: By revitalizing the Hirschbach textile factory, the project has highlighted the importance of making the Waldviertel's textile history visible. After the successful implementation of the exhibition "Textile Heritage | Active Future" a broader discussions has emerged in the region about the future of vacant textile buildings, many of which could benefit from similar initiatives.

Figure 14-15. Exhibition "Textile Heritage | Active Future" with Public Discussion in the Textile Factory Hirschbach. Source: dieTextilfabrik, Sven Wuttej. (2022)

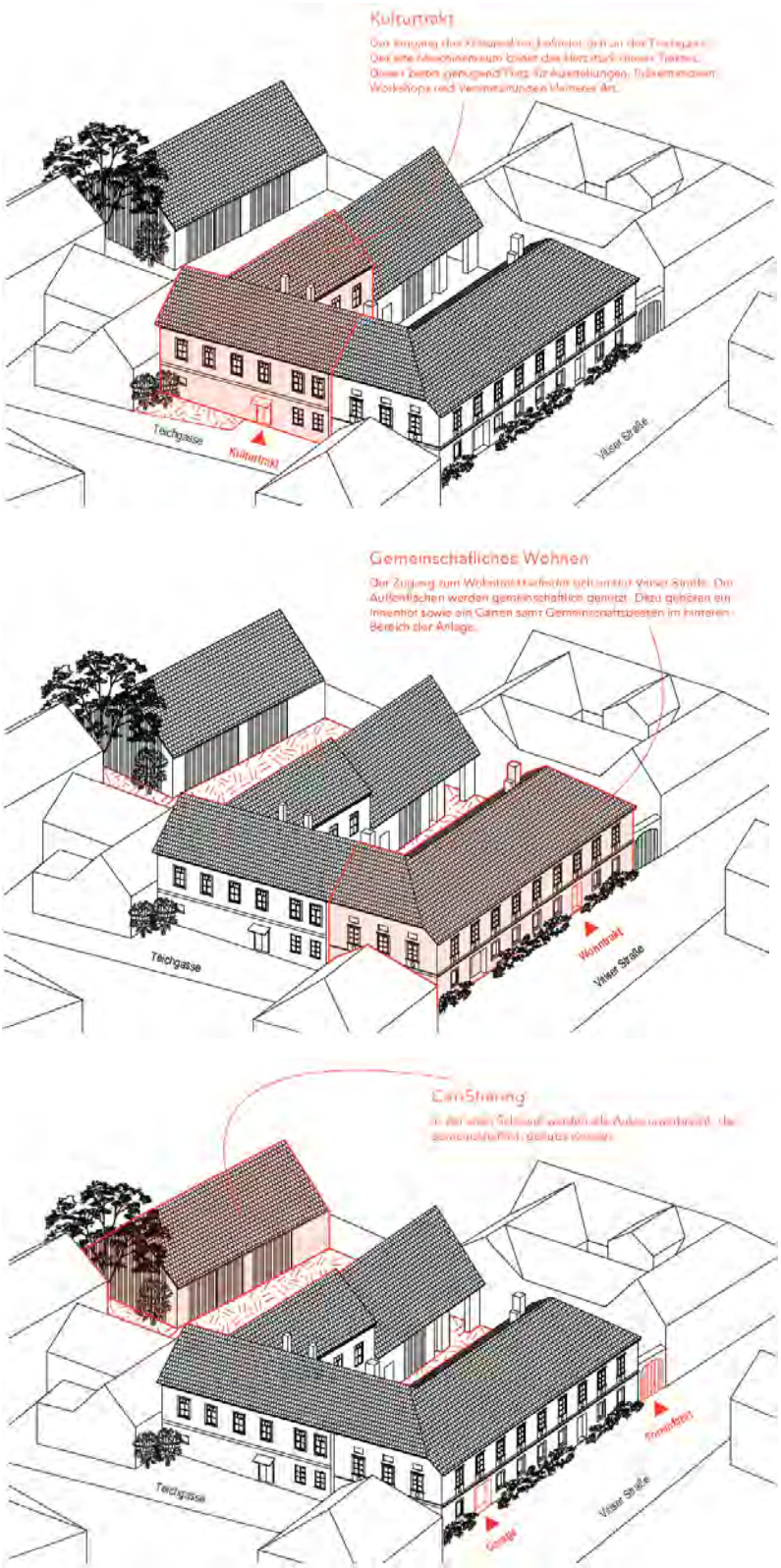


Figure 16-18. Future Implementation Steps: Space for Culture, Alternative Housing (Co-Living), Shared Culture. Source: dieTextilfabrik. (2022)

7. Key Take-Aways

The reactivation process of the Hirschbach factory offers valuable insights for other projects seeking to repurpose vacant industrial heritage buildings in rural areas. A continuous learning process includes the following key lessons:

- Community Involvement is Crucial: Projects with socio-cultural awareness and eco-social transformation potential require the early and ongoing engagement of the local community. Their input ensures that the project is relevant to local needs and generates broader sustained support.

- Balancing Uses and Preservation: Repurposing heritage buildings for different (public) uses can be challenging, but it is essential to strike a balance between preserving structural historical substance and meeting contemporary space-related functional needs.

- Flexibility in Design: The multifunctional spirit of the Hirschbach textile factory, merging housing, work, and cultural spaces, shows how adaptable historical buildings can be future proof. Flexibility is key to ensuring long-term meaningful uses and meeting people's needs.

- Economic Viability Through Innovation: Although financial challenges are common in such projects, innovation in space use, such as communal living, co-working spaces, and cultural events, can unlock new types of alternative financing streams.

8. Conclusion and Outlook

The Hirschbach textile factory case study demonstrates how vacant industrial heritage buildings can pursue the path of reactivation to serve community needs. By repurposing this textile relic into a hub for co-housing, working, and cultural activities, the project highlights the immense potential of such spaces for meaningful rural regeneration. Looking ahead, the lessons learned from Hirschbach's transformation can be applied to similar projects across Lower Austria and beyond. With persistent community involvement, similar practices, and innovative uses of space, vacant industrial buildings can be transformed from vacant relics into reactivated parts of village social life. This case study captures the transformative journey of the Hirschbach textile factory and reflects critically on the broader (positive) impacts.

Follow us >>>

IG **@dieTextilfabrik**

Facebook **@dieTextilfabrik**

Online **www.dietextilfabrik.at**

AI-detector scan results:

Zerogpt.com – 1,67% AI GPT

Justdone.ai – 0,00% AI-generated

9. References

Books

Buttenberg, L., et. al. (2014) *Raumunternehmen. Wie Nutzer selbst Räume entwickeln*. Berlin: Jovis Verlag 2014, pp. 5.

Henkel, G. (2020) *Das Dorf Landleben in Deutschland - gestern und heute*. Darmstadt: wbg Theiss, pp. 263-264.

Hokr, L. (1989) *Bandel in Handel und Wandel*. In: Das Waldviertel

Kalmár, J., Linke, R., Mayer, C. (2007) *Verschwundenes Waldviertel, Über Greißler und Wirtshäuser, Textilfabriken und Mühlen, Kinos und Bahnhöfe sowie Grenzen, die es nicht mehr gibt.* Schleinbach.

Katzenschlager, W., Knittler, H. (2007) *Historisches Weitra, Ansichten aus sechs Jahrhunderten*. Weitra

Komlosy, A. (1994) *Vier Jahre „Waldviertler Textilstraße*. Gmünd: Das Waldviertel, pp. 15-58.

Komlosy, A. (1990) *Waldviertler Textilstraße*. Niederösterreich: Waidhofen an der Thaya.

Rudda, A. (1995) *Ein Riese stirbt, Gründung, Aufstieg, Werdegang und Ruin der einstmals größten Strumpffabrik Österreichs verbunden mit einem Jahrhundert Zeitgeschichte von Heidenreichstein*. Niederösterreich: Waidhofen/Thaya.

Stadler, G. A. (2006) *Das industrielle Erbe Niederösterreichs*. Wien: Böhler.

Waldstein, M. (2021) *Das Waldviertel*. Wien: Styria Verlag.

Diploma Thesis

Albrecht, J. (2014) *ZWEIT.WERT, Nachnutzungsszenarien für die Adensamer Textilfabrik in Groß-Siegharts*. Wien: TU Wien.

Schilling, O. (2012) *Textilfabrik Eisenberger, Industrielles Erbe in Gmünd/Ceské Velenice*. Wien: TU Wien

Wenzel, T. (2007) *Die Bautypen der Waldviertler Textilstraße*. Wien: TU Wien.

Wiala-Zimm, R. (1995) *Anderlfabrik*. Wien: TU Wien.

Case Study Report

Integrating Traditional Dandaka Planning for Climate-Resilient Urban Housing: A Multi-Method Study on Thermal Comfort in High-Density Residential Buildings

Anurag Aman Kaushal, Centre of Excellence for Indian Knowledge systems, Indian Institute of Technology Kharagpur, India

Prashant Anand, Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur, India

Bharath H Aithal, RCG School of Infrastructure Design and Management, Indian Institute of Technology Kharagpur, India

Abstract

Investigating high-density urban housing profoundly shapes living conditions, sustainability, and urban development approaches. Traditional planning and architectural practices hold promise for enhancing comfort while promoting sustainability. This paper investigates how the traditional planning technique may enhance indoor thermal comfort in residential buildings. A comprehensive assessment is conducted using a multi-method approach incorporating computational modelling and field measurements to understand the effectiveness of planning principles on indoor living environment. By conducting comprehensive simulations and field data analyses, the research provides insights into the prudence of past planning approaches and indoor thermal conditions in the present times, contributing to sustainable and comfortable living environments. The computational modelling component involves developing and simulating virtual building models using the software Rhino, Ladybug and Honeybee. This research examines site layout, building layout and orientation to assess the thermal performance of residential buildings in warm and humid climates. The results quantify thermal comfort metrics including Predicted Mean Vote(PMV) and Predicted Percentage of Dissatisfaction(PPD) based on national and international standards highlighting the efficacy of Dandaka planning in creating comfortable built environments. Through on-site monitoring of indoor thermal conditions and occupant comfort surveys, these measurements show the impact of Dandaka planning on indoor thermal comfort. The outcomes of this research have implications for architectural design practices, urban planning strategies, and sustainability initiatives, offering valuable insights for creating more comfortable and energy-efficient built environments.

Keywords

Dandaka Planning, Outdoor thermal comfort, Indoor thermal comfort, Building simulation

1. Introduction

1.1. Background

In recent decades, urbanization has caused a global shift toward high-density living influenced by factors like population growth, economic opportunities and the continuous improvement of infrastructure and services in urban areas. Moreover, this rapid expansion is causing significant environmental challenges such as urban heat island(UHI) effect, where cities are consistently becoming warmer than their surrounding rural areas due to the dense concentration of buildings and infrastructure. The impact of UHI is diverse, affecting both energy consumption and public health. Higher urban temperatures lead to increased energy demands, as residents rely more on-air conditioning for cooling(Santamouris, 2020). This, in turn, escalates energy costs, increases greenhouse gas emissions, and increases the environmental impact of cities. Public health is also compromised as prolonged exposure to higher temperatures raises the risk of heat-related illnesses, particularly among vulnerable populations such as the elderly, children, and those with pre-existing health conditions(Santamouris, 2015).

Additionally, the urban heat island(UHI) effect is continuously increasing public health challenges by reducing comfort well-being. In high density areas where buildings are closely spaced with limited ventilation and airflow, the UHI effect causes natural air flow restriction tapping heat in both outdoor and indoor spaces, thereby increasing thermal discomfort and health risks. This lack of ventilation leads to thermal discomfort, where residents experience high levels of heat, affecting their physical well-being and reducing the overall liveability of urban areas(Paravantis et al., 2017). Addressing the UHI effect, therefore, requires a re-evaluation of urban planning and design strategies that prioritize climate resilience and thermal comfort in high-density environments.

1.2. The Relevance of Traditional Planning in Modern Contexts

Historically, urban planning actively integrated cultural, climatic, and environmental factors, with many traditional systems specifically for local climates and social needs. Among these, Dandaka planning, a traditional urban planning method from ancient India, represents climate-responsive design found in the text of Vastu Shastra. The concept supports harmony between the built environment and natural elements uniquely combining cultural and environmental adaptability(Narkhede and Chiplunkar, 2024). The term "Dandaka" refers to a straight, elongated layout that resembles a pole, or danda in Sanskrit. This layout is characterized by linear streets aligned in a grid-like formation, often running along orthogonal lines that intersect at right angles(Dagens, 2010).

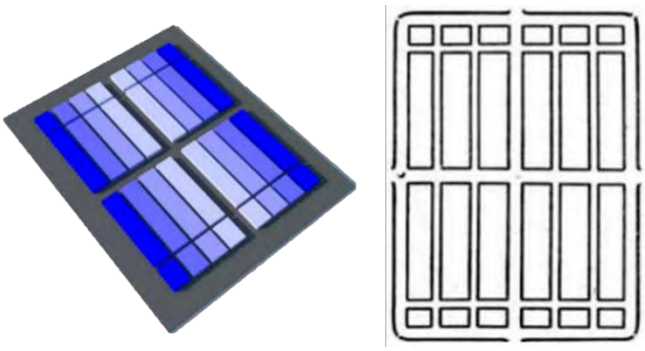


Figure 1. Dandaka layout for towns and villages

Incorporating Dandaka planning principles into contemporary high-density urban housing may provide numerous practical advantages. If implement in climate-resilient approaches it can help in decrease of dependence on mechanised cooling systems, leading to reduced energy consumption and lower greenhouse gas emissions. Moreover, environmentally sustainable nature of Dandaka planning also means that the urban spaces can be designed to meet both modern functional requirements and cultural values, fostering a sense of identity and continuity within the built environment.

1.3. Objectives of the Study

This study seeks to address the following objectives:

- This study evaluates the influence of Dandaka layouts on outdoor thermal conditions across different seasons by utilizing Universal Thermal Climate Index (UTCI) heat maps.
- The study examines indoor thermal comfort using Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) metrics, focusing on central and peripheral building zones to assess the impact of layout and orientation.

2. Literature Review

2.1. Ancient Indian Urban Planning Principles

Mayamata and Manasara, the important sources of ancient planning texts highlights various town planning methods that incorporate climate resilient, socially sensitive and environmentally balanced layouts(Dagens, 2010). These traditional structures demonstrate comprehensive understanding of spatial planning and architecture with ecological contexts and cultural environment. Sarvatobhadra and Dandaka planning methods provide strctured blueprints aims to enhance social cohesion, sustainability, human comfort and well-being. The Dandaka layout, prominently featured in traditional Indian planning, stands out for its linear, stick-like form, symbolically resembling a danda (Sanskrit for "stick" or "pole")(Sharma, 2022). This design is characterized by long, straight streets that intersect at right angles, usually aligned in east-west or north-south directions. This orthogonal grid arrangement facilitates airflow and maximizes cross-ventilation, making it an effective approach for climate adaptation.

2.2. Understanding Thermal Comfort in Urban Contexts

Thermal comfort is a key consideration in high-density urban areas, where building design, material choices, and layouts influence occupant comfort levels(Hensen, 1990). Thermal comfort assessment utilises PMV and PPD as its prominent factor to understand the comfort of the occupants considering air temperature, relative humidity and air velocity(Djongyang et al., 2010). Traditional planning approaches, such as the Dandaka layout, can contribute significantly to improve thermal comfort by setting passive cooling techniques within building structures and surroundings, reducing dependence on mechanised cooling and heating methods.

2.3. The Role of Dandaka Layout in Modern Urban Contexts

Adapting Dandaka planning principles to modern urban challenges offers a promising solution for improving thermal comfort, sustainability, and liveability in high-density environments(Patra, 2009). The Dandaka layout, with its orthogonal grid pattern and structured streets, promotes cooling through enhanced air circulation, natural shading, and the creation of cooler microclimates. In the context of dense

residential areas where air conditioning and mechanical ventilation are often necessary to maintain comfort, Dandaka planning offers a low-energy alternative that can minimize UHI effects and reduce overall energy consumption.

3. Methodology

3.1. Multi-Method Approach

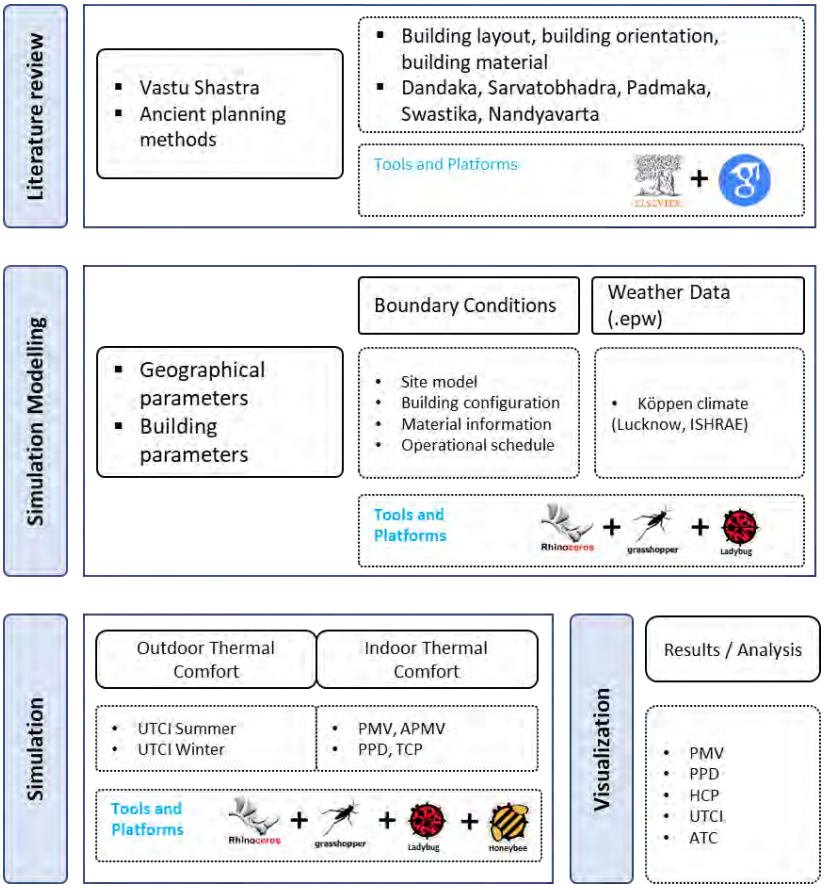


Figure 2. Methodology

The study uses a multi-method approach, combining computational modelling, on-site measurements, and thermal comfort analysis to evaluate the effectiveness of Dandaka planning. This approach allows for a detailed, empirical understanding of how traditional planning principles impact thermal comfort. The urban layout was modelled using Rhino, Ladybug, and Honeybee software. These tools enable detailed simulations of the sun's path, airflow, and temperature distributions throughout the year. The use of advanced simulation tools allows for precise modelling of Dandaka layouts under real-world seasonal conditions, providing insights into the spatial arrangement's thermal benefits. On-site temperature, humidity, and airflow measurements were collected to validate the computational model. Resident surveys captured feedback on thermal comfort, particularly in different building zones and at various times of day. This data provided a practical, human-centred perspective on the model's thermal comfort outcomes.

Table 1. Instruments used for data collection

Measured parameters		Range	Accuracy
Air temperature	T&D Temp-Humidity Sensors TR72A and SHA-3151	-25 to 70 °C	±0.3 °C
Relative humidity		0-99% RH	0.025
Globe temperature	Graphtec GL840	-200°C to 1760°C	± 1.55 ºC
Air Velocity	Kanomax Anemometer Model 6006	0.01 to 30.48m/s	±5% or ± 0.015

Thermal Comfort Analysis: PMV and PPD metrics were calculated across various zones within Dandaka-layout buildings, allowing for an assessment of indoor thermal comfort. By measuring PMV and PPD in both central and peripheral areas, the study evaluates how building orientation and layout influence comfort levels under different seasonal conditions.

3.2. Site and Climate Context

Lucknow, a city in India's humid subtropical zone, was selected as the study site due to its pronounced seasonal climate variations. Summers are particularly hot, with temperatures often exceeding 40°C, while winters are mild to cool. This climate provides a robust context for testing Dandaka's layout efficacy, as thermal comfort solutions must address both heat retention in summer and insulation in winter.

Table 2. Site location

Region and Building data	
Region	Lucknow, Uttar Pradesh
Climate	Subtropical
Building location	Indira Nagar, Lucknow
Building& Site selection criteria	Bungalows , Planned Colonies and Societies

4. Results and Analysis

4.1. Outdoor Thermal Comfort

The Universal Thermal Climate Index (UTCI) heat maps generated from this study's simulations offer valuable insights into temperature distribution patterns across Dandaka layouts. These maps illustrate how the strategic inclusion of buffer zones—such as green spaces, open courtyards, and vegetative barriers—contributes significantly to outdoor thermal comfort, especially during the summer months. Areas near these buffer zones consistently recorded lower temperatures than more densely built zones, with temperature reductions ranging from 2-3°C on average. This cooling effect is particularly beneficial in high-density urban areas, where minimizing the urban heat island (UHI) effect is critical for enhancing liveability and reducing reliance on mechanical cooling.

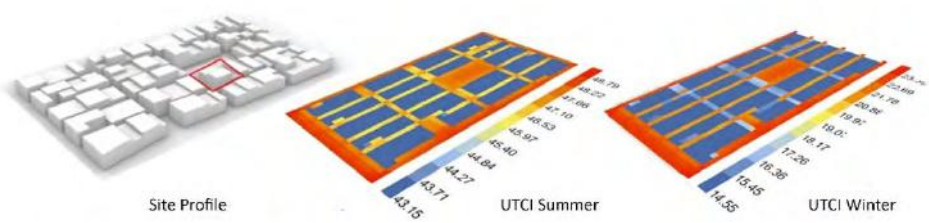


Figure 3. Outdoor thermal comfort

Seasonal Variation: During the summer, buffer zones in Dandaka layouts play a crucial role in alleviating localized heat build-up, making outdoor spaces more comfortable for residents and pedestrians. This finding shows the importance of incorporating green infrastructure into urban designs, as it not only enhances thermal comfort but also supports biodiversity and provides aesthetic value. In the winter, UTCI values are more moderate, allowing comfortable outdoor temperatures across most areas. The winter variation further underscores the adaptability of Dandaka layouts to seasonal climate changes, as they help regulate outdoor temperatures year-round.

4.2. Indoor Thermal Comfort

Indoor thermal comfort in high-density housing is a complex challenge influenced by building orientation, ventilation, shading, and overall layout. This study's analysis of PMV and PPD scores across various zones within buildings highlights how specific design strategies can improve or compromise comfort levels in different parts of a structure. Key findings reveal the distinct role of central and peripheral zones in shaping occupants' comfort experiences:

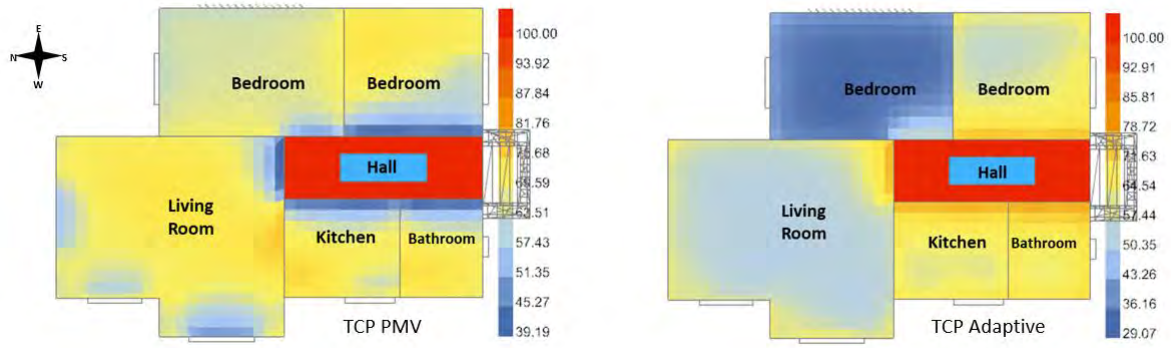


Figure 4. Indoor thermal comfort

- Central Zones: The study's data indicates that central zones exhibit lower PMV values, which translates to higher thermal comfort. These areas benefit from reduced sun exposure, as surrounding structures provide natural shading. Enhanced airflow is another contributing factor, as centrally located spaces can draw cooler air from surrounding buffer zones and shaded areas. This airflow dynamic allows central zones to maintain more stable and comfortable temperatures throughout the day, reducing the need for mechanical ventilation.
- Peripheral Zones: High PMV and PPD values in peripheral zones suggest a greater degree of thermal discomfort, especially during peak afternoon hours in the summer. These zones, often exposed to direct sunlight and with fewer shading options, tend to retain more heat, making them uncomfortable during warmer seasons. Afternoon temperatures in these areas frequently exceed the comfort range, underscoring the necessity for adaptive measures, such as improved shading, reflective building materials, or increased ventilation options.

The study's data further reveals that thermal comfort varies diurnally and seasonally, with peak discomfort commonly observed during summer afternoons. This supports the notion that Dandaka planning is well-suited to adapting to seasonal fluctuations, as it reduces thermal discomfort during both extreme summer

and moderate winter conditions. These findings advocate for urban designs that use passive strategies to manage indoor temperature variances throughout the day and across different seasons.

4.3. Diurnal and Seasonal Thermal Comfort Trends

The study's findings on seasonal and diurnal thermal comfort trends underscore the adaptability of Dandaka planning to varying climate conditions:

Winter (December to February): Lower PMV and PPD values in winter months suggest higher comfort levels during this period, particularly in central building zones. These zones exhibit optimal comfort due to moderated temperatures, as central shading and reduced exposure to outdoor temperatures create stable indoor conditions. Peripheral zones, although slightly cooler, still maintain acceptable comfort levels, highlighting the ability of Dandaka layouts to moderate extreme temperatures across all zones.

Summer (March to June): Elevated PMV scores in summer indicate increased discomfort in peripheral zones, especially during afternoon hours. These zones absorb higher solar radiation due to direct exposure, which leads to warmer indoor temperatures and greater thermal stress for occupants. Increasing shading elements, such as trees, pergolas, and extended eaves, could mitigate this discomfort by blocking excess sunlight, while enhancing ventilation could improve airflow and reduce retained heat.

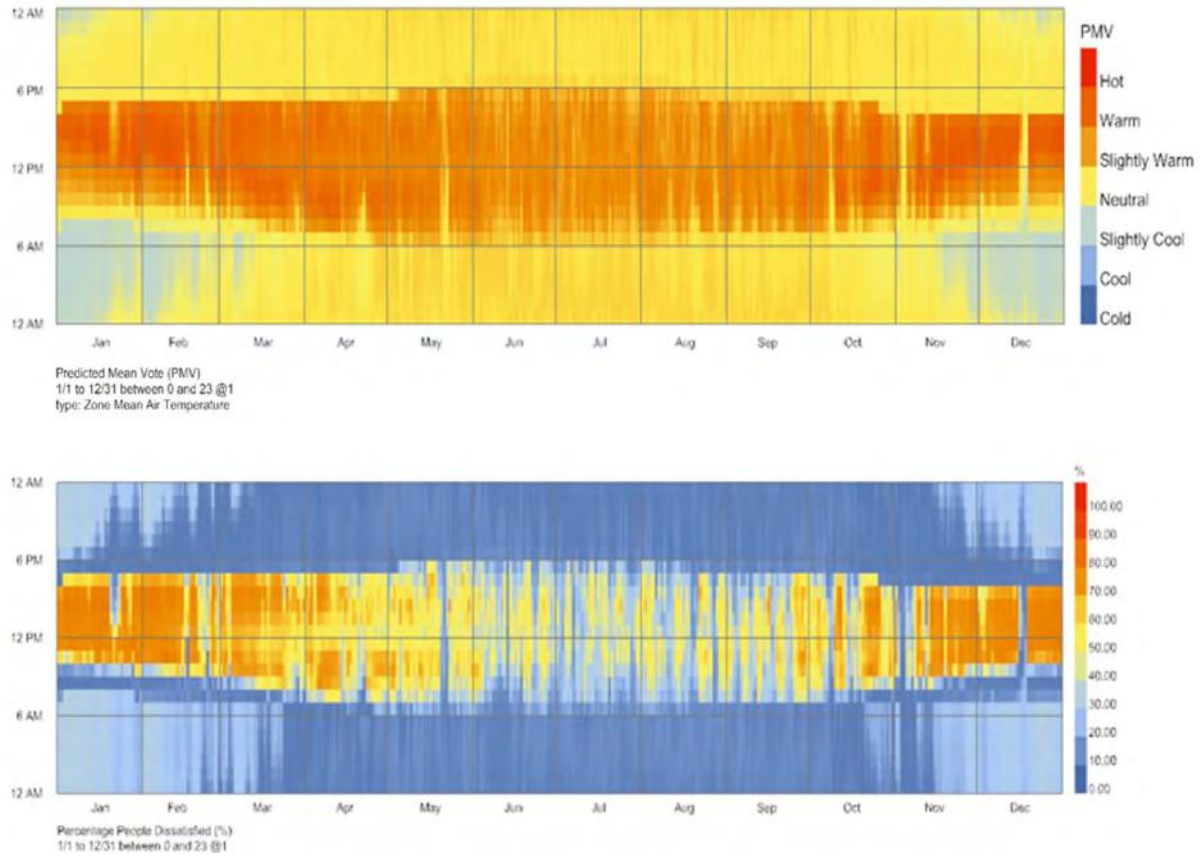


Figure 5. Annual indoor PMV and PPD map

The diurnal variation in thermal comfort, with peak discomfort in the afternoon hours, further emphasizes the importance of adaptive design strategies that respond to daily temperature shifts. By incorporating elements that provide shade during peak hours and maximize airflow at cooler times, Dandaka planning offers a framework for maintaining thermal comfort throughout the day and across seasons.

5. Conclusion

The study's results validate that Dandaka planning principles, especially its structured layout and orientation strategies, are effective in mitigating thermal discomfort. By optimizing natural shading and promoting ventilation, Dandaka layouts reduce the need for energy-intensive cooling systems, which aligns with the goals of sustainable urban development. This approach is also consistent with human-centred urban planning, which prioritizes resident well-being, environmental resilience, and community cohesion. The structured nature of Dandaka layouts fosters connectivity, social interaction, and walkability, creating environments that support mental and physical health. By reducing thermal discomfort through passive cooling strategies, Dandaka planning offers a sustainable, human-centred model that can enhance urban liveability while lowering environmental impact. To capitalize on the benefits of Dandaka-inspired planning, urban policies should focus on encouraging sustainable, climate-adaptive design principles. Encourage East-West Building Orientation: Aligning buildings along east-west axes should be incentivized, as it reduces direct sun exposure during peak hours, minimizes solar gain, and lowers cooling needs. Policies should require buffer zones with vegetation around buildings, as green spaces help reduce UHI effects, lower localized temperatures, and improve air quality. Urban designs should integrate passive cooling structures like pergolas, rooftop gardens, and shaded corridors. These elements can enhance outdoor and indoor thermal comfort, contributing to a more sustainable urban environment. These recommendations provide a framework for high-density housing models that prioritize environmental sustainability, resident comfort, and resource efficiency.

5.1. Limitations and Areas for Future Research

While this study offers valuable insights, its geographic focus on Lucknow may limit the generalizability of findings across other climates. Future research could examine Dandaka planning's applicability in different regions, such as arid or temperate zones, to assess its versatility in diverse climatic contexts. Additionally, integrating AI and machine learning into predictive modelling could improve the precision of thermal assessments and facilitate scalable urban design solutions.

5.2. Broader Implications

Dandaka planning offers substantial environmental and energy benefits by promoting passive cooling strategies that reduce reliance on air conditioning. This not only lowers energy consumption but also decreases greenhouse gas emissions, contributing to global climate targets. By integrating natural ventilation, shading, and green spaces, Dandaka layouts create low-energy, climate-adaptive housing that aligns with the principles of urban sustainability. This study emphasizes the importance of policy frameworks that support heritage-based urban designs. Governments should incorporate traditional planning methods, particularly in high-density zones.

The findings of this study illustrate that incorporating Dandaka planning principles into modern high-density urban housing can significantly improve climate resilience. By enhancing airflow, reducing heat retention, and optimizing shading, Dandaka layouts create a sustainable, heritage-inspired model for

tackling urban heat challenges. These results underscore the potential of traditional planning techniques to inform future urban developments that prioritize liveability, energy efficiency, and cultural alignment.

6. References

Dagens, B., 2010. Mayamatam (2 Volumes): Treatise of Housing Architecture and Iconography. Motilal Banarsidass.

Djongyang, N., Tchinda, R., Njomo, D., 2010. Thermal comfort: A review paper. Renewable and Sustainable Energy Reviews 14, 2626–2640. https://doi.org/https://doi.org/10.1016/j.rser.2010.07.040

Hensen, J.L.M., 1990. Literature review on thermal comfort in transient conditions. Build Environ 25, 309–316. https://doi.org/https://doi.org/10.1016/0360-1323(90)90004-B

Narkhede, D.-P., Chiplunkar, T., 2024. SYMBOLISM AND ANCIENT INDIAN TOWN PLANNING. History Research Journal 30, 104.

Paravantis, J., Santamouris, M., Cartalis, C., Efthymiou, C., Kontoulis, N., 2017. Mortality Associated with High Ambient Temperatures, Heatwaves, and the Urban Heat Island in Athens, Greece. Sustainability 9. https://doi.org/10.3390/su9040606

Patra, R., 2009. Vaastu shastra: Towards sustainable development. Sustainable Development 17, 244–256. https://doi.org/10.1002/sd.388

Santamouris, M., 2020. Recent progress on urban overheating and heat island research. Integrated assessment of the energy, environmental, vulnerability and health impact. Synergies with the global climate change. Energy Build 207, 109482. https://doi.org/https://doi.org/10.1016/j.enbuild.2019.109482

Santamouris, M., 2015. Regulating the damaged thermostat of the cities—Status, impacts and mitigation challenges. Energy Build 91, 43–56. https://doi.org/https://doi.org/10.1016/j.enbuild.2015.01.027

Sharma, A., 2022. Mandala Urbanism, Landscape, and Ecology: Interpreting Classic Indian Texts and Vaastupurusha Mandala as a Framework for Organizing Towns, Mandala Urbanism, Landscape, and Ecology: Interpreting Classic Indian Texts and Vaastupurusha Mandala as a Framework for Organizing Towns. Springer International Publishing. https://doi.org/10.1007/978-3-030-87285-4

OpenAI 2023, ChatGPT: Language model, OpenAI, accessed 31 October 2024, https://chat.openai.com

Quillbot 2023, Quillbot Paraphrasing Tool, Quillbot, accessed 31 October 2024, https://quillbot.com

Research Paper

The effect of subjective perception of the park environment on mental health among elderly people in cold region

a case study in Northeast China

Xueyan Ma, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Hong Leng, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Jingxin Qi, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

Background: Urban parks have a positive impact on the mental health of the elderly, but there are few studies on the impact of the elderly's perceived environment on mental health, and the evidence is often uncertain. The climate in cold areas is harsh, the quality of the winter park environment is poor, and the elderly's life is more difficult. Their mental health needs to be taken seriously. Our goal is to use the survey data collected in Northeast China in 2022 to study the path and effect of the subjective perceived environment of parks in cold areas on mental health.
Methods: We distributed 180 questionnaires in Jilin City, Jilin Province, Northeast China, to collect the elderly's subjective perception of park environment and their mental health data. The mental health was measured by SRHMS scale and the structural equation model was established to evaluate the impact of the elderly's subjective perception of park environment on mental health in cold cities.
RESULTS: We analyzed the reliability of the survey data and concluded that Cronbach's α coefficient is greater than 0.7, indicating that the data are reliable and good. According to the results of the structural equation model, there is a significant correlation between the elderly's subjective perception of urban parks in cold areas and their mental health level.
Conclusion: Through analysis, we conclude that the elderly can positively affect the mental health of the elderly by the safety of activities in cold urban parks, the quality of the marking system and the familiarity of parks. However, the accessibility of cold urban park landscapes is negatively correlated with mental health. It may be that the elderly in cold urban parks are more inclined to choose open places in order to obtain a warmer environment and a better social environment.

Keywords

Subjective Perception of Park Environment, Mental Health, The Elderly, Cold Region

1. Introduction

At present, the aging of the population in our country is severe, and the elderly are increasingly concerned. The elderly generally have mild mental health problems such as loneliness and depression. The Outline of the "Healthy China 2030" Plan puts forward the goal of promoting residents' mental health literacy and strengthening interventions on psychological behaviors such as depression and anxiety. Studies have shown that participating in and experiencing activities in parks can improve the elderly's bad mood, promote interaction and communication, and improve the elderly's social relationships (Li and Zhang, 2009). Active physical fitness and social interaction activities in the environment of urban parks can reduce the risk of common diseases in the elderly, relieve the elderly's mental pressure, and promote the elderly's physical and mental health (Tan, He, et al., 2020). Therefore, exploring the relationship between urban parks and the elderly's mental health is an important prerequisite for optimizing the urban park environment, actively intervening in the elderly's health, and promoting the elderly's active aging.

Scholars have made certain achievements in the study of the improvement of the mental health of the elderly by the environment of urban parks. There are many factors that affect the mental health of the elderly in the environment of urban parks. Different factors play different roles, and the ways and paths of action are also different. According to experimental studies, some scholars have pointed out that outdoor activities provided by parks can keep people away from negative mental health incentives and improve mood. Urban parks can provide rich sensory experiences and have a positive impact on mental health (Belanger, Gallant, et al., 2019; Kim, Kim, et al., 2020; Tao, Yang, et al., 2020). Park environments can improve mood and reduce stress through individual contact with the natural landscape (Ulrich, Simons, et al., 1991; Chiesura, 2004).It can also improve the individual's experience by reducing noise and optimizing air quality (Dong, Wang, et al., 2021; Gidlof-Gunnarsson and Ohrstrom, 2007) and provide a place for crowd activities to support the needs of social interaction between people (Kaczynski and Henderson, 2007; Ekkel and de Vries, 2017).

In the study of healthy cities in cold regions, Leng summarized the international experience of climate planning for human settlements in cold regions, and proposed special planning guidelines at the urban design level according to the climate characteristics of winter, through the guidance of sunshine environment, bad wind environment, thermal environment, urban color and night landscape, etc., to improve the quality of human settlements in cold cities (Leng and Yuan, 2008). Jiang et al. proposed that wind speed is the leading factor affecting people's outdoor activities during the transition season through research on the comfort of public space in cold cities during the transition season (Jiang and Leng, 2017). Li studied the residents' winter health needs for public space, and proposed the establishment of a public space allocation system to increase the possibility of people participating in public space activities; optimize the layout of public space, improve the accessibility and pedestrian connection of public space; optimize the design of public space, and improve the comfort of residents participating in public activities from the aspects of space form, landscape, functional facilities and physical environment (Li et al, 2018).

In the study of the impact of urban park environment on the mental health of the elderly, scholars all believe that park environment is related to mental health. Some scholars point out that urban parks provide support for the mental health of the elderly in three aspects: natural environment, individual experience and activity facilities. In the study of healthy cities in cold areas, scholars have emphasized the built environment factors that prevent residents from being affected by climate conditions in cold areas and affect thermal comfort. At the same time, scholars have emphasized the walkability and safety of public spaces in winter.

Although different researchers have the same views on the promotion of urban park environment on the mental health of the elderly, there are relatively few studies on the impact of subjective perception of urban parks on the mental health of the elderly and the mental health of the elderly in cold regions. Therefore, on the basis of previous research, the author conducted field research on urban parks in cold cities Jilin City and issued questionnaires, proposed the impact path of urban parks in cold regions on the mental health of the elderly, and used SPSS and AMOS quantitative analysis to verify the path significance and impact degree of the hypothetical model through structural equation model, which provided a research basis for the planning and design of urban parks in cold regions.

2. Study Design

The main content of this study is the impact of the subjective perception of the park environment in cold areas on the mental health of the elderly. Considering the particularity of winter climate conditions in cold cities, this study selected the investigation site in Jilin City, Northeast China, and took three urban parks in Jilin City as examples. Firstly, we constructed a theoretical model and propose the model hypothesis H1: the subjective perception of the environment of urban parks directly affects the mental health of the elderly. Secondly, we obtained research data through field investigation. Finally, we verified and analyzed the impact path and effect of the subjective perception environment of urban parks on the mental health of the elderly based on the data.

2.1. Investigation area

The investigation areas of this study are Beishan Park, Jiangbin Park and Linjiangmen Park. The three parks are all located in the main urban area, with a long history and dense population nearby, so there are sufficient survey samples. The natural landscapes, facilities configuration and park experience of the three parks are distinct and different, which can better reflect the diversity of park environments, basically covering the types of common urban parks, and meeting the sampling needs of various factors involved in the study, as shown in Figure 1-3.

Figure 1. The real scene of Beishan Park. Source: Photographed by the author.

Figure 2. The real scene of Jiangbin Park. Source: Photographed by the author.

Figure 3. The real scene of Linjiangmen Park. Source: Photographed by the author.

2.2. Questionnaire design and survey

This study uses qualitative and subjective evaluation to measure variables, asking respondents to rate relevant descriptions according to their true thoughts. The evaluation method is evaluated by Likert's 7-level scale. "1" means strongly disagree, "2" means disagree, "3" means slightly disagree, "4" means generally, "5" more agree, "6" agree, and "7" means strongly agree.

In order to obtain a measurement scale with good reliability and validity, this study systematically searched and organized the research literature on the subjective perception characteristics of urban parks and the mental health status of the elderly. Combined with the existing general measurement scale, the relevant measurement indicators were determined as shown in Table 1.

Table 1. Measurement indicator table of urban parks.

Type of measurement indicator	Measurement indicators	Reference sources
Subjective perception of park environment	Sense of safety in parks	Sugiyama et al.
	Landscape accessibility of parks	Leng,H.,et al.
	Park activity support	Wang, X.Y and Yang, D.F.
	Familiarity of the park	Afroditi
Mental health status of the elderly	Satisfaction with Living Conditions of the Elderly	Xu Jun et al.
	Sense of safety in their living environment	
	Happiness of the Elderly	
	Loneliness of the elderly*	
	Older people's sense of identity in life	
	Older adults' comprehensive self-assessed mental health	

Note: * means reverse scoring is required

In January 2022, the author conducted a questionnaire survey on the elderly in three urban parks in Jilin City, and a total of 180 questionnaires were collected. A total of 145 questionnaires were selected from

the completed questionnaires and those over the age of 55 as valid questionnaires, which met the reference standard of the sample size required for structural equation modeling.

3. Results

3.1. Descriptive statistical analysis

We put the survey data into the SPSS 23.0 software for statistics, and found that in terms of social interaction frequency, the elderly generally go to the park for 5 to 7 days per week in winter, and the daily activity time in the park is 2 to 3 hours. In terms of the number of social activity partners, the elderly generally participate in social activities with 1 to 3 partners. In terms of types of social activities, most of the elderly participate in 2 to 3 sports, and a small number only take walks; in terms of activity enthusiasm, the proportion of the elderly with high enthusiasm (53%) is slightly more than that with low enthusiasm (37%); in terms of contact with friends, most of the elderly (63%) keep in touch with friends in the park by visiting each other, greeting by phone, etc.

From the elderly mental health self-evaluation data, we can see that most of the elderly participating in the survey are at a good level of mental health, the elderly have higher scores of life satisfaction and environmental security, and the elderly have lower average scores of loneliness and life identity.

Table 2. Self-rated mental health of the elderly (out of 7). Source: Drawn by the author.

Variable	Beishan Park	Jiangbin Park	Linjiangmen Park	Mean	Variance
Life Satisfaction	5.54	5.36	6.30	5.83	1.68
Sense of Environmental Safety	5.58	5.36	6.19	5.80	1.66
Happiness	5.65	5.15	5.83	5.61	1.92
Loneliness (reverse scoring)	4.90	4.61	5.81	5.23	3.72
Sense of life identity	4.75	4.55	5.92	5.22	3.62
Self-rated Mental Health	5.69	5.15	6.09	5.74	1.80
Total	32.11	30.18	36.14	——	——

3.2. Exploratory factor analysis

We put the survey data into the SPSS 23.0 software for statistics, and found that in terms of social interaction frequency, the elderly generally go to the park for 5 to 7 days per week in winter, and the daily activity time in the park is 2 to 3 hours. In terms of the number of social activity partners, the elderly generally participate in social activities with 1 to 3 partners. In terms of types of social activities, most of the elderly participate in 2 to 3 sports, and a small number only take walks; in terms of activity enthusiasm, the proportion of the elderly with high enthusiasm (53%) is slightly more than that with low enthusiasm (37%); in terms of contact with friends, most of the elderly (63%) keep in touch with friends in the park by visiting each other, greeting by phone, etc.

Table 3. Reliability Test and Validity Test. Source: Drawn by the author.

Reliability statistic		KMO and Bartlett's Test			
Cronbach's α	n	KMO	Approximate Chi-squared value	df	Sig.
0.861	10	0.910	1191.487	45	0.000

3.3. Model fit and path analysis

The AMOS 26.0 software uses the maximum likelihood estimation method to estimate the parameters of the SEM. After operation, we obtain the parameter estimates and normalized path coefficients of the model, as shown in Figure 4. At the same time, we extract important fitting indices from the model estimation data, such as Table 3: chi-squared/degree-of-freedom (χ2/df), Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Root Mean Square Error of Approximation (RMSEA), comparative fitting index (CFI), Normed Fit Index (NFI) and Incremental Fit Index (IFI). Among them, χ2/df is 1.713, which is less than the critical value of 3.000, indicating that the model fits well; GFI, CFI and IFI are all greater than 0.900, and the model fits well. In summary, the SEM constructed in this study is relatively ideal.

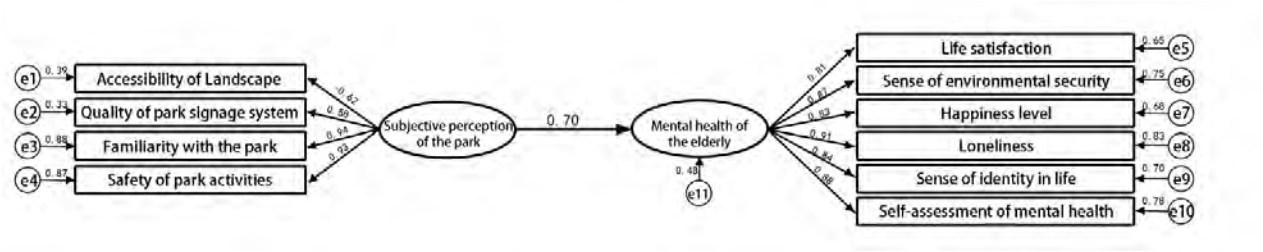


Figure 4. Path map of the influence of urban parks on the mental health of the elderly (estimated according to the standardization parameters of the model) .Source: Drawn by the author.

Table 4. Goodness-of-fit test of structural equation model. Source: Drawn by the author.

Fit Index	Reference Value	Model Prediction Value	Explanation
χ^2	——	42.835	——
df	——	25	——
χ^2/df	＜3	1.713	Less than 3 , indicating that the model fits well
GFI	＞0.90	0.947	Greater than 0.9, indicating that the model fits well
AGFI	＞0.90	0.884	Close to 0.9, indicating that the model fit is acceptable
RMSEA	＜0.08	0.070	Less than 0.08 , indicating that the model fits well
CFI	＞0.90	0.985	Greater than 0.9, indicating that the model fits well
NFI	＞0.90	0.966	Greater than 0.9, indicating that the model fits well
IFI	＞0.90	0.986	Greater than 0.9, indicating that the model fits well

The estimated values of the SEM path coefficients were calculated as shown in Table 5, where the estimated values of the normalized path coefficients reflect the relationship between each measurement variable and the degree of mutual influence of each measurement index. According to the P value, we can judge whether the path between the measured variables is significant. When P < 0.001, the path is significant at 99.9% confidence interval; when P < 0.010, the path is significant at 99% confidence interval; when P < 0.050, the path is significant at 95% confidence interval; when P > 0.050, the path is not significant. From the test results of the path coefficients, the assumption H1 was accepted.

Table 5. Results of path analysis between latent variables. Source: Drawn by the author.

Hypothesis	Path of measurement model	Estimation value of path coefficient	Standardized path coefficient estimation value	*P*	Conclusion
H1	Subjective perception of park environment—Mental Health	0.616	0.696	***	Accept

Notes: *** indicates significant at the 0.001 level.

4. Conclusion

4.1. Main findings

This study starts from the environment of urban parks in cold winter areas, pays attention to the mental health of the elderly, and intends to deeply study the relationship between the elderly's subjective perception and mental health status of urban parks in cold regions, and proposes the impact path of urban parks on the mental health of the elderly.

For the elderly, their subjective perception of urban parks in cold areas will have a positive impact on their mental health. The safety of park activities, the accessibility of the landscape, the quality of the park's sign system, and the familiarity with the park are the factors that affect the mental health of the elderly. Among them, the safety of park activities and the elderly's familiarity with the park are the main factors affecting the mental health of the elderly. It may be because compared with young people, the elderly are more fragile in physical state, more worried about physical and psychological damage, and have a higher demand for the safety of urban parks in cold areas. Therefore, the higher the safety of park activities, the higher the mental health level of the elderly. The elderly's familiarity with the park may be related to the elderly's sense of belonging. The more familiar the elderly are with the park, the stronger the sense of belonging, and the more it can affect the elderly's mental health. The accessibility of the park landscape has a negative impact on the mental health of residents, which may be because the accessibility of the landscape reflects the density of plants in the park. However, due to the cold climate, the park's winter landscape cannot provide enough green space for the elderly, and it takes up a lot of activity space in the park, reducing the scope of physical activity and social interaction of the elderly; in turn, it affects the mental health level of the elderly in reverse, and the elderly are more likely to choose to move in open areas with direct sunlight in winter. The quality of the park signage system has the least impact on the mental health of the elderly, and the park with better signage system can promote the mental health of the elderly.

4.2. Implications and limitations

This study provides new ideas for solving the health problems of the elderly in today's cold cities and exploring a healthy living environment: first, we should supplement the public facilities that are lacking in

most cold city parks to resist the severe winter climate; second, when planning the park environment, we should pay more attention to the refined design aimed at optimizing the elderly experience; finally, the subjective experience and satisfaction of the elderly in the city are crucial to public health. Before carrying out the senior-friendly design of urban parks, we should fully listen to the needs and opinions of the elderly.

However, this study also has certain limitations. First, we can only conduct a cross-sectional survey of the elderly's subjective perception and mental health, and lack of long-term tracking of the elderly's subjective perception and mental health. So the data may be affected by special events, resulting in inaccurate results. Second, the elderly's mental health data are self-reported according to questionnaires, and lack of auxiliary support for accurate instruments to measure their blood pressure, heart rate and other data. The influence mechanism of subjective perception of urban parks in cold regions on the elderly's mental health needs to be further explored.

Author Contributions

Conceptualization, Xueyan Ma. and Hong Leng.; formal analysis, Xueyan Ma.; funding acquisition, Hong Leng.; methodology, Xueyan Ma., Hong Leng., and Jingxin Qi.; validation, Xueyan Ma.. and Hong Leng.; writing—original draft, Xueyan Ma.; writing—revising and editing, Xueyan Ma. and Jingxin Qi.

Acknowledgments

This study was funded by the National Natural Science Foundation of China (No. 51978192).And we would like to thank the elderly who participated and the students of Harbin Institute of Technology who assisted in the questionnaire survey.

References

Afroditi S, Holly G, Kenneth R F, et al. (2012). 'Determinants of neighborhood activity of adults age 70 and over: a mixed-methods study', Journal of aging and physical activity, 20(2), p148-170.

Belanger, M., Gallant, F., et al. (2019). *'Physical activity mediates the relationship between outdoor time and mental health', Preventive Medicine Reports*, 16.

Chiesura, A. (2004). *'The role of urban parks for the sustainable city', Landscape and Urban Planning*, 68, p129-138.

Dong, W., Wang, N., et al. (2021). *'Relationship Between Perception of Green Space and Subjective Well-Being of Residents in Different Venues of Daily Activities: A Case Study of Xiangfang Old Industrial Area in Harbin', Landscape Architecture*,28(05), p23-29.

Ekkel, E. D., De Vries, S. (2017). *'Nearby green space and human health: Evaluating accessibility metrics', Landscape and Urban Planning*, 157, p214-220.

Gidlof, A., Ohrstrom, E. (2007). *'Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas', Landscape and Urban Planning*, 83, p115-126.

Jiang, C., Leng, H. (2017). *'Climate Comfortable Condition Analysis and Planning Implications of Residential District Public Spaces in Transition Season of Cities in Severe Cold Region: Taking Harbin as an Example', Urbanism and Architecture*, (01), p29-32.

Kaczynski, A. T. & Henderson, K. A. (2007). *' Environmental correlates of physical activity: A review of evidence about parks and recreation', Leisure Sciences*, 29, p315-354.

Kim, J., Kim, J., et al. (2020). *'Leisure Time Physical Activity Mediates the Relationship Between Neighborhood Social Cohesion and Mental Health Among Older Adults. Journal of Applied Gerontology*, 39, p292-300.

Leng, H., Yuan, Q. (2008). *'International Experiences and Inspirations of Climatic Planning of Human Settlement in Cold Regions', Urban Planning International*, (04), p100-103.

Li, S. And Zhang, W. (2009). *'Progress in Horticultural Therapy Scientific Research', Chinese Landscape Architecture*, 25(08), p15-23.

Leng H., Li, S.Y. (2017). '*Study on City Spatial Planning Strategy in the Winter Cities from the Perspective of Winter Public Health', Shanghai Urban Planning Review*, (03), p1-5.

Li, S.Y., Leng, H., et al. (2018). *'Research on Public Space Planning in Cold Cities Based On Public Health Demands In Winter', Urbanism and Architecture,* (24), p20-23.

Sugiyama, T. (2009). '*Associations Between Neighborhood Open Space Attributes and Quality of Life for Older People in Britain', Environment and Behavior*, 41(1), p3-21.

Tan, S., He, Q., et al. (2020). *'Study on the Influence of Urban Park Environment on the Elderly People's Daily Communicative Activities', Chinese Landscape Architecture*, 36(04), p44-48.

Tao, Y., Yang, J., et al. (2020). *'The Anatomy of Health-Supportive Neighborhoods: A Multilevel Analysis of Built Environment, Perceived Disorder, Social Interaction and Mental Health in Beijing', International Journal of Environmental Research and Public Health*, 17(1), p13-13.

Ulrich, R. S., Simons, R. F., et al. (1991). *'Stress Recovery During Exposure to Natural and Urban Environments', Journal of Environmental Psychology* ,11, p201-230.

Wang, X. Y., Yang, D.F. (2024). '*Identification and optimization of green space environmental elements affecting different health activities of elderly: A case study of Dalian, Journal of Human Settlements in West China*,39 (04), p87-92.

Xu, J., Tan, J., et al. (2003). '*Evaluation of the Self-rated Health Measurement Scale-the Revised Version 1.0', Chinese Mental Health Journal*, (05), p301-305.

Research Paper

Research on the spatial consistency of carbon emissions and economic development in Heilongjiang Province, China

Xiaochen WU, School of Architecture, Harbin Institute of Technology, Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Rong GUO, School of Architecture, Harbin Institute of Technology, Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Abstract

In order to achieve the carbon peak by 2030 while developing the economy, it is necessary to explore the spatial consistency characteristics and coordination relationship between carbon emissions and economic development. This research takes Heilongjiang Province as an example to calculate its carbon emissions from 2005 to 2020. Then the Tapio index, balance index, geographic concentration, and consistency index are adopted to analyze the dynamic evolution characteristics of the relationship between carbon emissions and the economic development. Finally, the ECC and ESC index are used to categorize the cities. The results are as follows: (1) The decoupling relationship between carbon emissions and economy is gradually shifting from weak decoupling to strong decoupling, and low-carbon economy has achieved initial results; (2) The imbalance has undergone a process of decreasing and then expanding; (3) The spatial consistency shows the characteristics of stronger in the southwest and weaker in the northeast; (4) According to the ECC and EGC indexes, cities are divided into low-carbon conservation zones, economic development zones, carbon sink development zones, and comprehensive optimization zones. The differentiated carbon emission reduction strategies for different regions are proposed, which could provide theoretical basis for planning as well as policy formulation to narrow regional disparities, and promote coordinated regional development.

Keywords

Carbon emissions, Economic development, Spatial consistency, Low carbon planning, China

1. Introduction

Climate change poses a global threat. The international community continues to take measures to address global warming and control greenhouse gas emissions, especially carbon dioxide emissions. China has taken the initiative to promise to control carbon emission intensity and put forward the 'double carbon' goal. Heilongjiang Province proposed that carbon peak should run through all aspects and the whole process of economic and social development.

As a developing country, how to balance economic development under the goal of achieving carbon peak and carbon neutrality is a key issue that needs to be studied. In the process of development, there must be differences in the spatial distribution of carbon emissions and economy, and the difference also forms a differentiated path to achieve the dual carbon goal. Studying the relationship between carbon emissions and economy is a key breakthrough to narrow regional differences and promote coordinated regional development.

In recent decades, the research on the relationship between carbon emissions and economic development mainly focuses on the decoupling relationship(Tapio, 2005; Zhao et al., 2017), as well as the Kuznets curve on the two(Li, 2018; He, Liu and Zhou, 2024). Some scholars have studied the coupling and coordination relationship between carbon emissions and economic development(Wang and Fang, 2024). As an important carrier for the implementation of various policies, the spatial analysis of the relationship between carbon emissions and economic development can better provide reference for the implementation of territorial spatial planning (Xiong et al., 2021; Li and Xiao, 2022;). However, there are few studies on carbon emissions and economic development in space. Therefore, this paper refers to the relevant research on the consistency of population and economic development, and analyzes the consistency of carbon emissions and economic development from a spatial perspective.

Taking Heilongjiang Province as a whole, we will first analyze the decoupling and imbalanced relationship between carbon emissions and economic development from a macro perspective. Then, on a city-by-city basis, we will analyze the carbon emission concentration, economic concentration, and spatial inconsistencies between carbon emissions and economic development in each city. Furthermore, cities will be categorized based on their contributions to Heilongjiang Province in terms of carbon emissions, carbon sinks, and economic development, as well as the carrying capacity of carbon sinks for carbon emissions and the economic benefits of carbon emissions. Finally, strategies will be proposed in light of the development characteristics of each city. The framework of the paper can be seen in Figure 1.

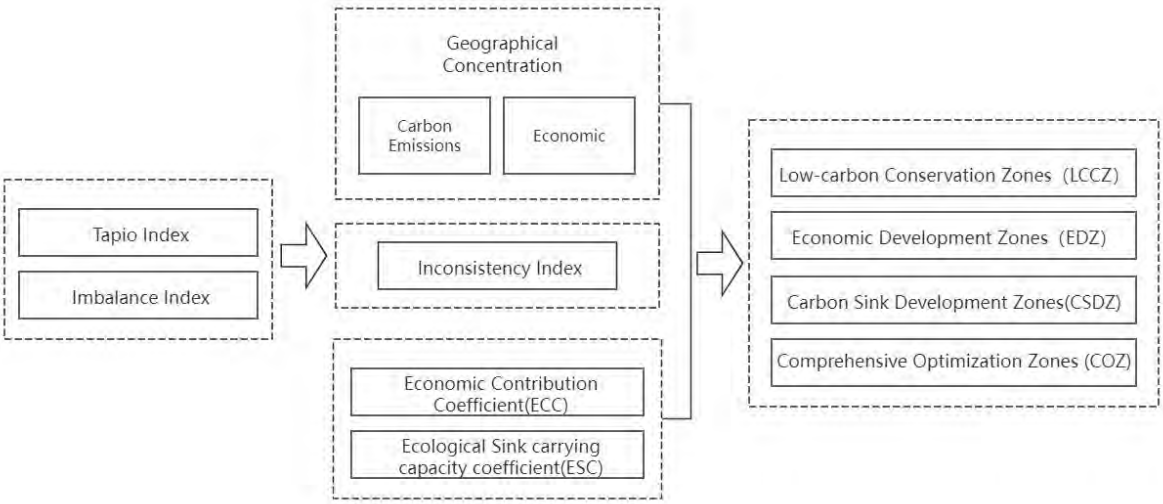


Figure 1. Framework of the research. Source: Author self-painted.

2. Research area, data sources and method

2.1. Research area

Heilongjiang Province is located in Northeast China, adjacent to eastern Russia, bordering eastern Mongolia, and is the northernmost and easternmost provincial administrative region (Figure 2), with an area of 473,000 km^2, accounting for 4.9% of China's total land area (Guo et al., 2022) . Heilongjiang Province is the primary energy industry base in China and contributes a large amount of carbon emissions. Additionally, the province is the main granary ensuring China's food security, and protecting its cultivated land areas is of great significance to strategic national development. Heilongjiang Province governs 13 prefecture-level administrative regions.

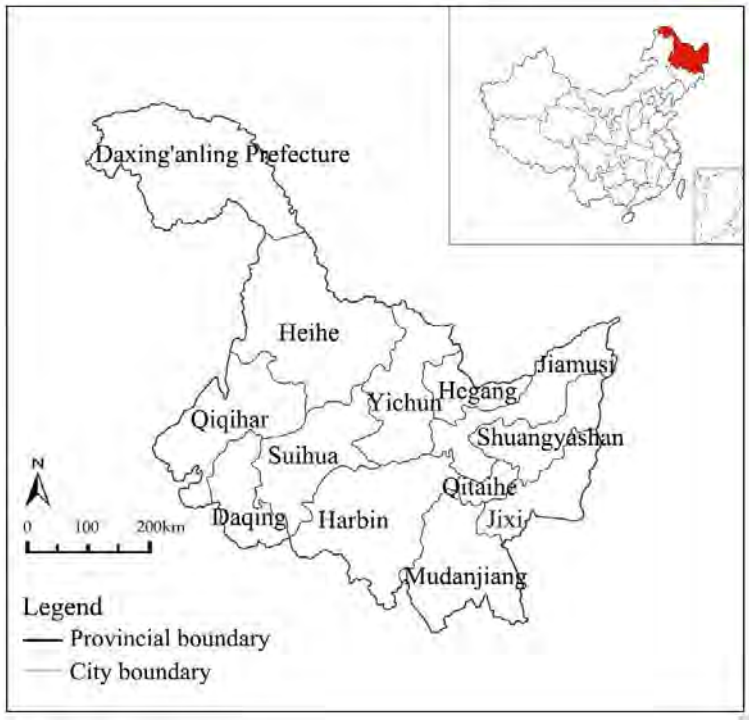


Figure 2. Location of Heilongjiang Province. Source: Illustrated by the author.

2.2. Data sources

The administrative boundary data for Heilongjiang Province were obtained from the National Geographic Information Resource Catalog Service System (https://www.Webmap.cn) (accessed on 20 October 2022). Statistically related data on energy consumption and economy were derived from or calculated based on the yearbooks of national, provincial, and local cities. The results of carbon emissions refers to the research on carbon emissions in the production-living-ecological space of Heilongjiang Province (Guo et al., 2023).

2.3. Method

2.3.1 Tapio index

The decoupling relationship between carbon emissions and economic development is usually used to measure the low-carbon development of the study area. The Tapio model has the advantages of low requirements for the selection of time base period, no need for a large amount of basic data support, quantitative description of the relationship between economic growth and carbon emissions, and can clearly reflect the decoupling state of each factor. It has been widely used in the study of the relationship between resource consumption, carbon emissions and economic growth (Zhou et al., 2017). The model is as follows :

$$T_t = \frac{\Delta CE_t}{\Delta G_t} = \frac{[CE_e - CE_s]/CE_s}{[G_e - G_s]/G_s} \quad (1)$$

In the formula, T_t is the decoupling elasticity coefficient, which represents the decoupling degree of carbon emissions to economic development in period t. ΔCE_t、ΔG_t represents the change rate of carbon emissions and economic growth respectively. ΔCE_s、ΔCE_e represent the carbon emissions of the starting year and the last year of the period t, ΔG_s、ΔG_e represent the economic development level of the starting year and the last year of the period t, respectively.

According to the relevant research of Tapio model, 0.8 and 1.2 are used as the critical values to divide the standard, and the decoupling relationship is divided into 8 types, and the energy consumption and GDP decoupling degree index and decoupling relationship judgment standard are established (Table 1).

Table 1. Decoupling relationship criteria. Source: Compiled by the author.

Decoupling relationship		△CE	△G	Tapio index（T）
Decoupling	Strong decoupling	<0	>0	T<0, 0.8≤T≤1.2
	Weak decoupling	>0	>0	0≤T<0.8
Negative decoupling	Recessionary decoupling	<0	<0	T>1.2
	Weak negative decoupling	<0	<0	0≤T<0.8
	Strong negative decoupling	>0	<0	T<0
	Expansive negative decoupling	>0	>0	T>1.2
Connection	Recessionary connection	<0	<0	0.8≤T≤1.2
	Expansive connection	>0	>0	0.8≤T≤1.2

2.3.2 Imbalanced index

In order to grasp the consistency of carbon emissions and economic spatial distribution in Heilongjiang Province as a whole, referring to the existing research (Jiang, Fan and Chen, 2014), the imbalance index is introduced to accurately measure the imbalance degree of carbon emissions and economy in the whole region. The formula is as follows :

$$E = \sqrt{\frac{\sum_{i=1}^{n}\left[\frac{\sqrt{2}}{2}(CE_i - G_i)^2\right]}{n}} \tag{2}$$

In the formula: E represents the imbalance index of the study area ; n is the number of administrative regions ; CEi represents the proportion of carbon emissions in region i to carbon emissions in Heilongjiang Province ; gi represents the proportion of GDP in region i to total GDP. The imbalance index reflects the equilibrium degree of carbon emission and economy in spatial distribution. The range of imbalance index is (0, + ∞) (Zhao, Li and Li, 2023). The smaller E means the more matching the regional carbon emissions and the level of economic development, that is the more balanced the regional development. The greater E means the lower the degree of coordination between regional carbon emissions and economic development, that is, the more unbalanced regional development.

2.3.3 Geographic concentration index

The carbon emissions geographical concentration and the economic geographical concentration comprehensively consider the relationship between regional carbon emissions, economic aggregate and regional area, and are effective indicators for measuring carbon emissions and economic spatial distribution (Wang et al., 2009; Liu, Shi and Li, 2014; Yan, He and Chen, 2017; Wang and Yang, 2019). It can not only reflect the status and role of a part in the region, but also directly reflect the concentration and trend of carbon emissions and economy in spatial distribution. The formula is as follows :

$$GC_{CE_i} = \frac{CE_i/\sum CE}{are_i/\sum are_i},\ GC_{G_i} = \frac{gdp_i/\sum gdp_i}{are_i/\sum are_i} \tag{3}$$

In the formula : GC_{CE_i} , GC_{G_i} respectively represent the carbon emissions and economic geographic concentration of a certain year in the i region ; CE_i, gdp_i and are_i represent the carbon emissions, regional GDP and land area of a certain year in region i.

2.3.4 inconsistency index

Referring to the relevant research on the inconsistency between population and economic development (Fu, Huang and Tang, 2018; Wei, Wang and Chen, 2020), the index of carbon emission and economic inconsistency is constructed, that is, the ratio of economic geographical concentration to carbon emission geographical concentration of an administrative unit in the study area (Guan et al., 2017) and the coordination degree of regional carbon emission and economy in spatial distribution is described from a local perspective. The formula is as follows :

$$\mathrm{IC} = \mathrm{GC_{Gi}}/\mathrm{GC_{CEi}} \quad (4)$$

The inconsistency index could characterize the degree of spatial differentiation of carbon emissions and economy, which is generally divided into three situations : (1) The degree of carbon emission agglomeration is higher than that of economic agglomeration (I<1). (2) Carbon emissions and economic agglomeration are basically the same (I=1). (3) The degree of economic agglomeration is higher than that of carbon emission agglomeration (I>1). The more I deviates from 1, the more obvious the spatial differentiation of carbon emissions and economy in the region is. On the contrary, it indicates that the level of carbon emissions and economic spatial agglomeration is closer, that is, the more balanced the regional development is.

2.3.5 Economy contribution coefficient and ecological support coefficient

The economic contribution coefficient (ECC) of carbon emissions is used to measure the difference in regional carbon emissions from the perspective of economic benefits, reflecting the size of regional carbon productivity (Zhao et al., 2014). The formula is as follows :

$$\mathrm{ECC} = \frac{\mathrm{G_i}}{\mathrm{G}} \Big/ \frac{\mathrm{CE_i}}{\mathrm{CE}} \quad (5)$$

In the formula, Gi and CEi represent the GDP and carbon emissions of city i, and G and CE represent the total GDP and carbon emissions of the province (Xu et al., 2022). When ECC > 1, it shows that the economic contribution rate of the city is greater than the contribution rate of carbon emissions, indicating that it has higher energy efficiency and carbon productivity ; conversely, it indicates that the city has relatively low energy efficiency and carbon productivity.

The ecological support coefficient (ESC) represents the quotient of the proportion of carbon absorption in a region to the proportion of carbon emissions in the region, reflecting the size of the regional carbon sink capacity (Li et al., 2022). The formula is as follows :

$$\mathrm{ESC} = \frac{\mathrm{CS_i}}{\mathrm{CS}} \Big/ \frac{\mathrm{CE_i}}{\mathrm{CE}} \quad (6)$$

In the formula, CSi and CEi represent the carbon absorption and carbon emission of i city respectively, and CS and CE represent the total carbon absorption and carbon emission of the whole province respectively. If ESC > 1, it indicates that the carbon ecological carrying coefficient is high, indicating that it has a high carbon sink capacity; if ESC < 1, it indicates that the city 's carbon ecological carrying coefficient is low, and its carbon sink capacity is also weak (Wang et al., 2022).

Referring to relevant research, according to the ESC and ECC of each city, the cities are divided into four categories: low-carbon conservation zones, economic development zones, carbon sink development zones, and comprehensive optimization zones.

Table 2. ECC and ESC classification reference. Source: Compiled by the author.

	ESC	ECC	Categories
1	ESC>1	ECC>1	Low-carbon conservation zone(LCCZ)
2	ESC>1	ECC<1	Economic development zones(EDZ)
3	ESC<1	ECC>1	Carbon sink development zones(CSDZ)
4	ESC<1	ECC<1	Comprehensive optimization zones(COZ)

3. Results

3.1. The Tapio index between carbon emissions and economic

GDP is increasing year by year, and carbon emissions are on the rise as a whole. There was a slight decline in 2014, 2015, 2017, 2020. The decoupling relationship between carbon emissions and economy is gradually shifting from weak decoupling to strong decoupling, and low-carbon economy has achieved initial results (Table 3).

Table 3. Results of Tapio index. Source: Compiled by the author.

Year	ΔC	ΔGDP	Tapio	Decoupling Degree
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]
				[illegible]

3.2. The Imbalance index between carbon emissions and economic distribution

From 2005 to 2020, the imbalance index showed a trend of decreasing-increasing-decreasing -increasing-decreasing which can be seen in Figure 3. indicating that under the influence of policies such as rapid urbanization and new industrialization, the spatial distribution pattern of carbon emissions and economy in Heilongjiang Province has changed significantly. The imbalance index of the two has experienced fluctuations from high to low. Regional development tends to be relatively balanced state.

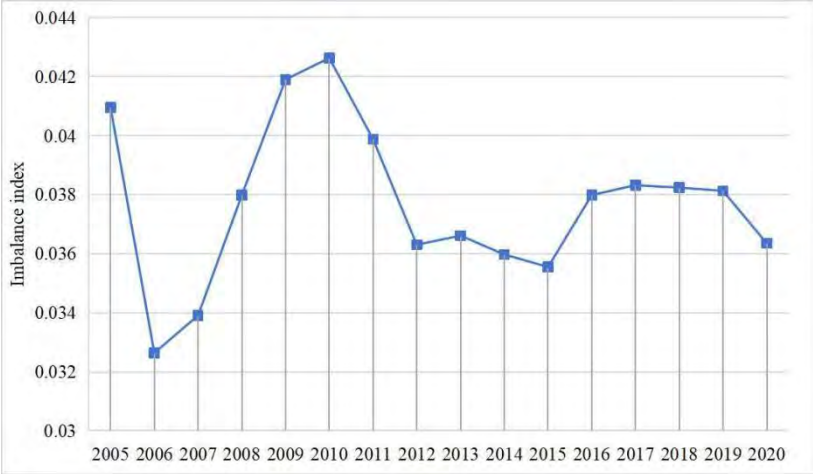


Figure 3. Imbalance index between carbon emissions and economic distribution in Heilongjiang Province,2005-2020. Source: Illustrated by the author.

3.3 Geographical concentration of carbon emissions and economic

The overall geographical concentration of carbon emissions shows a spatial distribution pattern of high in the southwest and low in the northeast (Figure 4). Among them, Daqing and Qitaihe have the highest concentration of carbon emissions, followed by Harbin and Jixi. The concentration of carbon emissions in other cities is at a medium or low level. Qitaihe has the smallest urban area, so the concentration level is at a high level. Due to the rapid development and factors gathering, carbon emissions in these cities are higher than others cities, which showing a higher level of concentration.With the proposal of the Ha-Da-Qi industrial corridor and the development of industrial agglomeration, the high concentration area of carbon emissions centered on Ha-Da-Qi will exist for a long time.

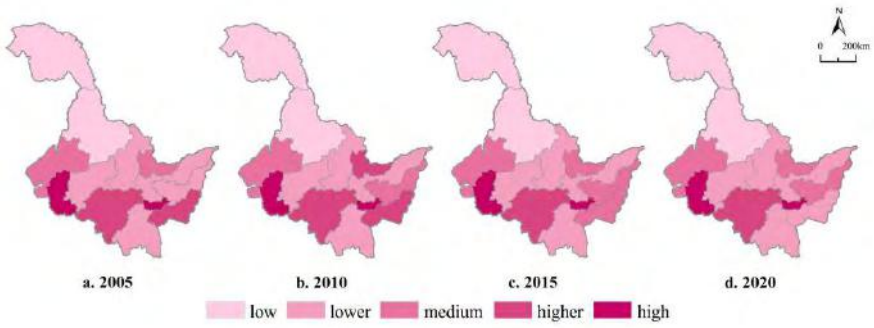


Figure 4. Geographical concentration of carbon emissions in Heilongjiang Province,2005-2020. Source: Illustrated by the author.

The overall economic geographical concentration shows a spatial distribution pattern of high in the southwest and low in the northeast (Figure 5). Among them, Harbin and Daqing are the cities with the highest economic concentration, followed by Qitaihe, Qiqihar, Suihua, Mudanjiang, and Jiamusi. The carbon emission concentration of other cities is at a relatively low level. Among these cities, Qitaihe has the smallest area, so its economic concentration is at a high level. Other cities show a higher level of concentration due to rapid development and factor aggregation. With the proposal of the Ha-Da-Qi industrial corridor and the development of industrial agglomeration, the high concentration area of economic centered on Ha-Da-Qi will exist for a long time.

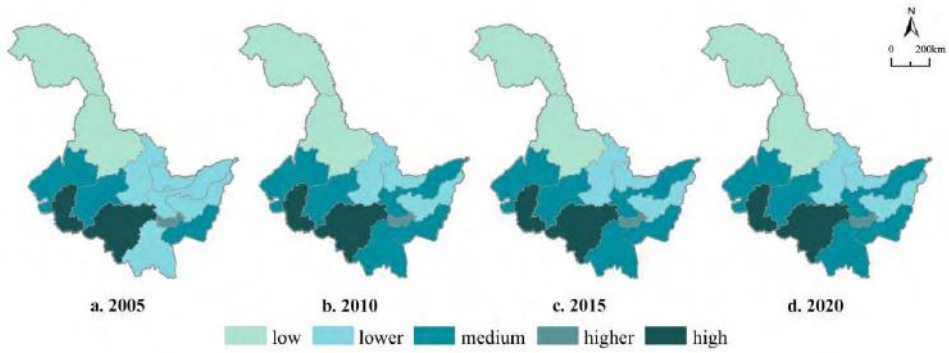


Figure 5. Geographical concentration of carbon emissions in Heilongjiang Province,2005-2020. Source: Illustrated by the author.

3.4 Inconsistency index between carbon emissions and economic distribution

Among the 13 cities, the number of balanced development zones increased from 3 in 2005 to 5 in 2020, indicating a gradually strengthening trend of balanced development (Figure 6). The economic polarization zones included Harbin and Daxing'anling Prefecture. As the capital of Heilongjiang Province, Harbin's rapid development produced corresponding carbon emissions, while Daxing'anling Prefecture was the opposite of Harbin, with the least economy and carbon emissions in Heilongjiang Province.

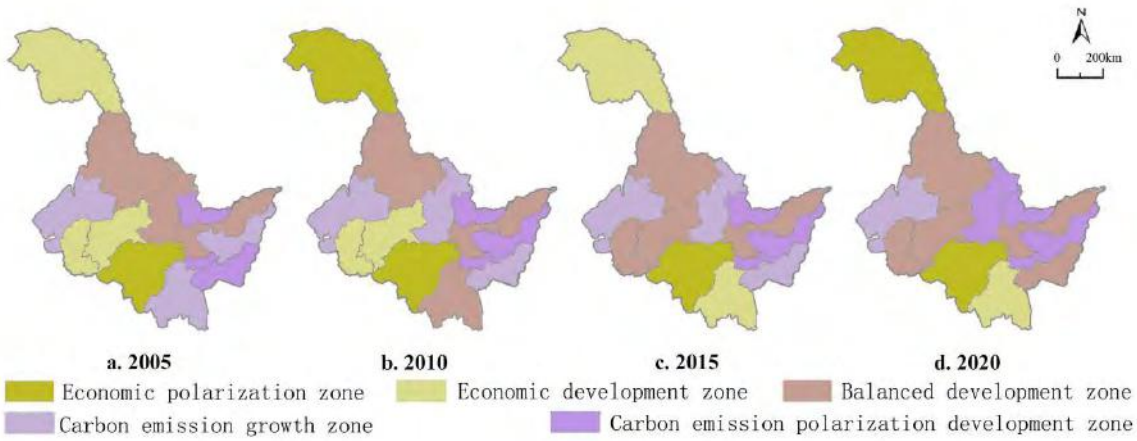


Figure 6. Inconsistency index in Heilongjiang Province,2005-2020. Source: Illustrated by the author.

The number of economic development zones gradually decreased. Mudanjiang experienced a transformation from a carbon emission growth zone to a balanced zone and then to an economic development zone, which indicated that the economic concentration degree of Mudanjiang was gradually greater than that of carbon emission.The number of carbon emission growth zones gradually decreased, and under the guidance of policies, these zones showed different development directions. The number of carbon emission polarization zones gradually increased, with carbon emission concentration higher than economic concentration. Due to the obstruction of production factors and technological factors, economic development was excessively dependent on carbon emissions. Carbon emissions and economic development were in a state of imbalance.

3.5 Classification based on ECC and ESC

In terms of the economic contribution coefficient of carbon emissions, the coefficient of Harbin, Jiamusi, Mudanjiang, Heihe, Suihua and Daxing'anling is more than 1, indicating that the economic contribution of these cities is greater than that of carbon emissions (Figure 7). They have higher energy efficiency and carbon production capacity. While the economic contribution coefficient of carbon emissions in other 7 cities is less than 1, indicating that their energy efficiency and carbon production capacity are both low.

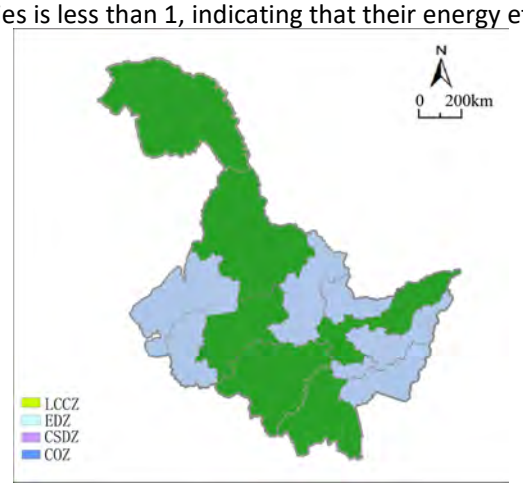


Figure7. ECC in Heilongjiang Province,2020

Source: Illustrated by the author.

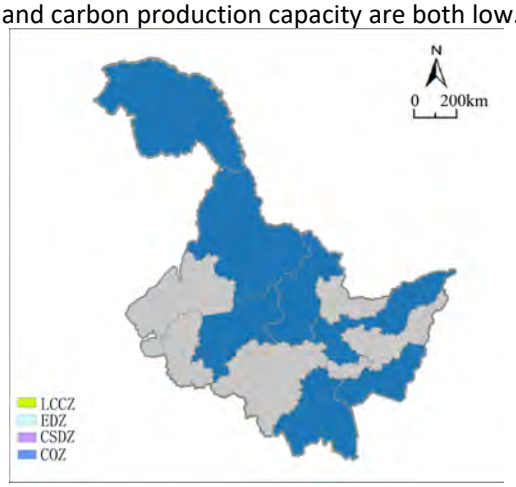


Figure 8. ESC in Heilongjiang Province,2020

Source: Illustrated by the author.

From the perspective of carbon ecological carrying coefficient, the coefficient of Jixi, Yichun, Jiamusi, Mudanjiang, Heihe, Suihua, and Daxing'anling is more than 1 (Figure 8), indicating that these cities have strong carbon sink capacity and can also carry a large amount of carbon emissions; while the carbon ecological carrying coefficient of the other six cities is less than 1, indicating that their carbon sink capacity is relatively weak. Among them, the carbon sink of Harbin is relatively high, but its carbon emissions are far greater than its carbon sink, which shows that the carbon sink of Harbin is difficult to carry its carbon emissions.

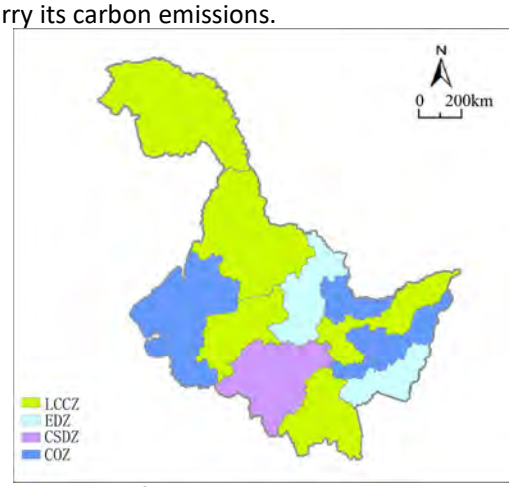


Figure 9. Classification based on ECC and ESC. Source: Illustrated by the author.

According to the ECC and EGC indexes, cities are divided into low-carbon conservation zones (LCCZ), economic development zones (EDZ), carbon sink development zones (CSDZ), and comprehensive optimization zones (COZ) which can be seen in Figure 9. LCCZ includes five cities, Mudanjiang, Jiamusi, Heihe, Suihua and Daxing'anling Region. It shows that carbon productivity and energy utilization are

gradually improved, and the ecological resources of carbon sinks are relatively abundant, with strong carbon absorption capacity and carrying capacity. The social and economic development and ecological resource protection are relatively balanced. EDZ includes Yichun and Jixi, which have relatively strong carbon sink capabilities but low economic contributions from carbon emissions, indicating low energy utilization rates. However, Yichun and Jixi contribute large areas of forest to Heilongjiang Province, and their ecological conservation significance outweighs economic development. Therefore, the two cities should prioritize the protection and enhancement of ecological resources and ensure ecological functions while developing their economies in a rational manner. Harbin is the only city classified as CSDZ, indicating relatively low carbon absorption capacity but good economic development accompanied by high carbon emissions. To address this, the city can appropriately increase carbon sink land through optimized land use. Additionally, reducing carbon emissions can be achieved by optimizing industrial structures and energy mixes. COZ includes six cities: Qiqihar, Hegang, Shuangyashan, Daqing, Qitaihe, and (assuming a typo in the original text, adding Harbin as the sixth city based on context). These six cities exhibit low carbon production capacity and low carbon absorption capacity. These cities should prioritize controlling carbon emissions and pursuing green development. While restricting the development of industries with high carbon emissions and low energy efficiency, they should increase investment in science and technology and introduce and learn from outstanding low-carbon technologies and experiences to transform their extensive production processes and improve energy utilization rates. Additionally, they should strengthen the management and protection of ecological resources, restore and enhance carbon sink ecosystems, and improve carbon absorption and carrying capacities.

4. Conclusions

The decoupling relationship between carbon emissions and economy is gradually shifting from weak decoupling to strong decoupling, and low-carbon economy has achieved initial result. The imbalance has undergone a process of decreasing and then expanding. The spatial consistency shows the characteristics of stronger in the southwest and weaker in the northeast. According to the ECC and EGC indexes, cities are divided into low-carbon conservation zones（LCCZ）, economic development zones（EDZ）, carbon sink development zones(CSDZ), and comprehensive optimization zones(COZ).

By analyzing the relationship between carbon emissions and economic , we can judge the decoupling state of economic and carbon emissions in Heilongjiang Province, which is convenient for relevant departments to formulate strategic plans for low-carbon development. From the balance and consistency analysis of the spatial distribution of carbon emissions and economic, we can identify the pattern of carbon emissions and economic in Heilongjiang Province from a macro perspective, and provide a basis for the overall level of territorial space low-carbon planning. Through the comprehensive index to classify cities, it is reasonably for relevant departments to formulate targeted and differentiated low-carbon planning strategies under the premise of economic development.

On the basis of this study, the following research will be carried out in the future : Combined with the land space planning of Heilongjiang Province and the development needs of Heilongjiang Province, the research results are applied to the spatial pattern optimization of the land space planning of Heilongjiang Province. In view of different types of cities, this paper explores the influence factors of imbalanced distribution between carbon emissions and economic development, and proposes differentiated planning strategies for various types of cities.

5. References

Tapio P.(2005) 'Towards a theory of decoupling: degrees of decoupling in the EU and the case of road traffic in Finland between 1970 and 2001', *Transport policy*, 12(2), pp.137-151.

Zhao X.R., Zhang X., Li N., et al.(2017) 'Decoupling economic growth from carbon dioxide emissions in China: A sectoral factor decomposition analysis', *Journal of cleaner production*, 142, pp.3500-3516.

He F.Y., Liu T.L., Zhou Z.J. et al.(2024) 'Research on the relationship between carbon emissions and economic growth based on EKC theory: a comparative analysis of Zhejiang Province and Anhui Province', *Ecological Economy,* 40(60), pp.21-29.

Li Z.G.(2018) 'Study on EKC inflection point between carbon emissions and economic growth in China based on variable parameter model', *Environmental engineering*, 26(02), pp.142-146.

Wang L., Fang X.M.(2024), 'Digital technology empowers coupling and coordinated development between economic growth and carbon emissions', *Journal of technical economics&management*, 10, pp.7-13.

Li C., Xiao B.X.(2022), 'The transmission path of "Carbon Emission Peak and Carbon Neutrality" goal in territorial space planning', *Planners*, 38(07), pp.66-71.

Xiong J., Lu K., Jiang Z.Y., et al.(2021), 'Study and thoughts on territorial spatial planning under the goal of carbon emissions peak and carbon neutrality', *Urban planning forum,* 4, pp74-80.

Guo R., Wu T., Wu X.C., et al.(2022) 'Simulation of urban land expansion under ecological constraints in HarbinChangchun urban agglomeration, China', *Chinese Geographical Science*, 32, pp.438-455.

Guo R., Wu X., Wu T., et al.(2023) 'Spatial-Temporal Pattern Characteristics and Impact Factors of Carbon Emissions in Productio-Living-Ecological Spaces in Heilongjiang Province, China', *Land*, 12, 1153.

Zhou X., Zhang M., Zhou M.H., et al.(2017) 'A comparative study on decoupling relationship and influence factors between China's regional economic development and industrial energy-related carbon emissions', *Journal of Cleaner Production*, 142, pp.783-800.

Jiang Z.L., Fan J., Chen D.(2014) 'Analysis of spatial agglomeration and equilibrium characteristics for population and economic in China during 2001-2010', *Economic geography*, 34(5), pp.9-13.

Zhao M.L., Li T.S. and Li J.L.(2023) 'Study on the consistency and influencing factors of population and economic spatial distribution in the Weihe River Basin', *Research of Soil and Water Conservation*, 30(5), pp.1-10.

Wang L., Duan X.J., Tian F., et al.(2009) 'Study on the relationship between population and economic spatial distribution in Yangtze River Delta', *Economic geography*, 29(10), PP.1619-1623.

Wang S.J., Yang H.R.(2019) 'Study on the evolution of population and economic spatial pattern in Central Plains Economic Zone of China', *Population journal*, 41(5), pp.35-44.

Yan D.S., He T., Chen W.(2017) 'Population agglomeration, economic dispersion and inconsistent pattern: evidence from the Yangtze River Delta', *Economic geography*, 37(9), pp.47-56.

Guan D.J., Tan J., Zhang M.J., et al.(2017) 'Spatial coupling distribution of population andeconomic development in Chongqing', *Human Geography*, 32(2), pp.122-128.

Liu N., Shi P.J., Li B.(2014) 'Space difference and correlation between population and economy in Gansu Province', *Arid land geography,* 37(1), pp. 179-187.

Fu J., Huang Y.Z., Tang J.(2018) 'Research on the coupling of economic and population development in Gansu Province', *China population, resources and environment*, 28(S1), pp.49-53.

Wei Z.W., Wang J.J., Chen J.H.(2020) 'Study on the unbalanced difference of population-economy spatial-temporal pattern evolution in China 's urban agglomerations', *Statistics&decision*, 36(18), pp.81-84.

Zhao R.Q., Zhang S., Huang X.J., et al.(2014) 'Spatial variation of carbon budget and carbon balance zoning of Central Plains Economic Region at county-leve', *Acta geographica sinica*, 69(10), pp.1425-1437.

Xu Y., Guo N., Ru K.L., et al.(2022) 'Characteristics and optimization strategies of territorial space zone in Fujian Province, China based on carbon neutrality', *Chinese journal of applied ecology*, 33(2), pp.500-508.

Li Y.Y., Wei W., Zhou J.J., et al.(2022) 'Changes in land use carbon emissions and coordinated zoning in China', *Environmental science*, 44(3), pp.1267-1276.

Wang Z.Y., Hu C.G., Zhang Y., et al.(2022) 'Characteristics of carbon emission pattern in Hubei territorial space and its improvement measures', *Planners*, 38(01), pp.24-31.

Case Study Report

Planning Heritage for Resilience Enhancement in Historic Cities

The case of Enshi, China

Jingwei JU, School of Architecture, Tsinghua University, China
Neng ZHANG, Architectural Design and Research Institute of Tsinghua University Co., Ltd., China
Yuanru LI, School of Architecture, Tsinghua University, China

Abstract

Cities are facing natural and societal disaster nowadays, which makes urban resilience more important to combat long-term uncertainties. Modern cities should learn from historic cities to enhance their own resilience, as the latter have developed complex structures over time that demonstrate significant resilience. Planning heritage, a vital aspect of historic urban identity, has tangible and intangible elements at the same time. It can provide a holistic perspective on heritage preservation. The historic city of Enshi in China has substantial planning heritage. However, it also faces challenges in urban resilience because of rapid urbanization. This study focuses on the historic urban area of Enshi. It tries to propose strategy suggestions to enhance urban resilience by integrating the preservation of tangible planning heritage and intangible planning legacy. Findings in this case study might be applicable for other cases and contribute to emphasis on planning heritage and its preservation worldwide.

Keywords

Urban resilience, Planning heritage, Planning legacy, Enshi, Historic city

1. Introduction

Cities are facing natural and societal disaster nowadays (Ahern, 2011; Godschalk, 2003). The preservation of heritage is benefitial to urban resilience (Resilient Cities, 2018). Existing research predominantly pay attention to built heritage (Jones and Pappas, 2023), intangible cultural heritage (Tavares et al., 2021) and cultural landscape (Moussavi.A and Lak, 2024). However, planning heritage, a special type of heritage generated by planning, is often ignored. However, preserving planning heritage plays a significant role in enhancing the resilience of historic cities.

2. The relationship between planning heritage and urban resilience

"Planning heritage" was first introduced by Ray Taylor (Taylor et al., 1975). After that, many studies have been done on planning heritage (APA, 2019; Freestone et al., 2008; Freestone, 2010; Ye et al., 2022; Zhang and He, 2023; Nakajima et al., 2015; Resta, 2016). Tangible planning heritage contains tangible planning heritage and intangible planning legacy (Wang and Li, 2023). Intangible planning heritage is built heritage with planning wisdom (Ye et al., 2022). Planning legacy includes representative thoughts, methods and regulations of planning (Zhang and He, 2022).

In order to improve urban resilience, we should preserve both tangible planning heritage and intangible planning legacy (Figure 1). For example, in Spring and Autumn Period of Ancient China (770-476 BC), the philosopher Guanzi summarized the principles of city construction: "A capital should be high enough to avoid flooding, yet close enough to have access to water." This perspective remains of significant relevance today.

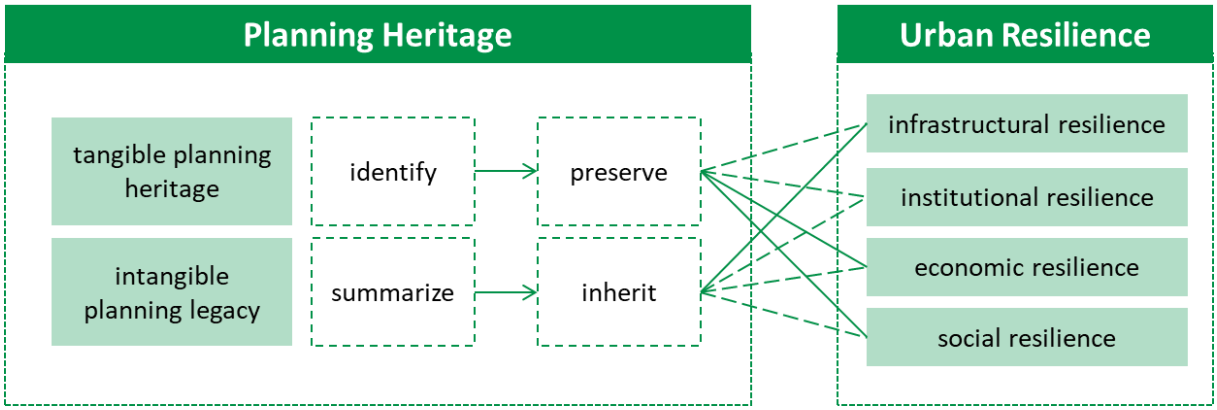


Figure 1. The relationship between planning heritage and urban resilience. Source: Authors.

3. Overview of historic city of Enshi

3.1. History and planning heritage

Enshi City is located in the southwestern part of Hubei Province, China. It is at the end of the second-level terrain step, and most part of the city is mountainous. The city's main urban area is situated within a basin. The Qingjiang River, first-level tributary of the Yangtze River, flows through the city (Figure 2). Enshi has a long history. The construction activities dated back to the 5th century AD. The administrative center city was established in the 6th century, and the city wall was built in the 13th century (Deng, 2011; He, 2014).

The planning and construction of Enshi in history are closely related to its natural environment. Within the city wall, several small hills with landmark buildings on them are significant city landmarks. The alignment of the city wall has been flexibly adjusted according to the terrain of the city. Besides, the natural landscape outside the city wall was named as the Eight Scenes of Enshi. They were important regional landscapes across various dynasties.

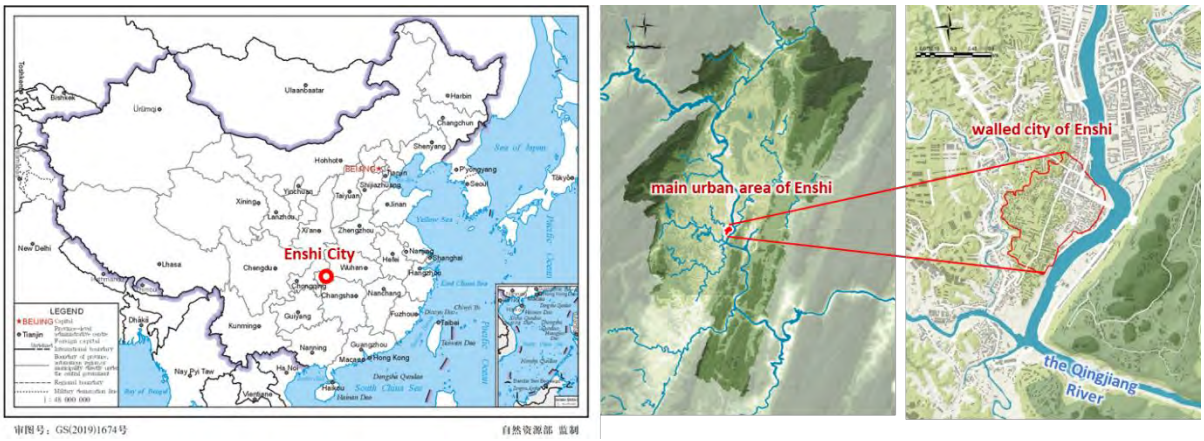


Figure 2. Enshi is nestled among high mountains, with the Qingjiang River flowing through it. Source: The left map is from Ministry of Natural Resources, PRC; other pictures were drawn the authors.

Enshi retains substantial planning heritage (Figure 3). For tangible planning heritage, the city wall and gates have been well-preserved. Small hills within the city, along with landmark buildings on them, remain largely intact. The layout of the streets and alleys has not changed significantly compared to historical periods. The surrounding environment still has close connection with the city. As for intangible planning legacy, the relationship between the city and water was very important in history, which was integrated into the construction of the city. The boundaries of the city wall were adjusted in response to water level changes, which reflect the adaptability of city planning and construction to natural environmental uncertainties. Therefore, Enshi's planning heritage remains relevant for modern urban planning.

Figure 3. Planning heirtage and planning legacy of Enshi. Source: Local gazatters were provided by local government; other pictures were taken by the authors.

3.2. Current challenges

The historic city of Enshi has been partly destroyed due to rapid urbanization, which further result in a decrease in urban resilience (Figure 4). Within the historic urban area, traditional dwellings have been replaced by multi-storey concrete buildings, leading to a gradual loss of traditional characters. Sightlines between important nodes have also been obstructed (Figure 5). Outside the historic urban area, urban construction ignored natural topography; hilly regions have been flattened, and river courses have been impacted.

Figure 4. The destruction of mountain-water cultural landscape pattern in 20 years. Source: Google Earth.

Figure 5. Destruction of cultural heritage in the historic urban area of Enshi. Source: The two images on the right were taken by the authors; the image on the left is available at: https://www.720yun.com/t/d26j5sywzy1?scene_id=11538839 (Accessed: 28 October 2024).

In addition, since the urban built-up area has expanded from high ground to riverbanks, the city becomes vulnerable to floods. On July 17, 2020, Enshi experienced unprecedented flooding, which caused the breach of riverbanks in the main urban area. The disaster caused the most severe economic losses in Enshi since 1949 (Figure 6) and proved the weaknesses of flood prevention measures in Enshi.

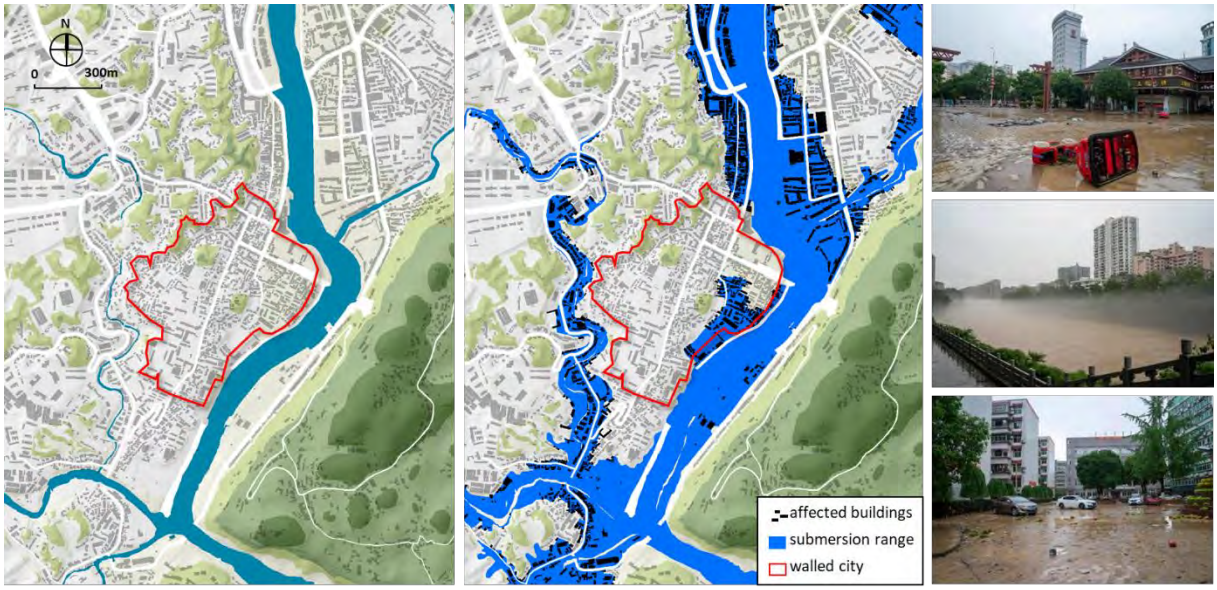


Figure 6. The historic urban area is threatened by flooding. Source: The two maps on the left were drawn by authors; the three picture on the right is available at: http://vip.people.com.cn/albumsDetail?aid=1346344 (Accessed: 28 October 2024).

4. How to enhance the resilience of historic city of Enshi

Enshi faces the challenge of decreasing urban resilience during rapid urbanization. The planning heritage of Enshi in history can be benefitial for improving its urban resilience nowadays. Based on this, the study proposes two strategies to improve the resilience of Enshi.

4.1. Identify and preserve tangible planning heritage

One of the most important aspects of urban resilience is diversity of cultural, social and economic systems. The preservation of tangible planning heritage can effectively improve the diversity of social structure, cultural atmosphere, and commercial activities.

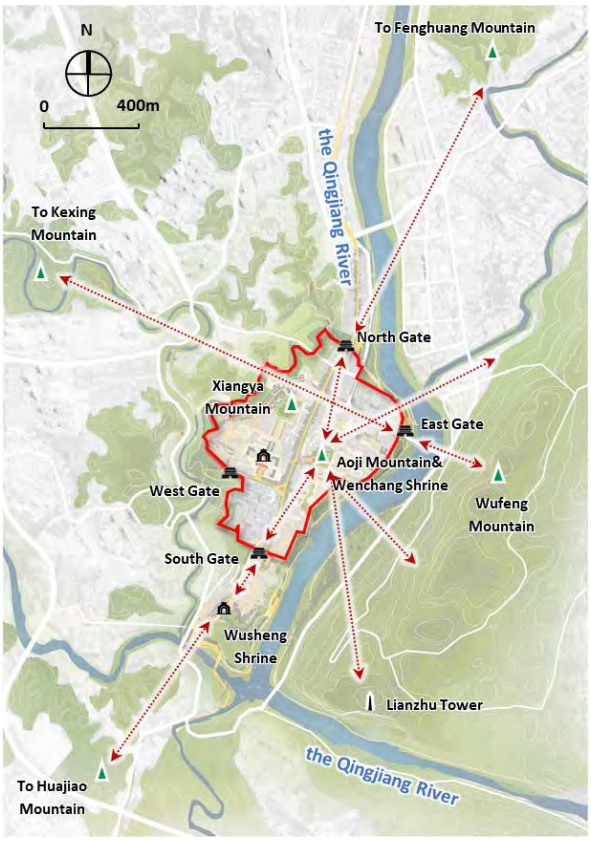
Since the construction of the city wall in the 13th century, the layout of Enshi has been continuously refined. A lot can be learned from tangible planning heritage during this process. The planning heritage of the historic city of Enshi can be categorized into four types: city wall and gates, street systems, landmark buildings, and regional landscapes. For different types of planning heritage, differentiated preservation measures should be applied. For the city wall and gates, existing sections should be restored, while damaged sections should go through archaeological exploration and be presented for public. For the street systems, historical pathways should be restored and facilitate pedestrian flow in the ancient city. For landmark buildings, illegal constructions should be removed to improve accessibility. For regional landscapes, view corridors between landmarks and regional landscapes should be preserved (Figure 7). The history of Enshi will be presented in a proper way by preserving tangible planning heritage. Besides, local commercial activities can be introduced to attract visitors, stimulate local commerce, and revitalize the community's social structure.

4.2. Summarize and inherit intangible planning heritage

Ancient Chinese planners emphasized the relationship between human and environment. They adjusted city planning according to changing nature. This planning legacy can inspire today's planning.

The planning history of Enshi reflects a wisdom of adaptation. Prior to the 13th century, when the water level of the Qingjiang River was high, the city was originally established on high ground to mitigate flooding. Over the centuries, as the river's shoreline receded, the city expanded to low-lying areas. In face of the evolving relationship between the city and water, the dynamic expansion of Enshi in history exemplifies traditional resilience.

As for today's planning, strict regulations should be established for urban blue line, flood risk management area and waterfront landscape control zone to improve urban resilience (Figure 8). In flood risk management area, development intensity should be limited, population density should be reduced, and land use pattern are suggested to emphasize ecological functions gradually. In waterfront landscape control zone, it is suggested to create attractive riverside landscape along the Qingjiang River.



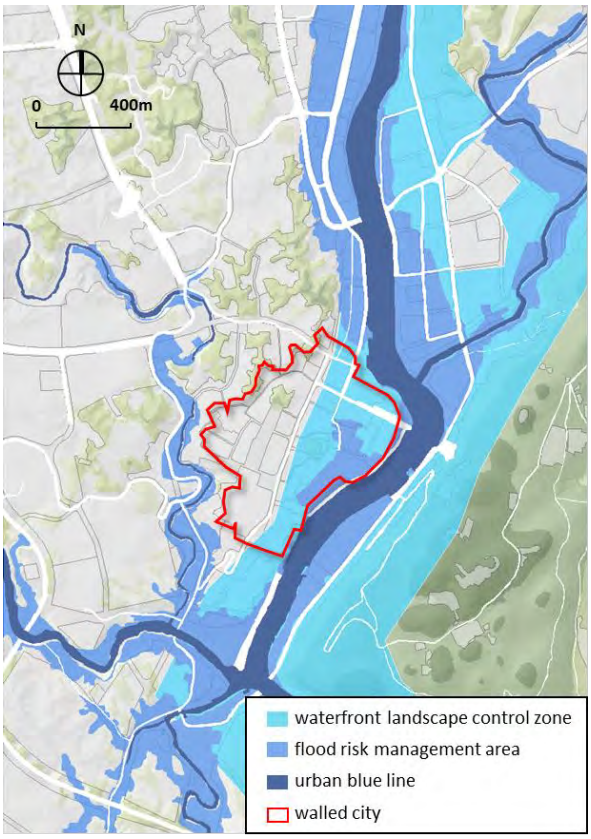


Figure 7. (left) Preserve and utilize the tangible planning heritage of Enshi to enhance the vitality of the historic urban area. Source: Authors.

Figure 8. (right) Summarize and inherit intangible planning heritage of Enshi to cope with flood disasters. Source: Authors.

5. Conclusion and discussion

Cities are facing natural and societal disaster nowadays. This study intends to improve urban resilience by perserving a representative type of cultural heritage—planning heritage. Based on the case of Enshi, this study constructs a multidimensional approach to improve urban resilience through the preservation and utilization of tangible and intangible planning heritage. Enshi retains significant planning heritage but faces the challenge of resilience decline during rapid urbanization. To address this challenge, the study first categorized tangible planning heritage and employs differentiated management strategies. Besides, the study summarizes and inherits intangible planning legacy, and reappropriate it for modern urban

development. This study aims to improve the urban resilience of Enshi. The strategies generated from this case study hold broad applicability. The importance of planning heritage should be emphasized.

Future research should focus on the influnece of planning legacy on urban resilience during the project's implementation process. Besides, the effectiveness of these strategies should be further tested in other cities.

Acknowledgments

We would like to thank Prof. Tinghai Wu of Tsinghua University for guiding the project and the report, and Ph.D. student Lingfan Chen, Ye Sun, and master student Kai Hu, Junqing Huang of Tsinghua University for their joint efforts in the project.

Funding

This work was supported by National Key Research and Development Program of China (NO. 2023YFC3803900).

Declaration of AI-assisted technologies in the writing process

During the writing process of this paper, the authors used AI-assisted technology (ChatGPT) to improve language because the mother language of the authors is not English. After using it, the authors reviewed and edited the paper carefully and take full responsibility for the content of the publication.

6. References

Ahern, J. (2011). From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. *Landscape and Urban Planning,* 100(4)**,** 341-343.

APA. (2019). *National Planning Landmarks* [Online]. Available at: https://www.planning.org/awards/landmarks/ [Accessed: 28 October 2024].

Deng, H. (2011). *Ancient City of Shizhou,* Wuhan: Hubei People's Press.

Freestone, R. (2010). *Urban Nation: Australia's Planning Heritage,* Melbourne: CSIRO Publishing.

Freestone, R., Marsden, S. & Garnaut, C. (2008). A Methodology for Assessing the Heritage of Planned Urban Environments: An Australian Study of National Heritage Values. *International Journal of Heritage Studies,* 14(2)**,** 156-175.

Godschalk, D. R. (2003). Urban Hazard Mitigation: Creating Resilient Cities. *Natural Hazards Review,* 4(3)**,** 136-143.

He, X. (2014). *History of Enshi,* Xi'an: Xi'an Press.

Jha, A. K., Miner, T. W. & Stanton-Geddes, Z. (2013). *Building Urban Resilience: Principles, Tools, and Practice,* Washington, D.C.: World Bank.

Jones, Z. M. & Pappas, T. (2023). Developing an identities-based approach to support more robust resilience and recovery in heritage planning and management. *Built Heritage,* 7(1)**,** 1-12.

Middleton, G. D. (2021). A tale of three cities: urban and cultural resilience and heritage between the Late Bronze Age and Early Iron Age in the eastern Mediterranean. *Urban History,* 48(4)**,** 724-748.

Moussavi.A, S. M. R. & Lak, A. (2024). Cultural landscapes in climate change: A framework for resilience in developing countries. *Journal of Environmental Management,* 362**,** 1-13.

Nakajima, N., Tsutsumi, T., Sano, H., Hatsuda, K., Nishinari, N. & Nakano, S. (2015). Recent Selections of "Planning Heritages" in USA and Australia. *AIJ Journal of Technology and Design,* 21**,** 789-794.

OpenAI. (2024). *ChatGPT*[Large language model]. Available at: https://chat.openai.com.

ResilientCities. (2018). *Resilient Cities 2018 & The 9th Global Forum on Urban Resilience and Adaptation* [Online]. Available at: https://resilientcities2018.iclei.org/ [Accessed: 28 October 2024].

Resta, G. (2016). The Italian Way: Urban Planning Heritage in Albania. *Architecture and Urban Planning,* 11(1)**,** 19-23.

Salat, S. & Bourdic, L. (2011). Power Laws for Energy Efficient and Resilient Cities. *Procedia Engineering,* 21**,** 1193-1198.

Tavares, D. S., Alves, F. B. & Vásquez, I. B. (2021). The Relationship between Intangible Cultural Heritage and Urban Resilience: A Systematic Literature Review. *Sustainability,* 13(22)**,** 12921.

Taylor, R., Cox, M. & Dickins, I. (1975). *Britain's Planning Heritage,* London: Croom Helm.

Wang, Z. & Li, B. (2023). Planning Heritage: Reflections on the Value of Rabat World Cultural Heritage. *City Planning Review,* 47(08)**,** 47-56.

Wu, T., Ye, Y. & Wu, W. (2021). Preliminary Discussion on the Philosophical Implications of Beijing's Traditional Central Axis. *Journal of Urban Regional Planning,* 13(02)**,** 1-10.

Ye, Y., Li, B. & Wu, T. (2022). Concepts of Planning Heritage and Corresponding Practices in the World. *Urban Planning International,* 37(02)**,** 82-87.

Zhang, Y. & He, Y. (2022). The Nature, Connotation, and Characteristics of Planning Heritage. *Urban Planning Forum,* (04)**,** 35-42.

Zhang, Y. & He, Y. (2023). Above Form: On the Value Form of Planning Heritage – Based on the Dialectical Perspective of "Tangible-Intangible". *City Planning Review,* 47(08)**,** 38-46+65.

Research Paper

A Study on Urban Planning to Protect Cultural Heritage from Air Pollution

Focusing on the protection of Gyeongju's cultural heritage from air pollution

Dong-Seok Kim, Dong-A university, Republic of korea

Seok-Ho Hong, Gwangju university, Republic of korea

Abstract

Air pollution not only harms human health and the environment, but also damages historical cultural heritage. It is mainly metal cultural heritage or stone cultural heritage that are outdoors that are affected by air pollution. Due to important air pollution factors such as sulfur dioxide (SO_2) and nitrogen dioxide (NO_2) chloride ions, cultural heritage suffer from phenomena such as dissolution, deterioration, corrosion, discoloration, and deprivation. In other words, corrosion and pollution of cultural heritage caused by air pollution can cause serious economic losses due to high maintenance and restoration costs. This paper selects sites in South Korea and analyzes sustainable future urban planning policy to cope with air pollution. The area selected as the research site is Gyeongju-si, Korea. Gyeongju-si is one of the oldest cities in Korea, and it is a place where cultural heritages are damaged by air pollution because there are many metal cultural heritages or stone cultural heritages outdoors. This study analyzes the air pollution level of Gyeongju-si through an environmental satellite (GEMS) and proposes an urban plan to cope with air pollution with the results of the analysis. The biggest sources of air pollution in urban planning are industrial facilities and transportation. The results were derived that industrial facilities that cause pollution should be distributed or facilities that can reduce pollution emissions should be added. This paper proposes urban planning policy, including technology for responding to air pollution, to provide theoretical grounds and references for protecting cultural heritages from air pollution.

Keywords

Urbanplannig policy, Cultural heritage, Air pollution

1. Theoretical Background

1.1 The Severity of Air Pollution in Republic of korea

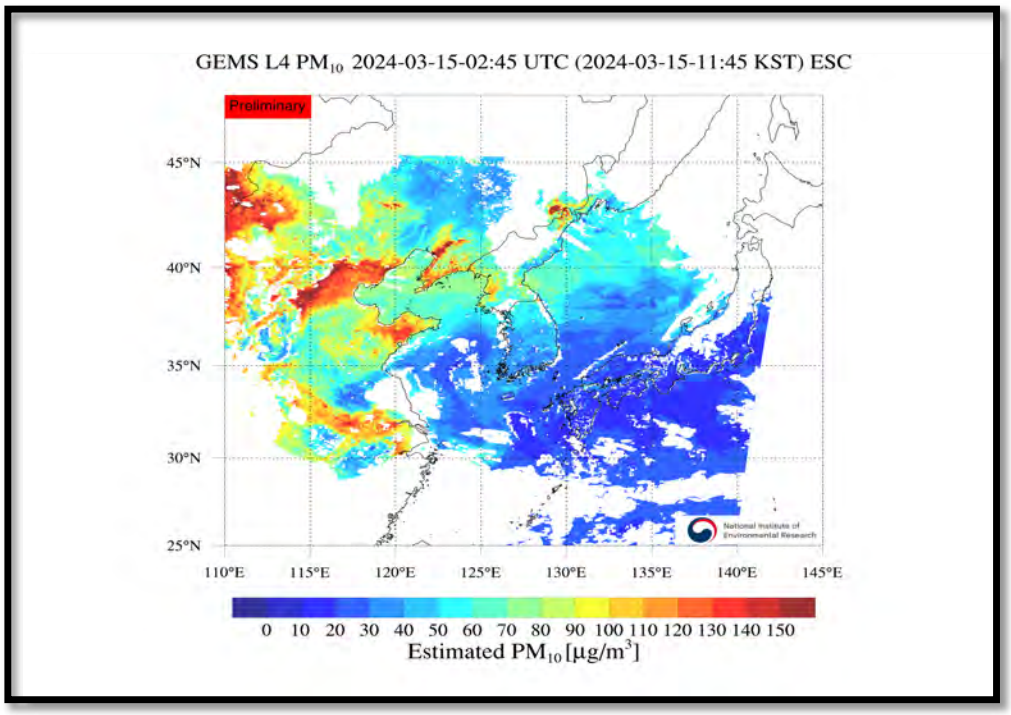


Figure 1. PM 2.5 (Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

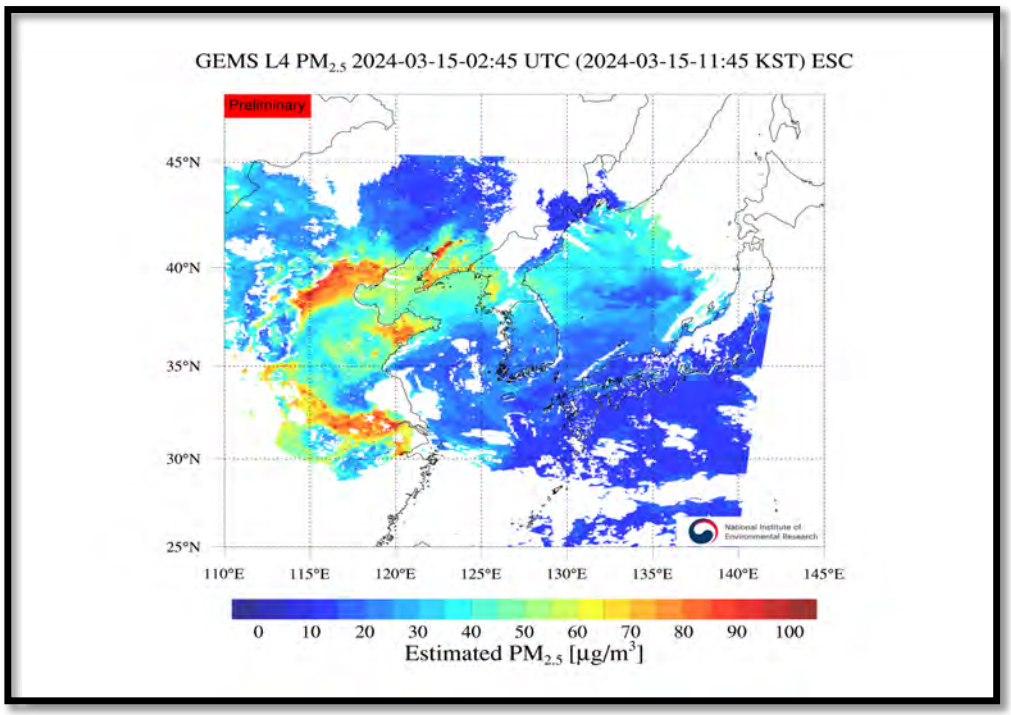


Figure 2. PM 10 (Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

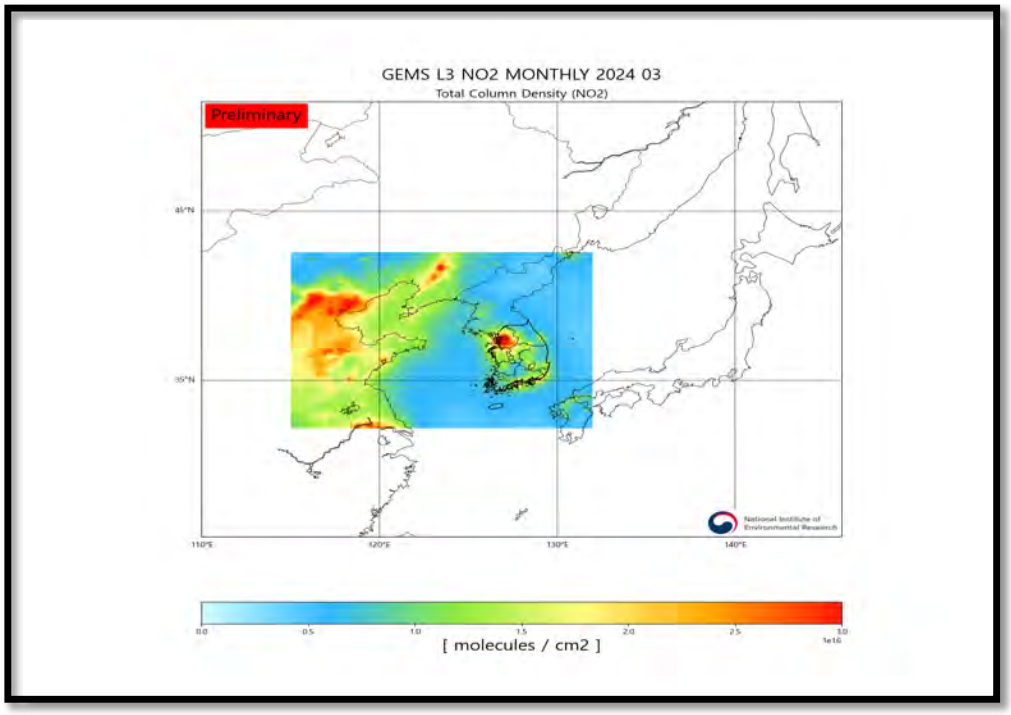


Figure 3. NO_2 (Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

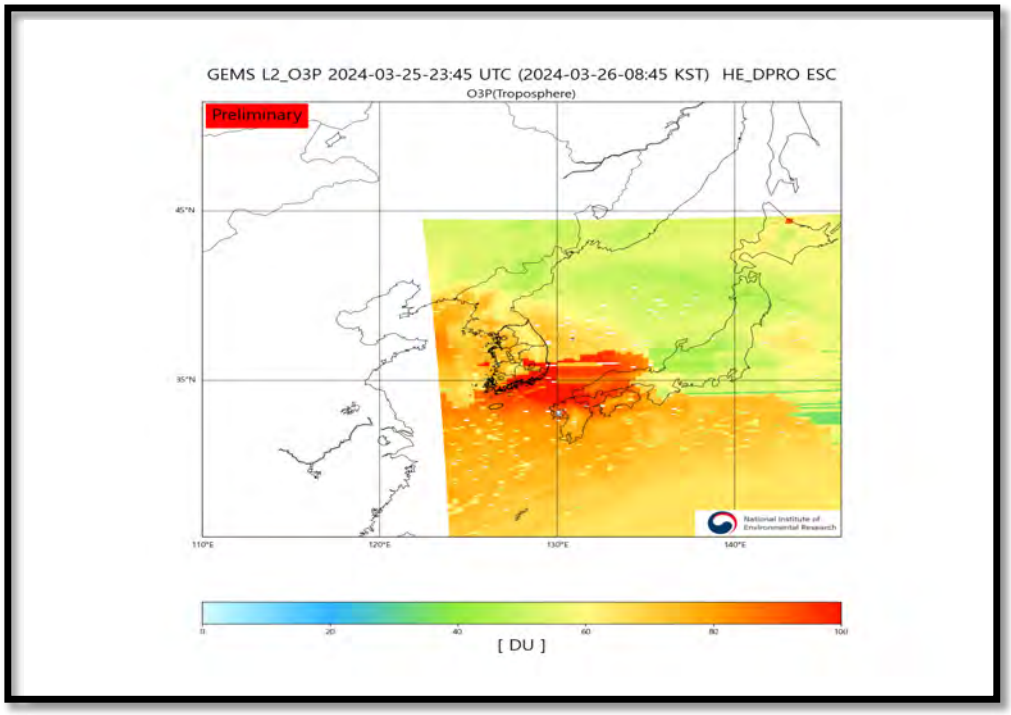


Figure 4. O_3 (Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

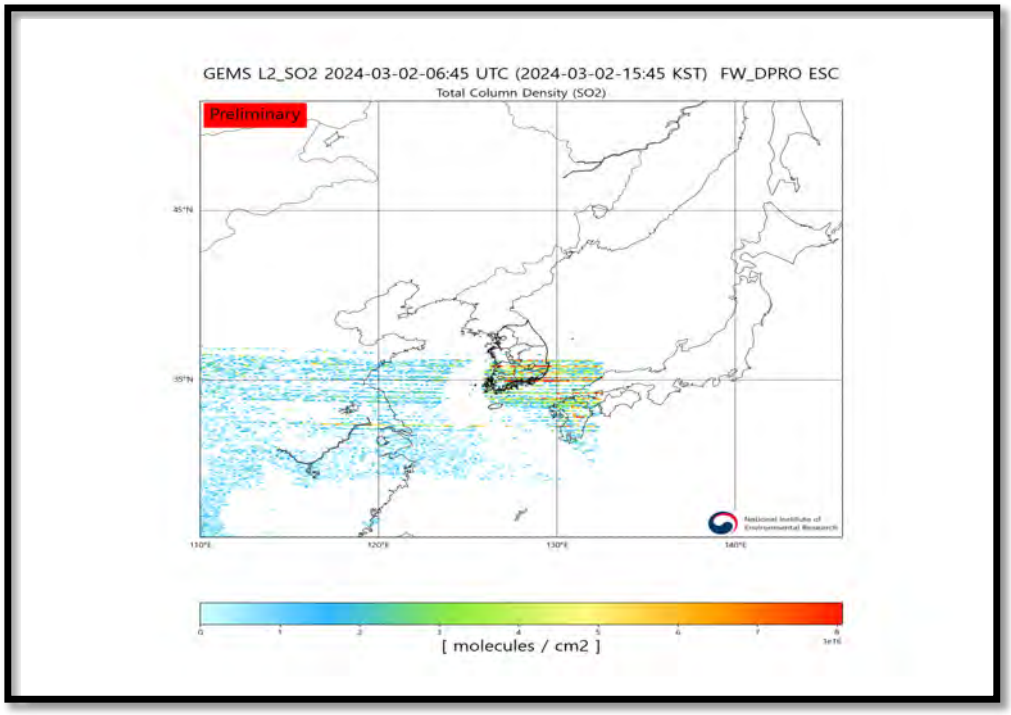


Figure 1. SO_2(Republic of korea 2022) Source: Korea National Institute of Envireonmental Research.

The images above represent the overall distribution of air pollutants across the Korean Peninsula. The WHO standards for air pollutants are as follows: PM2.5: 5 μg/m^3, PM10: 15 μg/m^3, NO_2: 10 μg/m^3, O_3: 60 μg/m^3, and SO_2: 40 μg/m^3 (World Health Organization, 2021). However, in most of the figures, it can be observed that air pollution levels exceed these standards, resulting in noticeable visual changes. This indicates the severity of air pollution in Republic of Korea.

1.2 Gyeongju as a Cultural Heritage Hub

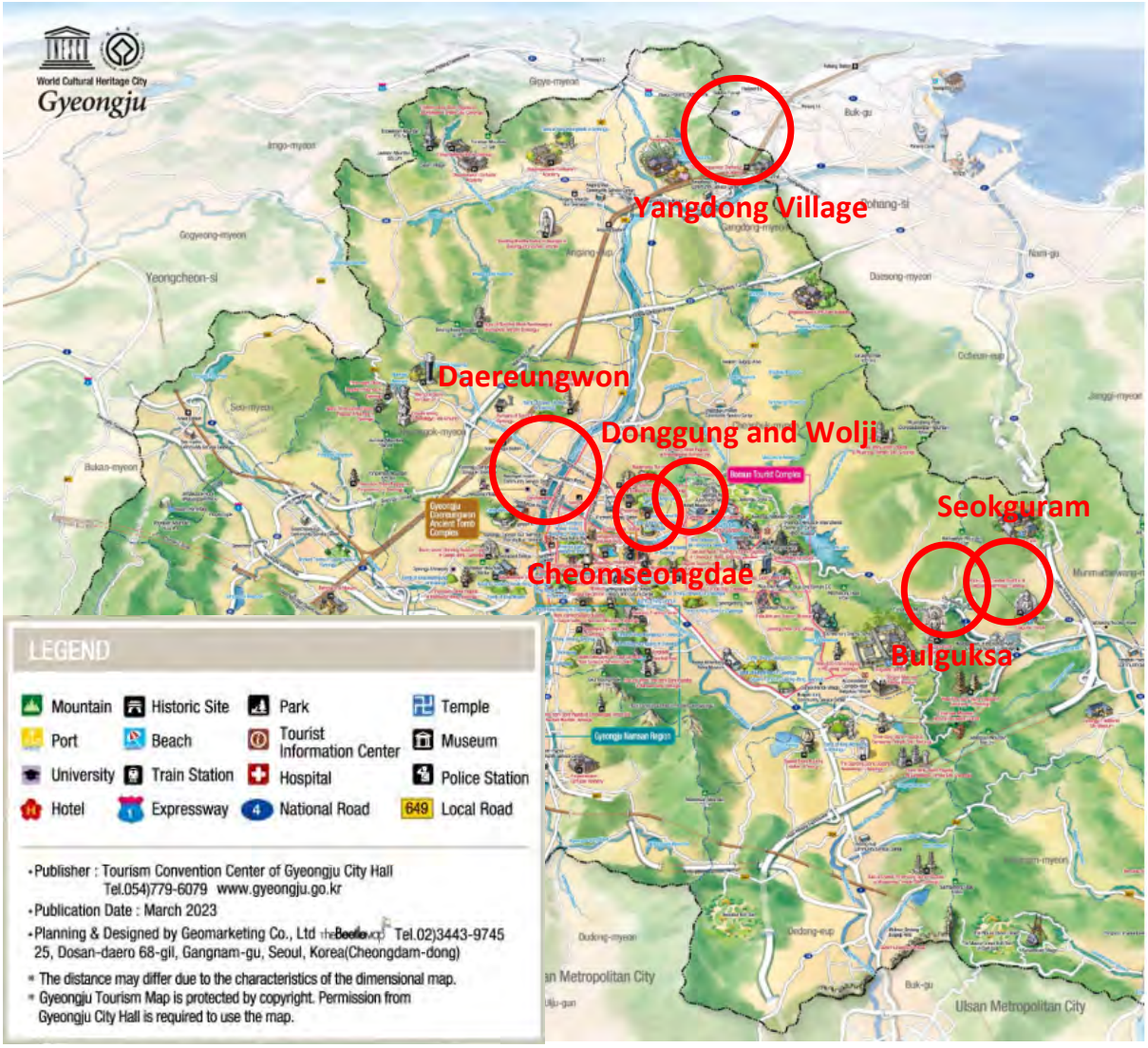


Figure 2. Cultural Heritage Site in Gyeongju, Republic of korea. Source: Gyeongsangbuk-do Province Gyeongju City Hall.

The reason for selecting Gyeongju as the study site is that the city has established itself as a hub of World Heritage. In addition to the five cultural heritage sites listed below, Gyeongju is home to various cultural assets within its historic areas, making it a historically significant city that requires preservation.

1. Seokguram Grotto and Bulguksa Temple

Seokguram and Bulguksa Temple are UNESCO World Heritage Sites and are ancient Buddhist ruins created during the Silla period. Seokguram is the only artificially made granite stone cave carrying Buddha statues, and Bulguksa Temple is a temple structure. It is an architecture and sculpture representing Buddhist culture in the Unified Silla Period around the 8th century, and Seokguram shows technical and artistic value in artificial stone caves and Buddha sculptures, and Bulguksa Temple is a valuable cultural property that is

evaluated as a building with a harmony of stone and wooden architecture(Korean National Commission for UNESCO, 2024).

2. Cheomseongdae Observatory

Cheomseongdae is the oldest observatory in East Asia and is a cultural heritage symbolizing governance and science, including agriculture and ritual schedule management (Korea Heritage Service, 2024). The 27 stone layers represent the twevle months of the year and the twenty-four solar terms and have cultural heritage value in that they contain scientific and astronomical knowledge.

3. Daereungwon Tomb Complex

Daerungwon is a UNESCO World Heritage Site. The ancient tombs of Silla royalty and aristocrats, representing the authority and wealth of the Silla royal family (Korean Heritage Service, 2024). In particular, the golden artifacts found in the Cheonmachong and Hwangnamdaechong show ancient culture and technology of Silla. It is also a place to represent the afterlife, the dignity of the ruling class, the social structure and funeral culture of the Silla period.

4. Donggung Palace and Wolji Pond (Anapji Pond)

Donggung Palace and Wolji Pond is also part of UNESCO World Heritage Site. The royal culture and architectural beauty of Silla can be seen through Silla's Byeolgung Palace and artificial ponds, and various Silla relics were found here, emphasizing historical and cultural importance (Korean Heritage Service, 2019).

5. Yangdong village

Andong Hahoe Village and Gyeongju Yangdong Village, which were established in the 14th and 15th centuries, are clan villages representing the Republic of Korea(Korean National Commission for UNESCO, 2024). In addition, Yangdong Village is a traditional Hanok village in the Joseon Dynasty and has been designated as a UNESCO World Heritage Site. Traditional architectural styles and living cultures have been preserved as Yangban families have lived for generations, and traditions that show the lifestyle and social structure of Confucian families in the Joseon Dynasty have been preserved.

2. Analysis of the Impact of Air Pollutants

2.1 Pollutants Affecting Cultural Heritage & Mechanisms of Damage

Cultural heritage structures affected by air pollution are exposed to various pollutants, including particulate matter (PM), nitrogen dioxide (NO_2), ozone (O_3), sulfur dioxide (SO_2), and carbon dioxide (CO_2). The following section will explain each pollutant and the mechanisms through which these pollutants cause damage to buildings.

- Particulate Matter(PM) contains corrosive chemical substances, which, upon deposition on structures, promote corrosion. Additionally, it acts as a catalyst for the formation of nitric ac(Oscar Julian Esteban-Cantillo et al.,2024).

-Nitrogen dioxide (NO_2) combines with water to form nitric acid, which primarily causes corrosion on limestone and marble, materials commonly used in cultural heritage structures (Silvestro Antonio Ruffolo et al., 2023).

-Ozone (O_3) oxidizes organic materials such as wood, weakening fibers, and accelerates the corrosion of metals and stone structures(Bo Xiao et al.,2022)

-When sulfur dioxide (SO_2) comes into contact with rain or moisture, it forms sulfuric acid (H_2SO_4), which is a component of acid rain. This sulfuric acid reacts with the calcium carbonate in stone, leading to the formation of gypsum (calcium sulfate), which weakens the surface of the stone over time(Oscar Julian Esteban-Cantillo et al.,2024).

- Carbon dioxide (CO_2) dissolved in atmospheric moisture, forms carbonic acid, which reacts with building materials, particularly those made of calcium carbonate ($CaCO_3$), such as limestone and marble (Spezzano, 2021).

2.2 Sources of Air Pollution

PM (Particulate Matter): Natural sources include sea salt, crustal dust, pollen, and volcanic ash. Anthropogenic sources predominantly stem from the combustion of fossil fuels in power plants and vehicles, heating of households, as well as non-combustion emissions from vehicular traffic and the resuspension of road dust(Dušan Jandačka, 2015).

NO_2 (Nitrogen Dioxide): Nitrogen dioxide is primarily emitted during land-based transportation, agricultural activities, fuel production, power generation, and the combustion of solid biofuels in households (Chowdhury et al., 2021).

O_3 (Ozone): Photochemical reaction of NOx from industrial sources and vehicles with VOCs emitted by automobiles, industrial sources, and solvents. (Raffee et al., 2022).

SO_2 (Sulfur Dioxide): Natural sources such as biological decay and sea spray emit sulfur, while anthropogenic sources like coal combustion, oil, and smelting operations release sulfur dioxide (SO_2) into the atmosphere. Approximately 70% of anthropogenic emissions are attributed to coal combustion (Kumar, 2020).

CO_2 (Carbon Dioxide): Natural sources of carbon dioxide emissions include volcanic eruption, fire, ocean vapors, dust storms, and the fermentation of organic materials. Anthropogenic sources, on the other hand, include industry, transport, agriculture, energy production, domestic heating (Abderrezak Khelfi, 2018).

2.3 The relationship between air pollutants and diseases

Air pollutants also harm cultural heritage, but PM, SO_2, NO_2, and O_3 are also causing diseases related to various fields such as cognitive disorder, respiratory tract, high blood pressure, cardiovascular system, and cerebrovascular system in cities. Many studies are still trying to determine the correlation, but some of the related diseases have been identified by the results of the studies.

-Exposure to Particulate Matter (PM) air pollution causes respiratory deposition by being transported to the alveoli through inhalation (Chen et al., 2023). PM10 and PM2.5 are predominantly present in the upper respiratory tract, PM2.5 and ultrafine dust are more deeply present, causing lung function decline, respiratory symptoms, bronchitis, lung emphysema, and circulatory diseases (Gandhimathi A et al., 2023). In addition, Chronic obstructive pulmonary disease (COPD) also shows that increasing PM10 by 10μg/m^3 increases COPD hospitalization by 2.7%, COPD mortality by 1.1%, and PM2.5 also has significant correlation (Zhu et al., 2020).

- "Short-term exposures to NO_2 may increase the risk of cerebrovascular mortality, specifically for ischemic stroke and sequelae of cerebrovascular disease" (Qian et al., 2023).

2.4 Gyeongju Air Quality Data

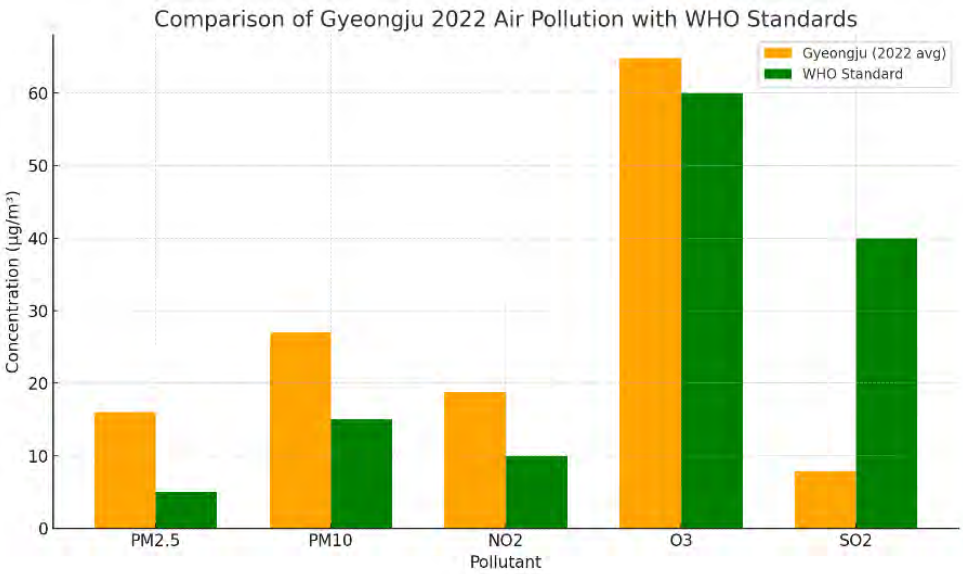


Figure 3. Comparison of Gyeongju 2022 Air pollution with WHO Standards. Source: National Institute of Envireonmental Research in korea.

	Gyeongju (2022 avg)	WHO(2021 standard)
PM2.5	16 μg/m³	5 μg/m³
PM10	27 μg/m³	15 μg/m³
NO_2	18.82 μg/m³(=0.010 ppm)	10μg/m³
O_3	64.79 μg/m³(=0.033ppm)	60μg/m³(peak season) [a]
SO_2	7.86 μg/m³(=0.003 ppm)	40μg/m³(24hours) [b]

Table 1. Comparison of Gyeongju 2022 Air pollution with WHO Standards. Source: National Institute of Envireonmental Research in korea.

[a] 99th percentile (i.e. 3–4 exceedance days per year) (World Health Organization, 2021).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running- average O_3 concentration(World Health Organization, 2021).

The above graph and table are data comparing Gyeongju City and WHO Air Quality Guideline based on the Korea 2022 Air Quality Yearbook of the National Institute of Environmental Research in Korea. It can be seen that Gyeongju, the target site, is two to three times different from WHO guidelines in most indicators (PM2.5, PM10, NO_2). In the case of O_3 and SO_2, the WHO's guideline provided the values of peak season and 24 hours rather than annual standards, so it could be compared indirectly. Among the air pollutants

that exceeded the standard, the biggest difference can be seen as PM10 (+12 μg/m ^{3}), and the relatively small differences were observed as NO_2 and O_3.

Of course, the environmental satellite data of the Korea National Institute of Environmental Research showed the seriousness of air pollutants exceeding WHO guidelines through graphs and tables, and it was determined that there would be a need to protect the cultural heritage of Gyeongju, Korea from air pollution.

3. Urban planning policy proposal

Establish effective air pollution measures in Gyeongju by identifying the characteristics and causes of air pollutants that damage cultural heritage. The causes of air pollution covered in Part 2 include transportation and industrial facilities. Analyze and propose urban planning policies that can be implemented in Gyeongju in air pollution.

Figure 4. Gyeongju Map. Source: Naver Map

Target Site: Gyeongju-si, Gyeongsangbuk-do, Republic of korea

Area: 1,324.95 ㎢

Population: 245,475

3.1 Transportation

The decrease in major air pollutants during COVID-19 was mainly due to reduced emissions due to reduced urban traffic due to the pandemic(Woo-cheol et al.,2021). This document shows the impact of the transportation sector on air pollution. Therefore, it is analyzed that it is necessary to reduce air pollution in the transportation sector. Deteriorated diesel vehicles contribute to the increase of air pollutants, which affect cultural heritage. This problem can be solved by inducing the transition to electric vehicles through a subsidy program for the disposal of aged diesel vehicles in Gyeongju.

In addition, if the vehicle stops for a long time, this means that there is more air pollutants emitted from the car (Kim, Hui-jae, 2014). Therefore, the idling of cars at signal intersections where cars stop without turning off their engines must be restricted. In Fig 6, the area where cultural heritage concentrated areas are selected is designated as an idle restricted area, and a 'heritage protection traffic tax' is imposed to protect heritage on cars that are not equipped with an automatic Idle Stop and Go system that passes through this area. In addition, by providing traffic signal information through vehicle-to-infrastructure to

vehicles, a system is introduced that calculates the signal waiting time based on the information, and the driver adjusts the speed and goes to the signal intersection to minimize signal waiting.

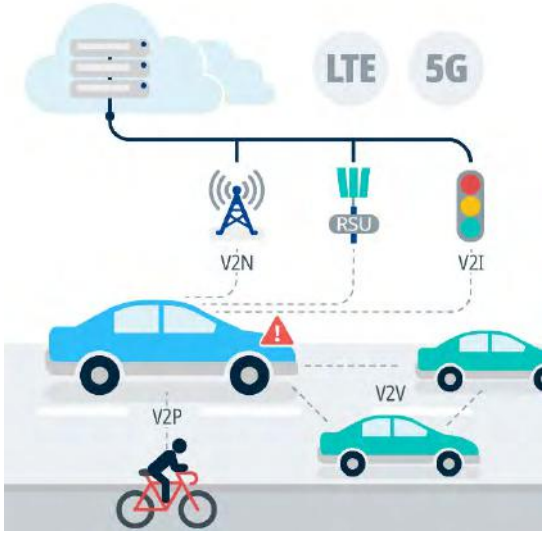


Figure 5. vehicle-to-infrastructure.

Source: Telecommunications Technology Association, TTA

3.2 Industrial complex planning Proposal

An issue to be considered in urban planning is the arrangement when planning an industrial complex. Gyeongju is a historical city, but it is adjacent to the sea where it can secure abundant industrial water and has a large land. Since the surrounding cities are Ulsan and Pohang, which are port cities with large-scale industrial complexes, there are many industrial complexes in Gyeongju.

Figure 6. Distribution Map of Gyeongju Industrial Complex.

Source: Korea Industrial Complex Corporation.

In Gyeongju, general industrial complexes occupy 15,520,121 ㎡, and nuclear power plants, which are national industrial complexes, occupy 3,692,816 ㎡. Fig 10, Indicating at the distribution of industrial

complexes, the main industries are other machinery and equipment, automobiles and trailers, other transport equipment, primary metal manufacturing, and textile product manufacturing. Ozone, emitted from industrial facilities such as chemical plants and oil refineries and from various sources such as natural generation, nitrogen dioxide generated in high-temperature combustion processes such as automobiles and power plants and chemical manufacturing processes such as burning fuels (mainly coal and petroleum), metal smelting processes, and other industrial processes are major air pollutants that damage cultural properties. In other words, when planning an industrial complex first, it must be distributed and arranged to prevent air pollutants emitted from factories.

Figure 7. Master Planning of Gyeongju Industrial Complex. Source: Gyeongsangbuk-do.

Fig.11 is a master plan for an industrial complex in Gyeongju, but it lacks a lot of green space. Most industrial complexes in Gyeongju, as well as this area, show similar characteristics. This paper propose to secure green areas to reduce pollutants generated from factories that cause air pollution. In order to increase green space by 30% and strengthen green network, green will be created throughout the building structure of the target area.

The theory of industrial complex planning in Gyeongju proposed by this paper increases the green area by 30% from the originally planned green area. To strengthen the green network, a natural space is created in some of the building structures in the target area. It is designed so that the shade of trees in the complex covers more than 30% of the area. Public green spaces or buffered green spaces are located within 300m of each other. In each green space is planned tbe planted with less than 10% of the same species, less than 20% of the same genus, and less than 30% of the same family. The building is arranged so that the wind road can be applied by analyzing the wind blowing pattern.

Monitor air quality by scanning satellite industrial complexes in real time through environmental satellites (National Institute of Environmental Research). Devices that communicate with this satellites using the Internet of Things (IoT) and automatically spray mist to dilute air pollutants when certain air pollution indices increase are placed in industrial complexes vulnerable to air pollution.

3.3 Energy Transition

At the 28th United Nations Climate Change Conference (COP28) held in Dubai, the United Arab Emirates, KHNP announced the Small Modular Reactor (SMR), a next-generation nuclear power plant. At COP28, nuclear power received attention as one of the energy sources to replace fossil fuels. Gyeongju was designated as SMR National Industrial Complex. As explained above, air pollutants are generated a lot in industrial complexes. If Gyeongju achieves the energy conversion from conventional fossil fuel energy to nuclear energy, it can reduce air pollutants generated from industrial complexes.

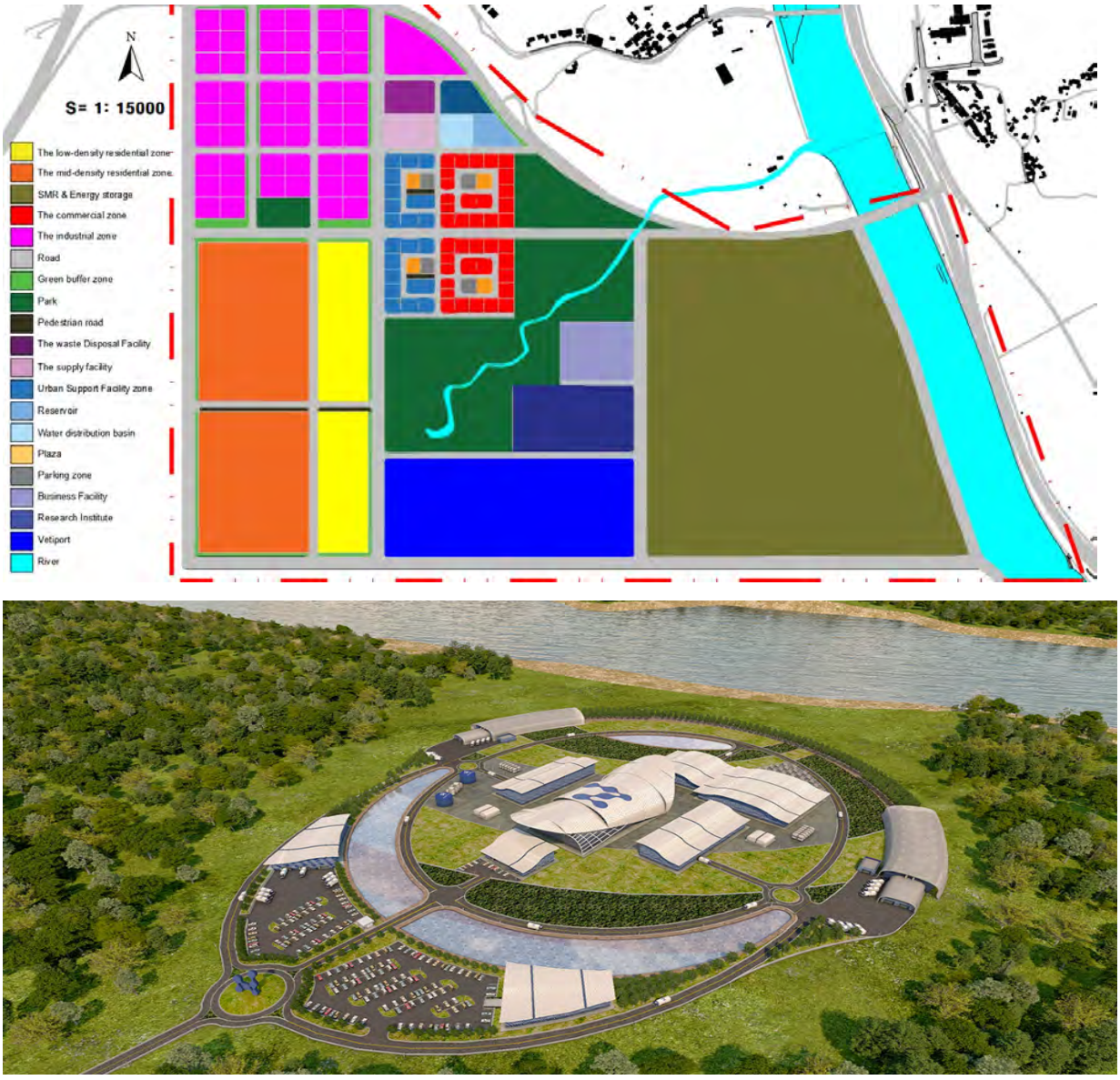


Figure 8. Urban Planning SMR Industial Complex. (Kim.D.S., 2024).

Fig 12 is an expected drawing of urban planning for a Gyeongju industrial complex that introduced SMR. Small modular reactors (SMR) are next-generation nuclear power generation technologies that compensate for the risk of accidents, construction costs, and time, which are the disadvantages of existing nuclear power plants. The SMR uses reactors with an output of less than 300 MWh and are called small nuclear power plants. Unlike conventional nuclear power plants, SMR has no major restrictions on location conditions and can be built in cities because it is safe (Kim.D.S., 2024).

It replaces fossil energy through nuclear energy by deploying SMR in industrial complexes that require a lot of energy. The replacement of fossil energy in industrial complexes will reduce air pollution, which means that cultural properties in Gyeongju can be protected from air pollution. Urban planning, including SMR, change the way energy is supplied in future cities.

4. Conclusion

This study compared air pollutant levels in Gyeongju, Gyeongsangbuk-do, Republic of korea, with the WHO Air Quality Guidelines, analyzing that most levels exceed WHO standards by two to three times. These pollutants, produced by fuel production, power generation, transportation, and heating of households, adhere to cultural heritage sites, leading to structural corrosion and surface weakness. Air pollution remains a persistent threat to cultural heritage, and even Gyeongju, a hub of Cultural heritage, is not immune to these risks. Because of its large number of industrial complexes and the resulting heavy traffic, Gyeongju's cultural heritages are exposed to high levels of air pollution. The damage caused by air pollution causes huge losses to cultural heritage.

This paper proposes urban planning and policies related to transportation, industrial complexes, and energy transition to tackle the air pollution issues. It is expected to give various implications in the process of making and implementing urban planning policies in response to air pollution in the future.

However, since the analysis was selected and analyzed at a specific time point and a specific area, there is a limit to interpretation through generalization. In future studies will be expanded the scope of the survey to all seasons and present an urban design drawing that visualizes the results in 3D.

5. References

Reference list

Abderrezak Khelfi (2018). Sources of Air Pollution. *Advances in environmental engineering and green technologies book series*, pp.220–258. doi:https://doi.org/10.4018/978-1-5225-3540-9.ch011.

Chen, T.-Y., Chen, S.-C., Wang, C.-W., Tu, H.-P., Chen, P.-S., Hu, S.C.-S., Li, C.-H., Wu, D.-W., Hung, C.-H. and Kuo, C.-H. (2023). The impact of the synergistic effect of SO2 and PM2.5/PM10 on obstructive lung disease in subtropical Taiwan. *Frontiers in Public Health*, 11. doi:https://doi.org/10.3389/fpubh.2023.1229820.

Choi, W.-C. and Cheong, K.-S. (2021). Analysis of the Factors Affecting Fine Dust Concentration Before and After COVID-19. Journal of the Korean Society of Hazard Mitigation, 21(6), pp.395–402. doi:https://doi.org/10.9798/kosham.2021.21.6.395.

Chowdhury, S., Haines, A., Klingmüller, K., Kumar, V., Pozzer, A., Venkataraman, C., Witt, C. and Lelieveld, J. (2021). Global and national assessment of the incidence of asthma in children and adolescents from major sources of ambient NO2. Environmental Research Letters, 16(3), p.035020. doi:https://doi.org/10.1088/1748-9326/abe909.

Dušan Jandačka (2015). Sources of PM10 Air Pollution in Rural Area in the Vicinity of a Highway In Žilina Selfgoverning Region, Slovakia. Civil and Environmental Engineering, 11(1), pp.58–68. doi:https://doi.org/10.1515/cee-2015-0008.

Gandhimathi A, Manju R, Ramadevi K, Rajalakshmi S and Mayilvahanan I (2023). A STUDY OF ENVIRONMENTAL IMPACT OF AIR POLLUTION ON HUMAN HEALTH: PM DEPOSITION MODELLING. Global NEST: the international Journal, 25(6). doi:https://doi.org/10.30955/gnj.004613.

Gyeongsangbuk-do, About Gyeongsangbuk-do Industrial Complex. (2019). Available at: https://www.gb.go.kr/Sub/open_contents/section/invest/page.do?mnu_uid=4167&LARGE_CODE=430&MEDIUM_CODE=30 [Accessed 31 Oct. 2024].

Kim, D.S. (2024). Future Scenario for Sustainable Carbon Neutral Urban Planning with SMR. Lecture notes in networks and systems, 851, pp.153–166. doi:https://doi.org/10.1007/978-3-031-71076-6_9.

Kim, Hui-jae (2014). “Analysis on Relationship between Urban Development Characteristics and Air Pollution Level - a Case of Seoul Metropolitan Region -.” Journal of Korea Planners Association, vol. 49, no. 7, 30 Nov. 2014, p. 151, https://doi.org/10.17208.

Korea Industrial Complex Corporation, Distribution Map of Gyeongju Industrial Complex. (2024). Available at: https://www.kicox.or.kr/home/mwrc/policyRsrch/fdrmPblictn/fdrmPblictn04.jsp [Accessed 20 Oct. 2024].

Korean Heritage Service. (2019). National Heritage Information. [online] Available at: https://www.heritage.go.kr/heri/cul/culSelectDetail.do?pageNo=1_1_1_1&ccbaCpno=1333700180000 [Accessed 30 Oct. 2024].

Korean Heritage Service. (2024a). *National Heritage Information*. [online] Available at: https://search.khs.go.kr/srch_org/search/search_top.jsp?searchCnd=&searchWrd=&home=total&mn=&gubun=search&query=%EC%B2%A8%EC%84%B1%EB%8C%80 [Accessed 30 Oct. 2024].

Korean Heritage Service. (2024b). *National Heritage Information*. [online] Available at: https://www.heritage.go.kr/heri/cul/culSelectDetail.do?pageNo=1_1_1_1&ccbaCpno=1333705120000 [Accessed 30 Oct. 2024].

Korean National Commission for UNESCO. (2024). *World Heritage Sites in Korea*. [online] Available at: https://unesco.or.kr/heritage [Accessed 31 Oct. 2024].

Kumar, A. (2020). A Review on Ionic Liquids as Novel Absorbents for SO2 Removal. *Water science and technology library*, pp.285–307. doi:https://doi.org/10.1007/978-3-030-38152-3_15.

National Institute of Environmental Research. (2024). Available at: https://nesc.nier.go.kr [Accessed 17 Oct. 2024].

Oscar Julian Esteban-Cantillo, Menendez, B. and Quesada, B. (2024). Climate change and air pollution impacts on cultural heritage building materials in Europe and Mexico. *Science of the total environment*, 921, pp.170945–170945. doi:https://doi.org/10.1016/j.scitotenv.2024.170945.

Qian, Y., Cai, R., Su, X., Li, Q., Jin, S., Shi, W., Chen, R., Wang, C. and He, J. (2023). Residential Nitrogen Dioxide Exposure and Cause-Specific Cerebrovascular Mortality: An Individual-Level, Case-Crossover Study. *Toxics*, 12(1), pp.10–10. doi:https://doi.org/10.3390/toxics12010010.

Raffee, A.F., Hamid, H.A., Rahmat, S.N. and Jaffar, M.I. (2022). The cause-and-effect analysis of ground level ozone (O3), air pollutants and meteorological parameters using the causal relationship approach. *Journal of Engineering Research*, 11. doi:https://doi.org/10.36909/jer.17233.

Silvestro Antonio Ruffolo, Francesco, M., Rovella, N. and Ricca, M. (2023). The Impact of Air Pollution on Stone Materials. *Environments*, 10(7), pp.119–119. doi:https://doi.org/10.3390/environments10070119.

Spezzano, P. (2021). Mapping the susceptibility of UNESCO World Cultural Heritage sites in Europe to ambient (outdoor) air pollution. *Science of The Total Environment*, 754(142345), p.142345. doi:https://doi.org/10.1016/j.scitotenv.2020.142345.

World Health Organization (2021). *What are the WHO Air quality guidelines?* [online] World Health Organization. Available at: https://www.who.int/news-room/feature-stories/detail/what-are-the-who-air-quality-guidelines [Accessed 30 Oct. 2024].

Xiao, B., Ning, L., Lin, Z., Wang, S. and Zang, H. (2022). The Impact of Air Pollution on the Protection of World Cultural Heritage in China. *International Journal of Environmental Research and Public Health*, 19(16), p.10226. doi:https://doi.org/10.3390/ijerph191610226.

Zhu, R.-X., Nie, X.-H., Chen, Y.-H., Chen, J., Wu, S.-W. and Zhao, L.-H. (2020). Relationship Between Particulate Matter (PM2.5) and Hospitalizations and Mortality of Chronic Obstructive Pulmonary Disease Patients: A Meta-Analysis. *The American Journal of the Medical Sciences*, [online] 359(6), pp.354–364. doi:https://doi.org/10.1016/j.amjms.2020.03.016.

Research Paper

Inquiries into Historical and Cultural Ecology of Adi Ganga, a Heritage River of Kolkata, India to forging Urban Climate Resilience

Amit BHATTACHARYA, Jadavpur University, India

Abstract

Urban rivers are living repositories of a city's cultural and environmental histories. They influence and shape spatial morphology, socio-economic sustenance, mobility pattern and ecosystem health in a constant dialogue with its populace. With unregulated anthropogenic interventions rivers are physically manipulated, overconsumed and in turn abandoned in perpetual environmental degeneration. Taking the River Adi (old) Ganga in Kolkata as research case this study offers insights into historical urban cultural ecology narratives of a currently forgotten river. The research aims to unearth the potential of resilience development through ecological and cultural assets preservation and enhancement of Adi Ganga reflecting upon UN SDGs. To assess the environmental impact of land use land cover changes on blue-green spaces surrounding Adi Ganga Landsat and Sentinel data are combined in GIS in this study. To bridge the gap tangible and intangible heritage values of the river and surrounding are evaluated with performance indicators. The findings demonstrate the significance of preserving and enhancing eco-culturally significant natural heritage resources in sustaining inclusive urban climate resilience. For good measure, the theoretical and methodological frameworks of this study can advocate for mainstreaming planning and policy decision to preserve, reserve and sustain urban natural and cultural heritage in forging climate resilience.

Keywords

Historical ecology, Cultural ecology, Natural heritage, Environmental impact assessment, Urban heritage, Climate change mitigation

1. Introduction

1.1. Context and study background

Urban waterscapes are often enmeshed with city's history, heritage and natural assets creating complex eco-cultural narratives. The blue-green system contributes to the sustenance of city's ecosystem, socio-economic dialogues and natural resilience to climatic woes. Kolkata, the eastern megalopolis of India has a remarkable blue-green landscape system intertwined with its urban fabric. Although it is currently threatened by aggressive urban growth the city still thrives on this sound nature-based eco-cultural setting. Kolkata's colonial past exhibited the history of tampering the natural water courses influenced by consumptive mindset of either revenue from trade or defense mechanism (Lahiri-Dutt 2015). These natural and altered aquascapes of Kolkata played an instrumental role in city's urban transformations, systems

functioning and eco-cultural sustenance (Munshi 1990). The 'colonial hydrology' (D'souza 2006) of Kolkata has a rich place-based heritage of wetlands, canals, lakes and inland navigation channels for the two-fold reasons of city level sewerage as well as carriage of goods and British army (Mukherjee 2009-2010). However, the nature-based resilient narrative of Kolkata withered out of prolonged neglect and oblivion of city authorities and citizen and faces existential crisis currently. Many contributors to this challenging scenario are discontinued interest on natural heritage preservation, paradigm shift in economical and socio-cultural values, misinterpretation of ecological asset, planning schemes devoid of nature, increased pollution, lack of fund for maintaining natural flow and cleanliness. These resulted in siltation, damage of riparian buffer, aquatic biodiversity and diminished socio-cultural association toward waterscapes of Kolkata. This study focuses on one such affected river Adi-Ganga (Old Ganges) which bears its heritage value till date due to its age-old transformational character and religious association.

This study acknowledges Adi Ganga River as an essential constituent of Kolkata's complex urban narrative which explores spatio-cultural dimensions toward finding its potential to forging climatic resilience. The heritage river is analysed with a historical and cultural value-based framework to interpret city-nature codependent dialogue. This narrative probes into deeper understanding of the historical transformation, cultural engagement and ecological resilience. Through these multitude of narratives, the river and the city shaped each other. It also endeavours to suggest restorative landscape strategies that may meaningfully integrate the natural and cultural values of this holy river (Paul 2020) into mainstream planning regime to develop urban climate resilience of Kolkata. Additionally, a resilient toolkit is recommended by imbibing a natural blue-green resource preservation approach with community engagement policies for implementing the climate adaptation strategies.

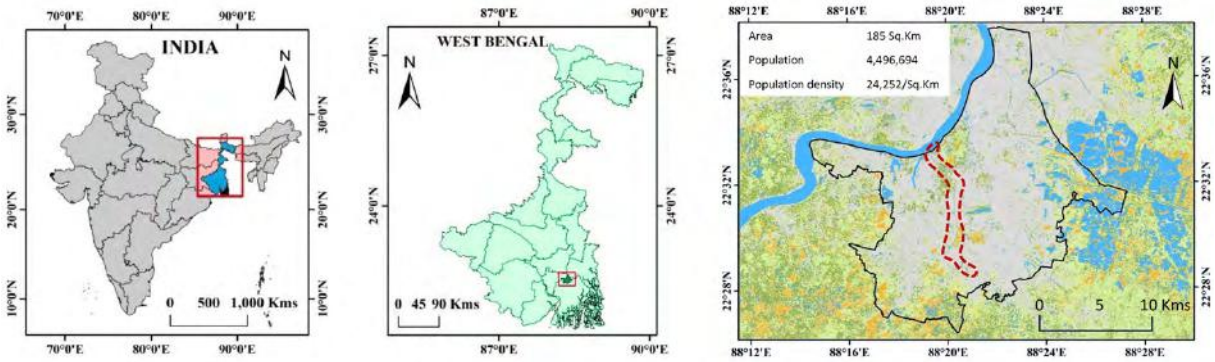


Figure 1: Context of the study area surrounding Adi Ganga in Kolkata, India

1.2. Adi Ganga – history and evolution

Adi ganga is a distributary channel (Paul 2020) of the main river of Kolkata Bhagirathi-Hooghly (Mandal, 2018). The river begins at Hastings area as a branch of the River Hooghly and directs herself toward south through Kolkata, eventually joining the Piyali River and ultimately leading to the Bay of Bengal (Figure 1). Like the Hooghly, Adi Ganga is revered in Hinduism for its link to the Ganges. According to Hindu mythology, to emancipate the souls of ancestors of King Bhagirath from a curse imprecated by Sage Kapil Goddess Ganga was worshipped and requested to come down to earth (Mani, 2015). The Goddess, symbolizing purity, was believed to be the only one capable of granting salvation through her touch. Bhagirath convinced her to descend to Earth as a river, but she initially lost her way. To fulfil her promise, she created multiple channels that reached the Bay of Bengal Sea, creating the Gangetic delta (Bhattacharya, 2023). Nowadays, the Ganges referred to as "Ma Ganga" or "Mother Ganges," (Dwivedi, 2022) reflects the deep cultural and environmental significance of the river in the history of Kolkata city (Paul, 2020).

A set of medieval literary works and folklores (Pattnaik, 2022) presents multifaceted illustrative mythical and historical narrative (Table 1) of the Adi ganga river (Bandyopadhyay, 1996). A few noteworthy of them are as follows,

Table 1: Medieval literature representing Adi-Ganga (prepared from the english translations of the literatures)

Sl.no.	Literature	Author	Contribution to narrative
1	Manasamangal Kabya	Poet Bipradas Pipilai	Presents the story of a tradesman's daughter-in-law taking the river route to reach to heavenly abode for saving her husband's life.
2	Chandimangal Kabya	Poet Kabikankan Mukundaram	Various imageries of social life around the river and town are presented.
3	Raymangal Kabya	Poet Krishnaram Das	Presents the mythic folklore tiger god Raydev and his miracles encircling the lives of people around Sunderbans aquatic regime where Adi-Ganga meets the Bay-of-Bengal.
4	Chaitanya Bhagabat	Poet Vrindavan das Thakur	The journey of famous saint Chaitanya is presented vividly along the river to reach to seashore

During colonial times, Adi Ganga served as a crucial trade route between the capital city Kolkata and the Southern visage of Sunderbans (Mukerjee 2020), while also being adapted for regional drainage needs, leveraging its natural tidal flows. When looked back for her origin through its documented history, this medieval era natural river existed as a navigation channel. It sprung to popularity when it was excavated by Major William Tolly of East India Company (Livinwatermuseum 2024) for primary navigation through in-land water system and city sewerage network in 18th century linking the mainstream Kolkata and its far southern visages at Sunderbans, Bay of Bengal (Figure 2 and 3). However, the river's degradation began when colonizers prioritized railways over water transport, leading to urbanization and neglect of maintenance. This transformation turned the once-vibrant river into a polluted, stagnant channel known as a nullah or sewage drain. The construction of a metro railway along the river's path further disrupted its flow and ecology, yet the channel remains vital for flood management in southern Kolkata. Unfortunately, much of the river is now clogged with untreated sewage and pollutants, posing serious ecological threats, particularly during monsoon floods, which severely impact marginalized communities living along its banks. In a deltaic city like Kolkata, safeguarding rivers like Adi Ganga is crucial for urban survival and ecological heritage. The story of Adi Ganga represents a fascinating blend of history and cultural legacy and ecological transformation, conformed by ongoing man-nature interfaces influenced by sociopolitical factors. Examining these narratives through a historical lens can provide insights for urban planners and ecologists, highlighting the importance of cultural-ecological resources and their intangible heritage. The narrative relating to the River Adi Ganga, from mythology to modern-day memories, can guide discussions on urban water sustainability and encourage interdisciplinary approaches to creating practical solutions for river management.

The situation of Adi Ganga, which has transitioned from a place of pious importance to a negotiated waterway and a refuge for displaced people, illustrates her cultural evolution and significance. This

complex realm of water regime, influenced by diverse socio-political relationships, was examined by environmental science communities and heritage practitioners in the times of conflict of having metro railway corridors on the river. This river spine has been a matter of attention due to many interventions backed up by political prowess (Bhattacharya, 2023) and caused a massive environmental and physical degradation around it (Miraftab, 2004).

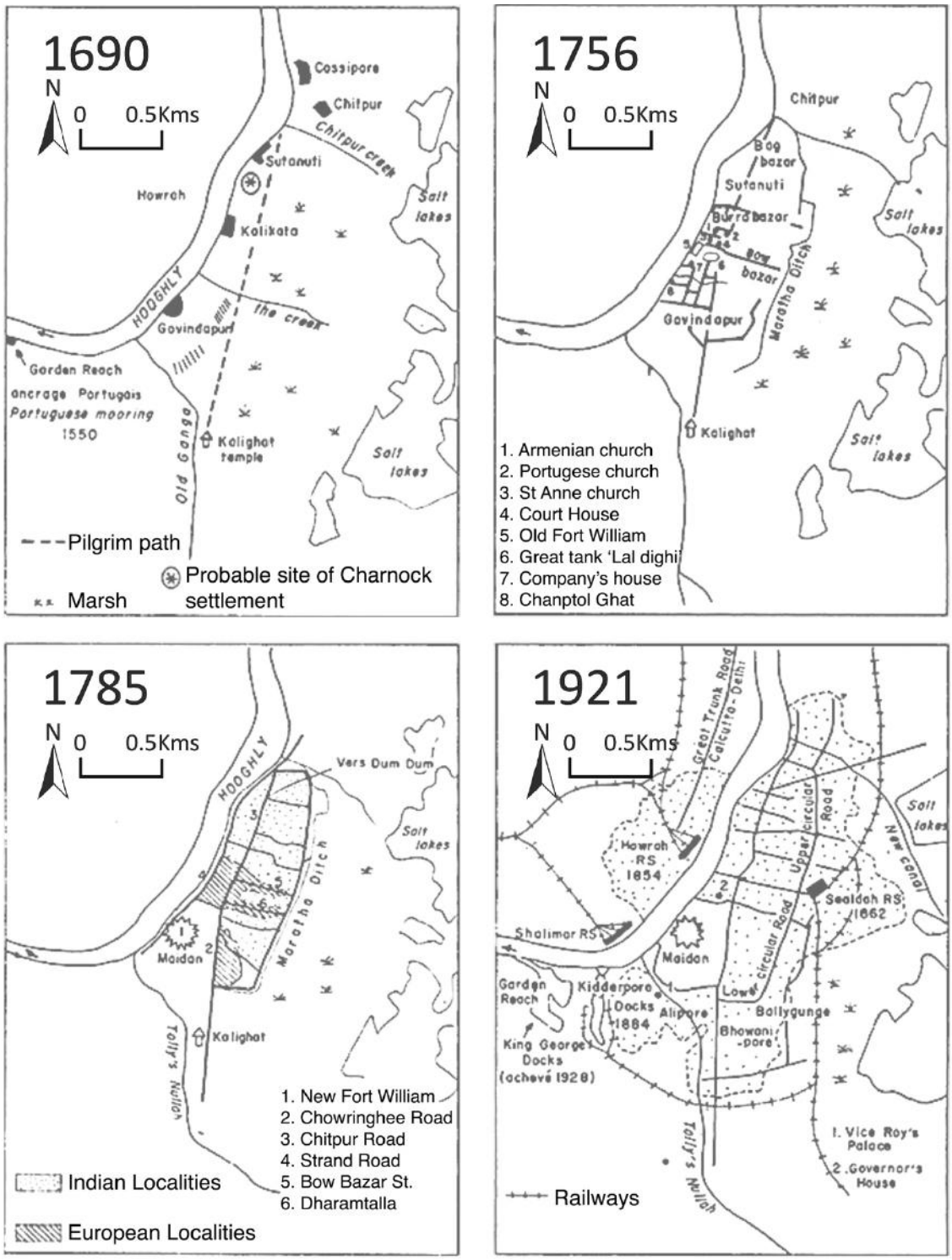


Figure 2: Chronological evolution of Adi Ganga river (Prepared from Munshi, S.K., The Genesis of the Metropolis')

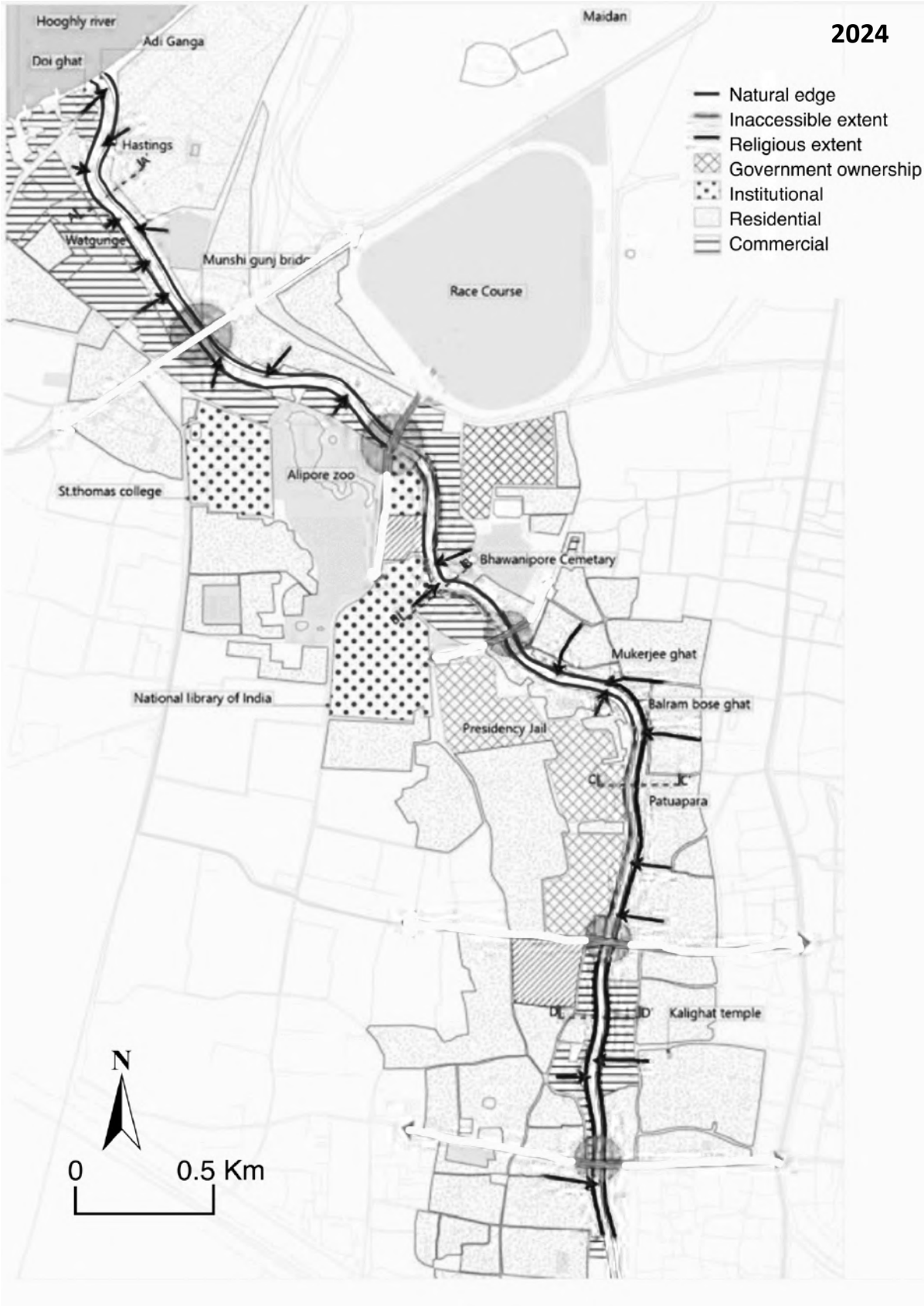


Figure 3: Current setting of Adi Ganga River (Prepared from Centre for Environmental Planning and Technology Portfolio "Adi Ganga")

2. Contemporary challenges surrounding Adi Ganga

2.1. Environmental unawareness

The challenge of revitalizing Adi Ganga hinges on its dual identity shaped by cultural and governmental influences. Kalighat, a highly populated area in Kolkata, developed around the Kali temple—an important Hindu pilgrimage site located by the river. The sacredness of the area has transformed the river into a communal space for disposing of flowers, incense, and ritual offerings, while also accumulating sewage in this urban setting. Metro pillars stretched along Kudghat area have disrupted the flow and quantum of water in the river (Livingwatermuseum 2024) and reinforced its perception as a nullah among locals, leading residents to discard their daily waste there, rationalizing their actions by claiming the river is already polluted. The Kolkata Municipal Corporation (KMC) has launched awareness campaigns, erecting banners along the banks to prohibit activities like drinking, storing, or using the river water, as well as dumping garbage and engaging in religious practices, but these efforts have had little impact.

2.2. Pollution

The rapid urban conglomeration along the Adi Ganga channel, combined with the erected metro railway piers (Roy, 2020), has made this British era aquatic drainage system incapacitated for drainage flow, transforming this vital canal into a repository for contaminated waste. The Kolkata Environmental Improvement Investment Programme report on the chemical analysis of Tolly's Nullah (KEIIP, 2018) indicates that over the past few years, there have been high to moderate levels of biochemical oxygen demand (BOD), chemical oxygen demand (COD) and coliform in the water (Roy, 2020). The stretch of Adi Ganga across the temple area of Kalighat has been identified as the most unhealthy and toxic area, exhibiting the highest cumulative coliform count throughout the tidal cycle (Bhattacharya, 2023).

Figure 4: Multiple urban ecological and development challenges for Adi Ganga. Source (left to right: Banerjee, Debika and Bhattacharya, Sreyashi; Getty Image; Banerjee, Debika and Bhattacharya, Sreyashi)

2.3. Erection of metro railway corridor on canal bed

In 1999, the state government proposed the implementation of an overhead corridor for metro railway along the canal bed (Figure 4) from Tollygunge crossing to Garia railway station. This made leading environmental activists of Kolkata criticizing the project due to adverse impacts it could have on the canal's aquatic regime and society at large. A petition, though made by activist Subhash Dutta in the High Court of Kolkata it was overruled to commence on the project under Section 11 of the Railways Act 1989 (Pattnaik, 2022).

The consequences of the metro rail project on the river have led to a gradual decline in activism aimed at reviving Adi Ganga, which many activists have deemed "dead." This construction obstructed the inherent flow of the river, and the accumulation of construction debris, city-sewage, and silt has overwhelmed the age-old drainage system that was originally devised to manage 100mm of water per day (Bhattacharya,

2023). Currently, during heavy rains and tropical cyclones that can bring up to 200mm of rainfall, flooding occurs more easily (Chatterjee, 2020). Additionally, many squatter settlements have moved to other areas along the same river flow, which has encroached into ecologically vulnerable spaces (Bhattacharya, 2023). Currently, approximately 49,000 people live in slums along Tolly's Nullah (Bhattacharya, 2023), accounting for nearly 20% of the local population (Mukherjee and Bardhan, 2021), leaving them in a precarious living situation.

4. Study aim and objectives

The primary focus of the research is to comprehend the current ecological challenges faced by the river and its surrounding urban eco-cultural setting. Furthermore, how the findings could be leveraged to reviving the ecological prowess of the river to develop urban climate resilience of Kolkata.

To create this understanding the following objectives are set as following,

- Archival research from colonial accounts and municipality documents to find the history of the river and its socio-political transformation.
- Study of urban transformations through digital tools to understand the ecological challenges and scope areas for reversion.
- Interpreting the findings to empower climate resilience associated with river ecosystem.

5. Method and tools

The current study is comprised of two segments. The first part explores the historical and geographical significance of the river to understand the factors contributing to its current condition. The second part conducts an environmental analysis of the landscape context of the river in immediate vicinity to examine the impact of climatic factors on socio-cultural connectedness of the city with the river. This takes into account many spatio-temporal factors such as land use and land cover changes, green cover variation and effective changes in temperature. The understanding of this dynamic relationship helps in strategizing the resilience planning for the river and its associated landscape.

The study relied upon published works of academicians, newspaper articles, archival data and a few literary works from medieval and current authors for extracting key data. Arc GIS is used to create maps and analyse the urban climatic woes of the river surrounding area in discussion.

6. Analysis

The current study is stretched over a unique span of 10 kms starting from its beginning point from Hooghly River to the area in proximity to Hindu pilgrimage site of Kalighat temple and crematorium. This stretch is steeped with and conformed by multitude of spatio-temporal influencers such as its colonial past, multi-cultural legacies, religious connotations, socio-economic transformations and environmental modifications sustained over centuries (Paul, 2020). Despite its utter significance for religious association and spiritual values it is yet to be considered as significant natural-cultural asset in mainstreaming resilience development for the city of Kolkata. The current condition is the outcome of many years neglect to preserve the river and its natural landscape system. The river has turned into backyard of the city where the sacred value is challenged by degraded visuals of sewage discharge, dumping of waste, unauthorised building activities encroaching into the river's fluvial plane. Thus, it is essential to preserve the cultural and natural heritage values of this blue-green spine of Kolkata to reconstituting urban resilience leveraging natural resources.

ICOMOS has established guidelines for Heritage Impact Assessment (HIA) (ICOMOS, 2011) applicable to cultural heritage sites globally. One notable guideline from the International Network for Cultural Diversity emphasizes Cultural HIA, focusing on both tangible and intangible elements as part of a sustainable development strategy. This guideline helps the current study with a value assessment process that begins by evaluating the cultural and natural heritage components ingrained with the river corridor.

The various analyses of reading the increase in built land cover (Figure 5), sharp decrease in natural green spaces (Figure 6) and rise in temperature in surrounding urban areas (Figure 7) showcases the river's ecological evolution and transformation impacting the city's resilience system. The current owes are human induced climatic changes. The city wide unprecedented rapid urban boom, 34% increase in the built-up area significantly reducing 25% of the natural green cover of the city and resulting into increased temperature regime. The river surrounding has no escape from it but shrinking within her narrow fluvial bed.

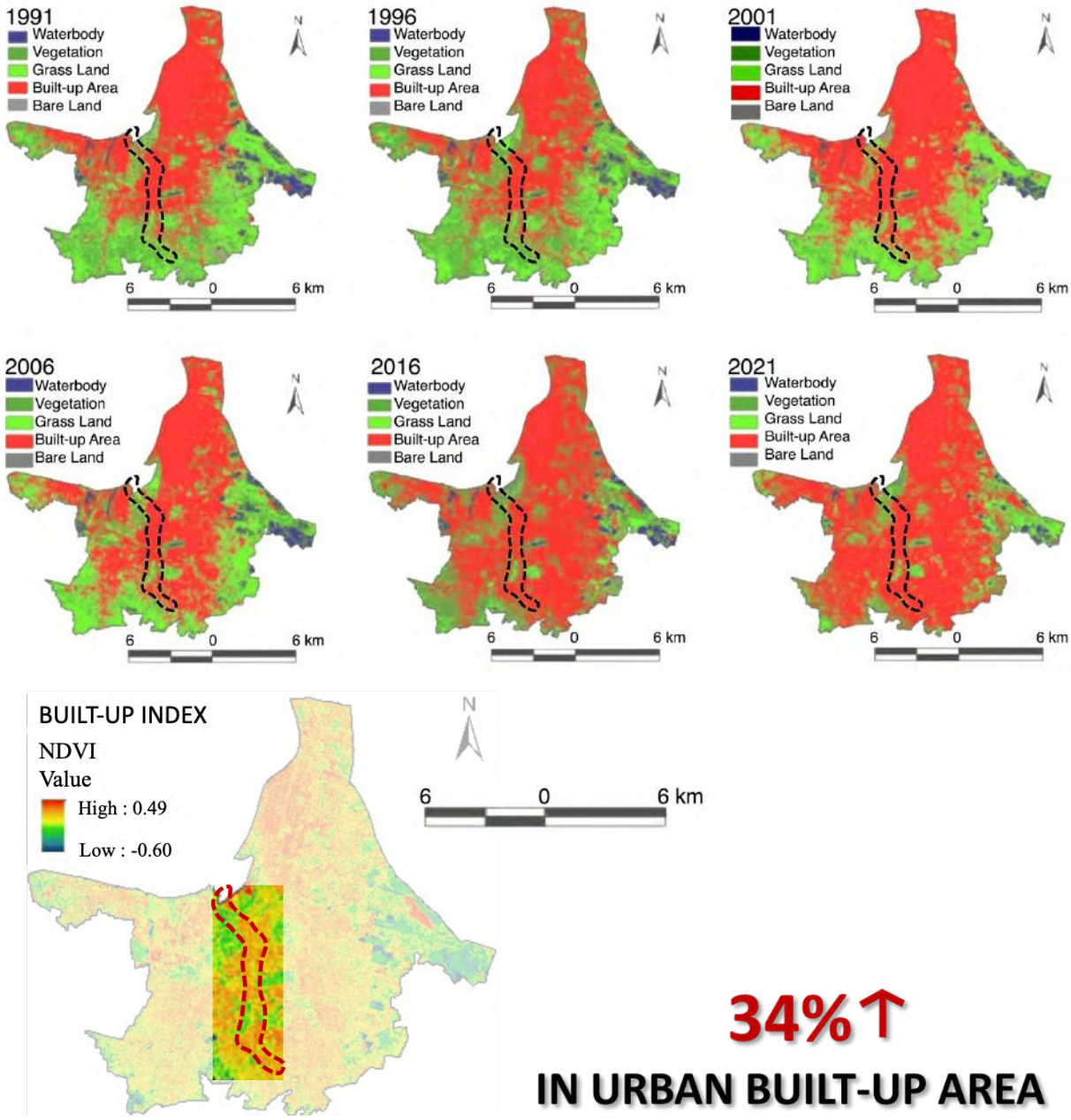


Figure 5: NDBI around Adi Ganga and Kolkata city. (Source: Kolkata Metropolitan Development Authority)

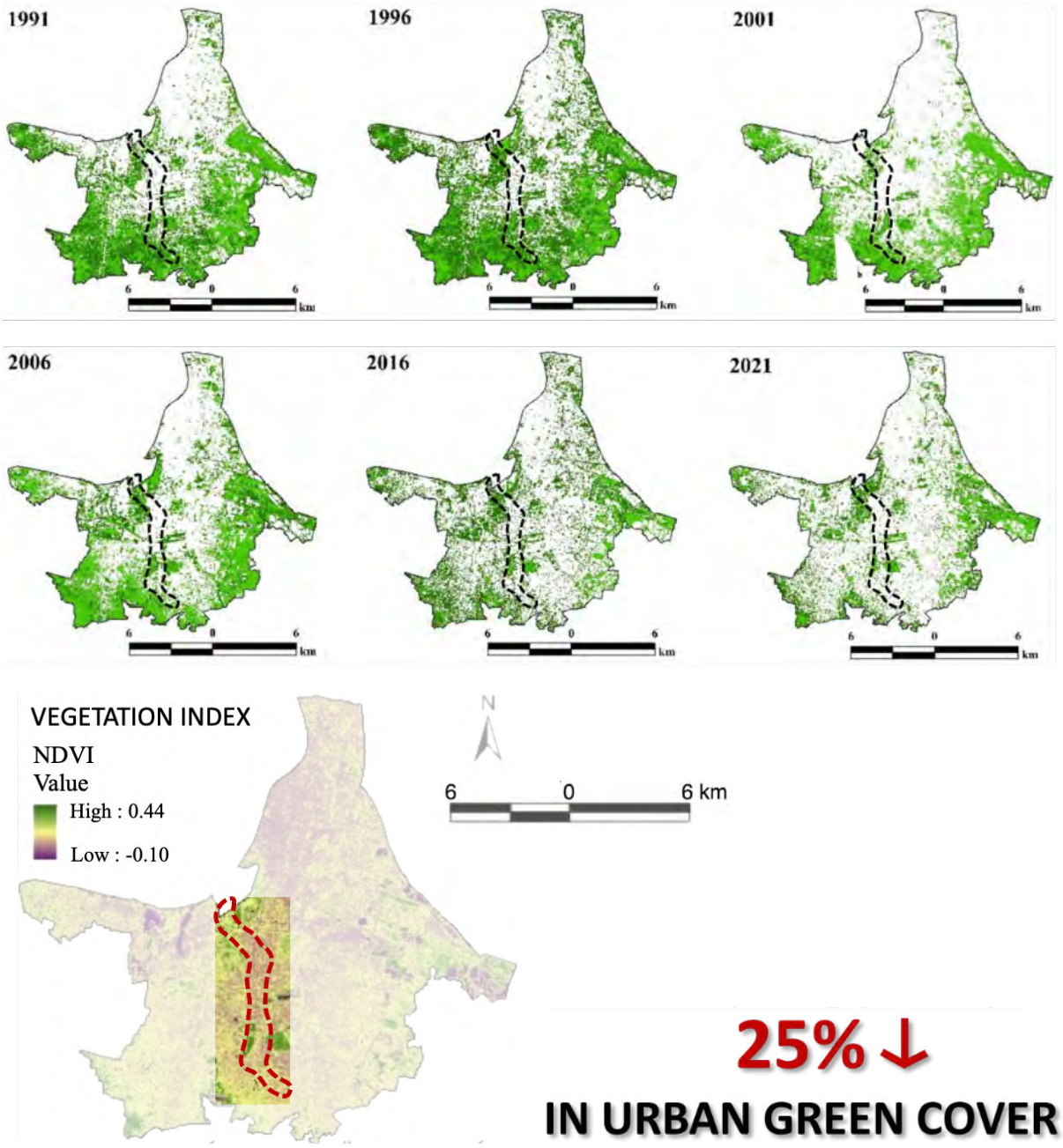


Figure 6: NDVI around Adi Ganga and Kolkata city. Source: Kolkata Metropolitan Development Authority

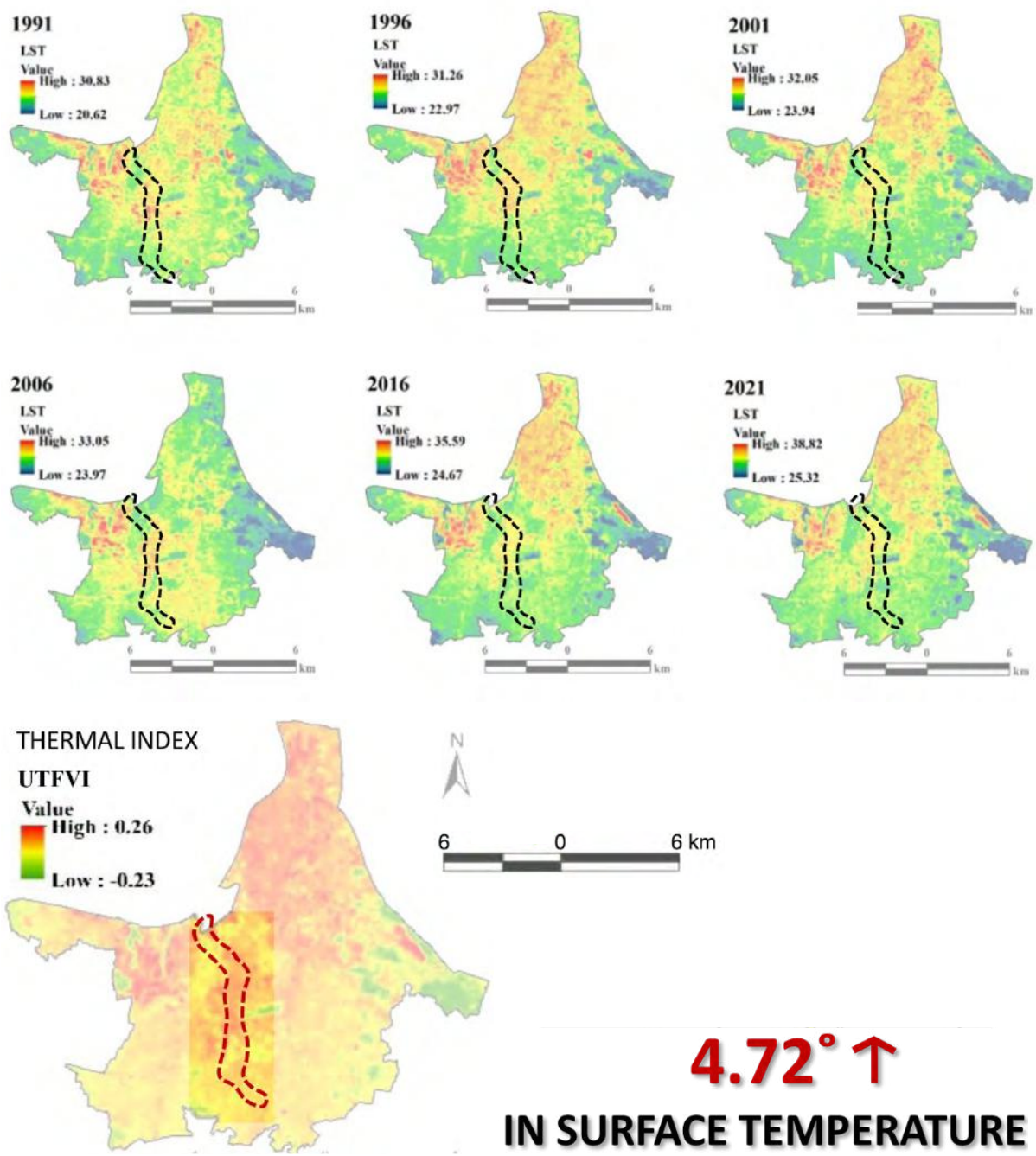


Figure 7: Land surface temperature around Adi Ganga and Kolkata city. Source: Kolkata Metropolitan Development Authority

7. Results and discussion

7.1. Landscape toolkits for climate resilience

Despite having significant environmental discourses in the blue-green spine of Adi Ganga, efforts to declutter her from encroachment are yet to meet success. Stakeholder's participation and community engagement are instrumental to connect environmental resilience with socio-cultural resilience encircling the river (Livingwatermuseum, 2024). Connecting the appropriate dots of nature-based solutions and

ecosystem-based adaptation fulfilling UN SDGs on environment and cultural embedded development the lost glory could be rediscovered that Adi ganga once boasted.

The offsetting of environmental adversities could be achieved by strategizing mitigation measures (Figure 8). These measures enhance the management plan's effectiveness, promote equitable urban development, and support heritage conservation. Additionally, their positive effects can facilitate resource allocation for compensation and strengthen spatial planning strategies to meet current socio-economic needs while safeguarding culturally significant natural sites. In terms of Environmental Impact Assessment (EIA), mitigation measures encompass a range of strategies, including those aimed at preventing or removing impacts, reducing negative consequences, and compensating for unavoidable effects (Davidson, 2006).

Figure 8: Process of resilience development strengthening Adi Ganga blue-green spine

- Establishment of a designated area for ritual activities.
- Removal of encroachments along the riverbank.
- Installation of a water filtration tank for purification.
- Capping off illegal sewage channels created by encroachers.
- Creation of dedicated spaces for community activities.
- Designated zone for immersing the idols to prevent contamination of water from various chemical based paints.
- Provide distinctive features for the artisans' community to invest in local trade counteract pressure of urbanization and upkeeping the heritage of the place.
- Develop a sustainable accessibility and mobility strategy to connect the Adi Ganga spine with rest of the city as origin destination dynamic (Figure 9).
- Develop sensitivity on both traditional as well as modern housing through educational initiatives aimed at preserving cultural inheritance of the local place.
- Develop sustainable remodelling and restructuring plans to maintain various designated historical structures, facilitating the adaptive reuse of heritage sites while protecting the Adi Ganga area.
- Implement strategic planning to enhance the intangible heritage of the region by supporting local traditions, customs, and cultural events in the central and surrounding areas of Kalighat.

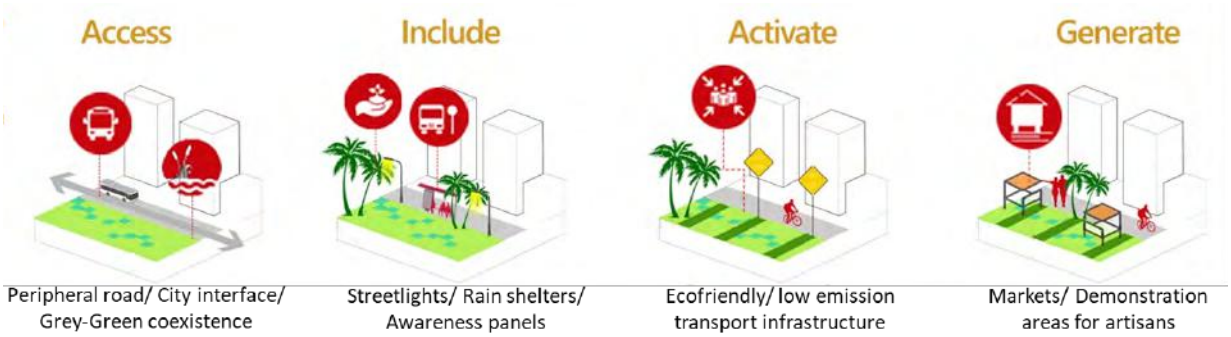


Figure 9: Mobility toolkit to connect Kolkata's urban population and Adi Ganga eco-cultural landscape spine

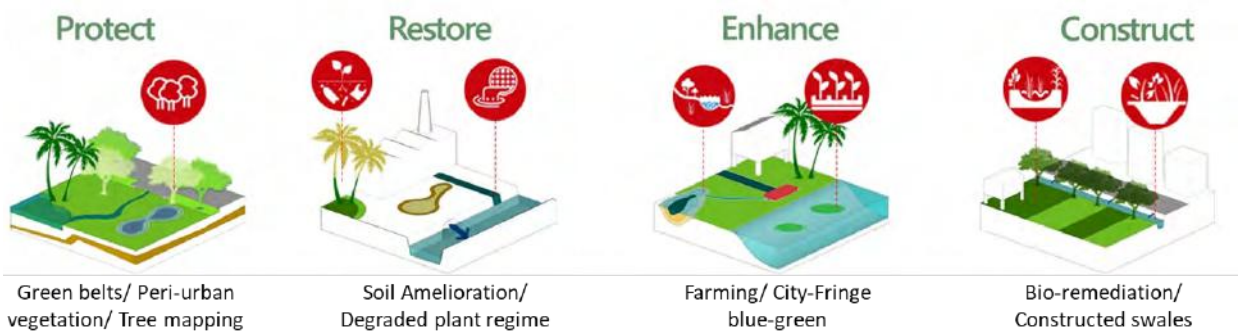


Figure 10: Nature-based urban green management toolkit along Adi Ganga eco-cultural landscape spine

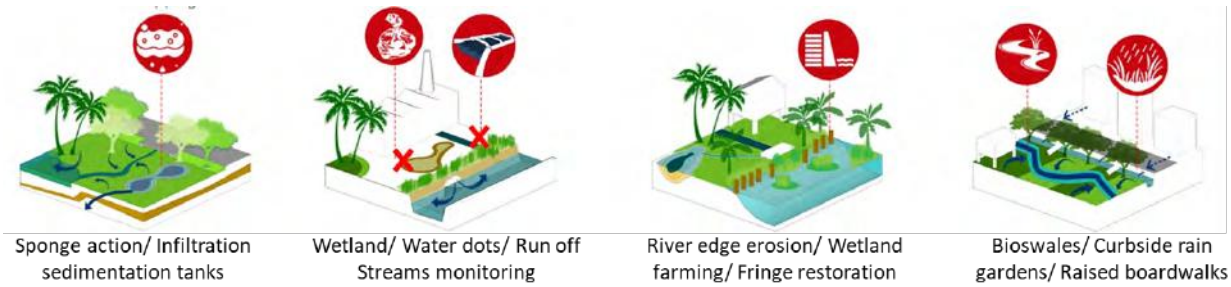


Figure 11: Nature-based urban blue management toolkit along Adi Ganga eco-cultural landscape spine

Figure 12: Community toolkit to build self-sustainability and culturally inclusive eco-sensitive society

With a comprehensive understanding of interconnected toolkit Adi Ganga could regain the natural strength for her cultural revival. The protective measures for natural landscape zones and buffers, creating awareness on cultural tradition and its critical features specific to the place could constitute a resilient

future for the river and in turn the city of Kolkata. The following methods could be adopted to forging environmental resilience,

a) Natural ecosystem restoration for environmental resilience- nature based methods (Figure 10 and 11) are proposed in this approach to restore the ecological value of Adi Ganga blue-green spine. In order to achieve this the Adi ganga spine is required to be prepared for natural disasters and climatic changes. Optimizing the natural buffer areas wherever feasible, allowing for more absorption and flood water negotiation can enhance its capacity for resilience. Implement nature-based solutions and ecosystem-based adaptations for restoring the urban biodiversity of the area. This would improve and enrich the quality of landscape and natural habitats around Adi Ganga.

b) Cultural and natural heritage conservation for social resilience- historical and cultural elements are two key pillars to build social resilience (Figure 12). The ritual paths leading to the ghats from neighbourhoods could be prioritized to re-establish the lost physical connection with water. Using urban design and reformation tools to re-establish the historicity of the place. Creating cultural tourism awareness and which would help in turn raise awareness toward the cultural and natural assets.

7.3. Sustainable heritage-based tourism curation

The development of various sustainable tourism models occurs at different times (Butler 1999). According to the World Tourism Organization, sustainable tourism addresses the needs of tourists, local trades and ecosystems while considering its current and anticipated socio-cultural, socio-economic and environmental impacts (Jennings, 2007). It aims to generate ongoing revenue and job opportunities for local communities while reducing negative effects on cultural and natural heritage. Through effective management, UNESCO's World Heritage and Sustainable Tourism program (UNESCO) emphasizes that tourism should be responsible for preserving cultural and natural heritage and fostering self-sustaining development. This calls for attention and critical judgement on the process of minimizing environmental risks that entails understanding of resilience potential of natural landscape systems of Adi Ganga.

A real ground strategy is the need of hour to forging resilience where these diverse transformations could be reversed to reshape the river's future. Engaging with relevant stakeholders, identifying sustainable funding mechanisms, setting of key performance indicators under by effective driving influence could write this success story. The river's culture, her nature are still thriving in this severely diminished conditions emanating the story of revival, resurfacing and reinvigoration.

8. Conclusion

The intricate cultural-ecological dynamics of the Adi Ganga blue-green spine highlight the need for solutions that consider the diverse perspectives involved in the decision-making process. Historical and cultural ecological studies of Adi Ganga reveal how the river has been shaped by socio-political changes, often manipulated by colonial powers and state authorities while marginalizing the ecological stewardship of the natural assets intermittently available. Addressing the river's revival cannot be simplified to the broad goal cosmetic beautification approach. This tends to overshadow the vital contributions of ecological landscapes connected to the river which is in vulnerable state.

To effectively rejuvenate Adi Ganga, it is essential to understand her historical significance and ecological heritage, formed through various interactions over time. The complex relationships between human and non-human elements along the river illustrate the dynamic interactions among stakeholders. By compiling and analysing historical records, as well as contemporary narratives from often-ignored stakeholders, we

can gain a comprehensive appreciation of the river Adi Ganga as integral component of Kolkata's yet thriving blue-green infrastructure (Mukherjee, 2022) paving the way for informed action policies.

Given the ongoing degradation of Kolkata's flood management and climate change vulnerabilities, it is vital to confront the impacts of the paleo-channel of Adi Ganga. Addressing these issues requires rejecting the colonial view that diminished the ecological resilience values of South Asian rivers undoing colonial hydrological practices. Restoring Adi Ganga's ecological potential cannot merely be a trendy phrase; it must involve addressing current socio-economic challenges with a profound scientific understanding. Shifting from a politicised and colonial perspective to embrace traditional legacy based knowledge system and multi-disciplinary approaches (Bhattacharya, 2023) can reveal the diverse possibilities for revitalising Adi Ganga, recognising the importance of various worldviews in river management (Escobar, 2020).

These strategies and toolkits reflect the unique river related knowledge of India and southern Asia at large (Bhattacharya 2023), enabling a move towards culturally and ecologically sustainable future by overcoming administrative biases. This can be achieved by examining river-society interactions from multiple scales and fostering collaboration between technical experts and regional stakeholders, leading to a sustainable natural heritage preservation and management strategies for urban areas in Kolkata.

4. References

Bandyopadhyay, S. (1996) 'Location of the Adi Ganga palaeochannel, South 24 Parganas, West Bengal: a review' *Geogr. Rev.* India. 58, p93–109.

Butler, R.W. (1999) 'Sustainable tourism: a state-of-the-art review'. *Tour Geogr*, 1, p7–25.

Chatterjee, A. (2020) 'The Cyclone Amphan and Its Impact in the City Kolkata', *Medium*, 13 June [online]. Available online at: https://medium.com/@anjan.chatterjee/the-cycloneamphan-and-its-impact-in-the-city-kolkata-c63aadc51dfa (accessed 31 October 2024).

Davison, R. and Galbraith, C. (2006) *Farming, forestry and the natural heritage: towards a more integrated future*. Scotland: The Stationery Office.

D'Souza, R. (2006) 'Water in British India: the making of a colonial hydrology'. *Historical Compass,* 4, p621-628.

Dwivedi, M and Sharma, M (2022) 'Ancient Indian Knowledge Given by River Ganga: A Study'. *Journal of Positive School Psychology*, Vol. 6, no. 3, p. 5684

Escobar, A. (2020) *Pluriversal Politics: The Real and the Possible*. Translated by David Frye. Duke: Duke University Press.

ICOMOS. (2011) *Guidance on Heritage Impact Assessments for Cultural World Heritage Properties*. Paris: World Heritage Centre.

Jennings, G. (2007) 'Water-Based Tourism, Sport, Leisure, and Recreation Experiences'. Routledge

Kolkata Environmental Improvement Investment Program. (2018) Sewerage and Drainage Network, KEIIP, Kolkata.

Lahiri-Dutt, K. (2015) 'Towards a more comprehensive understanding of rivers' in *Living Rivers, Dying Rivers,* eds R.R. Iyer. New Delhi: Oxford University Press.

Living Water Museum (2017) Adi Ganga: enmeshed water heritage of Kolkata, viewed on 6th October 2024

(https://www.livingwatersmuseum.org/adi-ganga-enmeshed-water-heritage-of-kolkata)

Mani, Vettam (2015-01-01) Puranic Encyclopedia: A Comprehensive Work with Special Reference to the Epic and Puranic Literature. Motilal Banarsidass.

Munshi, S.K. (1990) 'The Genesis of the Metropolis' in *Calcutta 1981: The city, its crisis and the debate on urban planning and development*, eds J. Racine. New Delhi: Oxford University Press.

Mandal, A. (2018) 'Myth and reality of the Adi Ganga: a paleo distributary of the Ganges in West Bengal, India'. *International Journal of Applied Social Science,* 5(8), p1347-1353.

Miraftab, F. (2004) 'Invited and invented spaces of participation: neoliberal citizenship and feminists' expanded notion of politics'. *Wagadu,* 1, p1–7.

Mukherjee, J. (2022) 'Living systems infrastructure of Kolkata: exploring co-production of urban nature using historical urban political ecology (HUPE)', *Environ*. *Urban,* 34, p32-51.

Mukherjee, A. B. and Bardhan, S. (2021) 'Flood vulnerability and slum concentration mapping in the Indian city of Kolkata: a post-Amphan analysis'. *Water Science*, 35, p109–126.

Pattanaik, S and Sen A. (2022) 'Regional Political Ecologies and Environmental Conflicts in India', Routledge.

Paul, S and Bardhan, S. (2020) *'Integrating a heritage river in the urban form through landscape interventions: studies on Adi Ganga, Kolkata'. ISUF: Cities in the Twenty-first Century.*

Roy, Anirban. (2020) *'Urban Transport Development and Environmental Issues: A Perceptive Study along the First Phase Extension Site of Metro Railways in Kolkata', Pratidhwani the Echo. Department of Bengali, Karimganj College, Assam, p149-159.*

UNEPWTO (2005) Making tourism more sustainable: a guide for policy makers. PA Tourism Policy.

Research Paper

Resilience Strategies of Chinese Unit Communities for Addressing Climate Change Risks

A case study of Harbin's historic industrial district

Zhuolin TAN, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, Harbin Institute of Technology, China

Yuan YUAN, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, Harbin Institute of Technology, China

Shuyu HUANG, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, Harbin Institute of Technology, China

Wei DONG, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, Harbin Institute of Technology, China

Abstract

The unit communities have challenges adjusting to the increasing requirements of urban expansion and suffer from ageing and neglected infrastructure that is inadequate for dealing with the growing risks caused by climate change. Community resilience is a collection of abilities that enable communities to effectively predict, adapt to, and recover from multiple hazards. This study combines field research and a literature review to identify the characteristics of unitary communities and to analyse the current problems and climate risk factors at both the objective built environment and subjective initiative levels. Then, we construct a unitary community resilience assessment system from the dimensions of community capital and residents' capacity, based on community resilience theory and previous resilience assessment studies, and use various assignment techniques to determine indicator weights. In addition, this study selected Harbin, a former industrial centre of China, as a representative city and selected 3 unit communities for the questionnaire survey. Finally, this study suggests three key strategies for improving community resilience and coping with climate risks: clarification of tenure matters, incremental renewal of community spaces, and revitalization of the communal character of community residents. Providing strategies and guidance to promote resilient responses to potential risks in unit communities.

Keywords

Community resilience, Post-unit system, Risk management, Resilience evaluation

0. Introduction

The "unit community," as a mode of living space organisation in China during a specific period, played a significant role in the early stages of urban development. It has the historical significance of witnessing the transformation of China's socio-economic system and the academic value of interpreting urban development and transformation. However, the "unit organisation" development model has progressively disintegrated due to the changes in the socio-economic system. The community's operating mechanism as the fundamental social and spatial unit of the city was forced to change during the process of de-embedding it from the unitary organisation. During the process of "re-organisation," the community's social structure and spatial patterns have taken on a more unique identity.

1. Characteristics of unit community and climate risk factors

1.1. The concept of the unit community

In the early days of the founding of the People's Republic of China, China established a vertical linkage control mechanism of "state-unit-individual" and a honeycomb-shaped "unit system" social structure based on the Soviet Union's planned economic system and social development model. With the continuous development of industry, the "units" in cities have continued to expand and have begun to have complex functions such as production, circulation, consumption, education, and management, forming unit communities(Luo et al., 2018, Yuan and Jin, 2021, Beatley and Newman, 2013). After the Reform and Opening-up, China transformed from a planned economy to a socialist market economy, and the unit system gradually disintegrated in the process of resource allocation and social structure change. In the late 20th century, the operation mechanism of urban communities began to be reconstructed, but there are still many "unit system" community spaces in cities, and the "unit" function still exerts its influence and role.

1.2. Characteristics of the unit community

In the process of disembedding from the unit organization, the operating mechanism of the unit community as the basic social space unit of the city has been forced to be reshaped. Its social structure and spatial form need to be reshaped, forming a relatively unique community feature(Aiken, 2012, Kelly et al., 2015, Norris et al., 2008). Different from general communities, its distinctiveness is primarily evident in spatial arrangement, functionality, resident identity, and historical significance, leading to spatial concentration and complexity, functional autonomy and exclusivity, diversity in resident interaction and identity, and unique historical attributes.

The production and residential areas in unit communities are typically in close proximity or interdependent. The communal areas frequently manifest as enclosed courtyards, delineated from exterior environments by walls. The courtyard areas are meticulously designed and systematically organized. The community's buildings generally exhibit an enclosed configuration, with internal amenities organized along a cross-axis, while ancillary services like commerce, education, and healthcare are allocated along this axis. This enables unit personnel to satisfy their need for production, sustenance, and recreation.

Furthermore, the functions of unit communities possess a degree of autonomy. They have autonomous management and building planning authority and are not integrated into the overarching urban planning system, enabling the residents to benefit solely from the available resources(Berkes and Ross, 2013, Meerow et al., 2016, Huang et al., 2022, Liao et al., 2022). Nonetheless, this autonomy also has considerable adverse effects when confronted with inescapable systemic changes. On one hand, following the dissolution of the unit system, the community experienced prolonged management deficiencies, resulting in a swift deterioration of public service facilities; on the other hand, the original residents struggled to adapt to the new community structure in a brief timeframe and exhibit minimal interaction with the newly arrived residents. Simultaneously, certain new residents experienced a deficiency in identification and belonging.

Nonetheless, the unit community, as a distinctive Chinese phenomenon, significantly influenced the initial phases of urban growth. It possesses historical relevance in observing the alterations in China's social structure and has academic worth in elucidating the evolution and transformation of Chinese towns. The prominent Soviet architectural style in many of Northeast China's former industrial centers possesses significant cultural preservation value.

1.3. Climate risk factors of the unit community

Owing to the above-noted features, unit communities experience both intense shock and continued impact from abrupt disasters and potential hazards that much surpass those encountered by ordinary communities. Field surveys of 23 unit communities in Northeast China's former industrial sector have identified various challenges these communities encounter due to the dissolution of the unit system and the reconfiguration of unit service facilities. Examine from the viewpoints of the objective environment and subjective initiative. Objective environment challenges primarily encompass irrational spatial configurations, deteriorating structures, obsolete infrastructure, insufficient service amenities, and disordered transportation networks. Basic surveys of community people reveal that concerns related to subjective initiative mainly encompass inadequate community management, an ageing population, poor educational and economic levels among residents, and a diminished understanding of catastrophe avoidance among the populace(Berkes, 2017, Li et al., 2022, Cumming et al., 2005, Li et al., 2018).

The unit community experiences intense shock due to its enclosed courtyard layout, deteriorating infrastructure, non-compliant auxiliary structures, disordered road networks, and spatial issues including deficiencies in community management and the absence of disaster response systems. When communities encounter abrupt natural disasters, such as floods and severe weather events (rainstorms, snowstorms, hurricanes, etc.), it hampers effective disaster management, including material storage, emergency evacuation, and repair and reconstruction efforts during risk occurrences. Moreover, outdated infrastructure and disorganized design can precipitate secondary disasters, including geological collapses, mob stampedes, and the descent of objects from elevated positions. The aforementioned issues have a continued impact on the unit community. The community, as the fundamental unit of the city, has exacerbated "urban diseases" including traffic congestion, housing shortages, inadequate water supply, environmental pollution, and disorder. Simultaneously, the aging population, declining sense of belonging among residents, and discordant neighborhood relations are susceptible to social risks such as income disparity and elevated crime rates (Figure 1).

Figure 1. Current situation of the unit communities in Northeast China. Source: Photograph by the author.

2. Research on community resilience in response to climate risks

Some researchers have determined that the meaning of community resilience may be broadly categorized into three characteristics based on their examination of current community resilience both domestically and internationally(Li et al., 2018, Bruneau et al., 2003, Carpenter et al., 2001, Carpenter et al., 2012, Fath et al., 2015, Allen and Holling, 2010, Holling, 1973). (1) It is a combination of multiple capabilities such as stability, recovery and adaptation. The community needs to have multiple capabilities such as robustness, redundancy, and rapidity at the same time, and cover the entire process before, during and after the risk occurs; (2) It is a comprehensive capability that is continuously improved during development, covering adaptability and response strategies in the face of various risks, and is a dynamic process of continuous evolution. A resilient community should be able to adapt to external changes in the long term and develop continuously. In the process of responding to risks, it has clear improvement capabilities in each stage from preparation, response, recovery to reconstruction; (3) Community resilience is the goal of sustainable development of the community. The ultimate goal of community resilience is to help the community itself be able to actively respond to sudden disasters and potential risks, and to build a sustainable and resilient living environment through the joint cooperation of residents, governments and non-governmental organizations.

In the same vein, the resilience traits that the community possesses are referred to as the characteristics of community resilience. In particular, it is a compilation of a variety of skills that the community possesses throughout the entire process of confronting hazards. Redundancy, robustness, diversity, adaptability, intelligence, and speed are among the resilience characteristics that have been summarized in existing research. In the context of community risk response, redundancy, resistance, and adaptation assume more significance. Redundancy signifies the surplus of diverse forms of community capital (such as infrastructure, resources, finances, and systems), serving as a precautionary measure prior to risk mitigation, thereby ensuring the community possesses adequate redundant capital to sustain its normal operations during adverse events; resistance pertains to the community's actions and reactions in the face of risks. The community can swiftly react by modifying its operational mechanisms to mitigate the adverse effects of the shock; adaptability encompasses the community's learning and feedback following the shock, enabling it to revert to its pre-shock state and enhance its resilience to unforeseen risks.

3. Construction of resilience assessment model for unit communities

3.1. Screening of community resilience indicators

This study filtered out an indicator library from two dimensions: community capital components and community residents' capacity variables that affect community resilience (Figure 2), based on the risk factors and community resilience characteristics encountered by the "post-unit system" communities. Over 20 specialists in pertinent study domains were chosen to do three rounds of indicator evaluation and selection to derive the final community resilience index(Lu et al., 2023, Folke et al., 2010, Walker and Salt, 2012, Walker et al., 2004). The components of community capital encompass the built environment, material capital, emergency response facilities, community infrastructure, and public service facilities. Meanwhile, the capabilities of community residents include community participation, neighborhood relations, social trust, residents' conditions, and community management. The dimension of community capital components identified four indicators: material space redundancy, service facility redundancy, emergency response facilities, and risk protection facilities, along with 22 associated descriptive indicators. The community resident capacity factor excluded five factors: human capital, risk response ability, social ties, resident engagement, and resident autonomy, together with 13 related descriptive indicators.

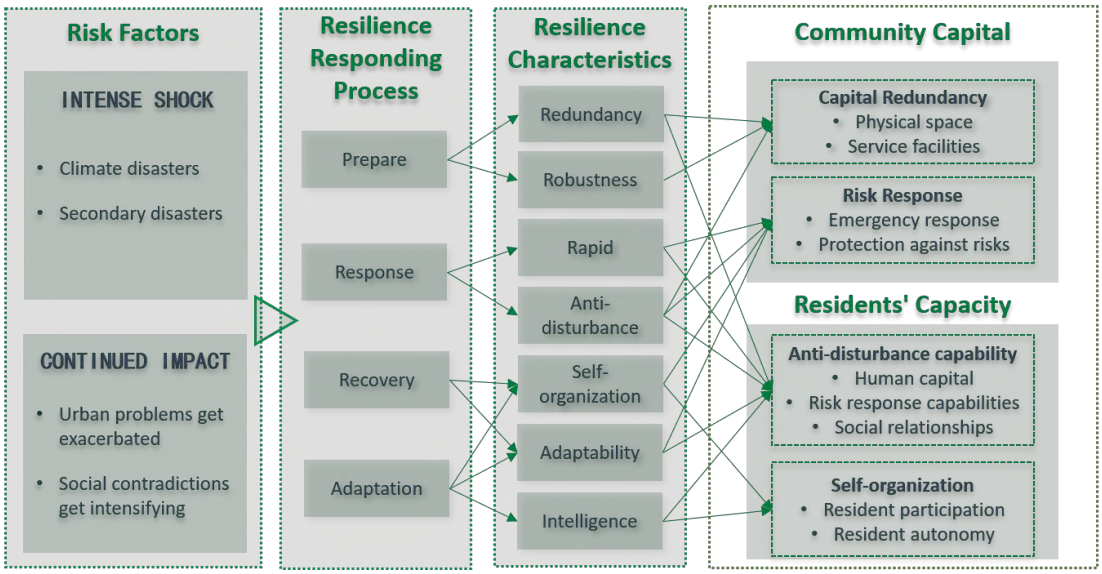


Figure 2. Related factors of community resilience indicators of the unit system.

3.2. Calculation of indicator weights

The study decided to use a combined weighting procedure to establish the indicator weights in order to prevent the evaluation results from being overly subjective. In other words, the evaluation model's hierarchical structure is built using the Delphi technique and the Analytic Hierarchy Process (AHP), and the Analytic Hierarchy Process and the Combinatorial Game Theory Algorithm (AHP-CGT) are then used to determine the final indicator weights(Folke, 2006, Godschalk, 2003, Turner Ii, 2010). The precise methodology of the combined weighting approach grounded in game theory is delineated as follows:

(1) Using x techniques to calculate indicator weights, any basic weight set is $P_k=(P_1,P_2,\cdots,P_x)$, and its linear combination formula is:

$$P = \sum_{k=1}^{x} \alpha_k P_k^T$$

In the formula, α_k is the linear combination coefficient, where $\alpha_k > 0$.

(2) To reduce the difference between P and P_k, the linear combination weight coefficient α_k is tuned. The formula is:

$$\min_g \| \sum_{j=1}^{n} \alpha_j P_k^T - P_g \|_2$$

In the formula, P_g is the basic weight set calculated by the g-th method.

(3) According to the differential properties of the matrix, the linear equations in the following formula are solved to obtain the optimal combination coefficients $\alpha_1,\alpha_2,\cdots,\alpha_x$.

$$\begin{bmatrix} P_1P_1^T & \cdots & P_1P_x^T \\ \vdots & \ddots & \vdots \\ P_xP_1^T & \cdots & P_xP_x^T \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \vdots \\ \alpha_x \end{bmatrix} = \begin{bmatrix} P_1P_1^T \\ \vdots \\ P_xP_x^T \end{bmatrix}$$

（4）The combination coefficient in the above formula is normalized, and the optimal combination coefficient α_k^* is obtained, which is then substituted into formula 1 to obtain the optimal combination weight P^*. Finally, the community resilience assessment model and indicator weights of the unit system are shown in Table 1.

Table 1. Resilience indicator system for unit communities in response to climate risks.

Dimensions	Primary indicators	Weight	Secondary indicators	Weight	Tertiary indicators	Weight
Community Capital	Capital Redundancy	0.17	Redundancy of physical space	0.58	Number and accessibility of disaster shelters	0.29
					Number of community interaction spaces	0.47
					Quality of buildings	0.24
			Redundancy of service facilities	0.42	Number of public service facilities for daily life	0.6
					Utilization rate of public service facilities for daily life	0.4
	Risk Response Facilities	0.22	Facilities of emergency response	0.74	The completeness of community water supply system	0.21
					The completeness of community power supply system	0.31
					The completeness of community lighting system	0.18
					The completeness of community fire protection system	0.3
			Facilities of protection against risks	0.26	The completeness of community sanitation system	0.05
					The completeness of community heating system	0.47
					The completeness of road system in the community	0.21
					The accessibility of roads around the community	0.27
Residents' Capacity	Anti-disturbance capability of residents	0.32	Human capital	0.18	Education level	0.37
					Health Level	0.21
					Income Level	0.16
					Age structure	0.26
			Risk response capabilities	0.31	Emergency response awareness	0.51
					Coverage ratio of medical Insurance	0.22
					Learning ability and sense of responsibility	0.27
			Social relationships	0.51	Social trust	0.34
					Neighborhood Relations	0.44
					Residents' sense of belonging	0.22
	self-organizing ability of residents	0.29	Resident participation	0.22	Active participation in activities	0.24
					Number of community prestige leaders	0.43
					Number of public discussion platforms	0.33
			Resident autonomy	0.78	Ratio of community managers	0.29
					Number of volunteer rescues	0.71

(Resource: Authors)

4. An empirical study on the resilience assessment of the unit communities in Harbin

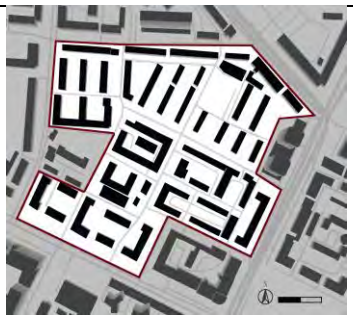
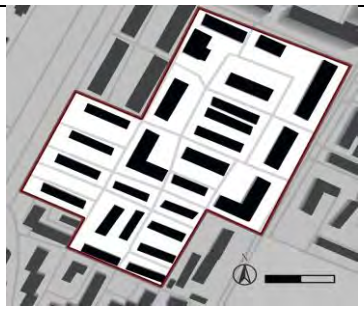
4.1. Research area and data processing

Harbin is a typical historical industrial region in Northeast China. The sector has advanced swiftly, resulting in the establishment of numerous work unit communities. The villages have characteristic Soviet-style elements in spatial organization, building configuration, and architectural design. During China's Reforms and Opening-up period, Harbin initiated the establishment of employee communities, incorporating Chinese traits into the original Soviet concept, leading to the emergence of row-style workers' housing. At this point, the distribution of typical unit communities has basically been fixed and has been preserved to this day. At the end of the 20th century, the development of the old industrial base in Northeast China entered a bottleneck period, the management power of public service facilities was transferred, and a large number of new commercial housing communities began to be built. Most communities have a spatial layout model of "demolishing the old and building the new" and "filling in every vacancy". The heterogeneity of the community has increased, and the aging of facilities and the lack of management have gradually evolved into a complex community where low-income, vulnerable groups and migrant workers gather (Figure 3).

Figure 3. Study area. Source: Drawing and photograph by the author.

This study identified DX, HL, and GLC communities as representative instances of unit communities. The three communities maintain numerous residential structures from the unit era, characterized by traditional courtyard-style elements, while also incorporating supplementary buildings following the unit conversion. Nonetheless, the three towns exhibit substantial differences in the spatial arrangement of public service buildings, border regularity, and courtyard enclosure techniques. The DX community exhibits poor management and unclear boundaries, the HL community demonstrates intermediate management but possesses numerous additional structures, while the GLC community showcases effective management, preserving the enclosed courtyard and spatial scale to the fullest extent. Table 2 presents the floor plans and feature analysis of the three neighborhoods.

Table 2. Analysis of the plan and characteristics of typical unit communities in Harbin

NAME	DX Community	HL Community	GLC Community
PLAN			
CURRENT SITUATION			
SPATIAL ENVIRONMENT	Semi-open community; irregular boundaries; courtyard-style enclosed building layout; chaotic internal road system; no clear public spaces; poor environment.	Semi-open community; relatively regular boundaries; row and enclosed building layout; narrow internal roads; public spaces available; average environment.	The community has clear walls, good privacy; well-defined boundaries; row and semi-enclosed building layouts; a relatively complete internal road system; spacious public spaces; and a slightly better environment.
SERVICES AND FACILITIES	There are a few commercial services within the community, located on the ground floor of the street-facing buildings.	There are many commercial services within the community, distributed throughout the community center.	There are no commercial service facilities within the community.
RESIDENT SITUATION	Residents have a relatively low level of education; income is low; the proportion of employees from the original units is relatively high.	Residents have a relatively low level of education; income is low; the proportion of employees from the original units is relatively high.	Residents have a low level of education; the aging problem is prominent; residents have a high income; the proportion of employees from the original units is relatively high.

The study conducted a questionnaire survey in 3 typical research areas, with 110 questionnaires distributed in each area, and a total of 303 valid questionnaires were collected, with an efficiency of 91.8%. The questionnaire content was divided into three parts based on the above-mentioned community resilience evaluation indicators: personal situation, built environment, and resident capabilities, with a total of 47 questions. The Likert five-point scale method (i.e., a scoring method of 1-5 points from low to high) was used to ask the respondents questions. The collected data was normalized by the min-max standardization method, and the collected data was weighted and calculated with the corresponding hierarchical indicator weights to obtain a comprehensive score. Finally, based on a five-point scale, the "post-unit system"

community resilience assessment results are divided into five categories on a hundred-point scale, namely poor, relatively poor, average, relatively high, and high.

4.2. Results and Analysis of Community Resilience Assessment

From the overall evaluation results, the average resilience of the three communities is 43.3 points, slightly higher than poor and at an average level. Among them, the resilience of the GLC community and the HL community is average, with total scores of 53.2 and 49.6 respectively, while the resilience of the DX community is at a poor level, with a total score of 27.2. It can be seen that community resilience has a strong relationship with the built environment. A good built environment can provide more material redundancy and complete risk response facilities, which is conducive to early preparation and timely response to risks. From the perspective of the dimension results (Figure 4), the community capital scores of the three communities are all lower than the resident ability scores, with an average difference of 12.9 points. The highest scores in both dimensions are in the GLC community, and the lowest scores are in the DX community; from the evaluation results of the four first-level indicators (Figure 5), among the average values of the first-level indicators of the three communities, the residents' anti-disturbance ability is the highest (14.8 points), and the material capital redundancy is the lowest (7 points). Among them, the residents' self-organization ability score of the GLC community is the highest, with 18.8 points, and the material capital redundancy of the DX community is the lowest, with 3.6 points; from the results of the nine second-level indicators (Figure 6), the scores of the second-level indicators of the three communities are basically similar, that is, there are obvious differences between the indicator scores. Among them, the scores of residents' autonomy, social relations and emergency response facilities are relatively high, and the scores of the other six indicators are all low, with the lowest score of residents' participation. In addition, HL community scored higher in service facility redundancy compared with the other two communities; finally, it can be seen from the scatter plot of the three-level indicator scores and weights (Figure 7) that the indicator scores and weights of the three communities show a relatively obvious linear relationship, the two are positively correlated, and most of the coordinate points are concentrated in the low weight-low score area, a small number are scattered in the high weight-low score and high weight-high score areas, and no coordinates fall in the low weight-high score area.

The unit community lacks public spaces with emergency risk avoidance functions and public service facilities to protect residents' daily lives, which results in the community's inability to provide sufficient material space redundancy and service facility redundancy, according to an analysis of the evaluation results of indicators at all levels and the current characteristics of the research area. When a function is harmed during risk-taking, the community operation mechanism cannot mobilize reserve resources to assure normal functioning due to the lack of redundancy. The safety of community members is at risk due to secondary risks including structure collapse, trampling, and material shortages, which are more likely to occur in unit communities that are subject to abrupt disasters like harsh climate. Furthermore, because of ambiguous property rights, disorganized management models, and unclear responsibility allocation in the unit community, private vehicles and mobile vendors seriously occupy road space, large garbage is strewn about randomly, and lighting facilities are dim, with the exception of lifeline facilities like water, electricity, and heating, sanitation, lighting, green space, and other facilities that are essentially unmanaged. It will be impossible to completely safeguard community members' lives and property when climatic hazards arise.

In terms of residents' capabilities, although the study area has a serious lack of material resources, community residents have relatively good social relations and resident autonomy. This may be because most of the residents in the study area are retired employees of their original units, have relatively familiar neighborhood relationships, and have a strong sense of belonging and trust in the community collective. When risks occur, they can actively respond to community calls and help each other among neighbors.

However, community residents lack a public discussion platform, and small repairs and activities in the community are basically organized by residents themselves, lacking funds and guidance from relevant personnel. In addition, due to the serious aging problem of community residents, most retired employees are at a disadvantage in terms of education and health levels, and cannot form redundancy in human capital when facing risks.

In conclusion, the primary issues with the resilience of the unit community are inadequate material capital redundancy, subpar community risk response infrastructure, and low resident resistance to disruption. One crucial issue that has to be resolved and improved is that these issues prevent the community from being completely ready and reacting quickly when faced with dangers. Although residents' ability to self-organize is a sign of some adaptability—that is, they have the potential to recover on their own following a risk—its evaluation score is low and still requires improvement.

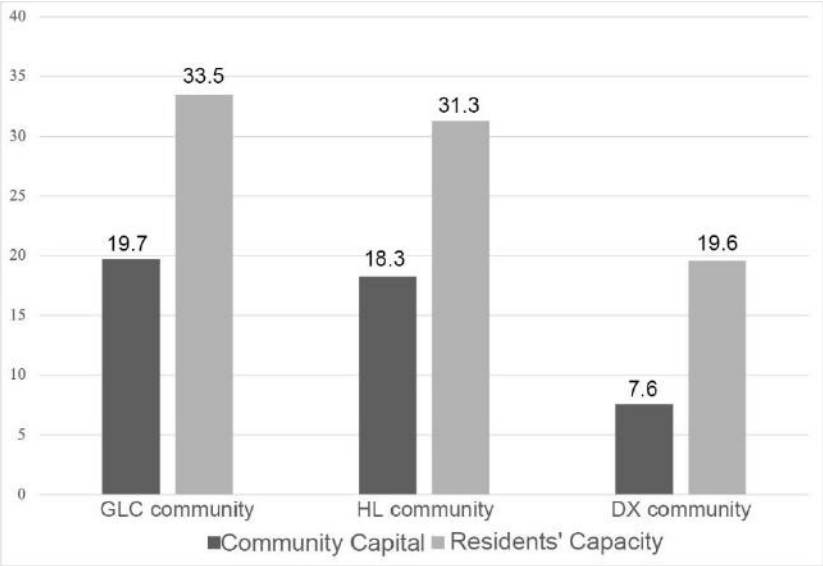


Figure 4. Scores of community resilience dimensions. Source: Drawing by the author.

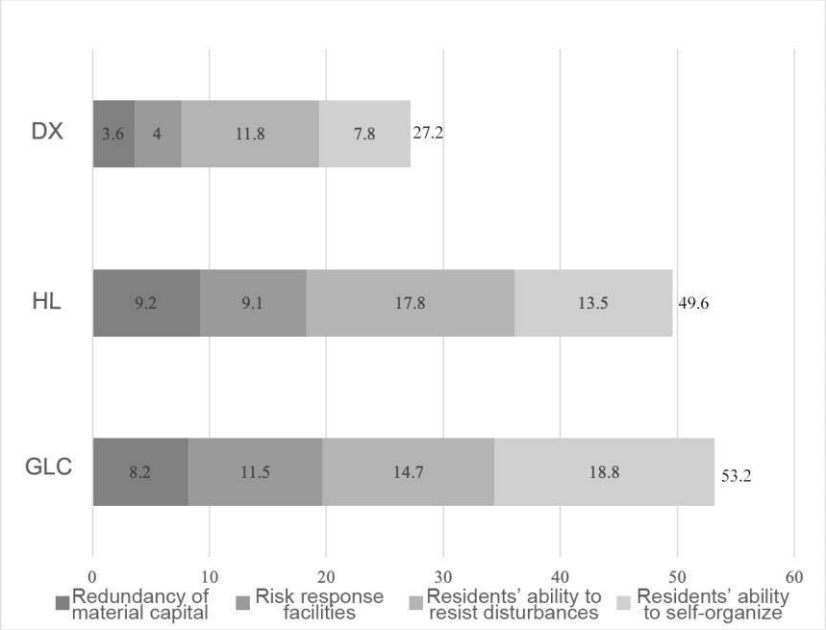


Figure 5. Scores of the first-level indicators of community resilience. Source: Drawing by the author

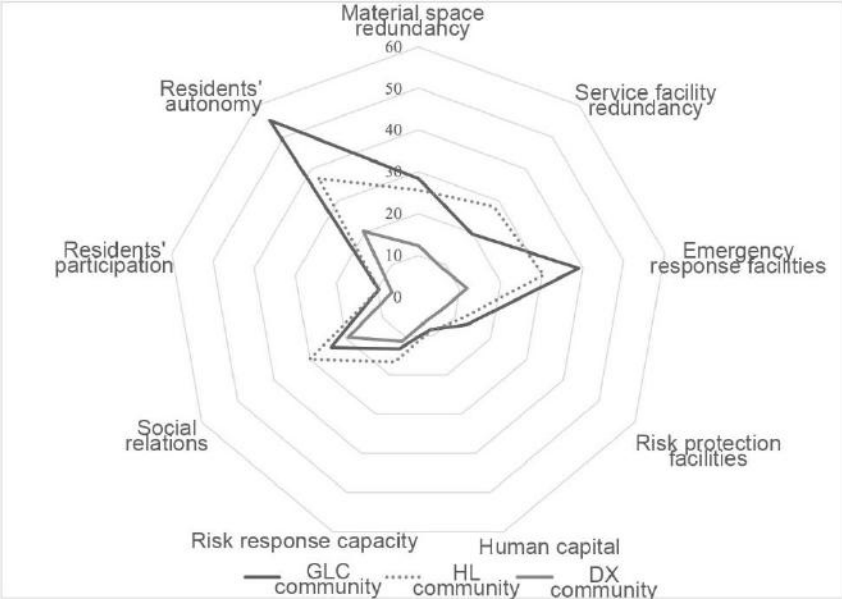


Figure 6. Scores of second-level indicators of community resilience. Source: Drawing by the author.

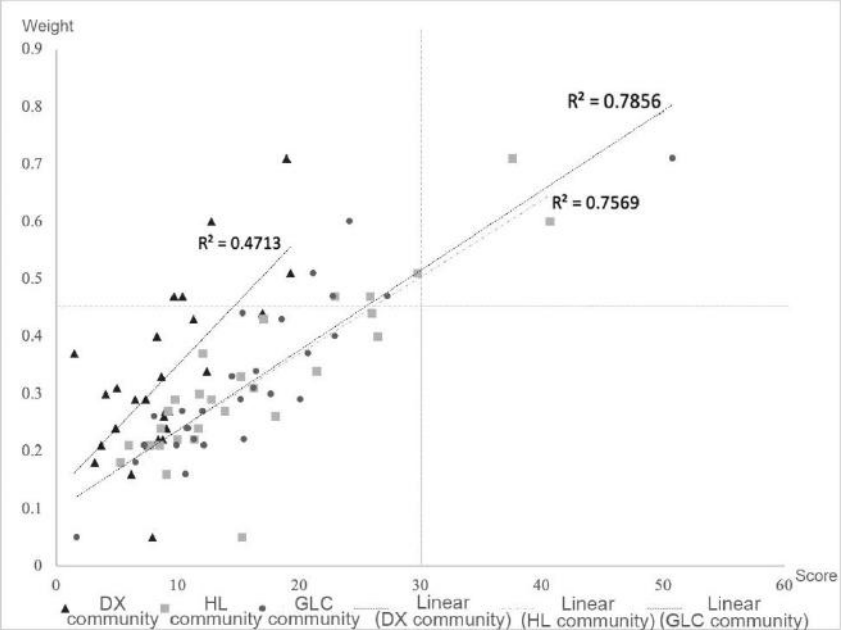


Figure 5. Distribution of scores of the three-level indicators of community resilience. Source: Drawing by the author.

5. Strategies to enhance the resilience of work unit communities under climate risk response goals

5.1. Clarify ownership issues and build a multi-party integrated risk management mechanism

Due to the deepening of the privatization of property rights, the management model that was previously completely state-owned began to change to a management model in which state-owned property rights,

mixed property rights and private property rights are intertwined. This change has led to confusion in property rights, resulting in confusion and lack of management in the unit community. This has resulted in spatial problems such as the failure to repair damaged infrastructure in a timely manner and the inability to update community public service facilities. Therefore, we believes that under the goal of improving resilience, multiple ownership institutions should be integrated to build a community management model of mutual cooperation between "government-enterprise-civilian", establish a policy coordination group, and concurrently serve as a risk response group to jointly decide on community renewal and transformation projects and risk response strategies. While resolving ownership disputes, it is also necessary to broaden the source of community construction funds, reduce the risk of single decision-making, and increase the degree of participation of community residents (Figure 8).

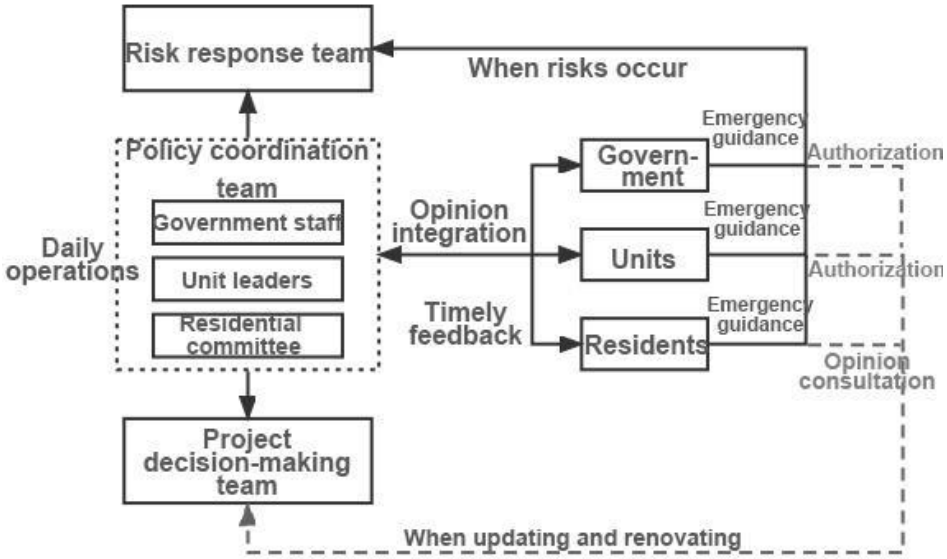


Figure 6. mechanism for multi-party integrated risk management. Source: Drawing by the author.

5.2. Micro-renewal of community space, gradually improving material capital redundancy

In the context of urban stock planning, old communities are turning to continuous repair and renewal, which is more suitable for the unit communities that are left over and have complex ownership issues. In terms of improving the redundancy of community material space, the adjacent group spaces within the community can be integrated, and scattered spaces can be transformed in a "needle-in-slot" manner. The open group space can be used as an emergency shelter when risks occur, and as a community public communication space daily, providing venues for residents' activities, disaster prevention publicity and other behaviors, and playing the aggregation role of public space. In terms of redundancy of service facilities, externally, the unit community can break the courtyard-style space enclosure of the community, open up the public service facility flow lines between the community and the surrounding cities, and realize resource sharing. Internally, corresponding service facilities can be added around the core functional points according to the daily life and activity flow lines of residents. In this way, it is connected with the external urban public service space to form a "point-line-surface" community public service facility space layout, thereby avoiding the problem of resource shortage when facing sudden risks.

5.3. Reconstructing the public nature of community residents and enhancing their adaptive capacity

The collective consciousness, common emotions and behavior patterns of the "unit" still have a profound impact on the community unit employees and residents. This unique behavior and cognition can become an important cornerstone to help the reconstruction of community publicity. The construction of community publicity can enhance the participation of community residents in decision-making and deliberation while enhancing the sense of identity and cohesion of residents, forming a self-organizing structure, thereby improving adaptive capacity. Specifically, through the "bottom-up" "empowerment mobilization" of community residents, that is, granting community residents some administrative functions and powers, community residents can be mobilized to participate extensively in community construction and management activities, forming community non-governmental organizations (NGOs) and non-profit volunteer organizations (NPOs). This kind of community self-organization is more open and flexible, and can enable community residents to "consciously", "spontaneously" and "equally" participate in the negotiation of community renewal projects and the formulation, response and implementation of risk response strategies, build a mutual assistance and sharing risk response platform, and improve the flexible mobilization of various resources in the community, so as to achieve the purpose of improving residents' adaptive capacity.

6. References

AIKEN, G. T. 2012. Community Resilience and Environmental Transitions. *Environmental Values,* 21**,** 536-538.

ALLEN, C. R. & HOLLING, C. S. 2010. Novelty, adaptive capacity, and resilience. *Ecology and society,* 15.

BEATLEY, T. & NEWMAN, P. 2013. Biophilic cities are sustainable, resilient cities. *Sustainability,* 5**,** 3328-3345.

BERKES, F. 2017. Environmental governance for the anthropocene? Social-ecological systems, resilience, and collaborative learning. *Sustainability,* 9**,** 1232.

BERKES, F. & ROSS, H. 2013. Community Resilience: Toward an Integrated Approach. *Society & Natural Resources,* 26**,** 5-20.

BRUNEAU, M., CHANG, S. E., EGUCHI, R. T., LEE, G. C., O'ROURKE, T. D., REINHORN, A. M., SHINOZUKA, M., TIERNEY, K., WALLACE, W. A. & VON WINTERFELDT, D. 2003. A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra,* 19**,** 733-752.

CARPENTER, S., WALKER, B., ANDERIES, J. M. & ABEL, N. 2001. From metaphor to measurement: resilience of what to what? *Ecosystems,* 4**,** 765-781.

CARPENTER, S. R., ARROW, K. J., BARRETT, S., BIGGS, R., BROCK, W. A., CRéPIN, A.-S., ENGSTRöM, G., FOLKE, C., HUGHES, T. P. & KAUTSKY, N. 2012. General resilience to cope with extreme events. *Sustainability,* 4**,** 3248-3259.

CUMMING, G. S., BARNES, G., PERZ, S., SCHMINK, M., SIEVING, K. E., SOUTHWORTH, J., BINFORD, M., HOLT, R. D., STICKLER, C. & VAN HOLT, T. 2005. An exploratory framework for the empirical measurement of resilience. *Ecosystems,* 8**,** 975-987.

FATH, B. D., DEAN, C. A. & KATZMAIR, H. 2015. Navigating the adaptive cycle: an approach to managing the resilience of social systems. *Ecology and Society,* 20.

FOLKE, C. 2006. Resilience: The emergence of a perspective for social–ecological systems analyses. *Global environmental change,* 16**,** 253-267.

FOLKE, C., CARPENTER, S. R., WALKER, B., SCHEFFER, M., CHAPIN, T. & ROCKSTRöM, J. 2010. Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and society,* 15.

GODSCHALK, D. R. 2003. Urban hazard mitigation: Creating resilient cities. *Natural hazards review,* 4**,** 136-143.

HOLLING, C. S. 1973. Resilience and stability of ecological systems.

HUANG, J., SUN, Z. & DU, M. 2022. Differences and drivers of urban resilience in eight major urban agglomerations: Evidence from China. *Land,* 11**,** 1470.

KELLY, C., FERRARA, A., WILSON, G. A., RIPULLONE, F., NOLè, A., HARMER, N. & SALVATI, L. 2015. Community resilience and land degradation in forest and shrubland socio-ecological systems: Evidence from Gorgoglione, Basilicata, Italy. *Land Use Policy,* 46**,** 11-20.

LI, K., HU, H. & ZHAO, H. 2022. Evolution analysis of regional social-ecological systems based on adaptive cycle theory and Pressure-State-Response framework. *Acta Ecol. Sin,* 42**,** 1-16.

LI, Y., KAPPAS, M. & LI, Y. 2018. Exploring the coastal urban resilience and transformation of coupled human-environment systems. *Journal of Cleaner Production,* 195**,** 1505-1511.

LIAO, L., DU, M. & HUANG, J. 2022. The effect of urban resilience on residents' subjective happiness: Evidence from China. *Land,* 11**,** 1896.

LU, M., TAN, Z. L., YUAN, C., DONG, Y. & DONG, W. 2023. Resilience Measurements and Dynamics of Resource-Based Cities in Heilongjiang Province, China. *Land,* 12**,** 22.

LUO, F., LIU, Y., PENG, J. & WU, J. 2018. Assessing urban landscape ecological risk through an adaptive cycle framework. *Landscape and urban planning,* 180**,** 125-134.

MEEROW, S., NEWELL, J. P. & STULTS, M. 2016. Defining urban resilience: A review. *Landscape and urban planning,* 147**,** 38-49.

NORRIS, F. H., STEVENS, S. P., PFEFFERBAUM, B., WYCHE, K. F. & PFEFFERBAUM, R. L. 2008. Community resilience as a metaphor, theory, set of capacities, and strategy for disaster readiness. *American Journal of Community Psychology,* 41**,** 127-150.

TURNER II, B. 2010. Vulnerability and resilience: Coalescing or paralleling approaches for sustainability science? *Global Environmental Change,* 20**,** 570-576.

WALKER, B., HOLLING, C. S., CARPENTER, S. R. & KINZIG, A. 2004. Resilience, adaptability and transformability in social–ecological systems. *Ecology and society,* 9.

WALKER, B. & SALT, D. 2012. *Resilience thinking: sustaining ecosystems and people in a changing world*, Island press.

YUAN, C. & JIN, Z. 2021. Assessing Urban Resilience for Resource-based cities in Northeast China Based on the Adaptive Cycle Framework.

Case Study Report

The Impact of Impervious Surface Increase on Urban Flood Risk

Case Study in Pearl River Delta (PRD) China

Xiaodi Wang, Danyun Jin, Yufei Sun, Liang Xiong*
Department of Landscape Architecture, China Agricultural University, China

Abstract

Urbanisation accelerates the hydrological cycle, with impervious surfaces significantly affecting runoff speed and extent. Beyond physical changes, urbanisation also involves cultural, heritage, and social integration. However, the connection between changes in soil moisture patterns and flood risk is unclear. We examined the impervious surface expansion and regional flood risk in the Pearl River Delta（PRD） from 1985 to 2022. Rapid urbanisation has replaced agricultural land and wetlands with impervious surfaces, weakening the natural infiltration of rainwater and increasing surface runoff, which heightens flood risks, particularly during extreme rainfall. The research investigated how the impervious surface change influences flood frequency and intensity, aiming to propose effective countermeasures. Using a random effects model, the relationship between impervious surface expansion, precipitation, and surface runoff by integrating impervious surfaces with historical flood-prone area records. The results revealed that impervious surfaces increased runoff, leading to frequent and intense floods, particularly in fast-growing cities. In peak rainfall, the urban drainage system couldn't contain the increased runoff, leading to urban flooding. Changes in impervious surfaces impact soil moisture, both being influenced by annual precipitation and affecting urban runoff. Sustainable urban development should improve rainfall and runoff management by adopting green infrastructure, using permeable surfaces, and optimising land use.

Keywords

Climate Change, Urbanisation, Runoff, Flooding, Resilience

1. Background

Flood risk in the PRD is exceptionally high due to rapid urbanisation. Li et al. (2021) found that the growth of impervious surfaces in the PRD significantly reduces rainfall infiltration, worsening floods. Similarly, Douglas (2018) highlighted impervious surface expansion as a key factor in increased urban flood risk, with existing drainage systems unable to cope with heavy rainfall. Green infrastructure and "sponge city" solutions are commonly proposed to address these challenges (Nguyen et al., 2019; Qiao et al., 2020). However, the rapid growth of impervious surfaces has significantly increased surface runoff, leading to frequent urban flooding (Li & Bortolot, 2022; Xu et al., 2020). Unlike natural land cover, impervious surfaces prevent rainfall from soaking in, causing much precipitation to drain poorly in low-lying areas. (Ding et al., 2024; Mahmoud & Gan, 2018). Urban flooding has resulted in economic losses, urgently needing effective solutions (Li et al., 2020). To explore the impact of impervious surface expansion on urban flood risk in PRD,

and use changes influence flood frequency and intensity, and propose solutions to mitigate flood risks were analysed.

2. Research area and method

Taking PRD as an example, we discussed the influence of impervious surface expansion on regional flood risk. In south China, the PRD is low-lying, densely covered with summer rivers, often hit by typhoons and heavy rains (Gu et al., 2011). With the acceleration of urbanisation, extensive wetlands and agricultural land regions have been replaced by impervious surfaces such as roads and buildings. This change has significantly increased surface runoff, resulting in frequent urban floods, which has caused severe threats to the regional social economy and ecological environment.

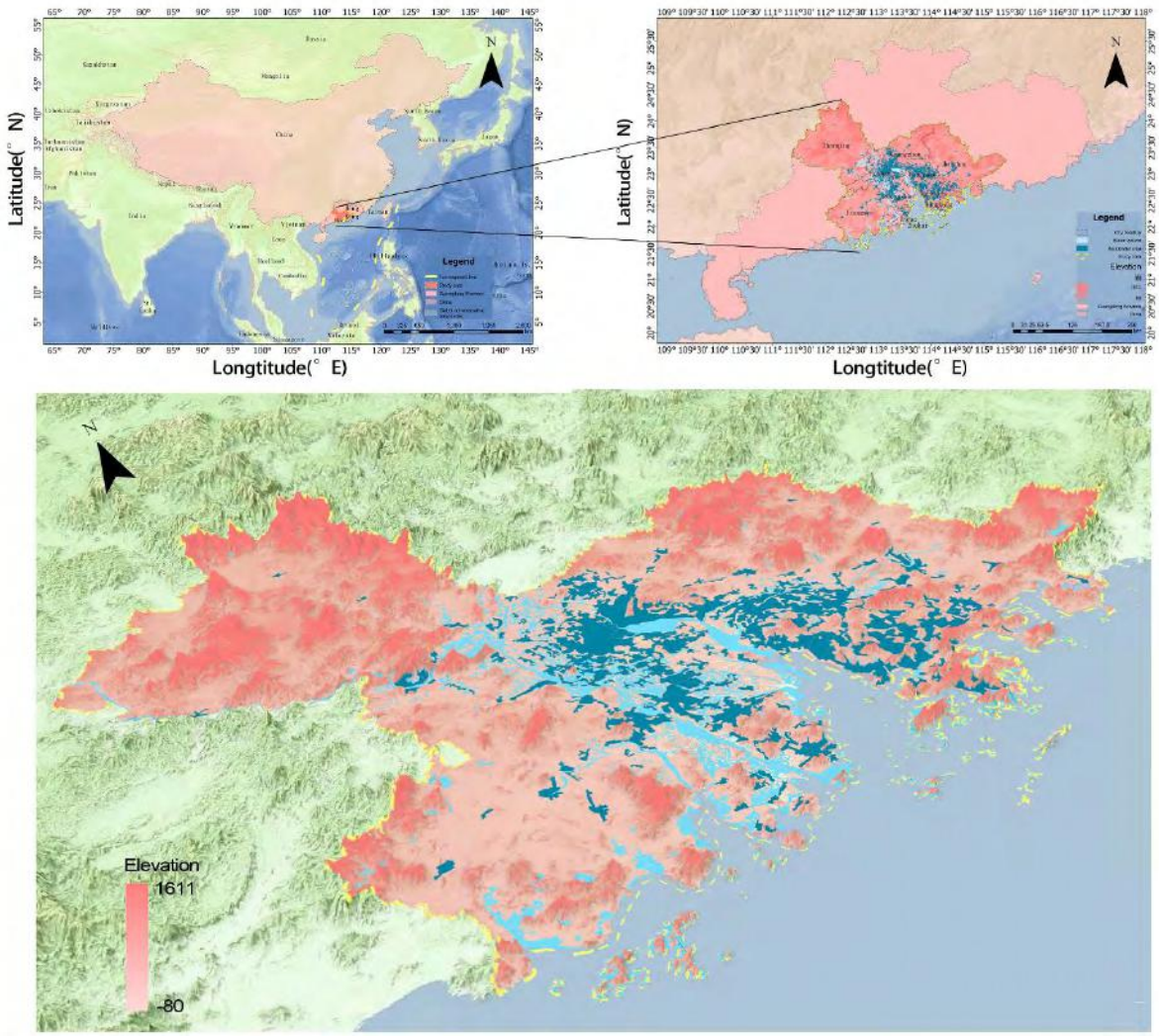


Figure 1. Study area

(The figure was drawn by the author, and data of the figure is from Digital Elevation/Terrain Model (DEM) NASA Earthdata, which illustrated on Google Maps.)

We superimposed the impervious surface data with the historical records of flood high-risk areas to identify flood high-risk areas. The relationship between them is discussed by analysing the degree of coincidence between impervious surface spread and flood-prone regions (Wang et al., 2020). The random Effects

Model analyses the correlation between impervious surface spread and flood risk (Verbeeck et al., 2011). The model is suitable for regional data analysis and can control different regional cities' heterogeneity and temporal dynamic changes. The model can quantify the relationship between increasing impervious surface and runoff change.

Table 1 The dataset of the Pearl River Delta

Data	Source
Impervious area	Annual Maps of Global Artificial Impervious Area between 1985 and 2018
DEM	Digital Elevation/Terrain Model (DEM) NASA Earthdata
Precipitation	NOAA National Centers for Environmental Information (NCEI)
Runoff	Global Runoff Data Centre (GRDC)

3. Results and Discussion

3.1. An increasing and impermeable surfaces

Fig. 2 shows the changing impervious surfaces of PRD cities from 1985 to 2022. The growth trend is significant, though the growth rate and expansion pattern vary. Guangzhou and Shenzhen consistently had highly impervious surfaces, especially after 2000, when urban expansion sped up.

Shenzhen's industrial growth in the 1990s and Guangzhou's expansion after 2005 were key factors. Dongguan and Foshan experienced rapid urbanisation in the late 1990s, significantly increasing impervious surfaces. From 2015 to 2022, the growth of impervious surfaces in cities sped up during rapid urban expansion. From 1985 to 1990, all towns saw rapid early expansion, marking the start of regional urbanisation, followed by steady growth from 2000 to 2015. Policies and economic growth drove further expansion, reflecting a new peak of urbanisation in PRD.

The expansion in different cities experienced inevitable fluctuations over time (Dou & Kuang, 2020). For instance, as shown in Fig. 2, Guangzhou and Dongguan saw temporary stagnation or declines in expansion during specific years. However, from 1985 to 2022, the overall trend for impervious surface areas in PRD has been upward (Qiu et al., 2024). This trend reflects the rapid urbanisation in the region and suggests that flood risk may increase (Lin et al., 2020; Muis et al., 2015).

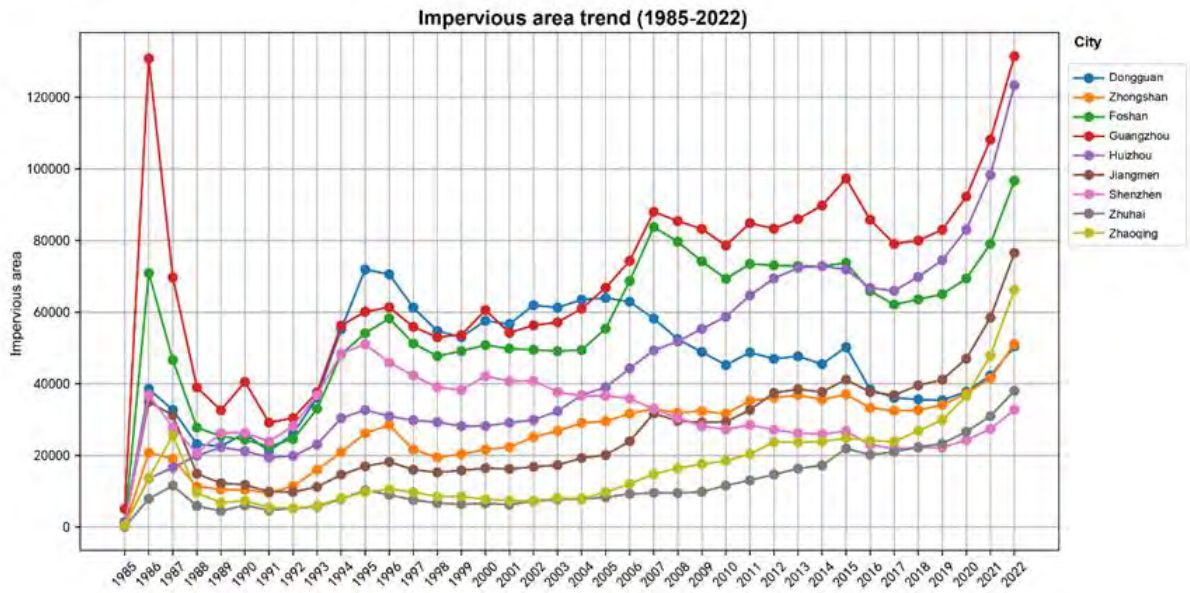


Figure 2. 1985-2020 Impervious area change trend

(The figure was drawn by the author, and data of the figure is from Annual Maps of Global Artificial Impervious Area between 1985 and 2018.)

3.2. The Interannual variation of precipitation

Precipitation fluctuated in cycles, such as from 1990 to 2000, when it increased, followed by a decline in the next decade. After 2010, precipitation fluctuations became more intense (Coumou & Rahmstorf, 2012; Prein et al., 2017; Trenberth et al., 2015; Westra et al., 2014). Maximum precipitation during typhoon seasons has been increasing yearly, indicating that extreme rainfall events are growing and affecting regional precipitation patterns (Dore, 2005; Guzman & Jiang, 2021). Rainfall changes in PRD cities are linked to flood risk. Years with maximum precipitation, such as 1994, 2008, and 2016, as shown in Fig. 3, also saw severe flooding.

Extreme events and changes directly increase surface runoff in impervious areas, intensifying regional flood risks (García-Ruiz et al., 2011). From 1985 to 2022, precipitation in the PRD showed significant spatial variation. The periodic nature of precipitation and its influence on extreme weather events present larger challenges for future flood prevention in the region (Merz et al., 2021).

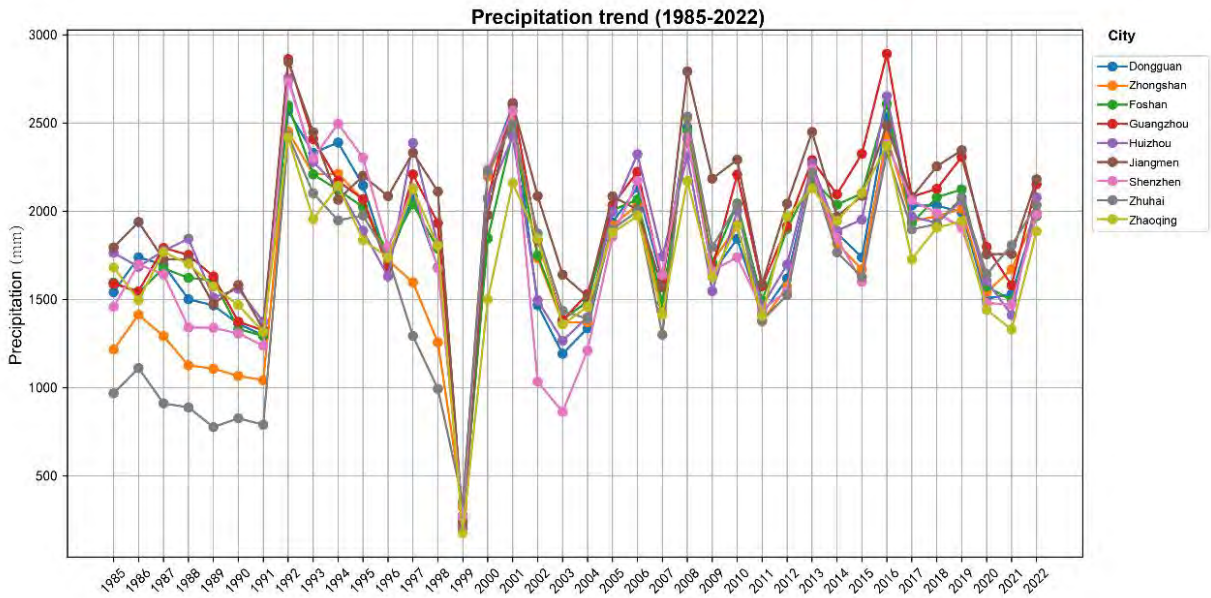


Figure 3. 1985-2022 Precipitation trend

(The figure was drawn by the author, and data of the figure is from NOAA National Centers for Environmental Information.)

3.3. Long-time series response of runoff

The relationship between the surface runoff change, impervious surface expansion, and precipitation trends is delineated in Fig. 4. Surface runoff of the city presented an increasing fluctuation, especially in high precipitation years like 1994, 2008, and 2016, which means the radiation intercepted by plants is of significant affected surface runoff, e.g., the cities of Zhaoqing, Jiangmen, and Huizhou were subjected to more surface runoff compared to other cities with annual values normally more than 0.03. It indicates excellent enhancements of runoff under storm rainfall, topographically conditioned by the circumstances, concentrated impervious surfaces, and efficiency in the drainage systems in the said cities. Although the surface runoff in Shenzhen, Dongguan, and Guangzhou was relatively stable, it tended to rise steadily with time, especially after 2010, due to rapid urbanisation and the expansion of impervious surfaces. Among them, 2008, 2016, and 2018 were the representative peak runoff years, which agreed well with heavy rainfall events, indicating increased precipitation intensity. This significantly raised the surface runoff, thus increasing the flood risk in the urban area. The surface runoff fluctuated periodically from 1985 to 2022, with apparent peaks at an interval of about 5 to 8 years, indicating that the trend in precipitation is closely related to regional flood risk (Musselman et al., 2018). Runoff was relatively lower in 2003 and 2014 due to regional droughts or reduced precipitation. Since 2010, cities have seen a steady increase in runoff due to the growth in impervious surfaces.

In highly urbanised cities like Guangzhou and Shenzhen, gradual increases in runoff reflect the reduced infiltration of rainfall into the ground since more areas are hardened, thus inducing a potential rise in the flood hazard.

From 1985 to 2022, the surface runoff of cities in PRD showed apparent fluctuation and uptrend and had a close relationship with the changes in precipitation and impervious surface growth. Extreme rainfall events were the primary drivers of increased runoff, while impervious surface growth further accelerated and intensified the transformation of rainfall into surface runoff (Fowler et al., 2021). These findings

provide critical data to support effective flood management policies, emphasising the importance of expanding green spaces and promoting permeable pavement in future urban planning.

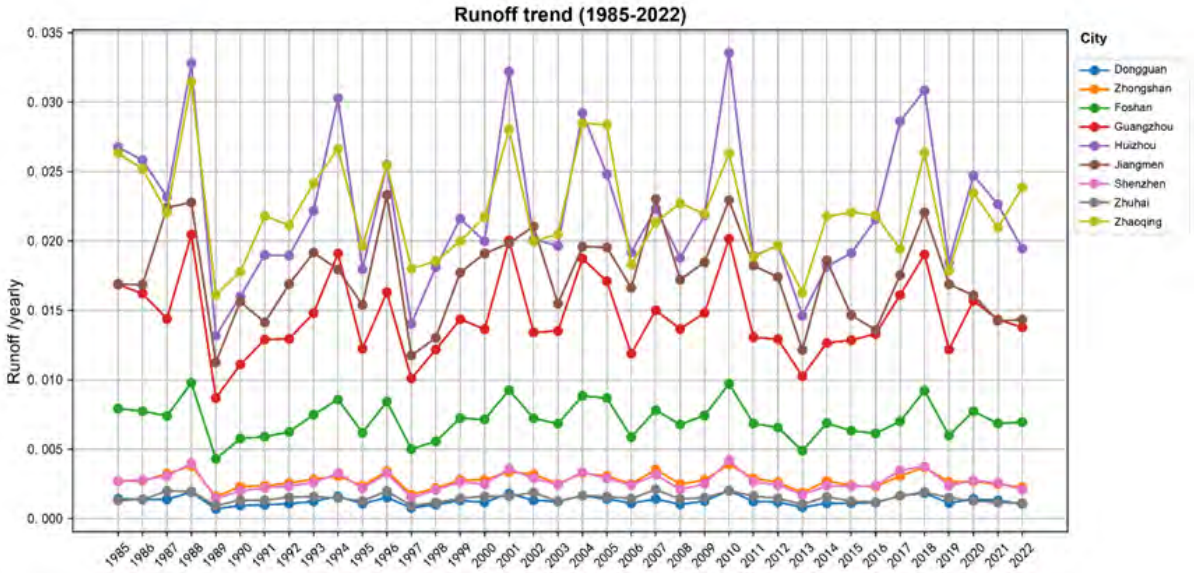


Figure 4. 1985-2022 Runoff trend

(The figure was drawn by the author, and data of the figure is from Global Runoff Data Centre.)

3.4. Contribution of increased impervious surface to flooding

Based on the analysis of impervious surface expansion, precipitation trends, and surface runoff changes, it can be concluded that the increasing impervious surfaces play a role in the flood risk in PRD. With the continuous expansion of impervious surfaces in Fig. 2, rainfall infiltration capacity has significantly decreased, resulting in a large amount of rainfall being unable to seep naturally into the ground, thus rapidly forming surface runoff. Fig. 4 shows surface runoff has steadily increased in cities with significant impervious surface expansion, such as Guangzhou, Shenzhen, and Dongguan, over the past decades. This trend demonstrates that hardened surfaces directly contribute to the rising flood risk by accelerating surface runoff formation. During peak precipitation years, such as 2008 and 2016, surface runoff also peaked due to concentrated rainfall, highlighting the compounding effect of impervious surface expansion and flood risk. The hardened surfaces cause rapid rainfall accumulation into runoff, increasing flood intensity and overwhelming urban drainage systems. The interaction between impervious surface expansion and extreme precipitation is a crucial driver of flood in PRD. Quickly expanding impervious surfaces in Guangzhou, Shenzhen, and Dongguan cities are subjected to heightened flood hazards. In these cities, for example, the increased annual precipitation and runoff show that the expanding impervious surfaces increase the frequency of flooding events (Zhang et al., 2018). Even cities like Zhongshan and Zhaoqing, which get less local rainfall, cannot escape flood conditions in years when the rainfall is high. Because impervious surfaces still heighten the threat of floods. The rising frequency of surface runoff and flooding incidents has greatly stressed urban drainage systems. Existing drainage infrastructure in the majority of cities has been unable to cope with increased runoff due to hardened surfaces entirely, and the result is frequent flooding, as evidenced illustrated in Fig. 4. Overall, the growth of impervious surfaces has been the leading factor in flooding, preventing rainwater infiltration, speeding up surface runoff, and amplifying the effects of precipitation events.

4. Conclusion

This work has fully explored the relationship between impervious surface expansion, precipitation change, and surface runoff change in PRD from 1985 to 2022. The paper shows that expanding impervious surfaces has reduced natural rainfall infiltration, leading to more surface runoff and increased frequency and severity of regional floods. This trend is most noticeable in fast-growing cities like Guangzhou and Shenzhen. However, the urban drainage systems in these cities have not kept up with the changes, leading to frequent flooding and waterlogging, which threaten regional safety, infrastructure, and economic growth. Managing floods in the PRD will face even more significant challenges.

Traditional drainage systems alone are inadequate to handle future flood threats. To enhance cities' ability to manage rainfall and runoff and contribute to more sustainable urban development, it is crucial to introduce green infrastructure, optimise land use, and promote permeable pavements. This trend is most profound in rapidly urbanising cities. The results can help understand how impervious surface expansion affects flooding and guide future urban planning and flood management.

5. References

Coumou, D. & Rahmstorf, S. (2012), "A decade of weather extremes", Nature climate change, Vol. 2 No. 7, pp. 491-496.

Ding, Y., Wang, H., Liu, Y., Chai, B. & Bin, C. (2024), "The spatial overlay effect of urban waterlogging risk and land use value", Science of The Total Environment, Vol. 947174290.

Dou, Y. & Kuang, W. (2020), "A comparative analysis of urban impervious surface and green space and their dynamics among 318 different size cities in China in the past 25 years", Science of the Total Environment, Vol. 706135828.

Fowler, H. J., Lenderink, G., Prein, A. F., Westra, S., Allan, R. P., Ban, N., Barbero, R., Berg, P., Blenkinsop, S. & Do, H. X. (2021), "Anthropogenic intensification of short-duration rainfall extremes", Nature Reviews Earth & Environment, Vol. 2 No. 2, pp. 107-122.

Gu, C., Hu, L., Zhang, X., Wang, X. & Guo, J. (2011), "Climate change and urbanization in the Yangtze River Delta", Habitat International, Vol. 35 No. 4, pp. 544-552.

Li, J. & Bortolot, Z. J. (2022), "Quantifying the impacts of land cover change on catchment-scale urban flooding by classifying aerial images", Journal of Cleaner Production, Vol. 344130992.

Li, L., Uyttenhove, P. & Van Eetvelde, V. (2020), "Planning green infrastructure to mitigate urban surface water flooding risk–A methodology to identify priority areas applied in the city of Ghent", Landscape and Urban Planning, Vol. 194103703.

Lin, W., Sun, Y., Nijhuis, S. & Wang, Z. (2020), "Scenario-based flood risk assessment for urbanizing deltas using future land-use simulation (FLUS): Guangzhou Metropolitan Area as a case study", Science of the Total Environment, Vol. 739139899.

Mahmoud, S. H. & Gan, T. Y. (2018), "Urbanization and climate change implications in flood risk management: Developing an efficient decision support system for flood susceptibility mapping", Science of the Total Environment, Vol. 636152-167.

Muis, S., Güneralp, B., Jongman, B., Aerts, J. C. & Ward, P. J. (2015), "Flood risk and adaptation strategies under climate change and urban expansion: A probabilistic analysis using global data", Science of the Total Environment, Vol. 538445-457.

Nguyen, T. T., Ngo, H. H., Guo, W., Wang, X. C., Ren, N., Li, G., Ding, J. & Liang, H. (2019), "Implementation of a specific urban water management-Sponge City", Science of the Total Environment, Vol. 652147-162.

Prein, A. F., Rasmussen, R. M., Ikeda, K., Liu, C., Clark, M. P. & Holland, G. J. (2017), "The future intensification of hourly precipitation extremes", Nature climate change, Vol. 7 No. 1, pp. 48-52.

Qiao, X., Liao, K. & Randrup, T. B. (2020), "Sustainable stormwater management: A qualitative case study of the Sponge Cities initiative in China", Sustainable Cities and Society, Vol. 53101963.

Qiu, L., He, J., Yue, C., Ciais, P. & Zheng, C. (2024), "Substantial terrestrial carbon emissions from global expansion of impervious surface area", Nature Communications, Vol. 15 No. 1, pp. 6456.

Trenberth, K. E., Fasullo, J. T. & Shepherd, T. G. (2015), "Attribution of climate extreme events", Nature climate change, Vol. 5 No. 8, pp. 725-730.

Verbeeck, K., Van Orshoven, J. & Hermy, M. (2011), "Measuring extent, location and change of imperviousness in urban domestic gardens in collective housing projects", Landscape and urban planning, Vol. 100 No. 1-2, pp. 57-66.

Wang, Y., Xie, X., Liang, S., Zhu, B., Yao, Y., Meng, S. & Lu, C. (2020), "Quantifying the response of potential flooding risk to urban growth in Beijing", Science of the total environment, Vol. 705135868.

Westra, S., Fowler, H. J., Evans, J. P., Alexander, L. V., Berg, P., Johnson, F., Kendon, E. J., Lenderink, G. & Roberts, N. M. (2014), "Future changes to the intensity and frequency of short-duration extreme rainfall", Reviews of Geophysics, Vol. 52 No. 3, pp. 522-555.

Xu, C., Rahman, M., Haase, D., Wu, Y., Su, M. & Pauleit, S. (2020), "Surface runoff in urban areas: The role of residential cover and urban growth form", Journal of Cleaner Production, Vol. 262121421.

Research Paper

Typhoon-Resilient Spatial Patterns in the Chaoshan Region of Guangdong, China

Leveraging Time-honored Indigenous Knowledge for Future-oriented Heritage Conservation and Resilience Planning

Jintu Xu, Southeast University, China

Xiliu He, Southeast University, China

Abstract

Enhancing urban-rural resilience against natural disasters has gained increasing global attention, particularly in coastal regions prone to typhoons. While current research on spatial resilience focuses on individual elements, systemic spatial connections remain understudied. This study develops a methodology to extract typhoon-resilient spatial patterns from coastal regions, focusing on the Chaoshan area of Guangdong, China. Through spatial feature extraction, pattern mining, and validation against typhoon events, complemented by indigenous knowledge interpretation, the study identifies two significant spatial patterns: a multi-layered windbreak system and a "fish farm - salt field - rice field" agricultural zoning arrangement. These patterns demonstrate sophisticated integration of traditional ecological knowledge with spatial planning principles, effectively mitigating typhoon impacts while maintaining productive land use. The findings contribute to resilience planning theory by emphasizing the critical role of systemic spatial interrelationships and provide practical insights for incorporating indigenous knowledge into contemporary planning practices. The study methodology provides a framework for analyzing resilient spatial patterns in other disaster-prone areas of the world.

Keywords

Typhoon resilience, Spatial patterns, Indigenous knowledge, Coastal settlements, Heritage conservation, Resilience planning

1. Introduction

1.1. Research Background

Globally, enhancing the resilience of both urban and rural areas to natural hazards has been in the spotlight of many countries over recent years, including those in the typhoon region. According to the latest data, storms-including typhoons-are one of the major types of natural disasters all over the world (UNDRR and CRED, 2020) (Figure 1). These extreme events are a serious threat to urban spatial development and heritage conservation, particularly in coastal areas where historical settlements have evolved over many centuries of adaptation to environmental challenges.

Current research into spatial resilience, although having made some significant progress, remains focused mainly on individual elements rather than systemic spatial connections (Sharifi and Yamagata, 2016). It is particularly problematic because sometimes effectiveness in resilience strategies cannot be derived independently but through its inter-relationship with other constituent spatial elements (Meerow et al., 2016). Local-scale levels of resilience equally often lack approaches that are context-adaptive and never consider resourceful indigenous stocks of knowledge based on generations or centuries of experiencing environmental adaptation (Hadlos et al., 2022).

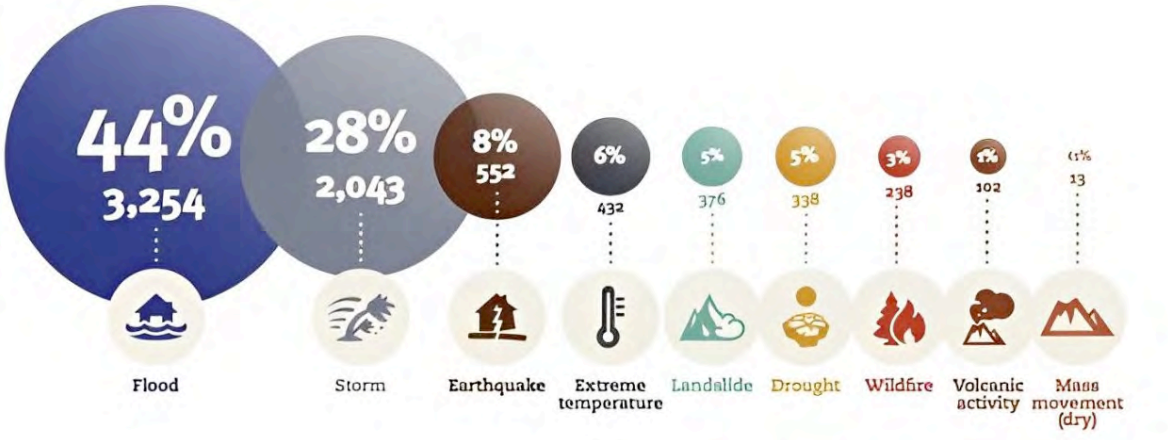


Figure 1. Percentage of occurrences of disasters by disaster type (2000-2019). Source: Centre for Research on the Epidemiology of Disasters (CRED) & United Nations Office for Disaster Risk Reduction (UNDRR).

There would always have been an interesting case study herein using ecological indigenous spatial wisdom to investigate this typhoon that has hit time and again, Chaoshan, Guangdong, China. For long, this frequent typhoon site transformed into a greatly productive agricultural spot and a great place for productive settlement, fully based on development in disaster-resilient settled experiences migrated accumulation in certain ways (Wang and Liu, 2021). These spatial patterns that have emerged in this region represent the sophisticated manifestations of indigenous knowledge and local urban planning philosophy, yet remain understudied in the context of modern resilience planning.

1.2. Research Objectives and Questions

This research develops a methodology to extract and analyze typhoon-resilient spatial patterns from coastal regions, focusing on the Chaoshan area of Guangdong, China. It points to two main questions: (1) What characteristic spatial patterns can explain the resilience of typhoons in the coastal settlements of Chaoshan? (2) How can the understanding of such patterns be interpreted through indigenous local knowledge so that their efficacy may be validated with regard to informing their future use in heritage conservation and locally adapted resilience planning?

The research will fill the knowledge gap between traditional wisdom and current planning practices through the identification and analysis of site-specific spatial patterns that have traditionally been effective against typhoon impacts. This research can contribute to deepening both theoretical understanding of the concept of spatial resilience and practical approaches in coastal urban planning by interpreting indigenous knowledge on the basis of spatial analysis techniques.

2. Literature Review and Theoretical Framework

2.1. Urban Resilience and Natural Disasters

There has been considerable evolution in the arguments on urban resilience in the last few decades, especially with regard to natural disaster threats. Resilience in urban systems is how cities maintain or rapidly return desired functions in light of disturbance, adapt to changed conditions, and can rapidly transform systems that currently limit or are expected to limit future adaptive capacity (Meerow and Newell, 2019). In the context of natural disasters such as typhoons, resilience involves physical infrastructure adaptability and socio-ecological system robustness. Researchers have also established the need for considering multiple dimensions of resilience jointly (Amirzadeh et al., 2022).

Traditional approaches concerned themselves basically with physical infrastructure, while on the contrary, there is presently a call to have a framework that is comprehensive in the social, ecological, and spatial dimensions of resilience (Sharifi, 2019). This is the recognition that, actually, effective disaster resilience requires analysis of the configuration of the interplay between the built environment and natural systems in all their complexities.

2.2. Spatial Patterns and Urban Morphology

Spatial patterns are defined by Alexander (1977) as relatively permanent associative integrations of urban spatial elements that emerge through a process of long-term human adaptation to environmental conditions. In disaster studies, these usually embody knowledge that has accumulated about effective spatial arrangements for mitigation (Kropf, 2018). The latest research was able to emphasize how specific spatial configurations can promote the enhancement of regions' resistance to and recovery from natural disasters.

There is an increasing application of advanced methodologies such as remote sensing and machine learning techniques in the analysis of spatial patterns with the aim to identify and validate effective spatial arrangements (Li et al., 2023). but little is known about how those patterns contribute to typhoon resilience, in particular in traditionally adapted coastal settlements.

2.3. Indigenous Knowledge in Disaster Risk Reduction

Among these underutilized resources in contemporary planning practices is indigenous knowledge on the reduction of disaster risks. That type of knowledge, usually developed over several generations through adaptation to the environment, can particularly be rich in the subtleties regarding local ecological processes and thus appropriate strategies related to risk reduction (Hadlos et al., 2022). Thus, on typhoon-prone coasts, indigenous knowledge has led to adaptive settlement and agriculture.

Indigenous knowledge (IDK) received increased interest in modern approaches to planning. In this respect, many studies have identified that traditional practices among the local community hold the key to sustainable and effective solutions against disaster risks (Hiwasaki et al., 2014). But how such tacit knowledge is to be translated into formal planning frameworks without losing its contextual relevance remains a challenge.

3. Methodology

3.1. Study Area

The Chaoshan region of Guangdong Province was selected as the site for this study due to the area's high annual frequency of exposure to typhoons and rich heritage in indigenous adaptation strategies. This is approximately 10,610 km² with a population of about 13.65 million people in 2020, encompassing several historically important coastal settlements. In this research, the area of interest was mainly the 500-meter buffer zone from the coastline because it is here that the typhoon impacts are strongest and the traditional adaptation patterns most clearly visible.

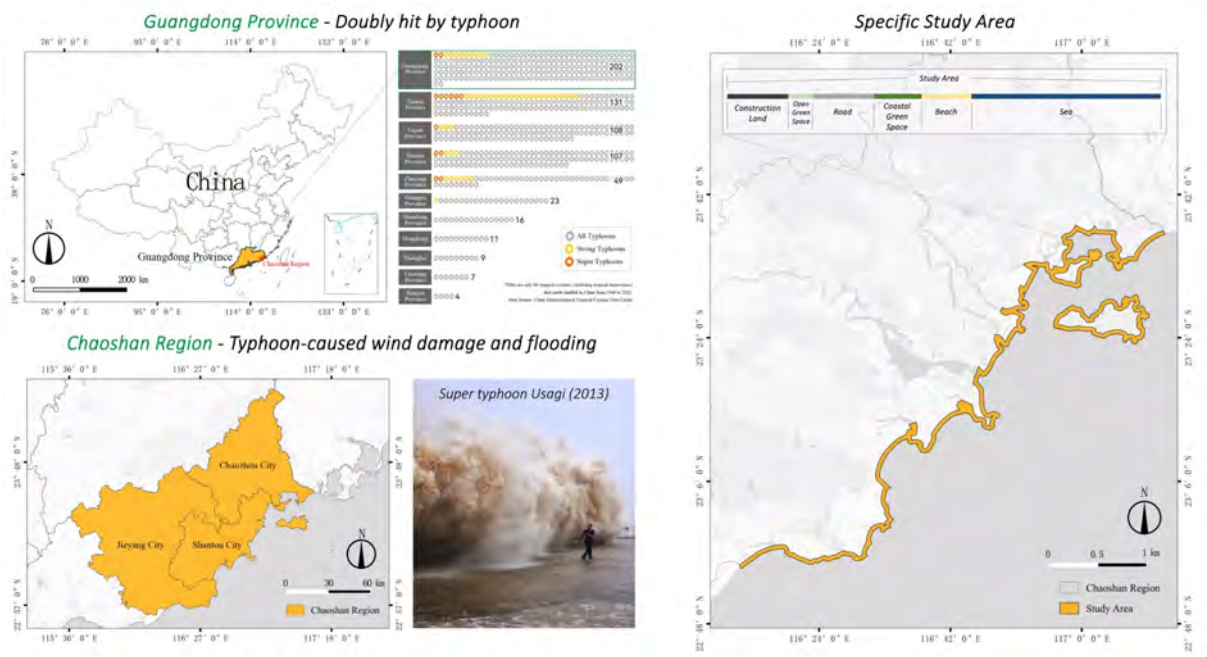


Figure 2. Study area. Source: Drawn by the author.

The region on average receives five typhoons annually with great impacts like strong winds, storm surges, and flooding. This represents an ideal case study for the investigation of typhoon-resistant spatial patterns because sophisticated spatial adaptation strategies have been developed by local communities through centuries of settlement.

3.2. Data Collection and Processing

Many types of sources have been used in this research to ensure comprehensiveness. The main spatial data used in this study are high-resolution satellite imagery and land use/land cover data from the SinoLC-1 dataset (Li et al., 2023). Temporal data included satellite imagery before and after Super Typhoon Usagi in September 2013 and enabled the assessment of the resilience of spatial patterns. On the other hand, indigenous knowledge was captured through local chronicles, historic documents, and semi-structured interviews with community elders.

3.3. Study Design

In this study, a four-step analytical framework was applied to identify and validate the typhoon-resilient spatial pattern (Figure 3). In stage one, the Object-based Image Analysis (OBIA) and remote semantic segmentation technique were used to extract the spatial features. Following Li et al. (2023), ten categories

of spatial elements, such as road networks, tree cover, cropland, buildings, water bodies, and wetlands, were considered for classification. For each of the extracted features, spatial dimensions, geographic locations, and relationships with neighborhood elements were analyzed.

Figure 3. Four-stage analytical framework to identify and validate typhoon-resilient spatial patterns. Source: Drawn by the author.

In the mining pattern stage, FP-Growth was applied as an algorithm to mine important spatial patterns from the real extracted features (Li et al., 2021). Further, we constructed characteristic connection matrices of spatial elements and calculated the support and lift values to determine meaningful spatial associations. The algorithm was set with a minimum support threshold value of 0.02 to ensure that very meaningful patterns would be found while eliminating spurious associations (Han et al., 2019).

Verification of the pattern was done as the third step in our analysis, taking as a case study Super Typhoon Usagi (2013). Pattern resilience was considered against three scenarios of sustaining structural integrity, recovery time, and continuity of functionality based on the assessment framework (Lei et al., 2015).

Interpretation of the pattern through indigenous knowledge analysis forms the last stage of analysis. We thus undertook a critical scrutiny of the local annals and historical accounts to supplement the semi-structured interviews executed on a random sample of twenty elderly residents. This methodological approach may also take into consideration calls by recent studies to include local knowledge in disaster resilience research, as the study of Hadlos et al. states (Hadlos et al., 2022).

4. Results

4.1. Spatial Pattern Mining and Verification

The major types of spatial elements extracted in the Chaoshan region include roads (Type 1), tree cover (Type 2), grassland (Type 4), cropland (Type 5), buildings (Type 6), barren and sparse vegetation (Type 7), water (Type 9), and wetland (Type 10). We constructed characteristic connection matrix tables to record the spatial relationships among elements such as relative distances, orientations, and areas.

The FP-Growth algorithm analysis revealed several significant spatial associations, with varying degrees of support and lift values. The spatial rules network visualization further revealed complex interconnections

among these elements (Figure 4). For example, key associations include: (1) Road-Building-Cropland relationship (support=0.0215, lift=46.5668), indicating a strong systematic arrangement of transportation infrastructure with settlements and agricultural areas. (2) Tree cover with buildings and cropland (support=0.0391, lift=25.5629), suggesting consistent integration of vegetation barriers with built environments. (3) Tree cover with buildings, cropland, and barren/sparse vegetation (support=0.0260, lift=38.4789), showing complex multi-element spatial arrangements.

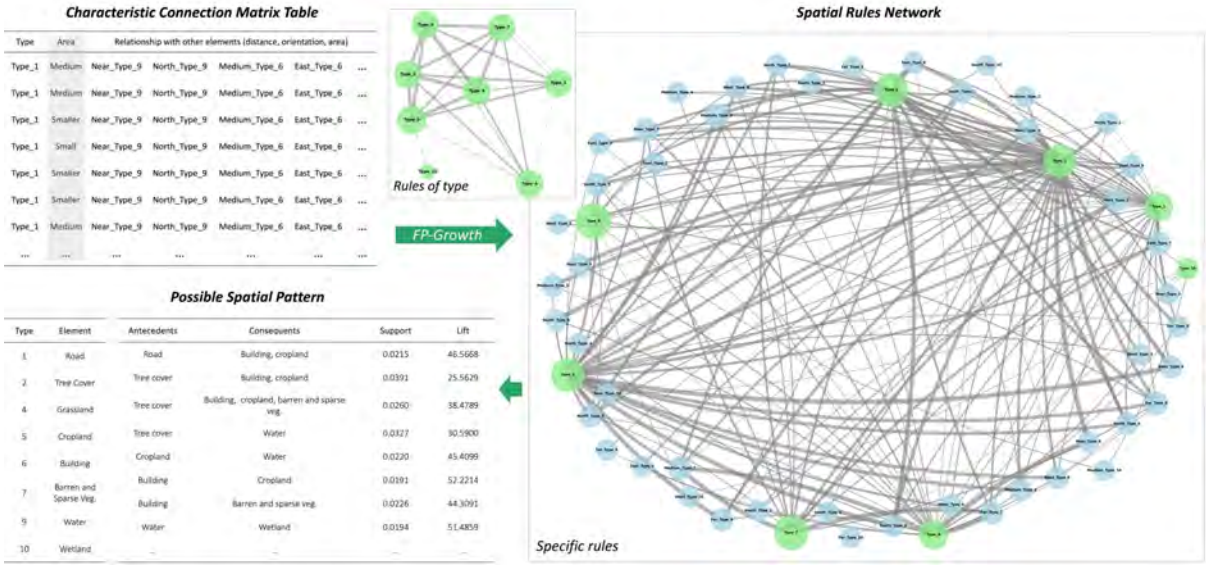


Figure 4. Results of spatial pattern mining by FP-Growth algorithm and its visualization. Source: Drawn by the author.

Using Super Typhoon Usagi (2013) as a temporal observation point, we identified three distinct situations through comparison of pre-typhoon and post-typhoon satellite imagery (Figure 5). The first situation showed patterns maintaining stability with minimal damage during the typhoon. The second revealed patterns that, although damaged, demonstrated rapid recovery to their original state, indicating high resilience. A third situation, where patterns transformed into new spatial forms, was observed but not included in our resilient pattern analysis due to uncertainty about their long-term stability.

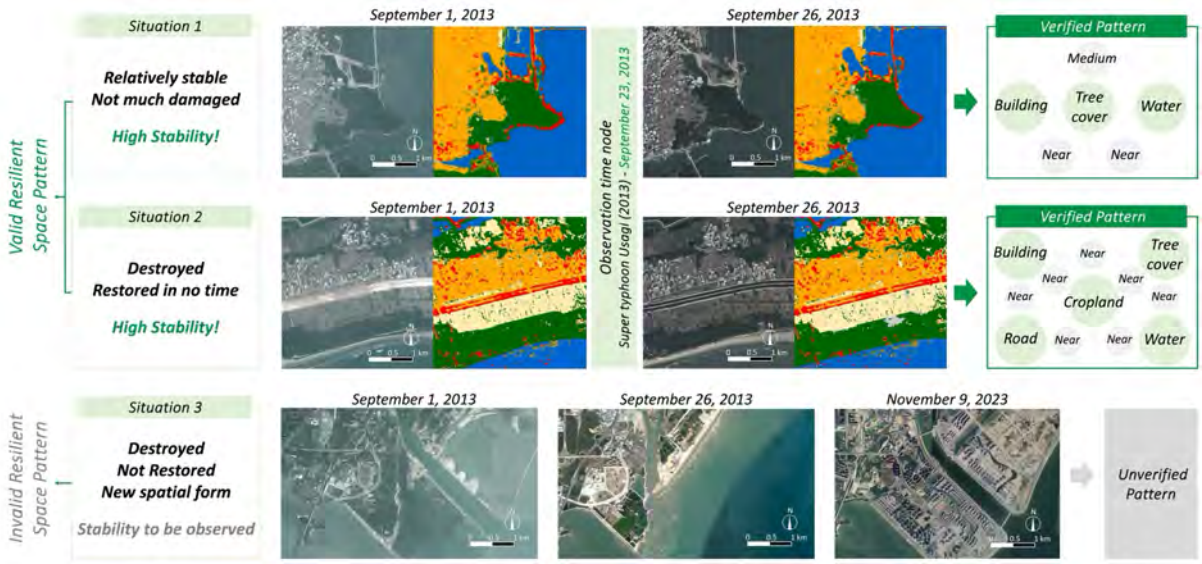


Figure 5. Identified three distinct situations through comparison of pre-typhoon and post-typhoon satellite imagery. Source: Drawn by the author.

4.2. Identified Typhoon-Resilient Spatial Patterns and Their Explanation by IDK

Two typical spatial patterns were identified through algorithmic rule mining and verification using historical satellite images.

The first typhoon-resilient pattern is a multi-layered windbreak forest system designed specifically to mitigate typhoon-induced sea spray and wind damage (Figure 6). This system manifests as a series of strategically positioned forest barriers that protect coastal settlements and agricultural lands. Along the coastline, windbreak forests are systematically integrated with seawalls, with vegetation root systems reinforcing coastal defense structures. Field observations and historical records indicate that over 75% of Chaoshan villages maintain settlement windbreaks, which evolved from the early immigrants' practice of surrounding thatched cottages with bamboo groves. These settlement windbreaks, now recognized as Feng Shui forests, serve both protective and cultural functions within the community structure (Chen et al., 2018). The agricultural areas are protected by a unique combination of street trees and fruit trees positioned along field boundaries, creating an economically efficient dual-purpose system that provides both wind protection and agricultural products.

The second significant and effective pattern is a distinctive coastal-to-inland spatial sequence that demonstrates sophisticated adaptation to both tidal dynamics and typhoon-induced flooding (Figure 7). This pattern consists of a systematic arrangement of fish farms, salt fields, and rice fields, progressing inland from the coast. The fish farming zone effectively utilizes the intertidal area, serving as an initial buffer against storm surges while maintaining productive aquaculture activities. The intermediate salt field zone represents a transitional space where communities have developed sophisticated soil management techniques to address salinity issues, including strategic freshwater pumping and salt-tolerant crop cultivation. The innermost rice field zone exhibits careful adaptation to seasonal typhoon patterns, with cultivation cycles aligned with the traditional lunar calendar to minimize crop exposure during peak typhoon seasons.

Figure 6. Typhoon-resilient pattern 1: Multi-layered windbreak forest system designed specifically to mitigate typhoon-induced sea spray and wind damage. Source: Drawn by the author.

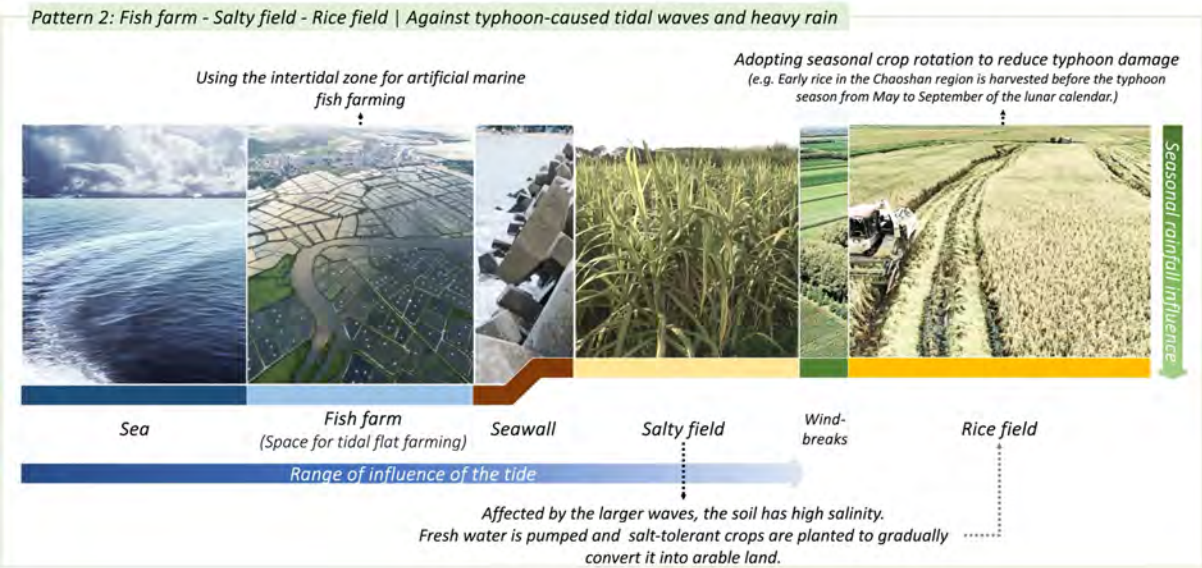


Figure 7. Typhoon-resilient pattern 2: Distinctive coastal-to-inland spatial sequence that demonstrates sophisticated adaptation to both tidal dynamics and typhoon-induced flooding. Source: Drawn by the author.

The efficacy of such spatial patterns is supported by several lines of evidence. For example, satellite images before and after Typhoon Usagi (2013) demonstrated that such spatial arrangements were resistant to extreme climate events, particularly in the traditional pattern areas. Semi-structured interviews with elderly residents provided the rich historical context for the development and evolution of such patterns, while local chronicles documented their long-term effectiveness in mitigating typhoon impacts. Of particular significance is how such spatial arrangements were integrated within traditional governance structures and community practices that ensured their preservation across generations.

5. Discussion

5.1. Integration of Indigenous Knowledge and Modern Planning

These typhoon-resilient spatial patterns revealed in this study have shown the real possibility of deeply integrating indigenous knowledge with contemporary planning practices. This multilayered windbreak system and the general agricultural zoning pattern demonstrate in-depth knowledge about environmental dynamics, which is instructive for modern-day resilience strategies. The findings accord with the recent scholarly emphasis on the primacy of indigenous knowledge in climate adaptation, as espoused by Hiwasaki et al. (2014), with specific spatial implementation strategies.

In integrating traditional knowledge with modern planning, the needed attention is accorded by the physical and spatial arrangement and their socio-economic mechanisms. The very persistence of Feng Shui forests through embeddings in local governance structures allows a foresight into how the old practices, in fact, keep finding their relevance through institutions. This observation lends credence to Jigyasu's argument (2016) that successful strategies of resilience need to consider both technical and social dimensions of traditional practices and that modern approaches to planning should similarly be embracing this duality.

5.2. Implications for Heritage Conservation

The spatial patterns in this research are representative of the complex integration between functional adaptation and cultural heritage values. These embody what Taylor and Lennon (2021) describe as living heritage, wherein traditional practices serve vital contemporary functions within a continuous cultural significance. The multifunctionality of these spatial arrangements resists conventional approaches to heritage conservation that artificially separate physical and intangible heritage elements.

Our findings thus suggest a radical reorientation in conserving heritage within coastal contexts is called for, shifting from one that treats their spatial patterns of artefactness as static aspects of history to approaches that place such artefactness within long-term dynamics while retaining essential protection functions into the present. And this role played by community governance in their perpetuation thus extends to how effectively conservational concerns can operate well beyond concerns of physical protection through and within social systems within which those patterns continually adapt and change.

5.3. Applications for Resilience Planning

These found patterns bring key messages for current resilience planning in coastal areas, as the systematic arrangement of protective elements shows how a set of risk-reduction strategies can be combined into coherent spatial frameworks that fit emergent trends in resilience thinking centered on systemic approaches rather than isolated interventions (Meerow and Newell, 2019). The graduated transition from sea to inland uses provides important lessons in the management of coastal vulnerabilities while maintaining productive land use, while the integration of settlement and agricultural systems illustrates how different land uses can mutually reinforce disaster resilience.

It is particularly relevant to consider traditional windbreak systems because of their multiple functions in a contemporary green infrastructure design. These systems show how protective functions can be combined with productive land uses and cultural significance and thereby offer a model for modern green infrastructure that goes beyond simple hazard mitigation toward incorporating broader social and economic benefits.

5.4. Research Limitations and Future Development

These findings must be interpreted in the light of several methodological limitations. While the FP-Growth algorithm identified the spatial pattern effectively, applications to complex spatial relationships may render this incapable of capturing all nuanced variations in spatial arrangements. While the paper appropriately limits itself to a 500-meter coastal buffer zone in its focus on immediate typhoon impacts, it misses broader spatial relationships extending further inland. Further, reliance on Super Typhoon Usagi (2013) as a principal verification case, while no doubt instructive, provides only a limited temporal window into the more complex history of typhoon impacts.

These limitations point toward several promising directions for future research. Comparative studies examining similar coastal regions facing typhoon risks could reveal variations in resilient spatial patterns and their cultural embedding, potentially identifying both universal principles and context-specific adaptations. The challenge of climate change suggests a need for research into how traditional spatial patterns might be adapted to address intensifying impacts, particularly in relation to sea-level rise and increasing typhoon intensity. Additionally, investigation of effective policy mechanisms for incorporating indigenous spatial knowledge into formal planning frameworks while respecting traditional governance systems would provide valuable guidance for practical implementation.

6. Conclusion

This study advances our understanding of typhoon-resilient spatial patterns in coastal settlements through systematic analysis of the Chaoshan region of Guangdong, China. Through the integration of spatial analysis techniques and indigenous knowledge interpretation, we have identified and validated specific spatial patterns that demonstrate effective adaptation to typhoon impacts while preserving cultural heritage values.

The research reveals how indigenous knowledge, accumulated through generations of environmental adaptation, has shaped sophisticated spatial arrangements that address multiple aspects of typhoon risk. The identified multi-layered windbreak system, combining coastal, settlement, and agricultural protective elements, demonstrates the integration of ecological understanding with practical risk reduction strategies. Likewise, the agricultural zoning pattern that graduates from fish farms through salt fields to rice fields bespeaks deep understanding of coastal dynamics and seasonal typhoon patterns.

Hence, these findings develop a significantly enriched contribution to theory in resilience planning, which draws heavily, for the very first time ever in documented history, onto systemic, spatially interrelational means that take a prominent role over individuals. What makes this finding particular is the expression wherein the efficacy to generate effective typhoon resilience rises not from discrete features alone or in concert through judicious placing to combine in expanded social-ecological systems and is what fundamentally reforms conventional ways where approaches toward achieving resilience have stressed isolated interventions instead of an integral-spatiated approach.

This is valuable learning that can be used in planning practice to devise context-specific resilience strategies. The spatial patterns extracted provide tangible examples of how traditional wisdom can be used to develop an informant approach to contemporary planning while ensuring continuity of the culture concerned. This developed methodology of spatial pattern mining combined with indigenous knowledge validation provides a framework that can be extended and used to investigate resilient spatial patterns in other disaster-prone regions globally.

The study's findings support the need for better conservation of indigenous knowledge systems in an attempt to learn from them in handling environmental problems relevant in the contemporary era. These need to be scaled up in response to increased vulnerabilities of climate change and extreme weather events along the coastlines across the globe. The identification and understanding of such traditional strategies of resilience is valuable in its adaptation processes.What should follow in future research is how these patterns are adaptable within a changing climate regime and their applicability across cultural and geographical divides.

7. References

Alexander, C. (1977) *A Pattern Language: Towns, Buildings, Construction*. New York: Oxford University Press.

Amirzadeh, M., Sobhaninia, S. and Sharifi, A. (2022) 'Urban resilience: A vague or an evolutionary concept?', *Sustainable Cities and Society*, 81, pp. 103853.

Hadlos, A., Opdyke, A. and Hadigheh, S.A. (2022) 'Where does local and indigenous knowledge in disaster risk reduction go from here? A systematic literature review', *International Journal of Disaster Risk Reduction*, 79, pp. 103160.

Han, J., Pei, J. and Kamber, M. (2019) *Data Mining: Concepts and Techniques*. Amsterdam: Morgan Kaufmann.

Hiwasaki, L., Luna, E., Syamsidik and Shaw, R. (2014) 'Process for integrating local and indigenous knowledge with science for hydro-meteorological disaster risk reduction and climate change adaptation in coastal and small island communities', International Journal of Disaster Risk Reduction, 10, pp. 15-27.

Jigyasu, R. (2016) 'Reducing Disaster Risks to Urban Cultural Heritage: Global Challenges and Opportunities', *Journal of Heritage Management*, 1(1), pp. 59-67.

Kropf, K. (2018) *The Handbook of Urban Morphology*. Chichester: John Wiley & Sons.

Li, Z., He, W. and Cheng, M. et al. (2023) 'SinoLC-1: the first 1-meter resolution national-scale land-cover map of China created with the deep learning framework and open-access data', *Earth System Science Data Discussions*, 2023, pp. 1-38.

Meerow, S. and Newell, J.P. (2019) 'Urban resilience for whom, what, when, where, and why?', *Urban Geography*, 40(3), pp. 309-329.

Meerow, S., Newell, J.P. and Stults, M. (2016) 'Defining urban resilience: A review', *Landscape and Urban Planning*, 147, pp. 38-49.

Sharifi, A. (2019). Urban form resilience: A meso-scale analysis. *Cities*, 93, pp.238–252.

Sharifi, A. and Yamagata, Y. (2016) 'Urban resilience assessment: Multiple dimensions, criteria, and indicators', *Urban resilience*, pp. 259-276.

Taylor, K. and Lennon, J. (2021) 'Cultural Landscapes and Asia: Reconciling International and Southeast Asian Regional Values', *Landscape Research*, 46(1), pp. 143-156.

UNDRR and CRED (2020) Human Cost of Disasters: An Overview of the Last 20 Years (2000-2019). Geneva: United Nations Office for Disaster Risk Reduction.

Wang, Z., Liu, J., Xu, N., Fan, C., Fan, Y., He, S., Jiao, L. and Ma, N. (2019). 'The role of indigenous knowledge in integrating scientific and indigenous knowledge for community-based disaster risk reduction: A case of Haikou Village in Ningxia, China', *International Journal of Disaster Risk Reduction*, 41, p.101309.

Li, H., Liu, Y., Zhang, H., Xue, B. and Li, W. (2021). 'Urban morphology in China: Dataset development and spatial pattern characterization', *Sustainable Cities and Society*, 71, p.102981. doi: 10.1016/j.scs.2021.102981.

Chen, B., Coggins, C., Minor, J. and Zhang, Y. (2018). 'Fengshui forests and village landscapes in China: Geographic extent, socioecological significance, and conservation prospects', *Urban Forestry & Urban Greening*, 31, pp.79–92.

Lei, Y., Liu, C., Zhang, L., Wan, J., Li, D., Yue, Q. and Guo, Y. (2015). 'Adaptive governance to typhoon disasters for coastal sustainability: A case study in Guangdong, China', *Environmental Science & Policy*, 54, pp.281–286.

Research Paper

Assessment of the Traditional Design Approaches of the Heritage City of Puri, India

Rabi Narayan Mohanty, Assistant Professor, Department of Architecture, Planning, and Design, IIT BHU, Varanasi, 221005, India

Ashaprava Mohanta, Assistant Professor, School of Architecture and Planning, KIIT Deemed to be University, Bhubaneswar, 751024, India

rnmohanty.apd@iitbhu.ac.in[1], ashaprava.m@gmail.com[2]

Abstract:

Puri, located in eastern India, is famous for its Kalinga-style temples and traditional buildings. This city has developed its architectural characters over the last 1600 years. This paper aims to analyse the architectural fabric of Puri's old vs new precincts. The applied research method involves site visits, architectural elements and styles documentation, and interviews with subject experts. The outcome of this research revealed that increased tourist counts and commercial activities have surged the construction of new buildings in different architectural styles in the core heritage precincts of Puri. Also, the haphazard construction of mid-rise buildings threatens Puri's traditional architectural characteristics. Moreover, this research prepared an inventory of design elements and styles. The outcomes of this research can be used by the development authorities and policymakers to improve and maintain the architectural characteristics of Indian heritage sites.

Keywords: *heritage sites, sacred sites, architectural vocabulary, Puri*

1. Introduction

Ancient heritage sites discourse traditional cultural, social, and artistic achievements of different societies (UNESCO, n.d.). Further, ancient heritage cities are renowned for their classical architectural masterpieces with intricate detailing, showcasing the creative capabilities of various artists, and they have been built for thousands of years (Hiraskar, 1991). Traditional architecture manifests cultural, climatic, religious, and geographical factors and the availability of materials and skilled artists; hence, each heritage place has unique architectural characteristics (English Heritage, 2007). However, with improvements in economic conditions and mobility infrastructure, heritage sites worldwide have significantly changed their morphology, land use and architecture in the 20th century (Rai, 2008). Further, in developing countries, the changes are rapid and unplanned, causing degradation of architectural harmony and loss of heritage uniqueness of the precincts (Timothy & Nyaupane, 2009).

India, a developing country, has 43 World Heritage Sites and several sites of state significance (UNESCO, n.d.). These heritage sites have evolved over a millennium and are part of India's rich cultural, art, and architectural legacies (MHUA & NIUA, n.d.). Millions of visitors throng to these heritage cities and generate employment opportunities and revenues for locals (Ministry of Urban Development, 2015).

However, sometimes, tourism has diabolical impacts on the built environment, as over-tourism causes several unpleasant situations for the locals (Singh, 2007). Since the late twentieth century, Indian heritage sites have undergone major transformations in their land use, transportation patterns, density, and tourist counts (MHUA & NIUA, n.d.). Further, tourism growth has increased the demand for mixed and commercial buildings in heritage precincts (MoUD, 2015). Moreover, the use of international and eclectic design approaches in core heritage precincts has imperilled heritage characteristics, including the architectural fabric of ancient India. This research explores the traditional design approaches of Puri, a major ancient heritage city in India.

1.1 Site brief

Puri is the resting place of Lord Jagannath, the eighth avatar of Lord Vishnu (Starza, 1993). This city experiences warm and humid climates with an average annual temperature between 28° and 38° C. With a population of 283000 in 2024, Puri allures 18 million visitors yearly (Odisha Tourism, 2024). Further, this place is renowned for its traditional art, architecture, culture, cuisines and festivals. It is a 'Grade One' heritage city (CPWD, 2013) and a 'Type A' tourist town in India (Puri Municipality, 2006). Also, this city celebrates the yearly ***'Ratha yatra'*** *(*Cart festival*)*, one of India's largest religious gathering events (G. Mohanty et al., 2010). Considering social, cultural, and heritage significance, Puri is the most preferred case study for this research. Figure 1 shows the location map of Puri in Odisha and India.

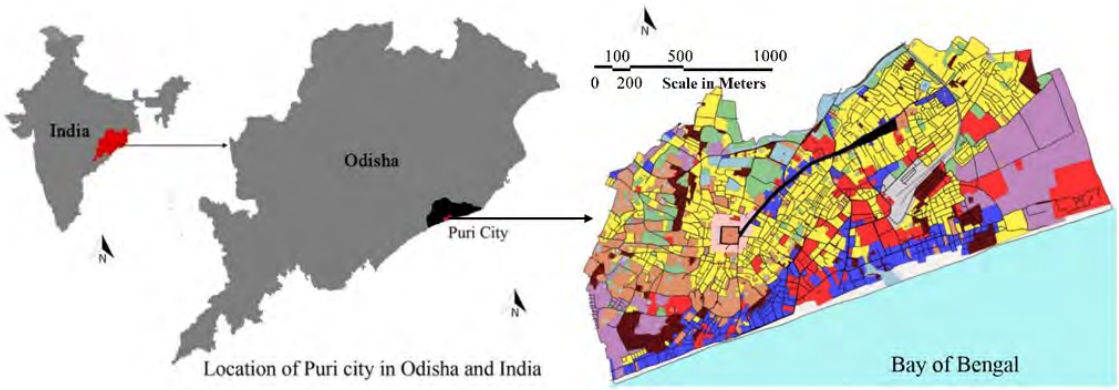


Figure 1: Puri's location in Odisha and India, source: authors

The study is divided into the following segments: introduction, site brief, literature review, research method, analysis, results, discussion and conclusion.

2. Literature review

Architecture is the physical manifestation of societies' cultural, geographical, climate, resources and religious characteristics (Hiraskar, 1991). Traditional architecture involves the locally available materials, construction techniques and design elements related to the socio-cultural practices of the place. Further, the construction process consists of the craftsmanship of skilled artists and designers developed over time. However, based on scale, design, and materials, the architecture of ancient settlements is classified into two groups: architecture of affluents and architecture of the peasants.

Architectural design is subjective and affected by the aesthetic sensibility of owners and designers. Also, the architecture reflects social, cultural, and religious parameters and societies' economic and administrative stability. Designing a new structure in heritage precincts is challenging as it involves designers' artistic capability and sensibility (English Heritage, 2007). However, on a few occasions, designers fail to understand the artistic characteristics of the built environment and cause visual nuisance through their design, which has no similarities with the traditional settings (Davies, 2003). Nasar (1994) terms this as an 'architect's aesthetics failure' to discourse heritage precinct design approaches. The design of heritage buildings in heritage precincts is classified into three groups: similar approach, mixed approach, and contrast approach (R. Mohanty et al., 2015; Tyler et al., 2018).

Design experts play a significant role in identifying design characteristics and elements of heritage settings (R. N. Mohanty & Mohanta, 2023; Sotoudeh & Abdullah, 2013). Further, Amir Hossein Askari (2012) has advocated for identifying the architectural characteristics and elements of heritage settings to maintain the visual harmony of heritage settings. The major architectural characters and elements comprised building designs, dimensions, materials, colours, and ornamentation (Oppong et al., 2018).

Kalinga Kingdom

A description of Kalinga cities is mentioned in sacred textbooks, such as Mahabharat and Rigveda. King Ashoka invaded the Kalinga kingdom in 232 CE (D. Das, 1977). Later, under the patronage, Buddhism flourished in Kalinga, including Puri, till the 7th century C.E. (Ray & Misra, 2016). Hinduism revived in India, including in the 6th century, and Puri became a major site for Vaishanavites in the 9th century C.E. (M. K. Das, 2015). Later, Kalinga architecture flourished in Ekamara Kshetra, the adjacent city of Puri, from the 8th century to the 14th century C.E. The early Kalinga temples were simple and had symbolic representations of elements of other regions; however, later, temples became complex and extravagant (Brown, 1959). The cultural heritage of Puri, which has evolved over the last 1500 years, comprises temples, religious buildings, water bodies, religious guesthouses (*Mathas)*, and art and sculpture related to the Jagannath cult (Mohanty, R.N et al., 2024). Figures 2 and 3 show the location of Puri's heritage buildings/structures and heritage precincts.

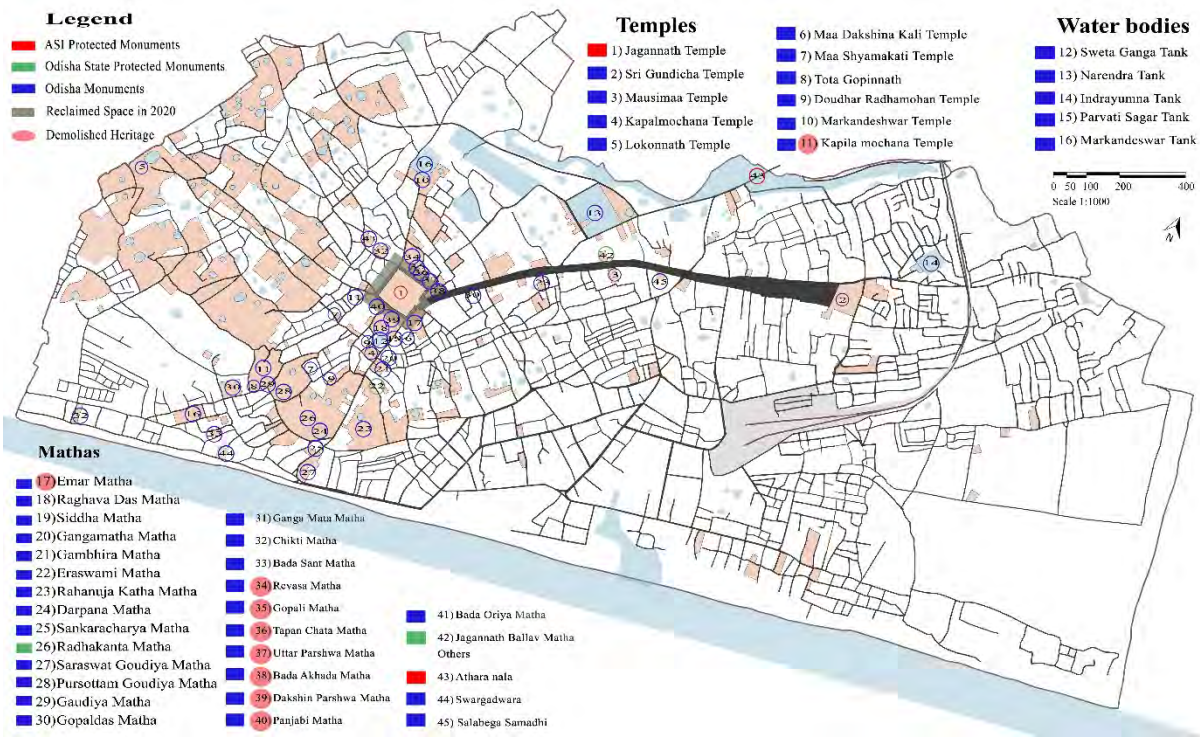


Figure 2: Location of heritage structures in Puri, source: Authors

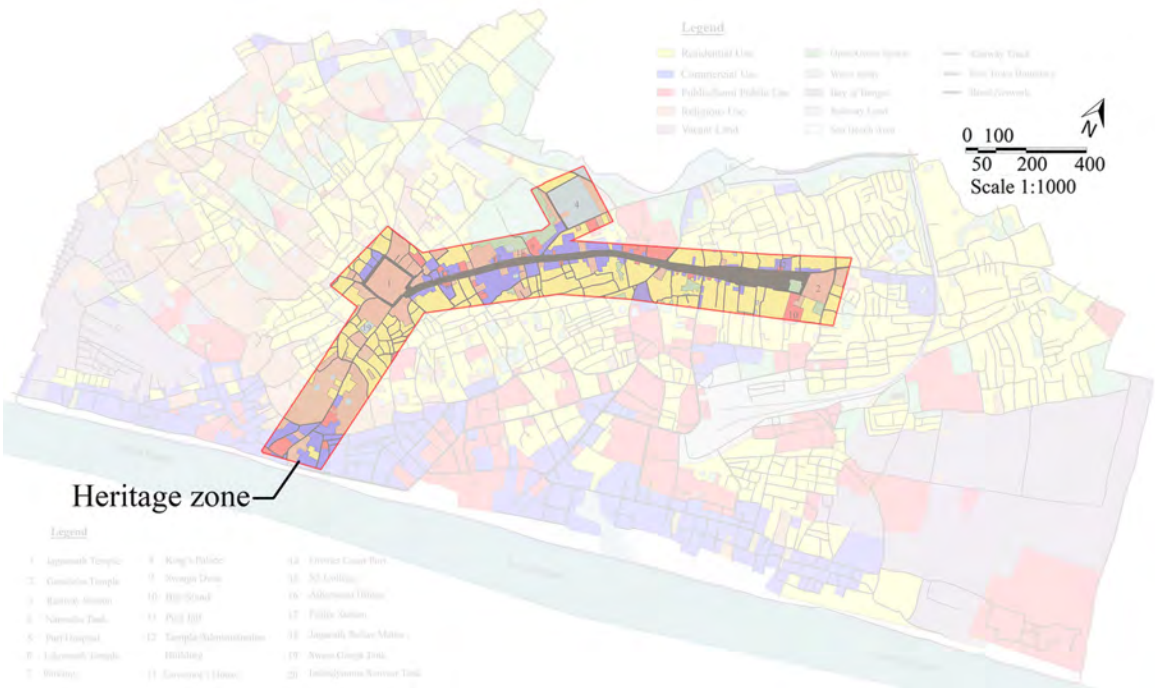


Figure 3: Heritage zone in Puri, source: Authors

3. Method

The research idea originated from a leisure trip at Puri. Authors, architects, and teachers by profession have observed changes in architectural characters from the core to the city outskirts. Later, detailed site

observations and literature reviews confirmed architectural character alteration over time. This study involved the following techniques: site observations, digitation, and interviews with historians and subject experts.

Literature related to the history of Puri, site visits, and discussions with subject experts were done to understand the development of Puri's architectural characteristics. Through site observations and literature reviews, 76 iconic heritage buildings in Puri were identified and documented (Figure 5). Further, 13 senior design experts (architects and urban designers) were identified and interviewed to understand Puri's design patterns and elements. Later, experts' opinions were used to categorise buildings' architectural characteristics and prepare building element inventories. The stakeholders are actively involved in different city agencies and have worked with them for over 15 years. Figure 4 shows the research method used in this study.

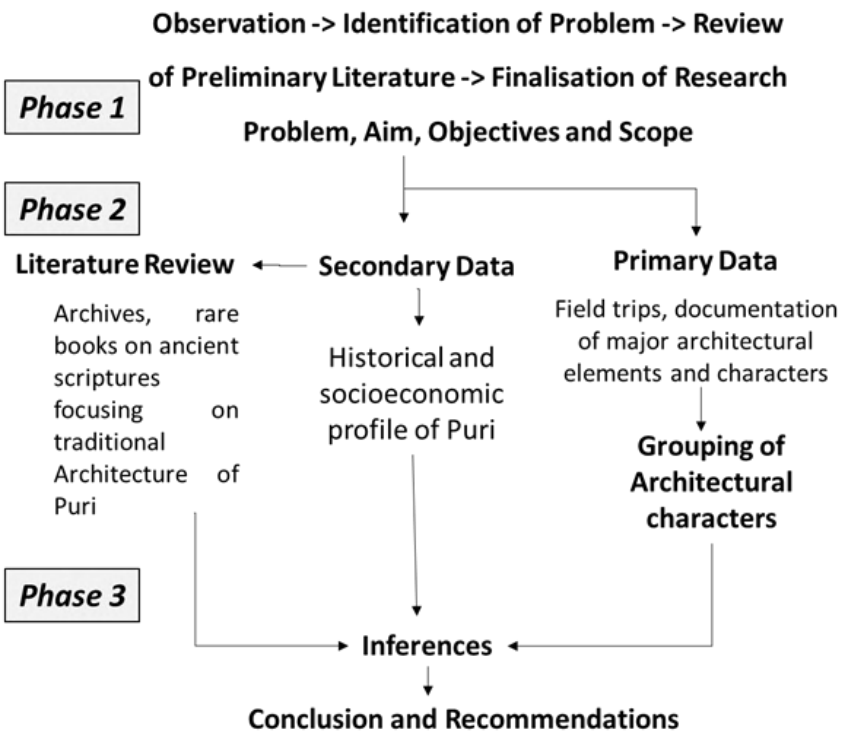


Figure 4: Applied research method of the study

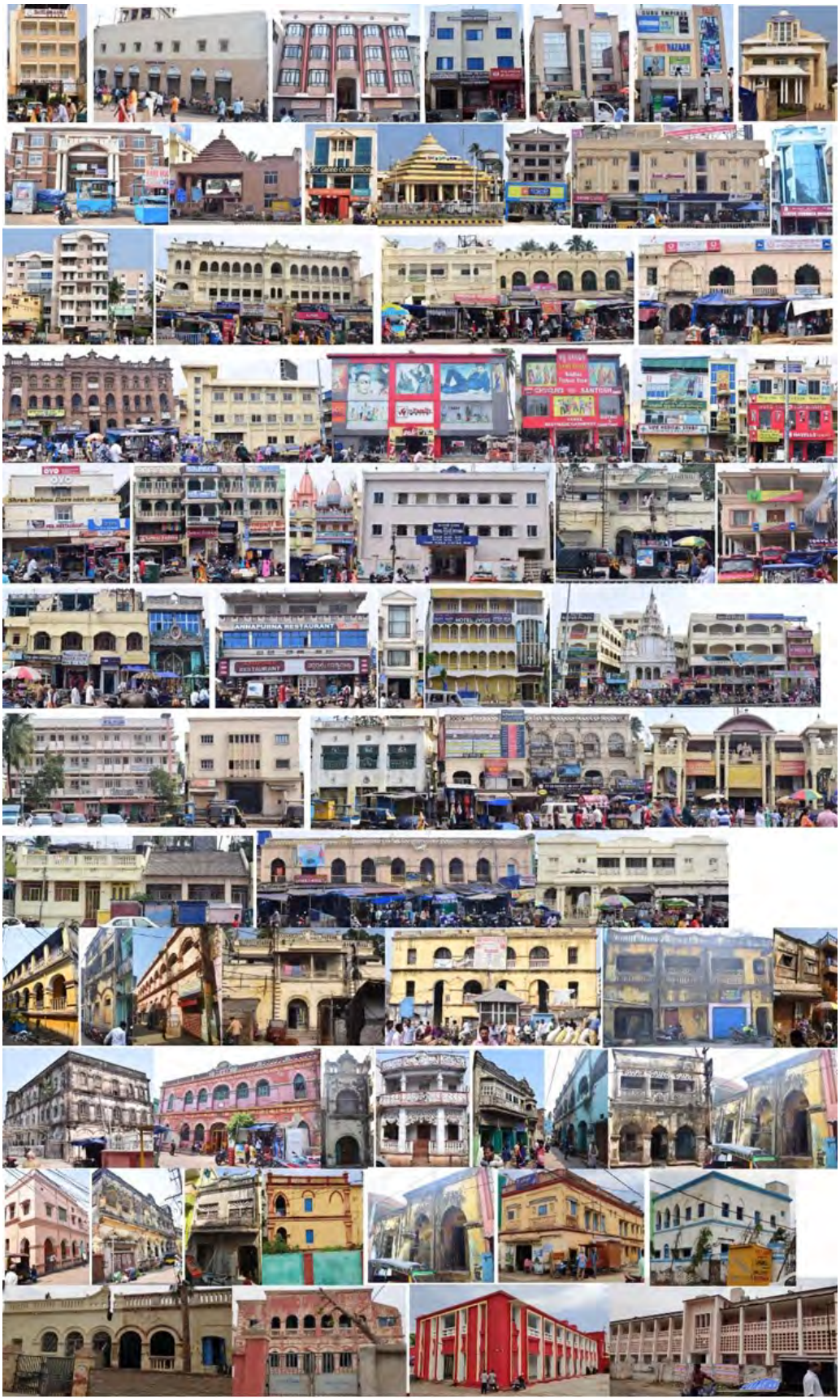


Figure 5: Identified buildings of Puri, source: Authors

4. Analysis and Discussion

4.1 Chronological Evolution

The extant literature on Puri reveals that the city's inception of human settlement is traced back to the 4th century C.E. Later, this city developed from a small fishing town to a prime religious town for Hindus. The literature review has revealed that rulers' political and religious ideologies have shaped Puri's development. Further, according to (G. Mohanty et al., 2010), the mythological layout of Puri is a Conch with the Jagannath temple placed in the heart of the conch on a hillock, Nilagiri (Figure 6). Puri's nascent phase of civilisation was from the 4th to the 9th century C.E. A few temples were built in Puri for Lord Vishnu during this period. Also, Puri was a small fishing town in this period.

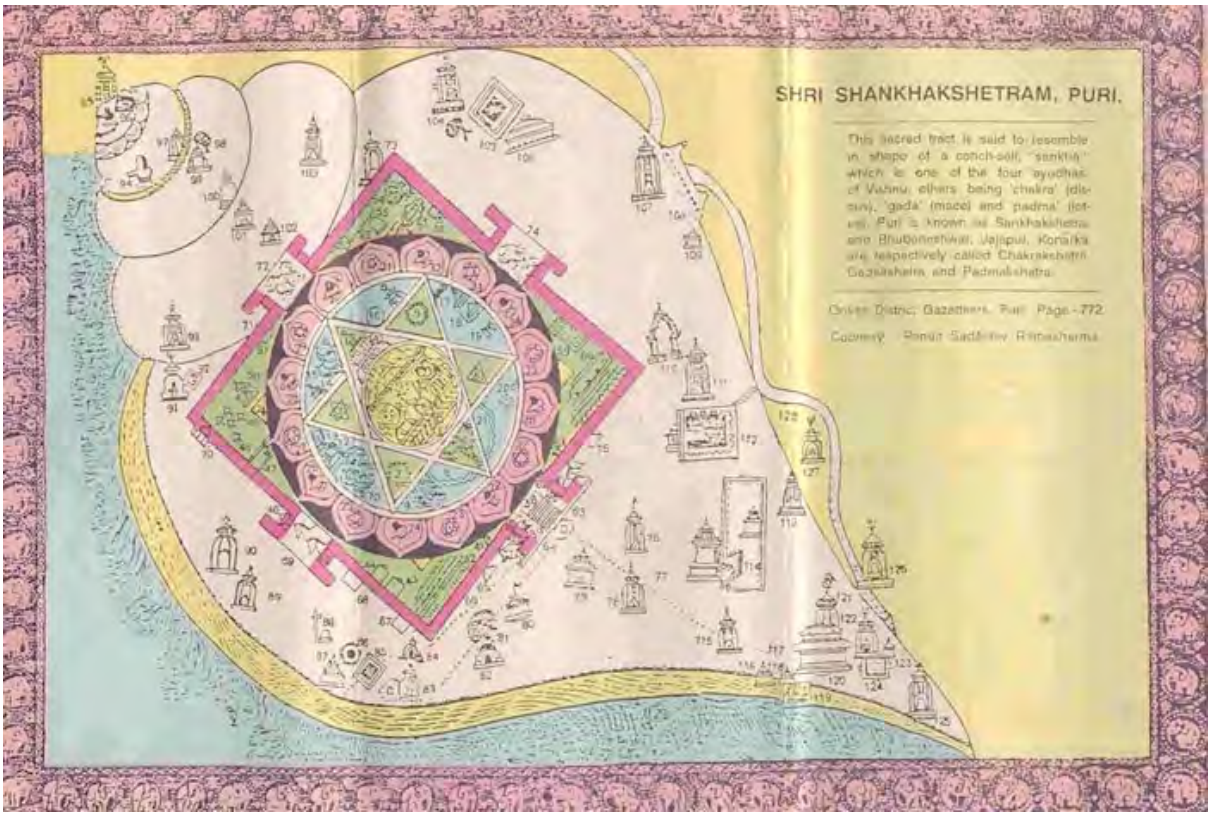


Figure 6: Mythological Conch shape map of Puri, source: (CEPT, 2013)

The period between the 9th and 15th century C.E. is considered the golden period for Kalinga architecture, as the Jagannath temple was started in 1098 and completed in the 12th century (Panda, 2016). Saint Shankaracharya (a Hindu cleric) declared Puri as one of the four most sacred sites (Char Dhams) in Hindus (G. Mohanty et al., 2010). Also, according to (*Jagannath Puri - Home to the Lord of the Universe*, n.d.), after the completion of the construction of the temple, Priests (Brahmins) were settled around the temple in eight colonies by the King for the smooth functioning of the temple. Ramblers with independent courtyards, allies, ponds, and green spaces are significant elements of these colonies. Also, the Gundicha

temple was constructed by Chodo Ganga Deva, a ruller of Puri, in the 12th century C.E. The extant literature suggests that the famous cart festival between the Jagannath and the Shree Gundicha temple was started in the 12th century.

In the 15th century C.E., many Hindu saints visited Puri; hence, for their comfortable stay, several 'Asharamas' and 'Mathas' were constructed in the surrounding precincts of the Servicemen colonies (refer to Figure 7 a). Later, Afghans and Mughals ruled Puri in the 15th century C.E. According to (Panda, 2016), the development of Kalinga temples in Puri was stopped in the Kalinga region during the Afghan and Mughal periods.

British colonial rulers ruled Puri from the 19th to the mid-20th century. In the Greco-Roman style, they constructed institutional buildings such as the collectorate office, court, and prison houses (Figure 7 c). Also, they brought Bungalow architecture to Puri for the comfortable stay of their bureaucrats (Kalia, 1994). In this period, these bungalows were constructed in a hybrid style, i.e., Indian, Persian and British colonial architecture (refer to Figure 7 b).

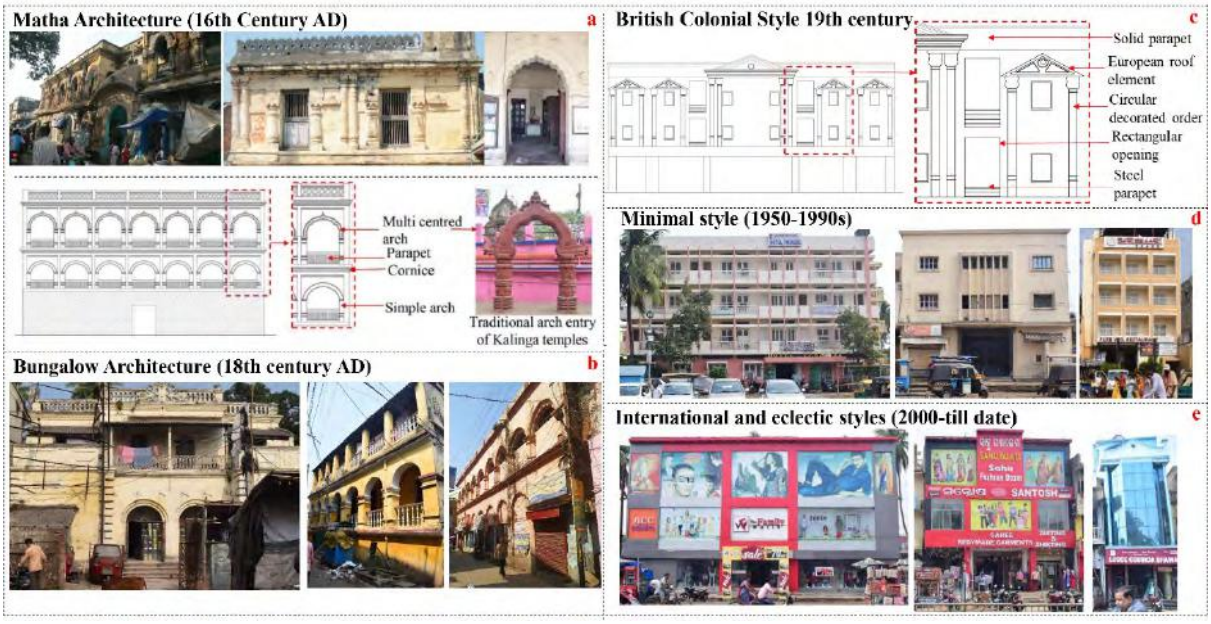


Figure 7: Architecture typologies of Puri, source: authors

The increased tourist count due to the betterment in site's accessibility and transportation amplified the construction of mixed-use and commercial buildings in the heritage precinct and marine road in the early 20th century. Later, the basic amenities of the Puri were improved, and institutional buildings (schools and colleges), commercial (lodges, hotels, eateries, and malls) and residences were constructed in a modern style from the 1960s to 1990s (Figure 7 d). However, since the 2000s, the eclectic style has become the most preferred option for commercial, residential and mixed-use buildings (refer to Figure 7 e). Moreover,

the increased spatial demand has changed the traditional characteristics of Puri's heritage precinct. In 2019, the Odisha government implemented a heritage regeneration scheme, *'Shree Mandira Parikrama',* around the Jagannath temple complex, and 75 m wide corridor spaces (plazas) with public amenities were created. However, several heritage buildings (*Mathas and Ashrams*) were demolished around the Jagannath temple in this project (Figure 3). This project has created displeasure among subject experts (historians and archaeologists) and locals (India Collective, 2019). Different rulers' impact on Puri's development is shown in Figure 8.

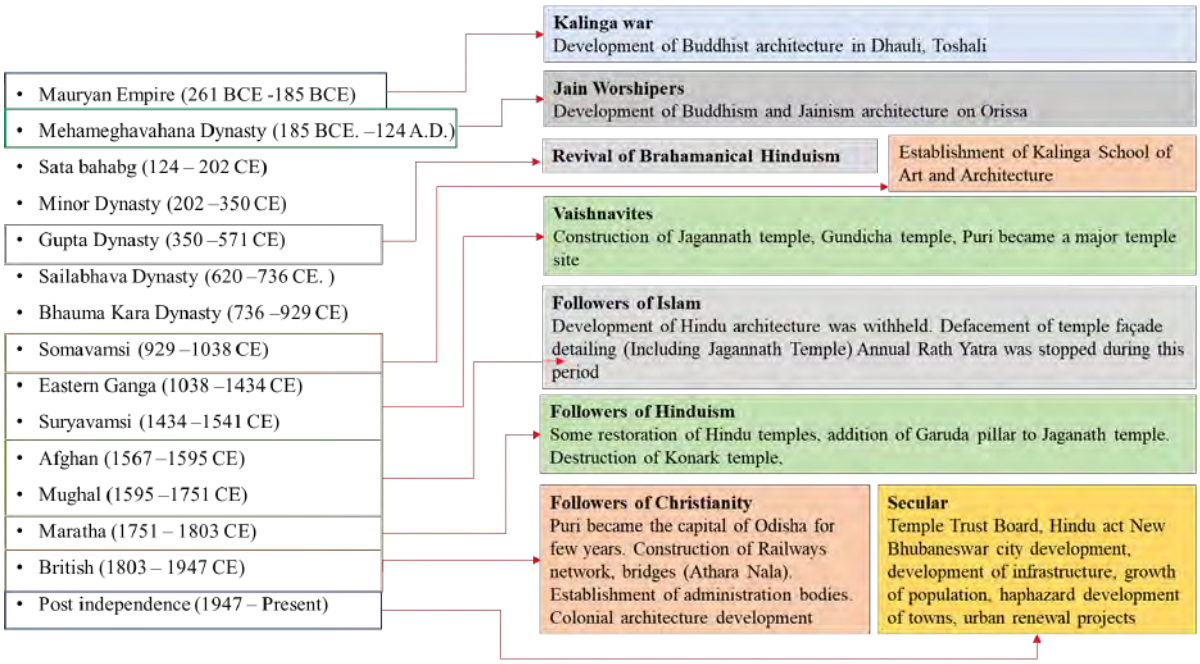


Figure 8: Impact of different rulers on the Built Environment of Puri, source: authors

Figure 9: Transformation of traditional buildings to contemporary buildings, source: Authors

4.2 Architectural Characteristics

In Puri, 'Kotah Ghar' Bungalows and '*Chala Ghar*' mud houses are the traditional buildings of the affluent and peasants, respectively. Mud houses are built with stone foundations, mud walls and thatched roofs with timber support. Most of the mud houses have a central courtyard, which is used for informal gatherings and day-to-day activities of houses. However, the Bungalow architecture was introduced by the British colonial rulers in the 19th century. This type of architecture has multi-centred arches, verandahs, flat roofs, and plastered walls and floorings. It uses stone, brick, lime, iron, and clay tiles for construction. Both types of architecture use passive techniques for cooling and user comfort.

However, with globalisation and modernism in Architecture, the traditional buildings of Puri were replaced with contemporary mid-rise and mixed-use buildings (Figure 9). The mixed-use buildings were constructed of cement, brick, concrete, steel, aluminium, and glass. Moreover, unplanned construction in heritage precincts has challenged architectural harmony and heritage visibility of landmarks and heritage structures (Figure 10).

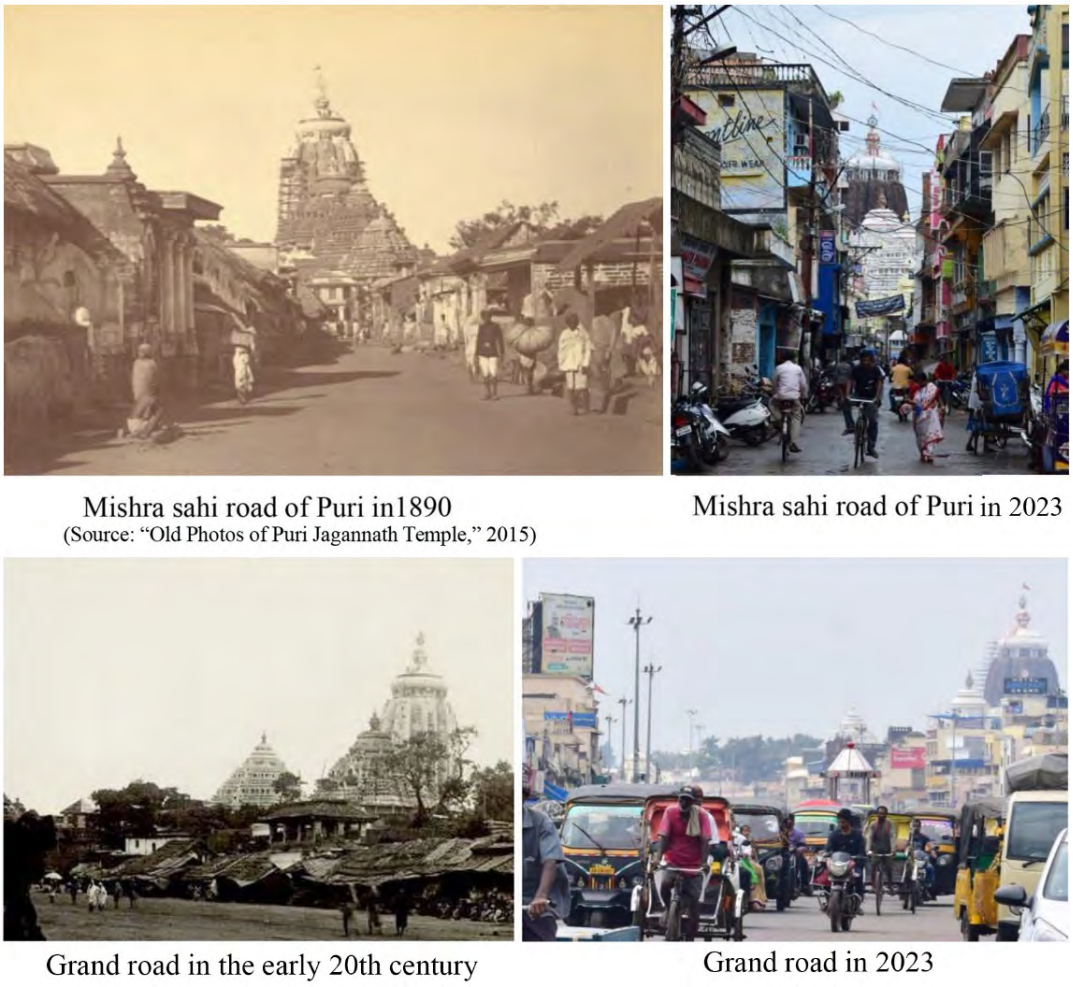


Figure 10: Transformation of heritage precincts of Puri, source: authors

Figure 11: Design approaches of Puri: (a) Buildings designed with classical (Indian) style, (b) mixed approach, and (c) contrast approach, source: Authors

4.3 Architectural Design Approaches:

The architectural characteristics and elements of these buildings were categorised by design experts into three groups as follows:

- **Similar approach**: These structures, mostly placed at the heritage zones, were constructed in the 19th century with local stone and lime, such as multicenter arches, ornamentations, and ornamentations (Figure 11a).
- **Mixed approach**: This hybrid style has traditional Indian, European and contemporary elements. This approach is mostly used in residential and commercial buildings (Figure 11b).
- **Contrast approach**: This approach consists of contemporary building materials and modern design elements and is mostly used in recently constructed commercial and mixed-use buildings (Figure 11 c).

Further, the authors classify Puri's buildings into several groups based on their architectural and construction characteristics, as shown in Table 1. The data collection was done in 2022 by the authoes.

Table 1: Building classification, source: authors

Style	Approval	Building Life	Building Offset	Façade materials and finishes	Roof types	Land-use	Building height
Indian classical	Approved by the governing building bylaws	Medieval era (15th to 18th century CE)	Attached buildings	Stone cladding	Spire	Religious	Single story
European classical	Illegal construction, but follows the basic bylaws	Early 20th century	Separated building	Brick walls with surface groves	Flat	Institutional	Two stories
Modern/ International	Illegal construction does not follow the basic bylaws	Post-independence (1950s)		Simple walls with no ornamentation and painted in ivory colour	Pitched	Residential	Three stories
Eclectics		Post India's economic liberation (2000s)		Brick with external tile cladding	Temporary roof (tin or thatched)	Commercial	Four stories
		Newly constructed		Brick with external glazing		Mixed-use	Five and above

Site observations and interviews with experts have discoursed major facade patterns of Puri (Figure 12 a). Sandstone and laterite stone are symbolic materials in Odisha. Hence, most of the new public buildings are

constructed with exposed stone. However, ivory is used in administrative buildings, and structural glazing is used in commercial buildings. Further, the traditional multicentered arch and Kalinga columns are elements of the heritage buildings of Puri (Figures 12 b and 12 c). However, site observations have revealed that these traditional elements have been replaced with simple arches, rectangular openings, and Greco-Roman orders in the new buildings.

Figure 12: (a) Structures with classical design approach, (b) structures with mixed approach, (c) structures with contrast approach, source: Authors

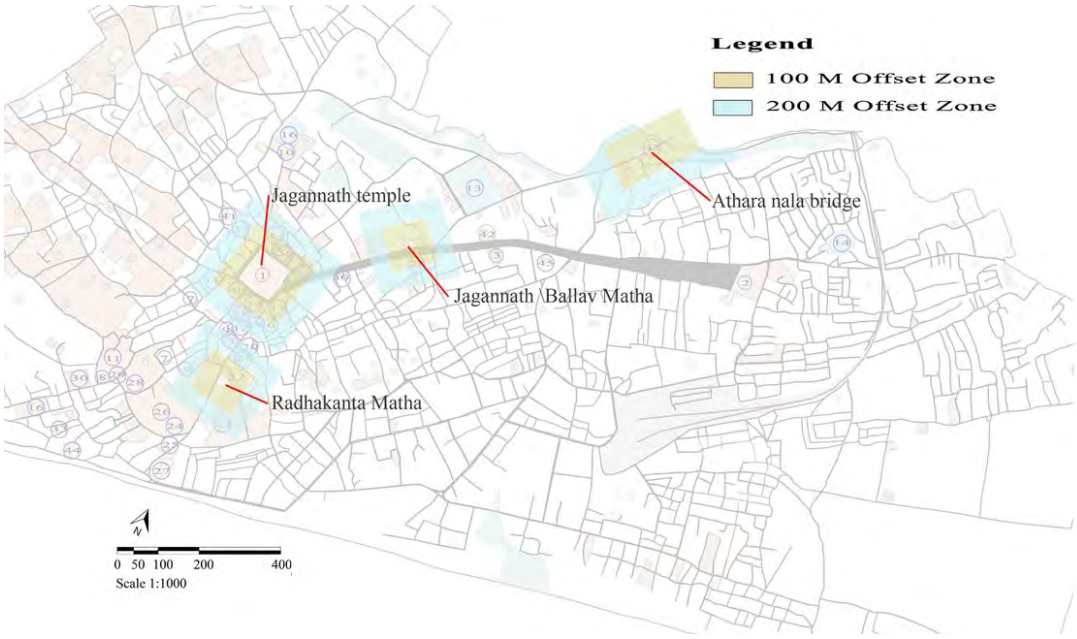


Figure 13: Protected zones in Puri according to the AMSAR Act., source: Authors

4.3 Heritage Encroachment and Demolition

Settlements around the Jagannath temple complex developed organically in 1600 years, giving rise to a unique flavour of Kalinga architecture. However, since the mid-20th century C.E., the construction of residential, commercial, and mixed-use structures has increased manifold. Further, these constructed buildings violated the later-implemented AMSAR 1958 ACT, which restricts the construction of buildings around 100 and 200m the listed heritage structures (ASI, 1958). Further, encroachment and the absence of preservation of unlisted heritage monuments are other significant issues for the city. Figure 13 shows the buildings around the ASI-protected structures under the AMSAR Act.

Millions of travellers visit Puri annually for religious, recreational, and heritage tourism reasons. However, most visitors have mixed and negative travel experiences in Puri's heritage-built environment. Hence, a major heritage regeneration project was essential to improve the travel experiences of visitors. The heritage corridor project *'Shree Mandira Parikrama'* was implemented by demolishing several 17th-century heritage buildings and structures. However, the implementation of *'Shree Mandira Parikrama'* project was criticised by historians, archaeologists, and locals as this project replaced the traditional built environment around the Jagannath temple with wide public spaces and plazas with modern design elements.

4.4 Experts Perspectives

Interviews with experts divulged that the absence of guidelines for infill buildings is a primary issue related to altering Puri's traditional characteristics. Also, few buildings follow the building bylaws and are approved by the local governing body (Figure 14). Further, the lack of site-specific guidelines has caused buildings in various styles and elements in the core heritage precincts (Figure 14 b). Also, there is a lack of awareness of heritage significance among locals and travellers, and incentives are other reasons for the heritage maintenance of Puri.

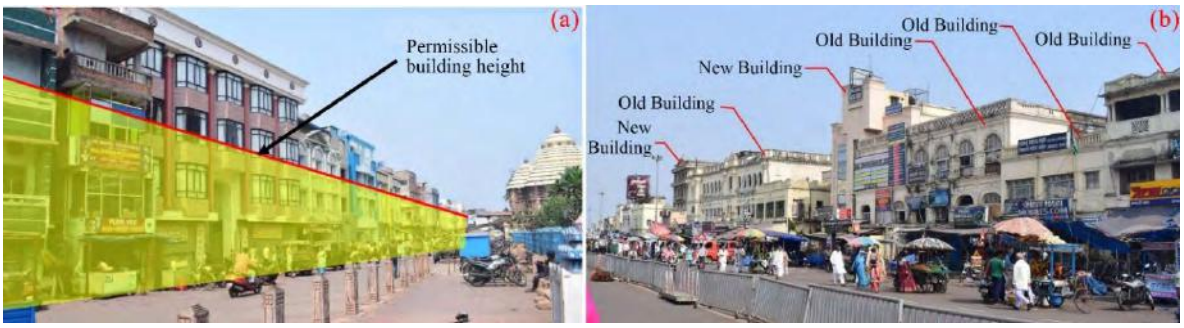


Figure 14: Streetscape images of Puri, source: Authors

5. Conclusion

Puri is a major heritage site in India. This city has developed its architectural characters under the influence of its rulers over the last 1600 years. Haphazard construction of mid-rise buildings in the core heritage zone is threatening the traditional design elements and ornaments of Puri, which are the major challenges of this city. Also, interviews with experts have revealed that the absence of heritage-related building bylaws and the implementation of building regulations have created several issues related to the architectural fabric of ancient Indian heritage sites.

Design experts categorised the identified buildings' architectural characteristics based on different architectural parameters. Further, an inventory of building styles and approaches was made to create a repository of knowledge and public awareness. Also, interviews with experts revealed major issues related to heritage management and the alteration of traditional characteristics of Puri.

However, this study has the following limitations: this paper does not discuss the economic aspects of the transformation of architectural settings. Also, this paper does not discuss residents' perspectives on architectural elements. Future research could focus on these aspects of Puri's architectural design and heritage management.

Funding:

This research is funded by the Indian Knowledge System Division, All India Council for Technical Education, Ministry of Education, Government of India (File number: AICTE/IKS/REP1/2021-22/03)

References

Amir Hossein Askari, K. (2012). Influence of Building Facade Visual Elements on Its Historical Image: Case of Kuala Lumpur City, Malaysia. *Journal of Design and Built Environment*, *Volume 5*(Issue 1), 49–59.

ASI. (1958). *The Ancient Monuments and Archaeological Sites and Remains Act*. https://architexturez.net/system/files/pdf/AMASAR ACT 2010.pdf

Brown, P. (1959). *Indian Architecture (Buddhist and Hindu Periods)* (1st ed., Vol. 1st). D.B. Taraporevala Sons & Co. Private LTD. https://www.indianculture.gov.in/ebooks/indian-architecture-buddhist-and-hindu-periods-0

CEPT. (2013). *Draft Comprehensive Development Plan-2031*. http://pkdapuri.in/pdf/PKDA_vol1.pdf

CPWD. (2013). *Handbook of Conservation of Heritage Buildings*. http://cpwd.gov.in/Publication/ConservationHertbuildings.pdf

Das, D. (1977). *The Early History of Kaliṅga: A Socio-economic and Cultural History of Coastal Orissa*. Punthi Pustak. https://books.google.co.in/books?id=ZcgBAAAAMAAJ

Das, M. K. (2015). *History of Odisha (From Earliest Times to 1434 A.D.)*. http://ddceutkal.ac.in/Syllabus/MA_history/Paper-16.pdf

Davies, M. (2003). *Design in the Historic Environment*.

https://www.buildingconservation.com/articles/design/design.htm

English Heritage. (2007). *Conservation Principles, Policies and Guidance*. https://content.historicengland.org.uk/images-books/publications/conservation-principles-sustainable-management-historic-environment/conservationprinciplespoliciesguidanceapr08web.pdf/

Hiraskar, G. K. (1991). *The Great Ages of World Architecture*. Dhanpat Rai Publications. https://www.goodreads.com/book/show/25990626-the-great-ages-of-world-architecture

India Collective. (2019). *Demolition around Shri Jagannath Puri Temple - Standing Up for Indic Civilizational Values Through Legal Intervention*. India Collective. https://www.indiccollective.org/portfolio-item/demolition-around-shri-jagannath-puri-temple/

Jagannath Puri - Home to the Lord of the Universe. (n.d.). Retrieved November 13, 2019, from https://www.tirthayatra.org/jagannath-puri/

MHUA, & NIUA. (n.d.). *Heritage City Development and Augmentation Yojana*. MHUA. Retrieved February 11, 2016, from https://www.hridayindia.in/

Ministry of Urban Development. (2015). *HRIDAY: Heritage City Development & Augmentation Yojana*. https://tourism.gov.in/prashad-scheme#:~:text=The full form of the,enriching the religious tourism experience.

Mohanty, R.N, Mohanta, A., & Chani, P. S. (2024). Changing Heritage Imageability of an Ancient Indian Sacred City – A case of Puri. *Journal of Cultural Heritage Management and Sustainable Development*. https://doi.org/10.1108/JCHMSD-02-2023-0015

Mohanty, G., Das, H., Pattanaik, A. K., Tripathy, M., Rath, P. K., & Satapathy, H. (2010). *Cultural Heritage of Odisha Volume XII Sri Jagannath Special Volume Puri District* (1st ed.). State Level Vyasakabi Fakir Mohan Smruti Sansad.

Mohanty, R. N., & Mohanta, A. (2023). Assessment of stakeholders' perspectives on infill buildings in the historical settings of an eastern India state – Odisha. *Journal of Cultural Heritage Management and Sustainable Development*, *ahead-of-p*(ahead-of-print). https://doi.org/10.1108/JCHMSD-06-2022-0094

Mohanty, R., P.S., C., & Chani, P. S. (2015). Infill design in the historic precinct of Haridwar. *Journal of Civil Engineering and Environmental Technology*, *2*(3), 265–270.

MoUD. (2015). *HRIDAY: Heritage City Development & Augmentation Yojana Ministry of Urban Development Government of India*.

Nasar, J. L. (1994). Urban Design Aesthetics. *Environment and Behavior*, *26*(3), 377–401. https://doi.org/10.1177/001391659402600305

Odisha Tourism. (2024). *Odisha Tourism*. Odisha Tourism. https://odishatourism.gov.in/content/tourism/en.html#upcomingEventHomeSection

Oppong, R. A. A., Marful, A. B. B., & Sarbeng, Y. K. K. (2018). Conservation and character defining elements of historical towns: A comparative study of Cape Coast and Elmina streets and castles. *Frontiers of Architectural Research*, *7*(1), 37–55. https://doi.org/10.1016/j.foar.2017.11.001

Panda, B. P. (2016). Temple of Orissa. *Global Journal of Indian History and Culture*, *1*(1), 1–6. http://globalvisionpub.com/globaljournalmanager/pdf/1451637027.pdf

Puri Municipality. (2006). *No Title*. http://jnnurm.nic.in/wp-content/uploads/2010/12/CDP_Puri.pdf

Rai, R. (2008). Threats to the spirit of the place: Urban Space and Squares, Historic City Core, Kathmandu. *16th ICOMOS General Assembly and International Symposium: 'Finding the Spirit of Place – between the Tangible and the Intangible.'* http://openarchive.icomos.org/227/

Ray, S. S., & Misra, K. (2016). *Odisha : an architectural Odyssey* (First). BLOOMSBURY. https://www.bloomsbury.com/in/odisha-9789385936036/

Singh, R. P. (2007). Urban Planning of the Heritage City of Varanasi (India) and its role in Regional Development.

In M. SCHRENK (Ed.), *REAL CORP 007 Proceedings / Tagungsband Vienna* (Vol. 8, pp. 259–268). CEIT ALANOVA Central European Institute of Technology, Dept. for Urbanism, Transport, Environment & Information Society. www.corp.at

Sotoudeh, H., & Abdullah, W. M. Z. W. (2013). Evaluation of fitness of design in urban historical context: From the perspectives of residents. *Frontiers of Architectural Research*, *2*(1), 85–93. https://doi.org/10.1016/j.foar.2012.10.007

Starza, O. M. (1993). *The Jagannatha Temple at Puri : Its Architecture, Art, and Cult* (1st ed.). E.J. Brill.

Timothy, D. J., & Nyaupane, G. P. (2009). Cultural Heritage and Tourism in the Developing World. In D. J. Timothy & G. P. Nyaupane (Eds.), *Cultural Heritage and Tourism in the Developing World: A Regional Perspective*. Routledge. https://doi.org/10.4324/9780203877753

Tyler, N., Tyler, I. R., & Ligibel, T. (2018). *Historic preservation : an introduction to its history, principles, and practice* (3rd (Ed.)). Norton Architecture.

UNESCO. (n.d.). *India - UNESCO World Heritage Centre*. UNESCO. Retrieved December 27, 2020, from http://whc.unesco.org/en/statesparties/IN

Case Study Report

Challenges of Urban Regeneration in Cultural Sites: The Creative Economy Policy in Song Wat District, Bangkok, Thailand

Siwaporn KLINMALAI, Thammasat University, Thailand

Abstract

The Song Wat area in Bangkok, Thailand, has played a critical role in the country's commercial trade since King Rama V's reign. During this period, a key road was established to alleviate congestion in the central wholesale trade zone, connecting it to Bangkok's first road with a public transportation system and facilitating the movement of goods along the Chao Phraya River. This development elevated Song Wat into a prominent wholesale and retail trade hub, leading to high population density and rising land values. However, Bangkok Metropolitan Administration (BMA) policies later restricted large truck transport in conservation zones to reduce pollution and manage traffic, significantly impacting Song Wat's economy and prompting many original business owners to relocate. The younger generations did not continue these businesses, leading to abandoned spaces and an aging population. In response, the BMA launched the Creative Economy policy to revitalize districts like Song Wat, promoting sustainable urban development by repurposing decayed spaces and preserving local culture. Despite progress, Song Wat faces challenges, including limited green space, aging infrastructure, and gentrification. This report summarizes an academic workshop's findings on enhancing walkability and public spaces to improve residents' and tourists' quality of life.

Keywords

Urban regeneration, Cultural heritage site, Creative economy, Song Wat Road

1. Introduction

Song Wat is a historical and cultural area that lies along the Chaopraya River in the Samphanthawong district of Bangkok. With an area of 1.4 square kilometers, Samphanthawong is the smallest district in Bangkok, while also having the smallest ratio of green space of just 2.15%, but with a riverfront area that spans 1.9 kilometers. Senior citizens comprise 27% of its 23,635 population, the highest ratio in Bangkok.

The name Song Wat translates as "drawn by the king," and points to its historical roots in the reign of King Rama V, when the king established Song Wat Road. During that time, the Chinese communities were encouraged to settle in the heart of the city to trade, but which resulted in overcrowding and frequent fires, such that Rama V then had to mitigate the congestion by building a new road, which he named "Song Wat." As the road runs parallel to the Chaopraya River, the area surrounding it quickly became a vital commercial hub as its strategic position was ideal for trade and logistics and it eventually became Bangkok's first CBD. Today, Song Wat is a melting pot of various cultures, heritage Thai-Chinese architecture, historical landmarks and bustling commerce.

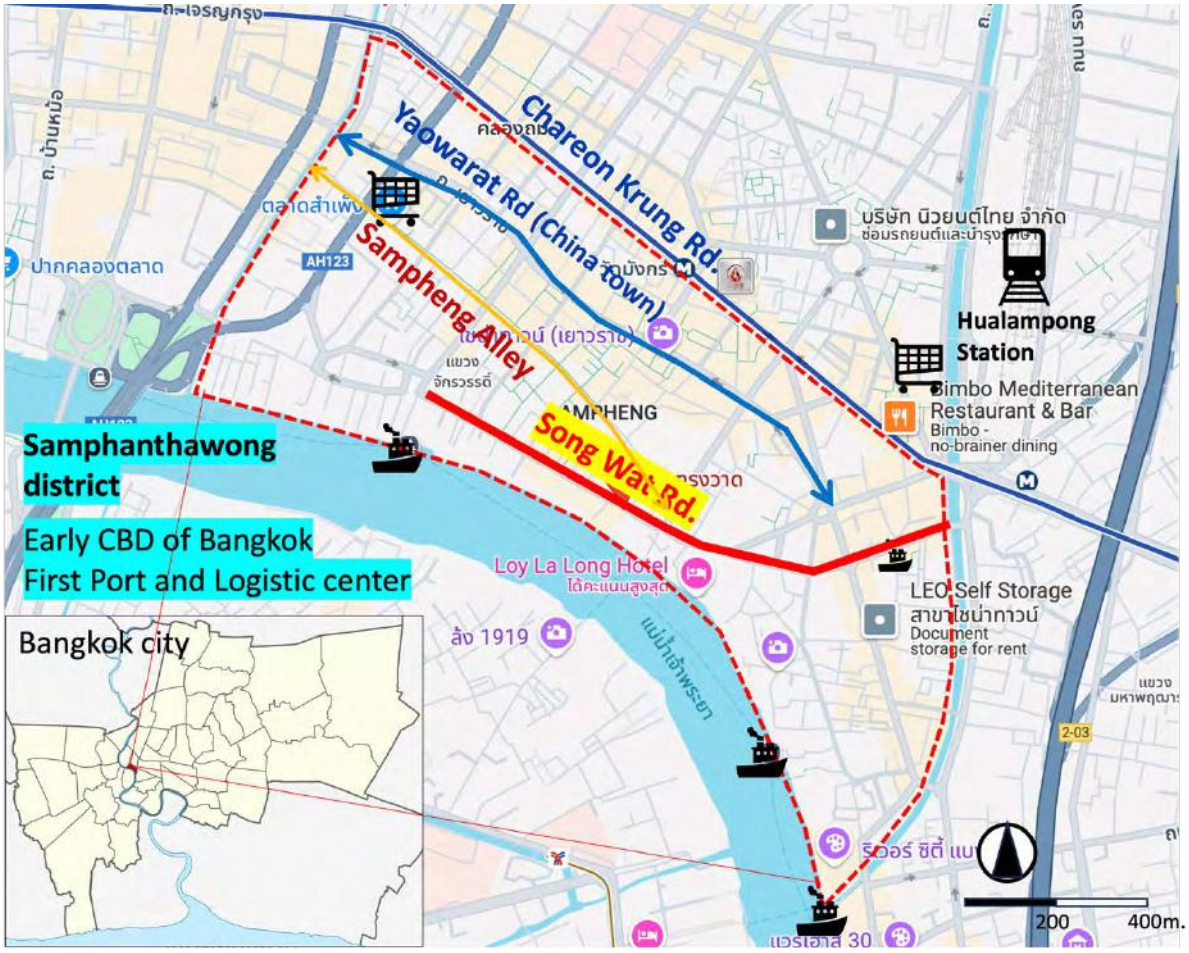


Figure 1. Map of Song Wat Road, adapted from google map

1.1. Historical Significance

Song Wat has been an area of significance since the times of King Rama I, when the Chinese communities were relocated to settle in Chinatown, and Sampheng alley was established as a hub for wholesale trading. But as the area became densely-populated and overcrowding resulted in frequents fires, Charoen Krung Road was constructed in 1862-1864 following western development models, complete with the first public tram system. Later in 1892-1900, Yaowarat Road was built and became the main retail center for the Chinese community.

In 1906, there was a great conflagration so King Rama V ordered the reconstruction of Chinatown that included the construction of a new road – Song Wat – thus the road could be seen as a tool of urban regeneration. In 1917, Samphanthawong district became Bangkok's first CBD, comprising the country's main hubs for both wholesale trading and retail commerce, as well as regional distribution centers for agricultural products through the rail system at Hua Lamphong Station. Song Wat Road acted as the center of warehousing and storage due to its positioning along the riverfront and proximity to the city's main cargo port.

In 2000, new city regulations prohibited large transport trucks from entering the inner-city area, this together with contemporary distribution methods resulted in the collapse of the wholesale business in Song Wat. The closures, downsizing and relocation of these local family-run businesses resulted in a fundamental shift in the commercial nature of the area.

Since 2016, the Song Wat area has become a beneficiary of the boom in tourism and growth of Chinatown, prompting the emergence of new businesses such as restaurants, cafés and tourist accommodations, allowing the area to retain its historical identity of small alleyways, cultural mix, and architectural heritage that can now be preserved as a tourism draw.

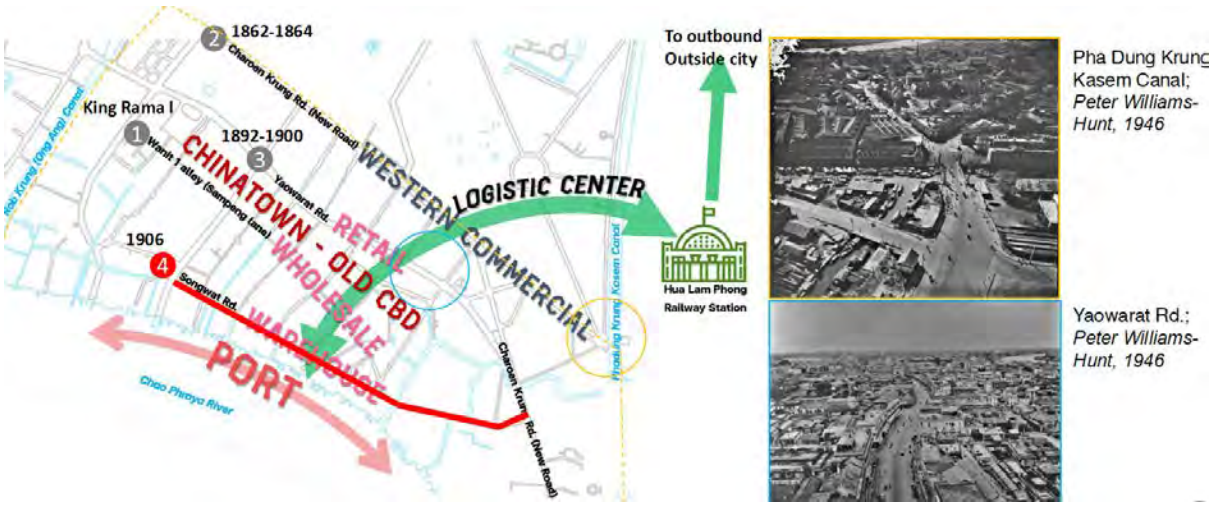


Figure 2. Early business district.

1.2. Importance of the District

The Samphanthawong district has a well-connected network of public transportation that includes an underground rail station, pedestrian walkways and important river piers, all lying within 550 meters. On a city policy level, Song Wat is being driven towards establishing a creative economy, whereby local identity acts as the foundation for local businesses and products. Story creation of the area is to be delivered through the digital experience economy, and the area will receive public funding to build infrastructure and host community activities.

One of the first pilot projects to be carried out was the Bangkok Design Week in 2021 initiated by the Creative Economic Agency. The event has been hosted annually from 2021-2024, gradually building up the image of Song Wat as a creative district, a hub for local crafts and heritage buildings for the younger generation. Young business owners in the area have come together to form the collective "Made in Song Wat," which organizes activities such as workshops and walking tours, demonstrating the strength of the local community in driving and stimulating the local economy. In 2024, outside organizations have begun to take notice and to be drawn to the area to stage design and culture related events, turning Song Wat into a destination for creative tourism and activities, in parallel with the existing commercial trade of the local Thai-Chinese community.

Figure 3. Cultural Events in Song Wat.

1.3. Challenges and Opportunities in Development

As an old CBD, the area has disadvantages in terms of being a high-density residential and commercial zone operating on old infrastructure. There is a lack of green and public spaces, and though it is situated along the riverfront, there is limited actual access to the river. Declining population in the last two decades compounding with a high ratio of senior citizens means that the local cultural heritage is at risk or in danger of gentrification and foreign capital invasion.

On the other hand, the area is rich in cultural heritage and the existing communities are an invaluable source of knowledge on the history of Bangkok's Thai-Chinese communities and their settlement. Its wealth of historical architecture and streets that support walkability present an opportunity to redefine the area as a tourist destination, particularly with the support from the city's creative district policy. Furthermore, there is strong collaboration among its culturally diverse population, which include Buddhists, Christians and Muslims

Figure 4. Problems and Opportunities Overview. Source: author

2. The project approach

This project is a collaboration between the Faculty of Architecture and Planning, Thammasat University, Kyoto Design School, Kyoto University and a number of public and private partners, including the Bangkok Metropolitan Administration, social workers and owners of local hostels, who are the key stakeholders from the area. The project was carried out in the form of an international workshop that prioritized stakeholder participation, with the aim of creating initial design proposals for regenerating the Song Wat area.

2.1. Objectives

The project aims to analyze the challenges and opportunities of the Song Wat area from various dimensions, investigating factors that would encourage walkability and access to public areas. Finally, propose initial design solutions and interventions that would benefit the local community, tourists and local workers alike, while still preserving the area's distinct identity and culture.

2.2. Methodology

The project was carried out in four main stages:

1) Site Surveys and Observations: the study area is demarcated by the underground rail station on Charoen Krung Road to the north of the Samphanthawong district, passing through Yaowarat Road and terminating at Song Wat Road. This encompasses the Issaraphap Alley, the shortest route connecting modern transportation with the riverfront area and Rachawong Pier. The study observed and recorded factors that contributed to the area's walkability, including the physical elements of the surrounding buildings, such as building façades and urban elements such as open spaces, landmarks, nodes and street furniture.

Figure 5. Site survey. Source: author.

2) Co-creative Workshops: once the physical data was collected, a participatory workshop was held and findings presented to the area's stakeholders, which included local business owners and local residents, in order to derive at a set of problems to be solved, which were then formulated into a design brief.

3) Stakeholder Interviews: in-depth interviews were held with representatives from the Bangkok Metropolitan Administration (BMA) to understand the government's policies for the area. Representatives from the local communities were also interviewed to gain insights into the advantages and disadvantages of the area as well as the specific requirements of the local residents, workers, and both short-term and long-term tourists.

4) Design Proposal: the information gathered through the previous three stages were then used to formulate 3 design proposals that try to address the needs of the stakeholders, namely walkability and the wellbeing of local residents, while also aligning with the government's creative district policies and retaining the area's distinct characters.

Figure 6. Workshop and stakeholders' engagement activities.

3. The project results and findings

As the area has been experiencing growth in tourism in the past four years from creative events, the resulting expansion of the local economy has meant an influx of jobs and workers into the area to the point where there is a shortage of public spaces and basic infrastructure and public facilities.

3.1. Challenges identified

1) Lack of walkability: even though the physical distance between the different zones is walkable, there are a number of difficulties, as Issaraphap Alley is very narrow but must contend with overlapping usage from tourists, workers and residents. This is worsened by a climate of extreme heat and the alley's lack of ventilation.
2) Lack of public facilities for tourists and local communities and workers: as the alley is so narrow, there is no open space left. The high density of shops, combined with price hikes in the land value has meant that existing owners of vacant properties would rather sell for profit than donate their lands for public use.

3.2. Design Proposals and Solutions

From the problems stated, the following measures have been proposed:

1) Measures for lack of walkability
   - Separating and layering of the circulation
   - Draw people from high-density areas to other spots
   - Provide shading over walkways
   - An online platform that provides navigational information, such as alternative routes away from highly-congested streets, and recommendations for nearby facilities

2) Measures for lack of public space and facilities
   - Provide adjustable street furniture for use by residents, workers and tourists
   - Renovate vacant areas into leisure spaces

Leading to the following design solutions:

1) Enhancing walkability through shaded walkways
   Providing a system of street furniture attached to steel structures that allow users to reconfigure the height for various uses, from seating and counter bar to overhead shading device and even as a second story walkway to expand circulation space. In addition, the steel structure can be used to attach signage for tourists.

2) Creating a hybrid platform for shared space and information

   The creation of a digital platform called "Song Wat Song WOW!" (figure 8) that would connect online and offline information. The app would contain useful information for tourists such as the locations of parking spaces, toilets, internet charging spots, and shop information, as well as navigation information such as traffic density in order to avoid highly congested areas and which would also help to divert tourist traffic towards less well-known areas and shops.

3) Designing space for community wellbeing
   The revitalization of vacant spaces (as shown in figure 9) is a crucial measure, as the area becomes more crowded, there is a need for more public spaces. From the site survey, it was

found that there are some large open spaces as well as vacant spaces next to buildings and in the alleyways that would benefit from a series of street furniture designed for their specific sites and uses, including:

- the large open space can be used as parking space and resting area for drivers and workers
- for the areas surrounding existing buildings and small alleyways, the insertion of seating areas, shading and wall decorations can help to create a more pleasant atmosphere
- for areas under large trees, planters can be designed to act as seating for local workers to rest or eat quick meals

Figure 7. Walkability Design Enhancement.

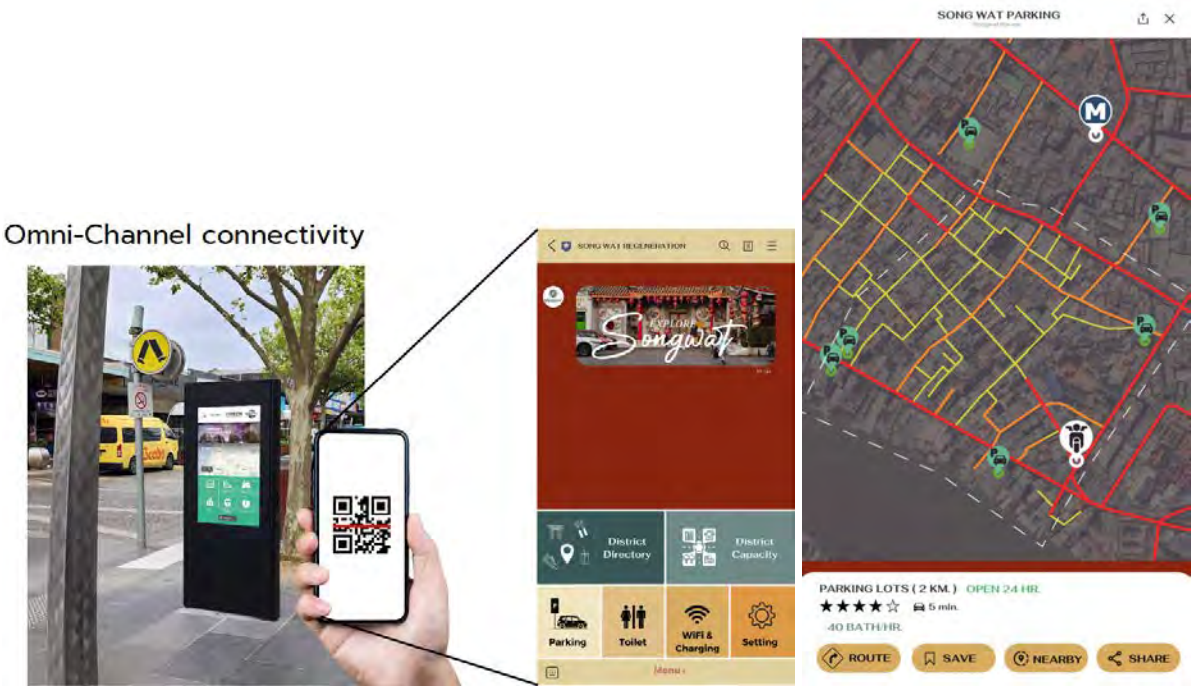


Figure 8. Song Wat Song WOW! App Interface.

Figure 9. Proposed community rest area.

4. Broader project impact

For local residents and workers, the design proposals would help them to maintain their traditional way of life while being able to share the public spaces with visitors more effectively, and to have a better quality of life through the provision of more relaxation areas. For local business owners, they would benefit from an increase in customers, who will find it more convenient to spend time in the area. Tourists would find the project implementations to help them better navigate the area and have better and more convenient experiences when visiting. The government and the city will have gained insights into the physical aspects of the area and possible strategies and solutions that would help in the implementation of the creative district initiatives. For the educational institutions involved, students have learned from real-world issues associated with area development and gained a deeper understanding of urban design.

5. Conclusion

The regeneration of the Song Wat area under the creative economy initiatives of the past few years with continual creative events have helped to stimulate the local economy and put the area on the map of the arts and tourism industries, while its rich historical and cultural heritage is being kept alive and passed on to a new generation of local business owners. However, from the findings of this project's co-creative workshop involving local stakeholders, it was found that the success of the creative economy initiatives that brought in more tourism and businesses has also adversely affected the walkability of the area in terms of the overcrowding of existing pedestrian infrastructure, as well as problems associated with the lack of public spaces and facilities and the lack of leisure and resting areas for local residents, workers and tourists. The project therefore proposes a series of design solutions that should alleviate the problems and respond to the needs of the local community, whether through the development of vacant spaces or the injection of street furniture to create a more livable and welcoming environment – physical and digital – for both locals and visitors alike.

The project demonstrates that in order to bring new things into historical and cultural areas, it is just as necessary to also introduce additional public spaces and facilities to ameliorate the increase in density and demand that would inevitably follow such changes. A design process for the creation of such spaces and facilities would also benefit from the participation of the various stakeholders, whose involvement would ensure that solutions respond to the real and distinct needs of the local communities.

In addition, online platforms and the use of technology to create a seamless experience between online and offline environments can help to provide conveniences and information about the area to the younger generations and tourists in a way that have the least impact on the daily lives of the local residents, while fostering interaction between them.

In conclusion, the urban regeneration of cultural sites through a creative economy needs to carefully consider the resulting impacts. Site owners and city authorities need to assess whether there is adequate infrastructure to support the impending changes to the area. There needs to be a balance between the positive and negative effects to the local community, while the preservation of historical buildings should cater to the lifestyles of both local residents and visitors. Lastly, the public sector must play a role in supporting the local community in becoming initiators of local events and activities, in order for the city and its people to grow sustainably.

6. Acknowledgement

This project was hosted by the Faculty of Architecture and Planning, Thammasat University, in collaboration with Kyoto University, the Bangkok Metropolitan Administration, Luk Hostel, and NGOs including We Park, Pun Muang, and Satarana. We extend our sincere gratitude to all partners for their invaluable contributions and support.

7. References

Bangkok Metropolitan Administration (2024). Bangkok Annual Work Plan 2024, [online]. Available at: https://webportal.bangkok.go.th/public/user_files_editor/130/BMAPlan/BMA_Plan_67%20%20.pdf (Accessed: 30 September 2024)

Carmona, M. (2021). *Public Places, Urban Spaces: The Dimensions of Urban Design*. 3rd edition. New York: Routledge.

Creative Economy Agency. (2022). *Thailand's creative industries movement report 2022. E-book* [online]. Available at: https://article.tcdc.or.th/uploads/media/2023/5/3/media_TH_Creative_Movement_FINAL.pdf (Accessed: 17 September 2024)

Fallmann, J. and Emeis, S. (2020). 'How to bring urban and global climate studies together with urban planning and architecture?', *Developments in Built Environment*. Volume 4 [online]. Available at: https://doi.org/10.1016/j.dibe.2020.100023 (Accessed: 19 September 2024)

Gehl, J. (2010). *Cities for People*. 1st edition. DC: Island Press

Ilugbusi, S.B., et al. (2024). 'Urban Resilience to Climate Change: A Review of Adaptation Strategies and Infrastructure Innovations', *Ecofeminism and Climate Change*. Volume 5(1) [online]. Available at: https://efcc.com.my/archives/1efcc2024/1efcc2024-18-23.pdf (Accessed: 18 September 2024)

Jacobs, J. (1961). *The Death and Life of Great American Cities*. Manhatton: Random House

Jaturasuwan, S. and Boonprasert, N. (2024). 'Made in Song Wat'. *Urban creature* [online]. Available at: https://urbancreature.co/made-in-song-wat/ (Accessed: 30 August 2024)

Kanchanasuppawong, J. (2021). *Guidelines for the renovation of shophouse as artist residency and gallery in a creative district: the case of song wat road, Bangkok*. [online]. Available at: https://digital.library.tu.ac.th/tu_dc/frontend/Info/item/dc:274954 (Accessed: 20 September 2024)

Phuaphongsakorn, P. (2023). Song Wat Guidebook. Bangkok: PRESS Creation

Montgomery, J. (2007). *The New Wealth of Cities: City Dynamics and the Fifth Wave*. UK: Ashgate.

Suvarnananda, C. and Kirdsiri, K. (2024). *The Regeneration of the Historic Area of Song Wat through the Adaptive Reuse of Heritage Buildings and the Sense of Place*, [online]. Available at: https://arch.su.ac.th/images/thesis/2567_Chomkwan.pdf (Accessed: 18 September 2024)

Suthisank, S. et al. (2021). The lost of street art "Thanon Song Wad", *Jayaphruekpirom Journal*. Vol.3(1) [online]. Available at: https://so16.tci-thaijo.org/index.php/JPPJ/article/view/72/46 (Accessed: 18 September 2024)

Tungwichitruek, P. (2023). 'Song Wat: Transform form Spice road to Creative district'. *Urban creature* [online]. Available at: https://urbancreature.co/song-wat-update/ (Accessed: 30 August 2024)

UNESCO (2021). 'Historic Urban Landscape Approach: Managing Heritage in Cities'. *United Nations Educational, Scientific and Cultural Organization* [online]. Available at: https://whc.unesco.org/en/activities/727/ (Accessed: 1 September 2024)

Zukin, S. (1995). *The Cultures of Cities*. Oxford, UK: Blackwell Publishing

Research Paper

Reviving Suburbia:
Integrating Urban Agriculture for Sustainable Community Development in the Boston Metropolitan Area

Yiqun Wang*, University of Innsbruck, Austria &Harvard Graduate School of Design, United States

*Corresponding author: Yiqun Wang, yiqunwang24@gmail.com

Jiayi Li, Harvard Graduate School of Design, United States

Abstract

By turning the suburban sprawl along Boston's Route 128 into a fruitful agricultural center, the project seeks to remedy the environmental damage brought on by too much asphalt and careless urban growth. Through the incorporation of urban agriculture into the suburban environment, the project promotes community involvement, revitalizes the ecosystem, and increases local food security. The project's effects on biodiversity, soil health, and social cohesion are assessed in this study using a combination of research approaches, such as stakeholder consultations, ecological evaluations, and GIS mapping. Significant gains in community resilience and environmental health are shown by the findings, providing a scalable model for sustainable suburban development.

Keywords

urban griculture, ecological restoration, suburban sprawl, community engagement, sustainability, local food security

1. Introduction and Project Context

1.1. Challenges of Suburban Sprawl

Similar to other suburban fringes in America, the growing suburban areas surrounding Boston's Route 128 have had significant negative effects on the environment and society. The growth of Westwood, Massachusetts, in particular, is a prime example of how issues common to expansive areas coexist with high property values maintained by appealing commuting options. Critical environmental indicators have been impacted by the widespread use of asphalt, which has also reduced green spaces, disturbed local ecosystems, and increased carbon emissions (Arnold and Gibbons, 1996; Ferguson, 1998). A rising worry in contemporary urban design is the pollution of water resources caused by stormwater runoff, which is exacerbated by the large impervious surfaces and the lack of public spaces (Booth and Jackson, 1997; Frumkin, 2002; Transit Cooperative Research Program, 1998).

Duany, Plater-Zyberk, and Speck (2000) noted that the effects of sprawl include ecological damage, increased traffic congestion, and community separation, all of which impair local resilience and the standard of living for locals. The Route 128/University Park Station neighborhood in Westwood, which is positioned as a suburban location with easy access to Boston, must contend with the demands of changing demographics and sustainability while also attracting a lot of commuter interest. The region's stability and modest transition in relation to suburban developments are reflected in its essentially static state since its

peak in the 1970s. To refocus attention from city centers to integrated neighborhoods that blend residential spaces, natural landscapes, and transit connectivity, modern urban planning is increasingly examining suburban peripheries for possibilities. Westwood enjoys great transit connections, including ties to Boston and New York via Amtrak's Acela and the MBTA commuter rail, thanks to its location at the intersection of Route 128 and I-93. The accessibility of the location is further improved by the nearby Norwood Memorial Airport, which offers pilot training and charter services. Desirable features of Westwood include quiet areas, good schools, and continuously high property values. However, promoting inclusive growth and environmental resilience is hampered by the extensive commercial zones and strong reliance on vehicle infrastructure. As a result, Route 128/University Park Station presents a perfect chance to investigate fresh development strategies that appeal to a larger population and promote sustainable expansion. Originally intended to be a stand-alone transit hub, isolated from neighboring neighborhoods and natural areas, the region may develop into a more inclusive and linked place. The development of Route 128 may transform it from a park-and-ride commuter site to a vibrant, coherent neighborhood that would satisfy the evolving demands of a dynamic suburban landscape by incorporating social, economic, and environmental sustainability (Harvard University Graduate School of Design, 2023).

1.2. Urban Agriculture as a Sustainable Design Solution

The sustainability issues brought on by suburban sprawl can be resolved through urban agriculture, which combines social, economic, and ecological advantages (Pearson, Pearson, and Pearson, 2010; Alaimo et al., 2008). In order to improve food security and advance sustainability, this project will build a robust local food system that reduces reliance on long-distance supply chains, utilizing the "farm-to-table" methodology. Incorporating agriculture into suburban landscapes also helps to promote soil health, address unused space, and maintain ecological balance (Lovell and Taylor, 2013).

Suburban areas frequently underutilize local resources, with each suburbanite indirectly consuming large tracts of land while having limited access to productive green spaces. For example, in some suburban contexts, people consume over 31 acres of land, though they only have direct access to less than 5 acres per person (Arnold and Gibbons, 1996). By making better use of these spaces for local food production, urban agriculture can lower transportation-related carbon emissions and improve food traceability (Brown and Jameton, 2000).

Local economics, resilience, and community health have all benefited from urban agriculture (Grewal and Grewal, 2012; Hodgson, Campbell, and Bailey, 2011). A move toward food self-sufficiency is seen, for example, in Massachusetts, where agricultural data indicates a growing desire for locally grown fruits and vegetables. Vegetable and greenhouse/nursery goods output increased in the state's agricultural economy between 2012 and 2017, a sign of growing demand for locally sourced, sustainable food. Urban agriculture and other sustainable techniques offer a chance to lessen ecological footprints while suburban areas continue to face the challenges of sprawl. The goal of this initiative is to create a "local, ethical, and educational agricultural landscape," fostering responsible resource stewardship and reestablishing suburban residents' connection to their environment. Converting areas surrounding transportation hubs—like the area around Route 128/University Park Station—into mixed-use open spaces or agricultural areas can encourage community involvement, draw in a varied population, and help achieve long-term sustainability objectives.

1.3. Research Scope and Methodology

A site-specific design approach is employed to sustainably rehabilitate these areas, addressing the ecological degradation linked to suburban sprawl, since the project focuses on the suburban area along

Route 128 where sprawl has had long-lasting environmental consequences (Daniels, 2011). In order to examine land use distribution, spatial patterns, and the incorporation of green areas, the methodology integrates ecological assessments with GIS mapping (Dietz, 2007; Colding and Barthel, 2013). Important information on biodiversity, water retention, and general ecological health is provided by these evaluations (Jacobson and Delucchi, 2009). According to Mougeot (2006), urban agriculture provides a sustainable framework that complements the project's objectives of developing a resilient, eco-friendly suburban landscape.

Figure 1. Suburb as Boston's Foodhub. Source: Authors.

The idea offers a thorough plan for Westwood's future growth, with a maximum floor area ratio of 0.4 throughout the property, or about 32,300 square feet (300,000 m²) of usable floor space. The design approach is shaped by several important challenges. First, improving accessibility is essential for promoting a wider variety of lifestyles and serving a diverse population because suburban growth is heavily reliant on

cars. Second, the emphasis on landscape and metropolitan design as defining characteristics of urban form takes precedence over traditional buildings in this lower-density suburban setting. A more landscape-centered approach is made possible by this change, which offers a wider range of design factors to consider. Thirdly, since a large portion of the infrastructure is expensive and outdated, adaptive reuse techniques are given priority, particularly for agricultural facilities. This method meets present and future needs by repurposing existing structures as productive agricultural areas rather than completely rebuilding them. Finally, the homogeneity of experience and lack of programming diversity—two major criticisms of suburban sprawl—must be addressed in new suburban construction. By developing diverse groups and a variety of spaces, this project hopes to foster programming flexibility and adaptability throughout time to meet changing community needs. By using this diverse approach, the project aims to turn the suburban neighborhoods along Route 128 into Boston's Foodhub, a resilient, multipurpose landscape that places an emphasis on ecological health, sustainability, and community inclusivity (Harvard University Graduate School of Design, 2023; Figure 1).

2. Key Design Elements and Implementation Strategies

2.1. Green Space and Impermeable Surface Reduction

With an emphasis on the biological conditions along Boston's Route 128 corridor, the site study highlights important environmental issues seen during a field visit (Figure 2). Three key concerns were emphasized: First, the community's surrounding woodland areas are extremely fragmented, which hinders animal mobility and reduces ecological connectedness. The overall environmental functionality of the area is diminished by this lack of consistency, which impedes wildlife's normal paths. Second, overuse of Asphalt in Car-Oriented Development: The property is mostly covered by asphalt roads and parking lots, much like many suburban areas in the US that are intended to favor automobile access. Because they reduce natural habitats and increase surface water runoff, these non-permeable surfaces have a detrimental effect on the ecosystem. Third, railroad Dividing Wetlands and Dispersing Polluted Runoff: A railroad passes through the area, further dividing vital wetland ecosystems. Furthermore, these wetlands' biological health is deteriorated and pollution is caused by the contaminated runoff from nearby roadways that is directed into them by the uneven topography. These problems are fully addressed in the suggested project. The effort seeks to reduce environmental harm while fostering biodiversity and food security by repurposing the property as a sustainable agricultural hub. Restoring native plant species to improve habitats and ecological stability, enhancing soil conditions and water retention capacity, and substituting farmland and green spaces for paved areas are important steps.

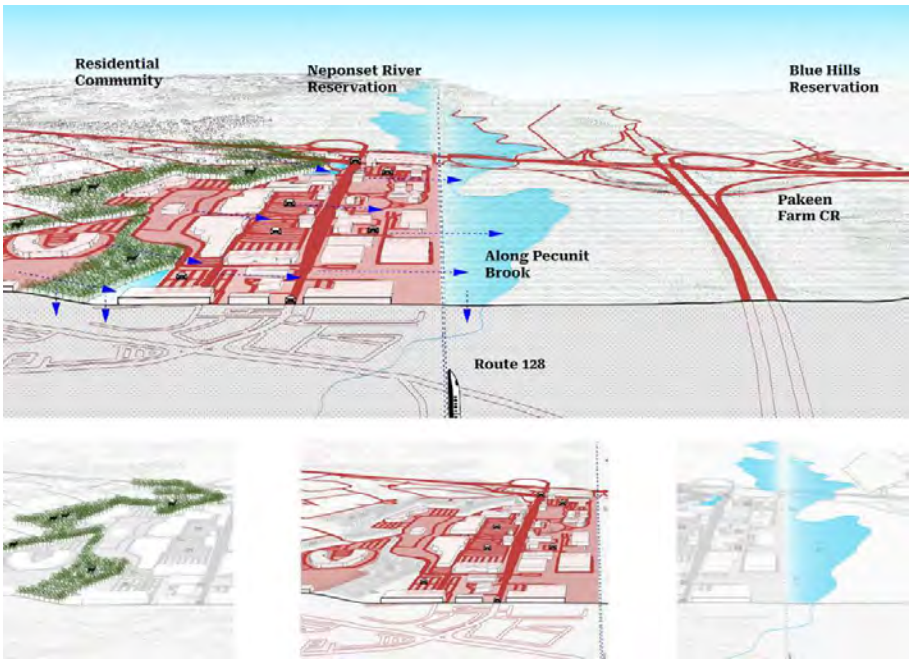


Figure 2. Site Portrait. Source: Authors.

2.2. Community-Driven Food Production and Agrarian Landscape Design

Environmental sustainability, food security, and social cohesion are all improved by local food production. In order to promote community involvement, this project incorporates multipurpose areas with areas set aside for agricultural operations (Twiss et al., 2003; Krasny and Tidball, 2009). Research shows that local aesthetics and public health are enhanced by community gardens (Glover, Parry, and Shinew, 2004). Furthermore, studies by Litt et al. (2015) show that social ties are strengthened and fresh product is more accessible when the community is involved in urban agriculture. This supports the findings of Colding and Barthel (2013), who found that community-driven initiatives boost social and environmental sustainability by fostering resilient urban green spaces (Figure 3).

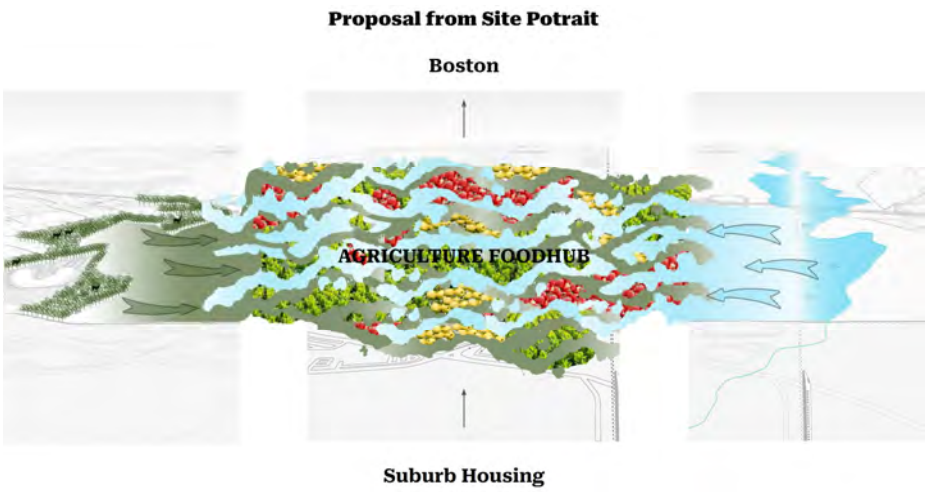


Figure 3. Proposal from Site Portrait. Source: Authors.

Building on this basis, the "Strategic Plan for Crops in Westwood" presents a thoughtfully planned agricultural landscape with native crops including lettuce, carrots, apples, grapes, and green beans that are tailored to Boston's climate and nutritional needs (Figure 4). These crops are dispersed throughout

designated zones, with high-density areas in the center for convenient access and regular harvesting. To strengthen farm-to-table linkages and give the community access to fresh, locally sourced produce, establishments such as a food hub and restaurant are situated close to access points. In order to create a sustainable, culturally integrated agrarian environment that satisfies both ecological and community demands, this strategy maximizes agricultural productivity while encouraging community engagement.

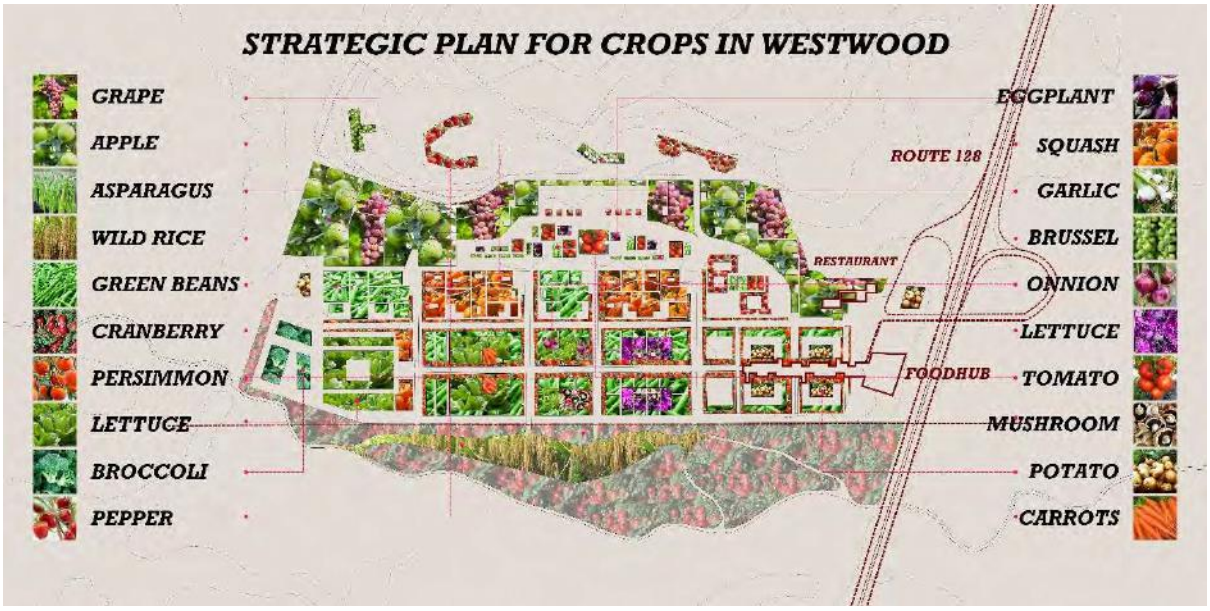


Figure 4. Strategic Plan for Crops in Westwood. Source: Authors.

3. Design Interventions and Future Pathways

3.1. Zoning Strategies

By integrating and balancing commercial operations, agricultural output, and residential community growth, the project's zoning design seeks to create a cohesive, multipurpose environment (Figure 5). Located on the upper part of the property, the Commercial Zone aims to modernize the existing commercial infrastructure while maintaining it in accordance with the project's revised objectives. The commercial zone supports the functional demands and economic vitality of the larger community by maintaining and expanding this region while offering necessary services and amenities. The Agricultural Zone in the center, which is intended to be "One Big Farm," turns existing land into a high-yield farming area that integrates effective water management and sustainability methods. This area creates a continuous green space that provides fresh vegetables, repurposes land for profitable agriculture with an emphasis on water conservation, and improves the ecological health of the region. The Residential & Food Hub Zone, which is located to the right of the plan, combines new housing construction with a central food hub to create a sense of community. By acting as a distribution point for locally grown goods, the food hub strengthens the link between sustainable food sources and urban living by bringing locals and the site's agricultural production into direct contact. This area promotes sustainable living and community involvement with housing that blends in with nearby agricultural areas and enhances the feeling of community.

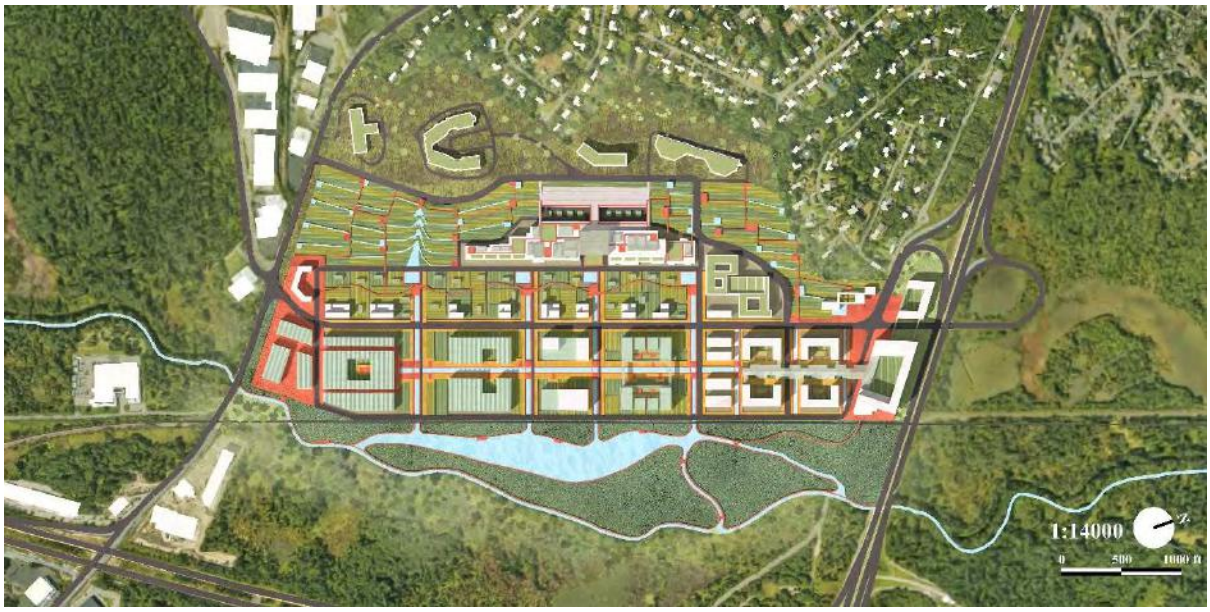


Figure 5. Master Plan. Source: Authors.

3.2. Adaptive Transformation of Existing Buildings

In order to promote community involvement and maximize agricultural output, this project integrates multipurpose communal areas with an adaptive reuse approach for pre-existing logistical facilities (Figure 6). Important amenities that foster social contact and give community members a place to engage with local food systems include greenhouse spaces, community kitchens, and locations for gathering in shade (Hodgson, Campbell, and Bailey, 2011). Long-term sustainability objectives are supported by this community-oriented design, which cultivates a feeling of shared identity and purpose (Langdon, 2007; Mougeot, 2006). The project also modifies current logistics warehouses to accommodate certain crop light needs, resulting in an agricultural environment that is both productive and climate-sensitive. The project creates "dark greenhouses" for crops that can withstand darkness, like mushrooms, and "bright greenhouses" for plants that like light, like lettuce, by modifying warehouses according to crop requirements. These focused improvements enable for growing a variety of crops without undergoing significant structural changes. The warehouses' high-tech experimental areas also improve the urban farming experience by allowing locals to engage with cutting-edge farming methods and pick crops. Underutilized infrastructure is transformed into productive areas through this integrated approach.

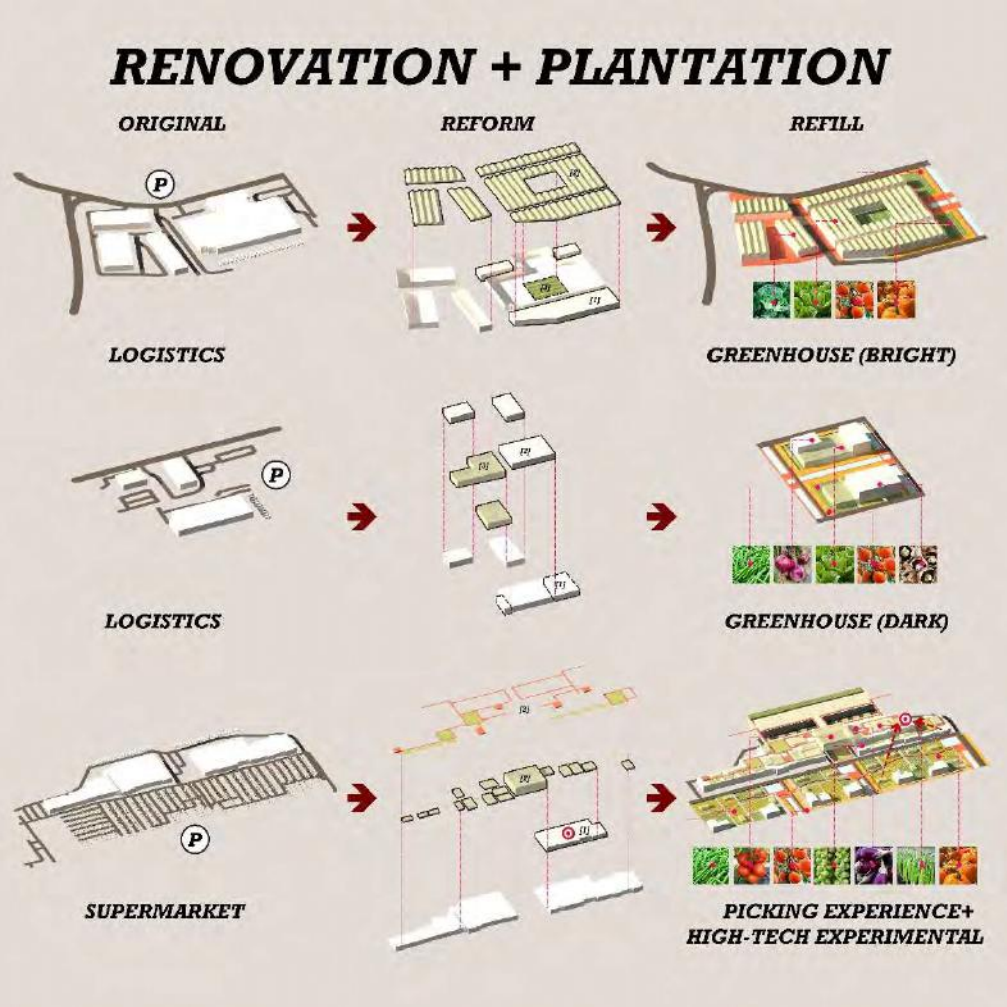


Figure 6. Renovation and Plantation. Source: Authors.

3.3. Time Scope

Using the Route 128/University Park Station district paradigm, this project aims to gradually and phasedly integrate sustainable development and urban agriculture in suburban regions (Figure 7). In phases from 2024 to 2050, the design presents a changing landscape, starting with greenhouses, terraced fields, and experimental agricultural plots. Foundational buildings that serve the residential and agricultural communities, like offices, stores, and garages, are the focus of the early stages. More farming fields, greenhouses, and a food hub will be built by 2030, creating an integrated setting where food production coexists with residences, workplaces, and parks. With each phase improving community engagement with agricultural and sustainable practices, the phased development promotes progressive adaption. More greenhouses, a hospital, and a restaurant will be added by 2040 and beyond, converting the region into a lively, mixed-use location that meets both functional and recreational demands. A self-sustaining community is promoted by the smooth ecological, educational, and social blending made possible by this meticulous design. As different facilities—like residential housing, greenhouses, food centers, and public spaces—are placed throughout the area to maximize accessibility and functionality, the idea of "coexistence and mixing" is essential to this design. Over time, the initiative transforms the suburban

landscape into a multipurpose ecosystem where urban agriculture is integrated into everyday life to promote environmental stewardship, community resilience, and food security.

Figure 7. Incremental and Phasing Plan. Source: Authors.

3.4. Broader Project Impact and Future Development

This project is an innovative approach to suburban sustainability, with broad implications for resource efficiency, adaptive reuse, community engagement, urban-rural connection, and scalable urban design. By using agriculture to rehabilitate suburban sprawl regions like Westwood, the initiative addresses the ecological issues of suburban expansion and creates "middle landscapes" that blend the best aspects of both urban and rural life. This strategy is predicated on the Middle Landscape idea developed by Peter Rowe, which encourages the integration of urban and rural landscapes (Rowe, 1992). Based on the concepts of adaptive reuse (Bullen and Love, 2011), the project aims to repurpose old infrastructure to promote environmental preservation, lessen the demand for new construction, and align with sustainability objectives. This tactic encourages resource preservation, community cohesion, and ecological health. By enhancing natural spaces and minimizing asphalt, the initiative seeks to reduce the carbon footprint typical of suburban areas, so addressing the issues of excessive energy usage and wasted land use. By minimizing the carbon footprint typical of suburban areas through the improvement of green spaces and the reduction of asphalt, the initiative seeks to solve the issues of excessive energy usage and inefficient land use. Community involvement in agricultural activities preserves cultural legacy, improves social ties, and increases environmental awareness by connecting traditional practices to modern ecological solutions for a climate-change-adaptable future. By combining public and educational facilities with agricultural plots, the plan also seeks to create a multipurpose urban region that promotes high-density growth within a flexible grid system. Its success in the Boston area fosters resilient, sustainable suburban development in other places by offering a scalable and flexible model for integrating urban agriculture and adaptive reuse into city planning worldwide.

Acknowledgments

The authors wish to acknowledge the use of artificial intelligence (AI) applications, including Grammarly and ChatGPT, during the writing process of this paper. Grammarly was employed for stylistic and grammatical corrections, ensuring clarity and accuracy, while ChatGPT provided iterative suggestions that enhanced the coherence and structural framework of the content.

The authors would also like to express gratitude to Professor Peter Rowe, Professor Stephen Gray, Professor Yun Fu, and Professor Michael Manfredi for providing invaluable guidance on this project through the Core Studio "Elements of Urban Design," Fall 2023, at Harvard University Graduate School of Design (GSD).

4. References

Alaimo, K., Packnett, E., Miles, R.A. and Kruger, D.J. (2008) 'Fruit and vegetable intake among urban community gardeners', *Journal of Nutrition Education and Behavior*, 40(2), pp. 94–101 [online]. Available at: https://www.sciencedirect.com/science/article/abs/pii/S1499404606008542 (Accessed: 17 January 2025).

Arnold, C.L. and Gibbons, C.J. (1996) 'Impervious surface coverage: The emergence of a key environmental indicator', *Journal of the American Planning Association*, 62(2), pp. 243–258 [online]. Available at: https://doi.org/10.1080/01944369608975688 (Accessed: 17 January 2025).

Booth, D.B. and Jackson, C.R. (2007) 'Urbanization of aquatic systems: Degradation thresholds, stormwater detection, and the limits of mitigation', *Journal of the American Water Resources Association*, 33(5), pp. 1077–1090 [online]. Available at: https://doi.org/10.1111/j.1752-1688.1997.tb04126.x (Accessed: 17 January 2025).

Brown, K.H. and Jameton, A.L. (2000) 'Public health implications of urban agriculture', *Journal of Public Health Policy*, 21(1), pp. 20–39 [online]. Available at: https://pubmed.ncbi.nlm.nih.gov/10754796/ (Accessed: 17 January 2025).

Bullen, P.A. and Love, P.E.D. (2011) 'Adaptive reuse of heritage buildings', *Structural Survey*, 29(5), pp. 411–421 [online]. Available at: https://www.researchgate.net/publication/235274709_Adaptive_reuse_of_heritage_buildings (Accessed: 17 January 2025).

Colding, J. and Barthel, S. (2013) 'The potential of "urban green commons" in the resilience building of cities', Ecological Economics, 86, pp. 156–166 [online]. Available at: https://doi.org/10.1016/j.ecolecon.2012.10.016 (Accessed: 17 January 2025).

Daniels, T.L. (2009) 'A trail across time: American environmental planning from City Beautiful to sustainability', *Journal of the American Planning Association*, 75(2), pp. 178–192 [online]. Available at: https://doi.org/10.1080/01944360902748206 (Accessed: 17 January 2025).

Dietz, M.E. (2007) 'Low impact development practices: A review of current research and recommendations for future directions', *Water, Air, and Soil Pollution*, 186, pp. 351–363 [online]. Available at: https://doi.org/10.1007/s11270-007-9484-z (Accessed: 17 January 2025).

Duany, A., Plater-Zyberk, E. and Speck, J. (2000) *Suburban nation: The rise of sprawl and the decline of the American dream*. Illustrated edn. New York: Farrar, Straus and Giroux.

Ferguson, B.K. (1998) *Introduction to stormwater: Concept, purpose, design*. New York: John Wiley & Sons.

Frumkin, H. (2002) 'Urban sprawl and public health', *Public Health Reports*, 117(3), pp. 201–217 [online]. Available at: https://www.researchgate.net/publication/11035517_Urban_Sprawl_and_Public_Health (Accessed: 17 January 2025).

Grammarly (2025) *Grammarly [AI software]*. Available at: https://www.grammarly.com (Accessed: 18 January 2025).

Grewal, S.S. and Grewal, P.S. (2012) 'Can cities become self-reliant in food?', *Cities*, 29(1), pp. 1–11 [online]. Available at: https://doi.org/10.1016/j.cities.2011.06.003 (Accessed: 17 January 2025).

Harvard University Graduate School of Design (2023) *Elements of Urban Design: Fall 2023-2024 STU 1221 Course Syllabus*. Cambridge: Harvard University [online]. Available at: https://www.gsd.harvard.edu/course/elements-of-urban-design-fall-2023/ (Accessed: 17 January 2025).

Hodgson, K., Campbell, M.C. and Bailkey, M. (2011) *Urban agriculture: Growing healthy, sustainable places*. E-book [PDF]. Chicago: American Planning Association. Available at: https://planning-org-uploaded-media.s3.amazonaws.com/publication/book_paperback/PAS-Report-563.pdf (Accessed: 17 January 2025).

Jacobson, M. and Delucchi, M. (2009) 'A path to sustainable energy by 2030', *Scientific American*, 301, pp. 58–65 [online]. Available at: https://doi.org/10.1038/scientificamerican1109-58 (Accessed: 17 January 2025).

Krasny, M.E. and Tidball, K.G. (2009) 'Community gardens as contexts for science, stewardship, and civic action learning', *Cities and the Environment (CATE)*, 2(1), Article 8 [online]. Available at: https://digitalcommons.lmu.edu/cate/vol2/iss1/8 (Accessed: 17 January 2025).

Langdon, P. (1994) *A better place to live: Reshaping the American suburb*. Amherst: University of Massachusetts Press.

Litt, J.S., Soobader, M.J., Turbin, M.S., Hale, J.W., Buchenau, M. and Marshall, J.A. (2011) 'The influence of social involvement, neighborhood aesthetics, and community garden participation on fruit and vegetable consumption', *American Journal of Public Health*, 101(8), pp. 1466–1473 [online]. Available at: https://doi.org/10.2105/AJPH.2010.300111 (Accessed: 17 January 2025).

Lovell, S.T. and Taylor, J.R. (2013) 'Supplying urban ecosystem services through multifunctional green infrastructure in the United States', *Landscape Ecology*, 28(8), pp. 1447–1463 [online]. Available at:https://www.researchgate.net/publication/257504191_Supplying_urban_ecosystem_services_through_multifunctional_green_infrastructure_in_the_United_States (Accessed: 17 January 2025).

Mougeot, L.J.A. (2006) *Growing better cities: Urban agriculture for sustainable development*. E-book [online]. Ottawa: International Development Research Centre. Available at: https://idrc-crdi.ca/sites/default/files/openebooks/226-0/index.html (Accessed: 17 January 2025).

OpenAI (2025) *ChatGPT (Jan 2025 version) [AI software]*. Available at: https://www.openai.com (Accessed: 18 January 2025).

Pearson, L.J., Pearson, L. and Pearson, C. (2010) 'Sustainable urban agriculture: Stocktake and opportunities', *International Journal of Agricultural Sustainability*, 8(1–2), pp. 7–19 [online]. Available at: https://doi.org/10.3763/ijas.2009.0468 (Accessed: 17 January 2025).

Rowe, P.G. (1992) Making a middle landscape. Cambridge: MIT Press.

Shinew, K.J., Glover, T.D. and Parry, D.C. (2004) 'Leisure spaces as potential sites for interracial interaction: Community gardens in urban areas', *Journal of Leisure Research*, 36(3) [online]. Available at: https://doi.org/10.1080/00222216.2004.11950027 (Accessed: 15 January 2025).

Transit Cooperative Research Program (1998) *The costs of sprawl—revisited*. E-book [online]. Transportation Research Board Report 39. Washington, DC: Transportation Research Board. Available at: https://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_39-a.pdf (Accessed: 17 January 2025).

Twiss, J., Dickinson, J., Duma, S., Kleinman, T., Paulsen, H. and Rilveria, L. (2003) 'Community gardens: Lessons learned from California Healthy Cities and Communities', *American Journal of Public Health*, 93(9), pp. 1435–1438 [online]. Available at: https://ajph.aphapublications.org/doi/full/10.2105/AJPH.93.9.1435?role=tab (Accessed: 17 January 2025).

Research Paper

Sustainable Conservation and Regeneration in the Face of Change: The Case of Ancient City of Suzhou

Jianqiang YANG, School of Architecture, Southeast University, China
Min WANG, School of Architecture, Southeast University, China
Ya-nan LIN, School of Architecture, Southeast University, China

Abstract

In recent years, based on the value of conserved historic towns and their contexts, there has been active exploration of methods to conserve urban heritage in the face of change, gradually combining the concept of conservation with organic regeneration. Strategies for urban heritage conservation are formulated with the identification and evaluation of heritage values as the foundation, and value conservation and inheritance as goals, emphasizing change management and sustainable urban development. Suzhou, a Chinese national historical and cultural city and a world heritage city, has preserved the traditional appearance of the ancient city and its dual chessboard spatial pattern of "parallel water and land, adjacent rivers and streets." This paper took the ancient city of Suzhou as an example, systematically reviewed its development, and assessed its value. In response to the current problems and challenges faced by the ancient city, it proposes specific strategies based on value-oriented historic city conservation and sustainable development concepts. The goal is to find sustainable conservation and regeneration methods that establish an organic connection between the conservation and development, promoting the comprehensive enhancement of the spatial environment quality and socio-economic vitality while ensuring the authenticity and integrity of the historic environment.

Keywords

Sustainable Conservation, Regeneration, urban heritage, Change, Ancient City of Suzhou

1. Introduction

The city of Suzhou is a “World Heritage City” and one of Chinese national historical and cultural cities, known for its profound historical deposits, rich cultural heritage, and beautiful garden landscapes. It was founded in 514 BC, more than 2,500 years ago. The site of the ancient city, encircled by a moat, has survived to the present day (Figure 1). Today, the ancient city of Suzhou is home to nine classical gardens that have been listed as “World Cultural Heritages”, including the Net Master’s Garden, the Lingering Garden, and the Humble Administrator’s Garden. The ancient city is also close to the Grand Canal of China (the Suzhou Section of the Jiangnan Canal) and its associated river courses, as well as several historical and cultural blocks and cultural relics. It is an outstanding example of the wisdom of the “city of water” in China and even in the world. Adhering to the urban development strategy of “developing new districts while conserving the ancient city” and the policy of “comprehensively retaining the style of the ancient city”, Suzhou has established an overall framework and system for the conservation of historical and cultural

heritages. Consequently, Suzhou has preserved and continued the "double-chessboard" pattern of "parallel water and land, adjacent rivers and streets" as well as the traditional features of "little bridge, running stream, and households" in areas south of the lower reaches of the Yangtze River. However, the ancient city of Suzhou is now facing a series of prominent problems, such as the overall degradation of water networks, the serious problem of population aging, the poor quality of the residential environment, and difficulties of conserving traditional dwellings. In this context, it is essential to systematically review the development and evolution of the ancient city of Suzhou, thereby identifying its values and features in terms of landscape patterns, water systems, classical gardens, and historical context. Guided by the value-oriented concept of conservation, utilization, and the sustainable development of historical cities, an organic link between the conservation and development of the ancient city of Suzhou needs to be established to conserve the authenticity and integrity of the overall historical environment. Further, ways of sustainable conservation and regeneration need to be explored, and the overall improvement of the quality of the spatial environment and the socio-economic vitality of the ancient city needs to be promoted.

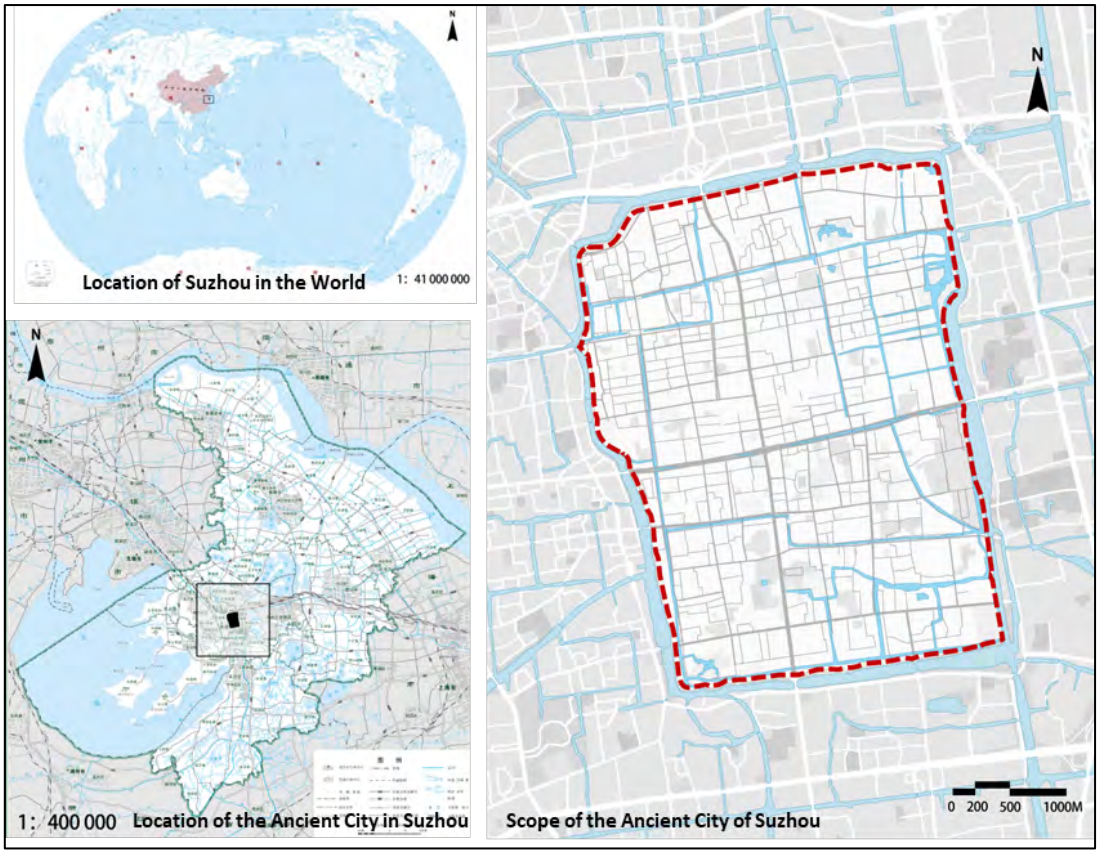


Figure 1. Location and scope of the ancient city of Suzhou. Source: Unless otherwise noted, all drawings in this paper are self-drawn by the authors.

2. Development, Evolution, and Features

The ancient city of Suzhou took shape during the heyday of the Song Dynasty. As a result of the sprouting of industry during the Ming and Qing Dynasties and the beginning of modern industrialization during the Republic of China, the structure of the city began to change. Roughly four major stages can be distinguished: transformation of structural morphology (1927–1949), decline of traditional features (1949–1977), emphasis on style conservation (1978–2011), and regeneration through optimization and improvement (2012–present).

In the first stage, the ancient city launched its urban construction based on the traditional pattern. Then, the traditional features were decline in the second stage. However, Suzhou began to realize that equal importance should be attached to both the conservation of the ancient city and urban development in the third stage. Therefore, with the planning strategies and the development of economic industry, Suzhou was able to comprehensively preserve and continue the traditional pattern and features by regeneration in the Fourth stage.

3. Values and Features

3.1. Unique pattern of mountain–water–city integration

The ancient city of Suzhou, located at the centre of the site, is “facing the mountains on one side, surrounded by lakes on seven sides; embracing rivers from all directions, circled by mountains and rivers in four corners”. It is a typical representative of the residential environment and spatial pattern of “living between mountains and rivers” (Figure 2).

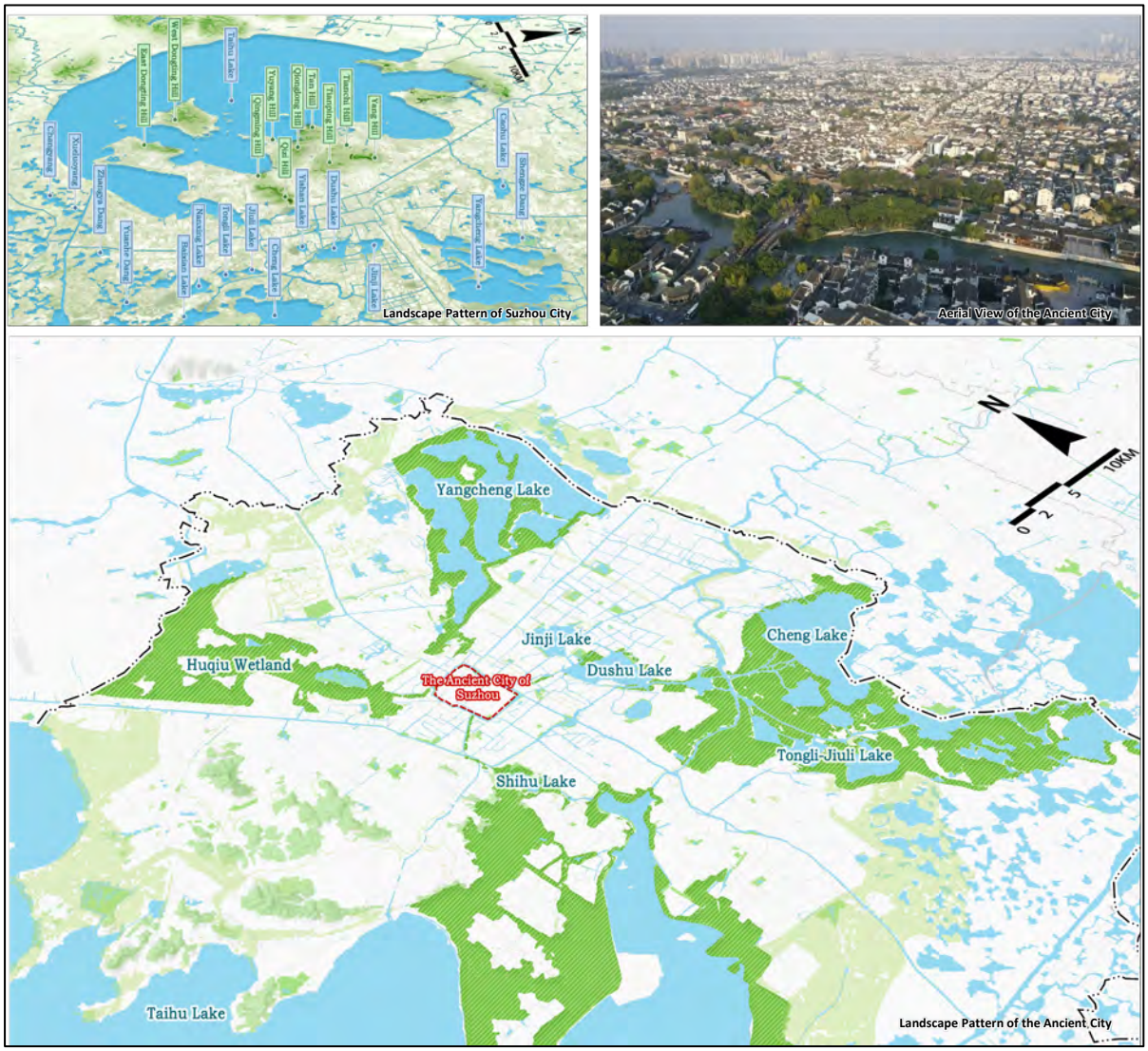


Figure 2. Landscape pattern of the ancient city of Suzhou. Source: The landscape pattern of downtown Suzhou was derived from the Overall Urban Design of Suzhou (2020), and other drawings were drawn by the authors.

3.2. Model of planning, construction, and conservation of a "city of water"

The ancient city of Suzhou is a perfect embodiment of superior site selection and reasonable city layout. The idea of "water-centred" urban planning and the features of a "city of water" adapted to water systems not only hold special importance in the history of urban construction in China, but are also very rare in the history of cities in the world. In this regard, the ancient city of Suzhou is an outstanding example of the wisdom of the "city of water" in China and even in the world. In contrast to Venice with its irregular layout of roads and river courses, Bruges with its radial pattern, and Amsterdam with its concentric circles formed by circular canal water systems around the downtown, the ancient city of Suzhou is unique because of its orderly "double-chessboard" layout and rich water networks (Figure 3). The water systems within the ancient city are interconnected with the Grand Canal of China, forming an organic whole that still plays an important role in transportation, culture, and tourism today.

Figure 3. Different textural morphologies of typical "cities of water" in the world. Source: Redrawn from Google Maps (https://www.google.com/maps/).

3.3. Rich cultural heritages represented by classical gardens

The classical gardens of Suzhou are representative of typical Chinese gardens, and thus occupy an important place in the history of gardens. Currently, there are more than 50 classical gardens in Suzhou, nine of which have been listed as "World Cultural Heritages" (Figure 4). There are also more than 300 protected cultural relic sites, historical buildings, and other historical and cultural heritages such as ancient

trees, wells, bridges, and memorial archways. As a long-term regional political centre, Suzhou was the birthplace and core inheritance region of Wu culture. The ancient city is the most characteristic, textbook, and concentrated embodiment of the entire Wu culture system.

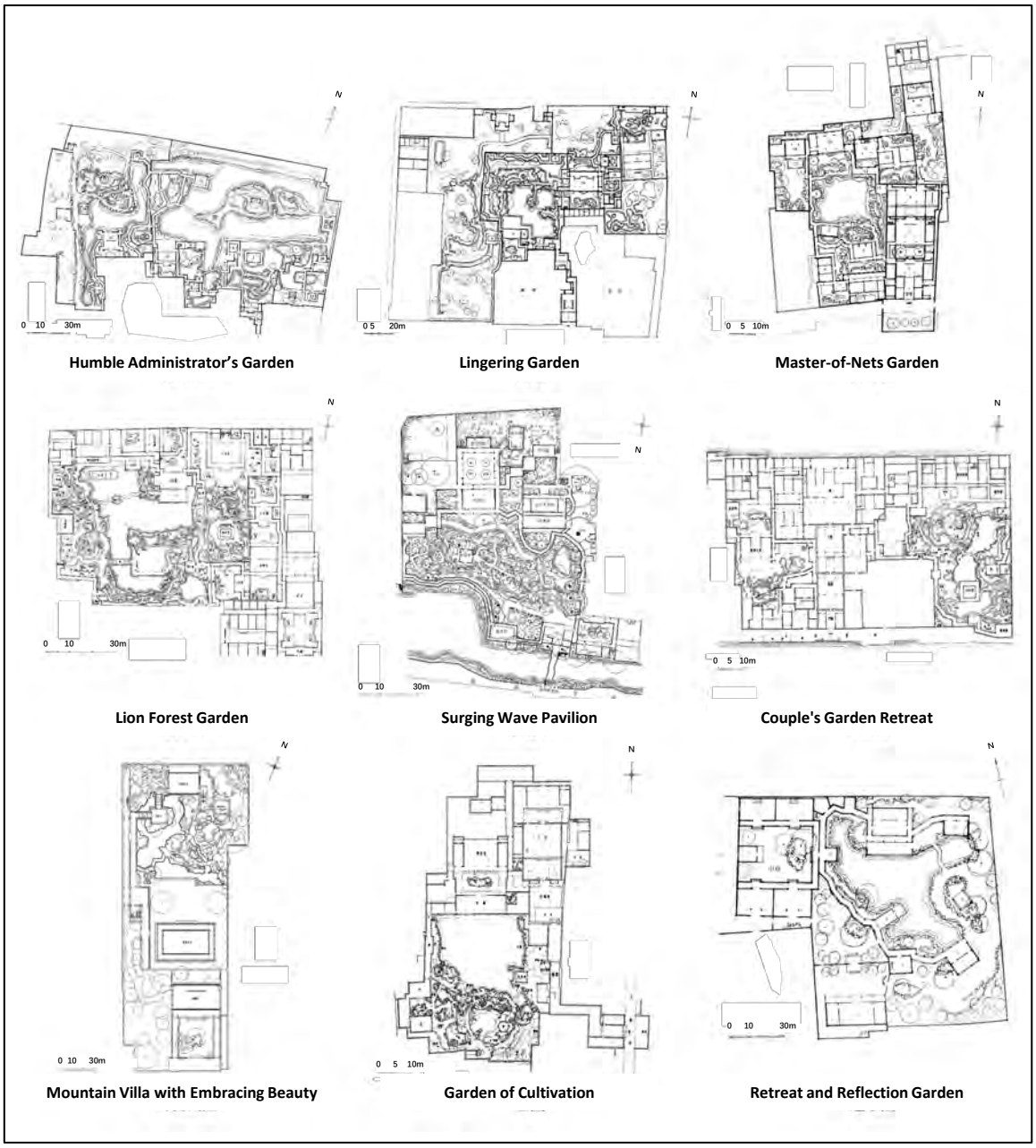


Figure 4. Plane layout of the Classical Gardens of Suzhou listed as "World Cultural Heritages". Source: Reference (Zhou 1990).

4. Problems and Challenges

4.1. Overall degradation of water networks

Before the 1380s, the ancient city had relatively complete water networks and densely distributed river courses. However, over time, they began to shrink gradually. Urban development gradually weakened the

transport function of ancient river courses. Moreover, with the continuous expansion of the city, the demand for construction land and transportation facilities surged, many river courses were filled and levelled up to facilitate urban construction. Since 2012, several river courses have been restored, but their structural integrity has been undermined by the overall degradation of water networks (Figure 5).

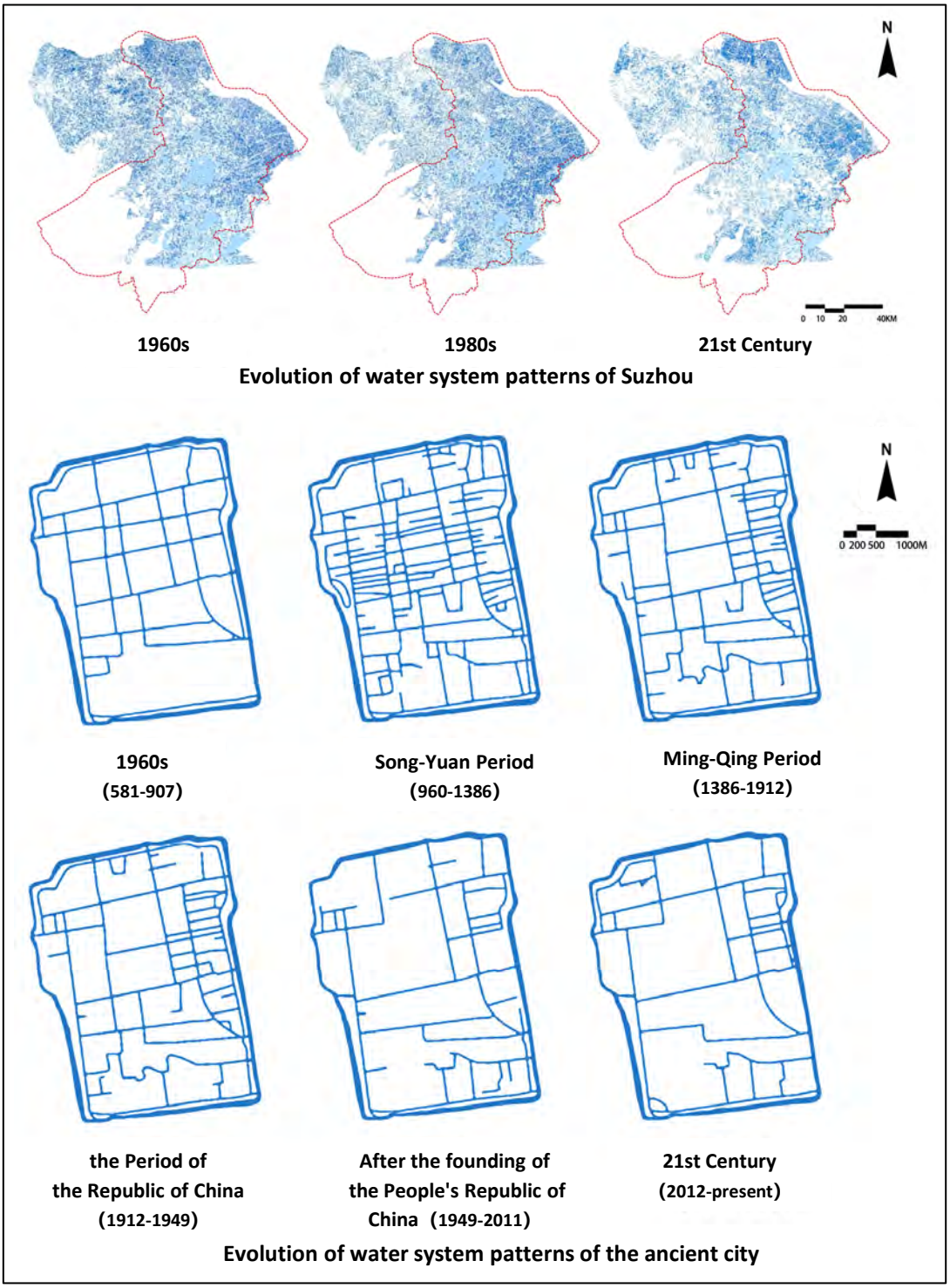
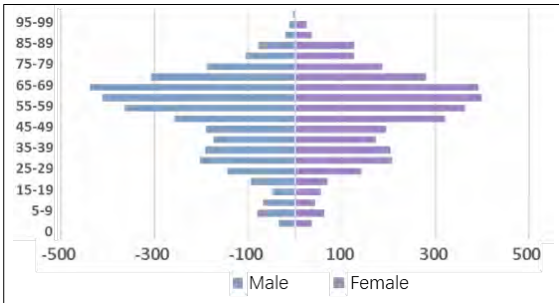


Figure 5. Evolution of water system patterns of Suzhou and the ancient city. Source: The water system evolution map of Suzhou was redrawn from Reference (WANG 2013), and that of the ancient city was drawn by the authors.

4.2. Serious situation of population aging

Compared with other parts of Suzhou, the ancient city has a higher proportion of elderly residents and a more prominent problem of population aging. According to data from the Seventh National Population Census of China, the proportion of people aged above 65 in Suzhou had exceeded 14% by 2020. This means that, according to international standards, Suzhou had entered the stage of moderate aging; however, the degree of population aging is even more serious in the ancient city (Figure 6). On the one hand, independent dwellings in the ancient city, built in the early years, often have a small net room area, which no longer meets the requirements of modern society for livability. On the other hand, new urban districts in surrounding areas are attracting more and more middle and high-income classes from the ancient city through the supply of high-quality educational resources, the creation of a comfortable residential environment, and the possibility of high returns on real estate investment.



Population age structure of Changmen Community

Elderly people gathering for activities in the community

Figure 6. Serious situation of population aging faced by the ancient city.

4.3. Poor quality of the residential environment

Facilities in the ancient city that are insufficient, outdated, and poor in quality can no longer meet the needs of different age groups in modern society. In particular, there is a lack of open spaces, educational facilities, age-friendly facilities, and parking facilities. In 2021, the greening rate of the ancient city was 6.48%. Faced with problems such as the insufficiency and uneven spatial distribution of open spaces and the poor quality of the ecological environment, the ancient city failed to meet the needs of modern residents for public life. The main reason is that the ancient city already has high construction density, which poses challenges to regeneration and limits the land available for redevelopment.

4.4. Difficulties faced by the conservation and regeneration of traditional dwellings

Traditional dwellings in the ancient city, mostly built in the Ming and Qing Dynasties and the Republic of China. However, because of the wide distribution and large quantities of traditional dwellings, a comprehensive conservation of all traditional dwellings in the ancient city is nearly impossible. In fact, many uninhabited dwellings have already been worn down by years without repair or have suffered constructive destruction as a result of modernized renovation. Although Suzhou has been exploring ways to conserve the historical context of traditional dwellings and renovate them in a modernized, livable fashion, consensus standards have not yet been established. The property rights of traditional dwellings are highly complicated.

5. Recognition and Reflections on Conservation of Urban Heritages in the Face of Change

As a special type of heritage with multi-dimensional value and dynamic features, historical cities belong to the category of typical living heritages. In this regard, a series of questions need to be addressed: How can an association between conservation and regeneration be established based on the development laws of historical cities and the core values of historical cities? How can urban regeneration be comprehensively and correctly understood? What kind of urban regeneration should be adopted to improve the functions and quality of historical cities and realize both their cultural inheritance and sustainable development? Addressing these questions requires deep reflections on the conservation, regeneration, and regeneration of historical cities.

5.1. Trends of international conservation of cultural heritages

The international conservation of cultural heritages has gone through a development process of "monuments–historical areas–historical cities–urban heritages". In this process, the objects of heritage conservation have been constantly expanded and diversified, and the concept of conservation has also been gradually transformed and deepened. Initially, heritage conservation focused on individual historical relics and sites as well as their surrounding areas (ICOMOS 1931, ICOMOS 1965). Later, the objects of heritage conservation gradually expanded to a complete series of heritages such as historical cities, historical gardens, cultural landscape, and intangible cultural heritages (ICOMOS 1982, ICOMOS 1987, ICOMOS 2004, ICOMOS 2005). In recent years, efforts have been actively made to explore measures for the conservation of urban heritages in response to changes, with the purpose of preserving the value of historical towns and backgrounds. There has been a tendency to gradually recognize the multiple values of cultural heritages, including historical, aesthetic, cultural, social, and environmental values, as well as to emphasize the combination of conservation and organic regeneration. Based on the identification and assessment of heritage values, urban heritage conservation strategies aimed at value conservation and inheritance can be formulated to promote the overall conservation of the historical environment and the sustainable development of cities (EH 2008, ICOMOS 2011, UNESCO 2011).

5.2. Major transformations in the conservation of historical cities in China

After more than three decades of rapid urban development, China has shifted from high-speed growth to medium and high-speed growth, entering a new stage of people-oriented transformation that emphasizes quality improvement. The new tasks faced by the conservation of historical cities in this stage include the improvement of the residential environment, the conservation of traditional features, and the enhancement of urban vitality. The National New Urbanization Plan (2014–2020) proposed to emphasize the construction of cities of culture. It indicated the necessity and importance of incorporating the conservation of cultural heritages into the overall social and economic development strategies of cities. The conservation of urban-rural cultural heritages is a complex social system project that is related to not only the inheritance of history and culture but also the improvement of urban quality and the promotion of the social civilization (ICOMOS 2005). The Opinions on Strengthening the Protection and Inheritance of History and Culture in Urban and Rural Construction (2021), issued by the General Office of the CPC Central Committee and the General Office of the State Council, proposed to promote the integrated development of the conservation and inheritance of history, culture, and urban-rural construction. This important document serves as an important basis and guideline for China's urban-rural planning and construction in the new era. It is of profound strategic importance for continuing urban culture, highlighting urban features, enhancing urban cultural charm, and achieving urban sustainable development.

5.3. Strengthening the overall association between the conservation and inheritance of history, culture, and urban regeneration

Both "the conservation and inheritance of history and culture" and "urban regeneration" are important components of urban development. The conservation and inheritance of history and culture constitute an important prerequisite for urban regeneration. Adhering to the craftsmanship spirit, to integrate historical and cultural heritages into contemporary urban construction and social life and sustain and stimulate the vitality and charm of historical cities. Gradual and prudent organic regeneration should be adopted with a scientific, rigorous, and professional attitude. As a historical city with a long-standing history and profound deposits, Suzhou has preserved rich historical resources and many areas with fine traditional features. As an important spatial carrier of modern urban life and urban development, it is a living cultural heritage undergoing constant adaptive changes. The paths towards the sustainable conservation and regeneration of the ancient city of Suzhou should be adopted to boost its revival and sustainable development.

6. Paths towards the Sustainable Conservation and Regeneration

6.1. Strengthening the overall conservation of the spatial pattern

Efforts should be made to continue the overall ecological pattern of "mountains and rivers in four corners" and the important ecological corridors in Suzhou. Further, the overall pattern and style of the ancient city should be conserved, highlighting its "double-chessboard" pattern of "parallel water and land, adjacent rivers and streets". Based on this framework, attention should be directed to the overall conservation of its morphological features, color tone, skyline, texture, landscape visual corridors, valuable buildings, and its typical elements such as river courses, ancient bridges, ancient trees, and ancient wells.

6.2. Optimizing the comprehensive capacity

Research on the capacity of the ancient city should strike a balance between the conservation and inheritance of history and culture and the improvement of urban development and vitality. The capacity of Suzhou is mainly composed of sub-capacities related to population, industry, tourism, space, and transportation (YANG and WANG 2023). To establish a comprehensive capacity assessment and optimal decision-making framework, the diversified development needs of the ancient city should be comprehensively considered. These are the improvement of its functional structure, the conservation and inheritance of its history and culture, the intensive use of land, and the improvement of the residential environment. It is also necessary to scientifically identify Suzhou's real capacity and existing problems, and to determine the reasonable limit of capacity optimization. Further, the overall structural morphology should be optimized, thereby realizing fine control.

6.3. Adopting small-scale progressive organic regeneration

Over the course of traditional urbanization based on incremental expansion in the past, the ancient city failed to coordinate the relationship between conservation and development. On the one hand, the excessive emphasis on the conservation of the ancient city, while achieving remarkable results in terms of conservation of physical spaces, nevertheless caused a series of problems. Examples of these problems are population aging, infrastructure aging, low economic vitality, and poor environmental quality. On the other hand, the blind pursuit of economic growth led to damages related to conservation and construction and caused problems such as over-development and destruction of traditional features. Therefore, to achieve the sustainable development of the ancient city, targeted measures adaptable to the characteristics of

different regeneration areas, such as preservation, conservation, regulation, improvement, repair, regeneration, and rejuvenation, should be taken to achieve steady, gradual, and diversified organic regeneration.

6.4. Fully utilize the endogenous force of public participation

Residents should be encouraged to actively and continuously participate in the whole process of regeneration. The will of residents should be fully respected during the regeneration of their dwellings. Regular community talks and residents' congresses can be organized with residents' representatives and other stakeholders. In these congresses, issues on the planning, design, project implementation, and other aspects of regeneration can be discussed, and residents' opinions and suggestions can be collected to realize the diversified governance and co-building of the ancient city.

6.5. Improving the supporting system of conservation and implementation

Under the overall framework of the construction of the national governance system, the regeneration of the ancient city should focus on connotative development. To establish a systematic framework for regeneration, the local government should promulgate relevant laws and regulations as well as policies, including regulations on urban regeneration, detailed rules for implementation, plans released in relation to various kinds of urban regeneration projects, and project implementation guidelines. By relying on the centre for conservation and management of big data platforms, a unified regeneration information system can be created, which can provide a service guarantee for the implementation and whole-life-cycle management of regeneration projects.

7. Discussion and Conclusions

The ancient city of Suzhou has experienced four major stages of structural morphology. Guided by long-term strict conservation, control, and active and effective dispersion policies, Suzhou has preserved and continued the "double-chessboard" pattern and the traditional features. Suzhou is an outstanding example of the wisdom of the "city of water" in China and even in the world. After entering this new period of development, Suzhou's ancient city also faces many new challenges. These include the overall degradation of water networks, the serious situation of population aging, the poor quality of the residential environment, the difficulties of conserving traditional dwellings, the impossibility to carry on traditional lifestyles, and the delay in adjusting regeneration policies.

In response to these challenges, Suzhou has adhered to the concept of multi-goal coordinated development and has actively explored paths for the sustainable conservation and regeneration of its ancient city with the ever-changing reality. It has also put forward several core strategies such as strengthening the overall conservation of the spatial pattern of the ancient city, optimizing its comprehensive capacity, adopting small-scale progressive organic regeneration, fully utilizing the endogenous force of public participation, and improving the supporting system of conservation and implementation. These strategies offer useful implications for the conservation and development of historical cities. In future research, the complexity and heterogeneity of the conservation status of historical cities need to be considered. Empirical research should be conducted on different types of historical cities to accumulate, identify, and summarize more replicable and transferable experiences as well as enrich existing theory and practice paradigms in relation to the conservation and regeneration of historical cities.

8. References

EH. (2008). 'Conservation Principles, Policies and Guidance.' [online] Available at: https://historicengland.org.uk/advice/constructive-conservation/conservation-principles (Accessed: 20 Sep. 2024).

ICOMOS. (1931). 'The Athens Charter.' [online] Available at: https://www.icomos.org/en/167-the-athens-charter-for-the-restoration-of-historic-monuments (Accessed: 20 Sep. 2024).

ICOMOS. (1965). 'The Venicean Charter.' [online] Available at: https://www.icomos.org/en/participer/179-articles-en-francais/ressources/charters-and-standards/157-the-venice-charter (Accessed: 20 Sep. 2024).

ICOMOS. (1982). 'The Florence Charter.' [online] Available at: https://www.icomos.org/en/newsletters-archives/179-articles-en-francais/ressources/charters-and-standards/158-the-florence-charter (Accessed: 20 Sep. 2024).

ICOMOS. (1987). 'Washington Charter.' [online] Available at: https://www.icomos.org/images/DOCUMENTS/Charters/towns_e.pdf (Accessed: 20 Sep. 2024).

ICOMOS. (2004). 'The World Heritage List: Fill the Gaps—An Action Plan for the Future.' [online] Available at: https://whc.unesco.org/uploads/activities/documents/activity-590-1.pdf (Accessed: 20 Sep. 2024).

ICOMOS. (2005). 'Xi'an Declaration.' [online] Available at: http://www.iicc.org.cn/Publicity.aspx?aid=563 (Accessed: 20 Sep. 2024).

ICOMOS. (2011). 'The Valletta Principles for the Safeguarding and Management of Historic Cities.' [online] Available at: https://civvih.icomos.org/wp-content/uploads/2022/03/Valletta-Principles-GA-_EN_FR_28_11_2011.pdf (Accessed: 20 Sep. 2024).

UNESCO. (2011). 'Recommendation on the Historic Urban Landscape.' [online] Available at: https://whc.unesco.org/uploads/activities/documents/activity-638-98.pdf (Accessed: 20 Sep. 2024).

WANG, L. (2013). Study of River System Structure, River-Lake Connectivity and Function in the Core Regions of Taihu Lake Basin. Nanjing, Nanjing University.

YANG, J. and WANG, M. (2023). 'A study on the comprehensive evaluation and decision optimization of Suzhou old town capacity.' City Planning Review 47(10): 43-53.

Zhang, Y. (2004). Maps of the ancient city of Suzhou. Suzhou: Gu Wuxuan Press.

Zhou, W. (1990). History of Chinese classical gardens. Beijing: Tsinghua University Press.

Case Study Report

From Heritage to a Sustainable Solution: Drinking Fountains of Fethiye, Türkiye

Melis YILMAZ, Istanbul Technical University, Türkiye

Cemile TIFTIK, Istanbul Technical University, Türkiye

Abstract

Considering the increasing use of plastic, low recycling rates, and the environmental and health risks associated with bottled water; the importance of drinking fountains becomes more evident. The study aims to promote sustainable urban development strategies based on cultural heritage while simultaneously lowering plastic waste and enhancing public health by revitalizing the culturally significant charity fountain network in Türkiye. It includes expressing the significance of the environmental and social benefits of drinking fountains; examination of current conditions and offering suggestions for system improvements. Focusing on the case of Fethiye, Türkiye, the study examines charity fountains as an eco-friendly alternative to bottled water. The methodology of the study includes the creation of water diagrams of the case study area and conducting a questionnaire about charity fountains with the users of the area. The research shows that long-term residents of Fethiye are more aware of and trust local charity fountains, while recent arrivals largely lack this trust. Due to limited information about fountain locations and water quality, new residents struggle with awareness and trust, highlighting the need for improved public information and visibility efforts.

Keywords

Drinking fountains, Charity fountains, Clean water & sanitation, Sustainable development goals, Awareness of sustainability

1. Introduction

There are serious environmental and public health problems stemming from the growing usage of plastic bottles. Globally, 485 billion PET bottles were produced in 2016 (Statista, 2017). The plastic used by the bottled water industry is mostly polyethylene terephthalate (PET), which makes up 5.5% of this global plastic production. While 19% of the plastic waste was incinerated, nearly 50% went to sanitary landfills and the remaining 22% was disposed of in uncontrolled dumpsites; only 9% of plastic waste was recycled, and plastics accounted for %3.4 of greenhouse gas emissions (OECD, 2022). In the case of Türkiye, following the initiation of the Zero Waste Project; the recovery level, previously at %13 (2016), increased to %22.4 in 2021 (GEKADER). Furthermore, Orb Media (2017) found that 93 out of 11 brands of bottled water contained microplastics. Bottled water, in fact, contained approx. %50 more microplastics than tap water.

This study investigates the historical significance and current relevance of charity fountains as an environmental friendly alternative to bottled water. The study focuses on the significance of cultural heritage in fostering sustainable urban development. Charity fountains, an integral part of Ottoman architecture, not only symbolize cultural heritage but also can offer a viable solution to modern environmental challenges. According to TDK, charities (hayrat) is firstly a *noun:* ''favor to earn good deeds (sevap)'' and secondly again a *noun* which ''structures built for the benefit of the public such as schools, fountains, hospitals, etc.'' Charity fountains, often built as charitable donations are one of the important structures of Ottoman Architecture. The fact that these fountains, which are often located within a complex, are small in size and less expensive than other charitable structures, played an active role in the selection of these structures as charities (Koçyiğit, 2019). Neighborhood fountains gained great importance in the periods when water could not reach the houses, and the fountains were differentiated according to their formal features as well as their functions. Fountains have been classified in different ways by researchers based on their location and shape (Tanışık, 1943).

This study focuses on the charity fountains along the seashore of Fethiye, Türkiye as a case study area. The aim of the study is to analyse these fountains as a sustainable alternative to bottled water and to suggest improvements. Within the scope of the research, an analysis of the ecological and social benefits of drinking fountains is presented through a case study. The legal framework regarding charity fountains was examined, water resources and components in the case study area were visualized with diagrams, and supported with photographs. In addition, a questionnaire was conducted to evaluate the usage patterns of drinking fountains, awareness, and perceptions of people. The study aims to provide useful information for urban planners and policymakers on how heritage infrastructure can contribute to a more resilient and sustainable urban future. The study encourages the restoration and promotion of drinking fountains as a mechanism to minimise plastic waste and protect public health.

2. Sustainability Aspect of Charity Fountains

Embodied energy refers to the total energy used in acquiring, producing, transporting, using, and disposing of a product or building material. Similarly, the CO2 released during the life cycle of a material or product is named as embodied carbon (EC). LCA (Life-Cycle Assessment) is a cradle-to-grave analysis which calculates a lot of impacts along with the embodied energy and embodied carbon whose emission is the number one cause of man-made global warming (Calkins, 2011). Every substance has embodied carbon and energy, impacting the environment to varying degrees, and PET bottles are no exception.

In addition; significant inequality continues even with increased access to safe water, with one in three individuals in the world having no safe water for consumption, and two in five not even having access to basic toilet and hand-washing facilities. The 2030 Agenda for Sustainable Development, which includes 17 Sustainable Development Goals (SDGs) intended to promote peace and prosperity for present and future generations, was accepted by all United Nations Member States in 2015.[1] This case study on charity fountains supports Sustainable Development Goals 6 (Clean Water and Sanitation) and 11 (Sustainable Cities and Communities), demonstrating how historical preservation may drive climate-resilient urban practices. With the plastic waste crisis exacerbating environmental challenges, revitalizing these fountains can reduce plastic consumption and greenhouse gas emissions. The widespread use of drinking fountains can significantly reduce waste generation, energy consumption, and CO_2 emissions, while also ensuring access to clean water.

[1] https://sdgs.un.org/goals

Lynch (1979) stated that there are five elements which create the image of the city. These elements are paths, edges, districts, nodes, and landmarks. Nodes which are points, the strategic spots in a city may be primarily junctions, places of a break in transportation, a crossing or convergence of paths, or moments of shift from one structure to another. Or the nodes may be simply concentrations, which gain their importance from being the condensation of some use or physical character, such as a street-corner hangout or an enclosed square. Some of these concentration nodes are the focus and epitome of a district, over which their influence radiates and of which they stand as a symbol. They may be called cores (Lynch, 1979). And water fountains have the potential to become a node where people come together in front of, socialize and become a noticeable point because especially charity fountains are not particularly uniform and may have design differences depending on the person who commissions them.

4. The Case of Fethiye

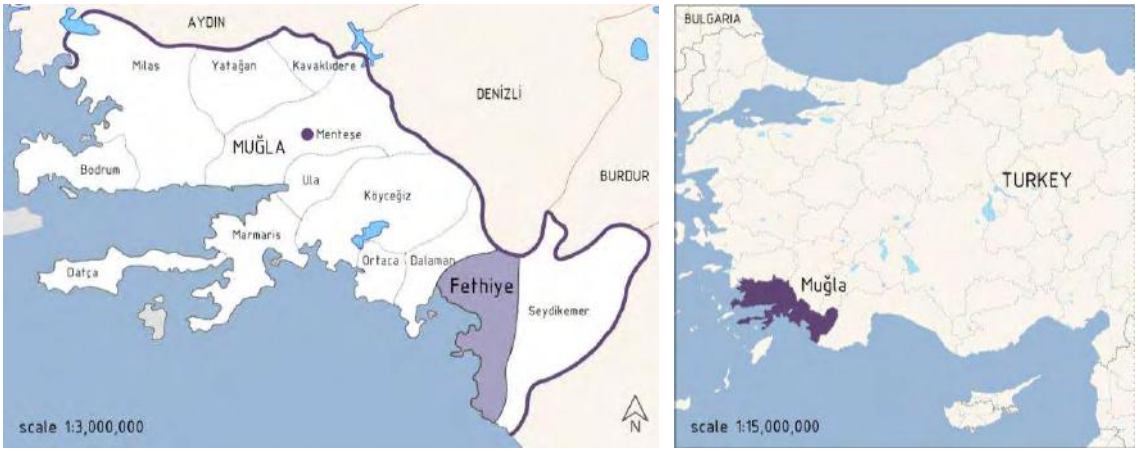


Figure 1. Map of Fethiye, Muğla. Source: M. Yılmaz, 2024.

Fethiye is located in southwest Türkiye in Muğla, with a population of 177,569 as of 2024 (Muğla Governorship). The annual average temperature of Muğla is 15.1 °C. During the most oppressive period of the year (from June 20 to September 16); due to the humidity reaching 40% in August, the weather can be suffocating, flattened, or unbearable. It can reach 33 degrees in July-August, and it is between 25-28 degrees on average between June and September.[2]

Before a charity fountain can be built in a public area, necessary permissions must be obtained from the relevant authorities of the provincial and district municipalities. In the case of Fethiye; an application should be made with a petition to the Development Directorate or the Park and Gardens Directorate of Fethiye Municipality. If the municipality approves, it is reported to MUSKI (Muğla Water and Sewerage Administration General Directorate) that it would be appropriate to open a subscription. According to this subscription, the monthly water bill must be paid by the fountain owner. These fountains are mostly built by their relatives or friends in the name of a deceased person. It was stated by the Fethiye Park and Gardens Directorate that there has been no demand for a charity fountain to be placed in a public space approx. in the last 20 years. According to information obtained from MUSKI, there is only 1 official subscription as a charity fountain in the system (within the scope of Fethiye Center). This may be because existing fountains were previously built and not recorded online.

[2] https://tr.weatherspark.com/y/95926/Fethiye-T%C3%BCrkiye-Ortalama-Hava-Durumu-Y%C4%B1l-Boyunca

Within the scope of this research, water maps were created, the current situation was photographed and a questionnaire was carried out. With the preliminary observation, it was determined that the most intense period of Kordon (seashore) was between 19.00 and 20.00 and the census was carried out at this time interval. Assuming that the average person passes through any point of Kordon in 1 hour and according to a 10% margin of error; it was decided to hold a questionnaire with 82 people (Appendix A). Research Groups were divided into three groups people who have lived in Fethiye since their birth, ''Fethiyeliler'' (28 participants); people living in Fethiye for more than 3 years (27 participants); people who have been in Fethiye for less than 3 years (27 participants). By analyzing these data, pie charts were created on the general view of bottled water, visibility of drinking fountains, and reliability of drinking fountains; the relationship with the determined research groups was examined and interpretations were made.

Kordon of Fethiye connects the Çalış district to downtown with a linear organization: the road, the cycle route, the walking trail, the green area, and the hard-floor promenade stretch along the coastline (*figure 2&3*). Within the scope of this research, this layered Kordon section, approx. 2.8 km between Uğur Mumcu Park and Şehit Fethi Bey Park was examined.

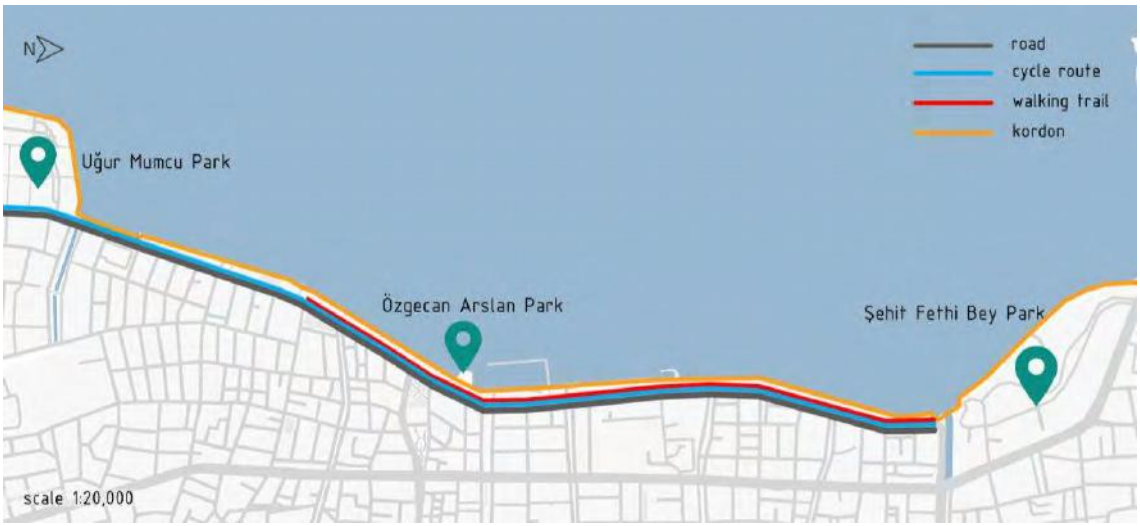


Figure 2. Linear organization diagram of Fethiye, Kordon. Source: M. Yılmaz, 2024.

Figure 3. The view of Fethiye, Kordon. Source: M. Yılmaz, 2024.

There are active 5 water sources along the Kordon in total. One of them is spring water and the others are charity fountains. One of these fountains is situated right next to a taxi station on the Kordon. This fountain, whose bill is paid by the taxi station, is also open to public use. Apart from these, there are 4 more fountains that have been cancelled, one of them was only disconnected from water, while the other charity fountain was demolished in 2024. As learned from the taxi drivers at the station next to the fountain, the owner of the fountain decided to cancel the fountain due to high water bills caused by the abuse of the fountain by boats on the shore. The fountains built in Şehit Fethi Bey Park and opened for use in 2018 are not functional at the moment.

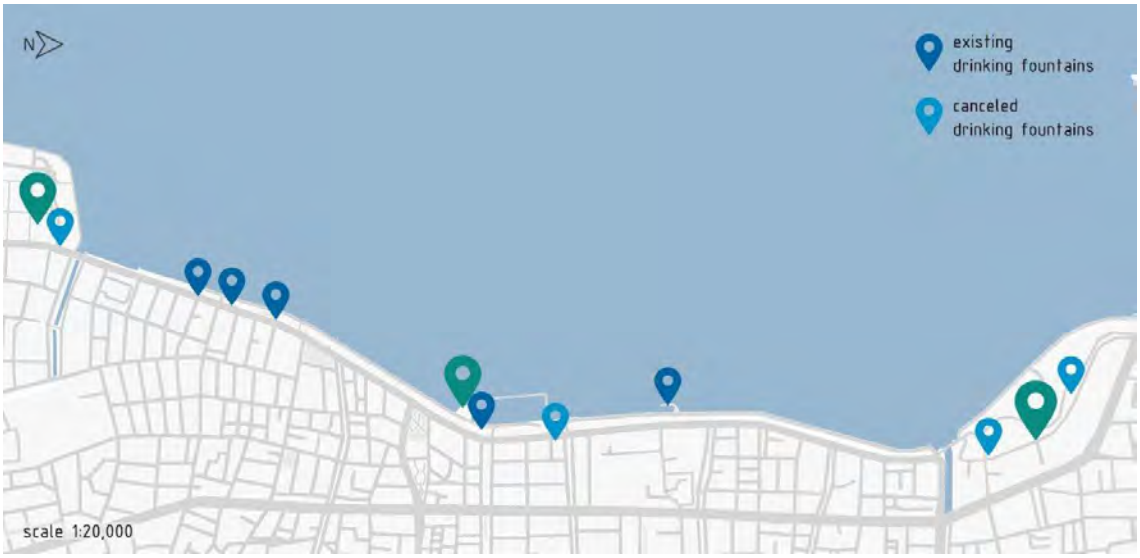


Figure 4. Map of drinking fountains of Fethiye, Kordon. Source: M. Yılmaz, 2024.

Figure 5. Existing charity fountains. Source: M. Yılmaz, 2024.

Along the Kordon; in addition to the charity fountains, there are 3 solar-powered water vending machines and 1 municipal buffet for water supply. There are 2 water bowls for animals in the part close to Uğur Mumcu Park and 4 recycling units concentrated in the middle part of the promenade (*figure 6*).

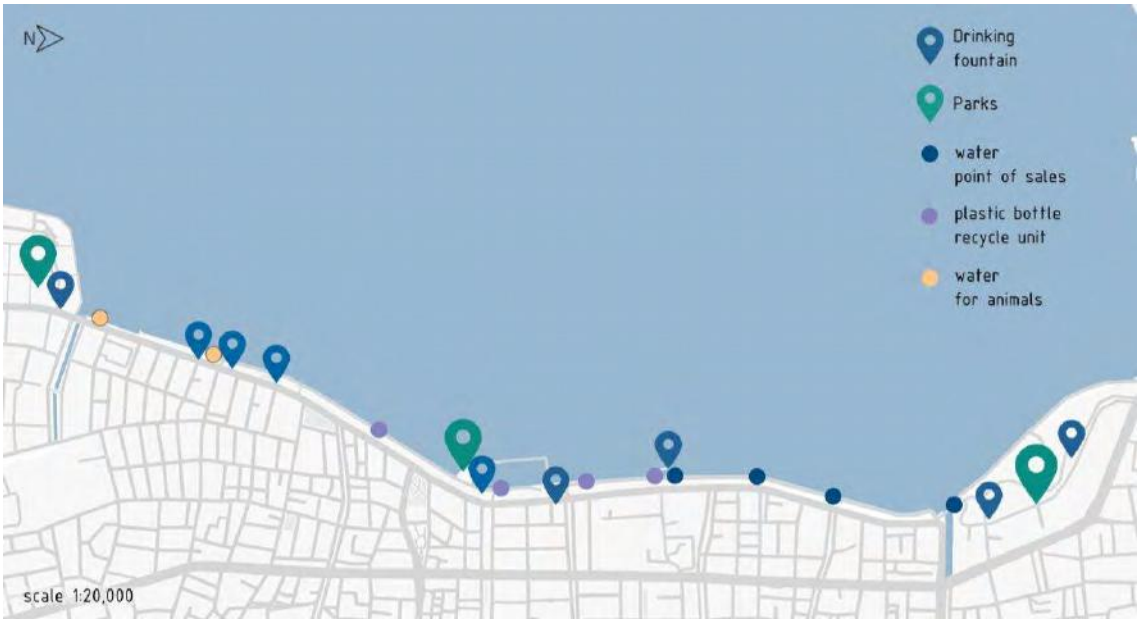


Figure 6. Map of water elements of Fethiye, Kordon. Source: M. Yılmaz, 2024.

Figure 7. Water points of sale (Left: buffet, Right: solar-powered vending machine). Source: M.Yılmaz, 2024.

As seen in the the bottled water overview charts *(figure 9)*; Although %70 of people are aware of the harmful effects of plastic on water, about %75 of them do not carry water bottles and about %85 of them use plastic bottles.

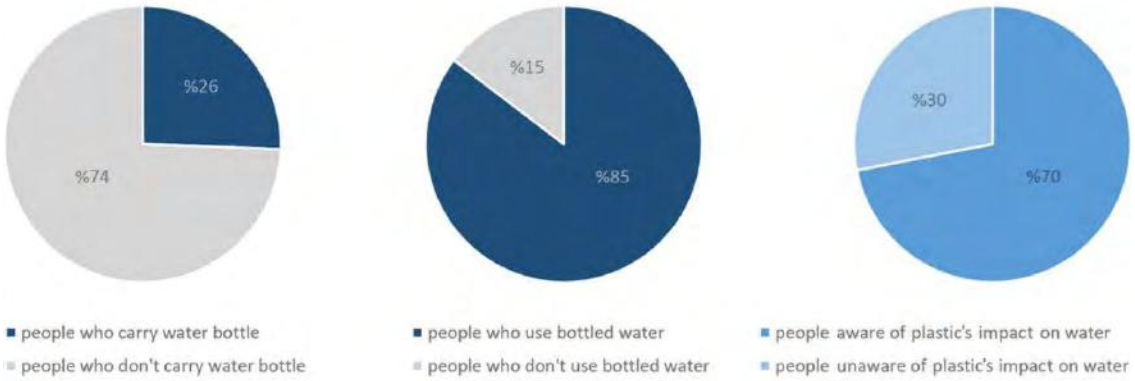


Figure 8. Pie charts related to the bottled water overview. Source: M. Yılmaz, 2023.

The majority of the people living in Fethiye since birth (%79), 74% of those living in Fethiye for more than 3 years, and 59% of those living in Fethiye for less than 3 years, noticed the charity fountains *(figure 9)*. It can be understood from the charts that there is a relationship between the time lived in Fethiye and the awareness of these fountains, and as the time to experience the region has increased, the awareness of the fountains has also increased. Similar to this inference; there is also a relationship between the time lived in the region and the reliability of the fountains. The vast majority (%64) of those born and raised in the region trusted the charity fountain waters, and only %4 said they did not. On the contrary, the vast majority of those who have lived in the area for a short time (less than 3 years), %52 stated that they do not trust the water comes from charity fountains according to charts related to the reliability of the charity fountains *(figure 10).*

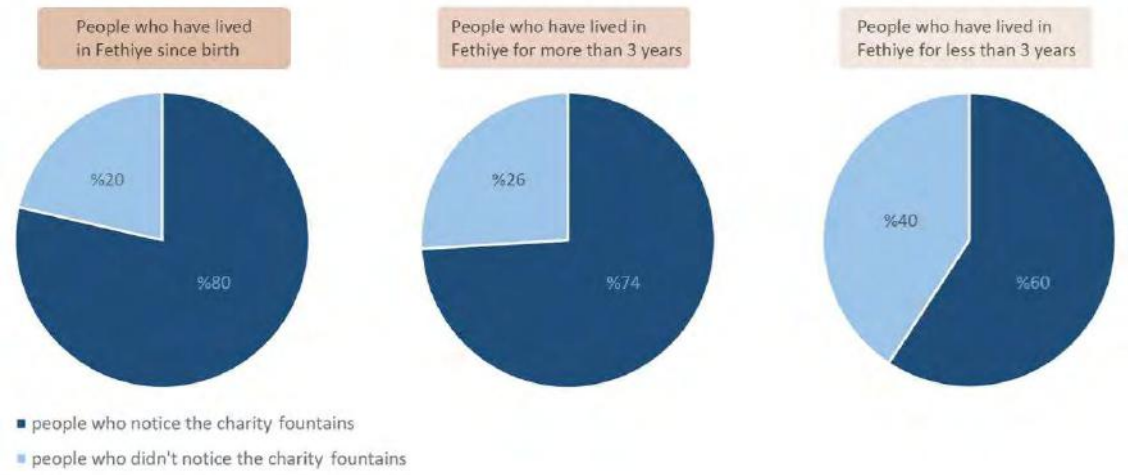


Figure 9. Pie charts related to the visibility of the charity fountains. Source: M. Yılmaz, 2023.

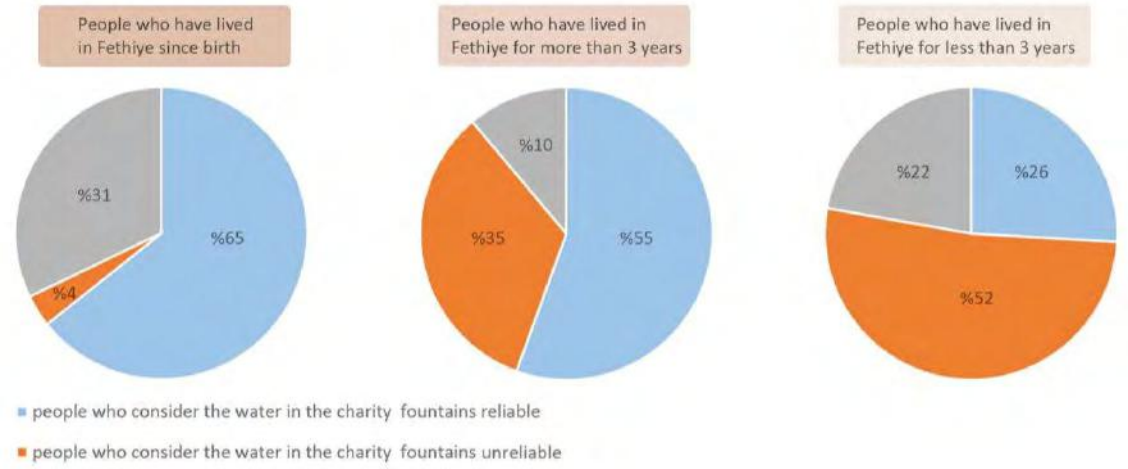


Figure 10. Pie charts related to the reliability of the charity fountains. Source: M. Yılmaz, 2023.

Of the 82 people interviewed, 16 people reported their concerns about where the water was coming from and said they could drink it if they knew the source and were sure of the safety of the water. Some of these people also made suggestions that signboards could be placed for informational purposes. 2 people stated that politicians drinking from the charity fountains and advertising will increase credibility.

4. Discussion

This study focuses on sustainable alternative to plastic bottled water, charity fountains. By increasing public water access and reducing plastic pollution, charity fountains support the aims of SDG 6 (Clean Water and Sanitation) and SDG 11 (Sustainable Cities and Communities). The main objective of the study is to promote sustainable urban development strategies based on cultural heritage, reduce plastic waste, and improve public health by revitalizing the culturally significant charity fountain network in Türkiye. In this context, the social and ecological sustainability of fountains was examined through a case study.

As the findings of research reveal; there is a relationship between the time lived in the region and the awareness of these fountains. The majority of the people living in Fethiye since birth (%79) were aware of drinking fountains. Similar to this inference; there is also a relationship between the time lived in the region and the reliability of the fountains. The vast majority (%64) of those born and raised in the region trusted the charity fountain waters. On the contrary, the vast majority (%52) of those who have lived in the area for a short period, stated that they do not trust the waters come from charity fountains. No specific information about the location or reliability of the fountains is given on any signs or websites. For this reason, it becomes difficult for people new to the region to notice the fountains and trust the water. It's evident that there is a need for enhancing transparency about water sources and safety, coupled with digital tools such as water maps, which can enhance public trust and utilization of drinking fountains.

In addition, Vending machines, which sell plastic bottled water and are advertised as being ''sustainable'' because of work with solar energy, were placed on the part of the Kordon which does not have a charity fountain in the summer of 2020 by the municipality. Instead of developing and supporting the existing charity fountain network, which has been a part of the culture since the Ottoman Empire and is located in parallel with the flow of the Kordon (walking trail, cycle route, and hard surface), it has taken a different direction. However; regarding global warming, high CO2 emissions, and plastic pollution, efforts should be made to strengthen the existing system, make it accessible to more people and raise awareness.

The locations of water fountains can be accessed online on the municipalities' pages, these locations can be included in Fethiye Municipality's web page or an application can be developed for Fethiye. Or/and, a map of the fountain locations (which may be similar to the one created in this study) with the source of the water, test results, and information about the fountains can be placed as a signboard at the beginning and end of the Kordon so that even someone without internet can access it. Thus the visibility and reliability of the fountains can be increased. According to Fethiye water map prepared by the author and the results of the survey, it has been seen that there is no balanced distribution in terms of water elements. Plastic bottle recycling units and water containers prepared for animals are concentrated in certain regions. For animals, only 2 water bowls along the cordon are insufficient, the number can be increased. More to be done for animals; an integrated urban element can be designed for the food and water needs of animals.

5. References

Bulut, Y., and Atabeyoğlu, Ö. (2007) 'Fountains as Urban Furniture in Historical Urban Structure and Usage Culture: Erzurum City Case', *Building and Environment*, 42, p2432–2438.

Calkins, M. (2011) *The Sustainable Sites Handbook: A Complete Guide to the Principles, Strategies, and Practices for Sustainable Landscapes*. Wiley.

Çavdar, M. B. (2019) *İstanbul'un Mekansal Değişimi Sürecinde Osmanlı Çeşmesinin Değişimi ve İstanbul Mekanı Kullanıcılarının İmgesindeki Yeri* (Master's thesis, Istanbul Technical University).

Koçyiğit, F. (2019) 'Osmanlı Mimarisinde Meydan Çeşmeleri', *Akdeniz Sanat Dergisi*, 13, p339–354.

Lynch, K. (1979) *The Image of the City*. MIT Press.

OECD. (2022) *Global Plastics Outlook: Economic Drivers, Environmental Impacts and Policy Options*. OECD Publishing, Paris. Available at: https://read.oecd-ilibrary.org/environment/global-plastics-outlook_de747aef-en#page46 (Accessed: 5 April 2024)

Statista. Packaged water consumption per capita in the European Union (EU) 2010–2020. Available at: https://www.statista.com/statistics/620191/packaged-water-consumption-in-the-european-union-per-capita/ (Accessed: 15 May 2024)

Orb Media. *The Invisibles*. Available at: https://orbmedia.org/the-invisibles (Accessed: 15 May 2024)

United Nations. *Sustainable Development Goals*. Available at: https://sdgs.un.org/goals (Accessed: 10 June 2024).

Turkish State Meteorological Service. *İl ve İlçeler İstatistikleri – Muğla*. Available at: https://www.mgm.gov.tr/veridegerlenen/il-ve-ilceler-istatistik.aspx?k=undefined&m=MUGLA (Accessed: 10 June 2024).

Muğla Governorship. *İlçelerimiz*. Available at: http://www.mugla.gov.tr/ilcelerimiz (Accessed: 10 June 2024).

Weather Spark. *Fethiye Türkiye Ortalama Hava Durumu Yıl Boyunca*. Available at: https://tr.weatherspark.com/y/95926/Fethiye-T%C3%BCrkiye-Ortalama-Hava-Durumu-Y%C4%B1l-Boyunca (Accessed: 10 June 2024).

Acknowledgment

My gratitude to ÖZYER GROUP & Sandrine Mohler for their generous financial support, which has made my participation in the 60th ISOCARP World Planning Congress possible.

APPENDIX A

Survey Questions

1. How old are you?

Under 25, 25-40, 40-60, over 60 years old

2. How many years have you lived in Fethiye?
3. How often do you use Kordon?

Every day, 2-3 times a week, once a week, once a month, rarely

4. What is your general purpose for using the lanyard?

For walking, transportation, sightseeing, sitting, other

5. Did you notice the fountain (charities) along the kordon?
6. Have you used the fountains along the kordon before? If not, under what conditions can you consider using it?
7. What is your reason for using / not using?
8. Do you find the water coming from the fountains reliable?
9. Do you buy plastic bottled water, how often do you buy it?

A few every day, 1 every day, 2-3 times a week, once a week, once a month, rare

10. Do you know the effects of plastic bottles to water, do you read about the topic?
11. Do you carry water bottle with you?
12. Are you interested in / following the news about environmental issues?

Research Paper

Urban Shrinkage and the Future of Built Heritage:
a Resilience Perspective

Elena BATUNOVA, Chair of Urban Design and Institute for Urban Design and European Urbanism, RWTH Aachen University, Germany

Abstract

This paper examines the concept of built heritage resilience in urban shrinkage, highlighting the need to reconsider heritage use, management, and preservation approaches in declining urban areas. Urban shrinkage, spreading worldwide and provoking implementation of right-sizing strategies, creates new, unfamiliar challenges for heritage resilience, which is traditionally considered in the framework of urban growth. The research question guiding this essay is: How does urban shrinkage impact the resilience of built heritage? The paper explores diverse dimensions of the resilience of built heritage and hypotheses for future research.

Keywords

Built heritage, heritage resilience, urban shrinkage, shrinking cities

1. Introduction.

The concept of heritage emerged as a response to rapid urban growth and the pressures of fast-paced urban development. The destruction and fear of loss associated with modernity and continuous urbanisation remain essential contributors to heritage-making. Destructions increase the values of rarity and uniqueness, which help "export" heritage (Heinich, 2011; Kirshenblatt-Gimblett, 1995). The heritage concept initially concentrated on the protection of individual objects – precious remnants of the past – from the destructive forces of urban expansion. Over time, the concept of heritage has continuously evolved by incorporating more categories (Dallen, 2014; Podder et al., 2018), becoming more inclusive in terms of diverse aspects (e.g. tangible and intangible) and values (Smith & Akagawa, 2009; Fredheim & Khalaf, 2016). In terms of relation with urban space, heritage concept expanded from focusing on isolated historical buildings to considering urban areas and cultural landscapes. (UNESCO, 2011; Veldpaus et al., 2013).

The approaches to heritage protection have also experienced significant transformations. In the Western tradition, materialistic vision and consequent obsession with material authenticity have long dominated conservation practices (Djabarouti, 2022; Veldpaus et al., 2013). The ongoing shift towards adaptive reuse and integration of heritage into everyday urban life and economy emphasises a necessity to rethink the previously settled rigid approaches (Cherchi, 2015). Today, heritage is increasingly recognised not as a static construct but as a dynamic component of the urban environment—one that must adapt to the ongoing transformations natural for urban life (Licciardi & Amirtahmasebi, 2012).

The concept of resilience provides a valuable framework for understanding the relationship between heritage and urban change (Garcia & Vale, 2017). It offers insights into how heritage can cope and adapt to the constant transformations that characterise urban development. However, much of the existing discourse on heritage resilience and the heritage concept itself results from thinking within the growth paradigm, often overlooking the perspective of urban shrinkage. At the same time, urban shrinkage raises new questions for heritage studies and creates unique challenges and opportunities for heritage preservation. What happens to urban heritage when there are no more risks related to development

pressure, commercialisation, and investment? Does it mean that heritage is safer in shrinking cities? What are the new risks? How should new approaches to heritage protection consider non-growing reality? Those are just a few of many questions that have seldom been asked, let alone answered.

This paper explores the resilience of built heritage in an urban shrinkage context. The guiding research question is: How does urban shrinkage impact the resilience of built heritage? It is the first attempt to draw attention to the issues associated with built heritage in urban shrinkage conditions and highlight some directions that require further research and discussion.

2. Heritage and resilience.

The constant transformation of the heritage concept is rooted in its nature as a social construct evolving with our changing understandings and concerns (Smith, 2006). Heritage reflects the present; the present is a moment in our timeline where we create and produce heritage (Kirshenblatt-Gimblett, 1995; Silverman et al., 2017).

The concept of urban resilience emerged as a response to global challenges that a contemporary city faces. (Coaffee & Lee, 2016; Colomer, 2017). Climate change, pandemics, global conflicts, and mass migrations require a city's capacity to resist and recover from diverse shocks and destructions, learn from them, and improve their adaptability to possible future challenges. Urban resilience is becoming relevant and is studied in relation to different components of urban – from urban-built fabric and technical infrastructure to urban communities and heritage.

The academic literature presents various ways in which heritage and resilience are interconnected.

One way of connection is the understanding that heritage must be dynamic and adaptable to survive in constant urban transformations and numerous threats linked to urbanization, socio-economic changes, unsustainable tourism, or resource shortages, referred to as heritage resilience (Murthy, 2013; Garcia & Vale, 2017). Various threats challenge the ability of built heritage to resist in its original form. Such understanding results in the process in which traditional conservation approaches with a focus on materiality are complemented by adaptability and reuse strategies. This perspective of heritage resilience calls for the active transformation of heritage into a resource for community identity, economic development and sustainability (Berg, 2017).

The other relationship between heritage and resilience is when the historic environment can be a source of urban resilience. Historical sites accumulate traditional knowledge and techniques that can provide insight into ways of addressing contemporary urban challenges (Fatiguso et al., 2017). This perspective emphasizes the social and cultural values of heritage that can contribute to increasing urban resilience.

Furthermore, heritage can serve as an element of community resilience providing a sense of identity and continuity (Fabbricatti, Boissenin & Citoni, 2020). In times of shocks, crises, and dramatic changes, heritage can serve as an anchor, helping communities confront uncertainty and maintain a connection to their common past. Heritage, in this way, can also contribute to local economic resilience, integrating traditional local craftsmanship and monuments into local products that can be exported.

Different ways of understanding how heritage and resilience can be interconnected emphasize the need to evolve flexible and adaptive heritage policies. However, while recent research has explored urban heritage resilience as a means to adapt to global challenges, these discussions have largely overlooked the specific realities of urban shrinkage.

3. Built heritage in shrinking cities: why should we care?

The reality of shrinking cities needs to be added to heritage discussions. This reality is growing fast and spreading worldwide, driven by local and global processes – such as demographic transitions, climate change, wars, and economic migrations provoked by globalisation (Martinez-Fernandez et al., 2012). The number of shrinking cities in the world already goes into the thousands. However, heritage debates rarely question critically the future heritage meanings for a society facing challenges related to urban shrinkage.

Urban shrinkage remains an ambiguous concept, with population decline often being the only universally agreed-upon indicator (Mallach, 2017; Olsen, 2013; Haase et al., 2014). However, when considering urban shrinkage from the built environment perspective, the mismatch between socio-demographic processes and physical infrastructure becomes a key characteristic of shrinking cities (Reis, Silva & Pinho, 2015). Shrinking cities suffer from the redundancy of urban "hardware" – buildings, constructions, and infrastructure, simultaneously experiencing a lack of resources for the existing urban environment maintenance, and, in general, adapting urban form to new conditions is a heavy burden for a shrinking city (Herrmann et al., 2016).

The fate of built heritage in shrinking cities warrants special consideration for at least two reasons.

The first reason is the global character of the urban shrinkage phenomenon (Batunova, 2021). Some of such cities became world-famous – such as Detroit in the United States, which faced significant population decline due to deindustrialisation and suburbanisation, or Leipzig in Germany, which experienced shrinkage because of economic restructuring after reunification. Many other cities are experiencing urban shrinkage due to multiple factors, including demographic transition, globalisation, global labour division and migration, political transformations, wars and conflicts, and climate change (Haase et al., 2014). The increasing presence of shrinking cities in the urban agenda requires new strategies and approaches to urban planning and management in such a context. However, our knowledge of shrinking cities is still very limited.

Second, the primary responses to urban shrinkage have often been "right-sizing" strategies, including demolition programs. The lack of urban resources becomes the main driving force behind significant changes in urban policy to optimise budget spending in shrinking cities. Smart shrinkage and right-sizing strategies are widely used in Europe and the USA (Bernt, 2009; Bontje & Mustard, 2012). They are based on the physical reduction of redundant urban infrastructure to eliminate the burden of maintenance, fragmentation, and the city's negative image. These approaches may be motivated by different factors—such as a necessity to maintain the local real estate market, improving the city's image, or reducing infrastructure costs—but they frequently counter the goals of built heritage conservation (Mallach, 2011) and can impact the resilience of built heritage.

4. Resilience of built heritage in shrinking places.

The impact of urban shrinkage on the resilience of built heritage can be understood through several interrelated dimensions of resilience.

One of the most evident dimensions is physical resilience. Urban shrinkage often leads to widespread abandonment, vacancies, and underutilized infrastructure, resulting in urban fabric perforation (Florentin, 2010). The erosion of urban fabric disconnects built heritage from its surroundings, decreasing its functional and symbolic meaning within the city. The example of the iconic Michigan Central Station in Detroit can perfectly illustrate this statement. The station was abandoned and became an isolated, dilapidated structure that lost its role within the city context (Rottman, 2011)

Urban shrinkage can affect the environmental resilience of built heritage. As the urban fabric erodes, it becomes increasingly challenging to sustain infrastructure networks, which reduces the environmental

benefits typically associated with compact urban forms. In cities like Cleveland, Ohio, shrinking populations have made it difficult to maintain infrastructure systems initially built to serve much larger communities (Schwarz & Hoornbeek, 2009). Moreover, in shrinking cities, it is much more challenging to apply the strategies of building reuse due to economic decline and decreasing investors' interest. Thus, many historic buildings remain vacant in the shrinking Russian city of Vorkuta due to the lack of economic incentives despite their historical significance (Gunko, Batunova, & Medvedev, 2021).

Demographic changes in shrinking cities are associated with quantitative population decline and ageing and population replacement due to migration. The transforming composition of local society influences socio-cultural resilience of built heritage. Whose heritage should be preserved and for whom - are the questions that naturally appear in relation to built heritage. In shrinking cities, new residents may not share the same attachment to existing heritage, leading to a disconnect between the community and the built environment. For example, the once-thriving Jewish community in the Serbian city of Subotica left behind the remarkable heritage of their Synagogue, which, without the community to sustain its cultural significance, became unused and lacked meaning for the non-Jewish population (Camprag, 2019). As these cultural connections erode, heritage becomes less central to the identity of the community, which in turn impacts efforts to maintain and preserve these sites. The socio-cultural resilience of built heritage in shrinking cities is therefore closely tied to the ability of communities to adapt, maintain their connection to heritage, and find new ways to sustain its relevance in a changing social landscape.

The economic resilience of built heritage in shrinking cities suffers from economic decline and depopulation because the economic resources available for heritage preservation are decreasing. This issue is strongly connected with the political aspects. Shrinking cities, whose regional and national economic role is decreasing, tend to lose their political influence, which impacts their capacity to attract state investments. When a place becomes less significant to the state or regional authorities, public investment in heritage often declines, leaving the built environment vulnerable. For instance, in many post-industrial cities across Eastern Germany, the reduced political clout of these areas has resulted in fewer resources being allocated for the preservation of their built heritage (Neugebauer, 2022).

Therefore, urban shrinkage can impact different dimensions of the resilience of built heritage – physical, environmental, social, cultural, economic, or political. This impact calls for a necessity to learn more about the processes that affect built heritage under urban shrinkage conditions, and which approaches to heritage management, preservation and adaptation work effectively or need rethinking. A better understanding of such processes and issues can help in developing and implementing wiser and more effective solutions, instruments and approaches to urban heritage by urban planners, policymakers and local communities.

5. Conclusion.

Urban shrinkage is no longer a rare condition relevant for isolated specific cases of urban environment. It spreads worldwide and is increasingly recognised as a critical element of contemporary urban challenges. Urban development professionals and politicians must prepare to address the complexities of urban shrinkage, just as they have learned to manage urban growth. While there has been progress in understanding and addressing the challenges of shrinking cities, the work remains in its infancy. Still, many important actors and decision-makers impacting urban development consider urban shrinkage taboo and associate it only with negative connotations (Hospers & Reverda, 2014; Pallagst et al., 2017).

The need to develop new approaches to deal with different components of "urban" in urban shrinkage is already well-pronounced in academic literature (Pallagst et al., 2017). However, many aspects of urban development are almost not discussed. Heritage resilience is one such aspect.

There is still much to learn about urban shrinkage, how it changes the operation and interrelation of different urban elements and aspects, and its impact on built heritage. Many questions should be asked, and many questions will require research to be answered. What is more effective – adaptation, conservation or abandonment of built heritage? How do we deal with the underlying challenges? How do we overcome physical and social disconnection of heritage? What are the costs of saving energy-inefficient buildings? Can nature reclaim built heritage? Should built heritage be living or frozen? What should be in the focus – the present or the future community? Is heritage a source or a burden for a shrinking city? What should be prioritised – local or national issues? Those are just a few examples that can be relevant for heritage resilience research in an urban shrinkage context.

Studying the issue of heritage resilience in shrinking cities can contribute to its revaluation in such a vulnerable context and its transformation into a relevant resource for community well-being. It will contribute to the development of new approaches that move beyond the traditional view of heritage as merely a resource to be capitalised on as a tourist product. Developing comprehensive and collaborative approaches will require integrating theoretical and empirical knowledge of scholars, professional experts, politicians, decision-makers, activists, heritage promoters and its users, and many other actors involved in built heritage use, management, popularisation or preservation.

Acknowledgements

This work is the result of the collaborative research project between the Karlsruhe Institute of Technology (KIT), RWTH Aachen University, and GWZO Leipzig. The “Cities Building Culture (CBC): The Residential Heritage of the Soviet Union in Times of Multiple Crises” project is financed by the German Federal Ministry of Education and Research, grant number 01UC2410B. The results presented in the paper are part of the subproject "Integrated Approaches” led by RWTH Aachen University.

References

Batunova, E. (2021). Urban Shrinkage, Aging, and Economic Change. In W. Leal Filho, A. M. Azul, L. Brandli, P. G. Özuyar, & T. Wall (Eds.), Sustainable Cities and Communities (pp. 1–9). Springer International Publishing. https://doi.org/10.1007/978-3-319-71061-7_102-1

Bernt, M. (2009). Partnerships for Demolition: The Governance of Urban Renewal in East Germany’s Shrinking Cities. International Journal of Urban and Regional Research, 33(3), 754–769. https://doi.org/10.1111/j.1468-2427.2009.00856.x

Berg, S. K. (2017). Cultural heritage as a resource for property development. The Historic Environment: Policy & Practice, 8(4), 304–322. https://doi.org/10.1080/17567505.2017.1399582

Bontje, M. & Musterd, S. (2012). Understanding Shrinkage in European Regions. Built Environment 38, 153–161. https://doi.org/10.2148/benv.38.2.153

Camprag, N. (2019). Built heritage in disadvantaged contexts: The case of Subotica’s synagogue, Serbia. Territorio : 91, 4, 2019, 67–76. https://doi.org/10.3280/TR2019-091007

Cherchi, P. F. (2015). Adaptive Reuse of Abandoned Monumental Buildings as a Strategy for Urban Liveability. ATHENS JOURNAL OF ARCHITECTURE, 1(4), 253–270. https://doi.org/10.30958/aja.1-4-1

Clarke, N. J., Kuipers, M. C., & Roos, J. (2020). Cultural resilience and the Smart and Sustainable City. Smart and Sustainable Built Environment, 9(2), 144–155. https://doi.org/10.1108/SASBE-09-2017-0041

Coaffee, J., & Lee, P. (2016). Urban Resilience: Planning for Risk, Crisis and Uncertainty (1st ed. 2017 edizione). Red Globe Pr.

Colomer, L. (2017). Heritage on the move. Cross-cultural heritage as a response to globalisation, mobilities and multiple migrations. International Journal of Heritage Studies, 23(10), 913–927. https://doi.org/10.1080/13527258.2017.1347890

Dallen, J. T. (2014). Views of the vernacular. Tourism and heritage of the ordinary. In: Kaminski, J., Benson, A. M., & Arnold, D. (Eds.). (2014). Contemporary issues in cultural heritage tourism. Routledge, Taylor & Francis Group

Djabarouti, J. (2022) Imitation and intangibility: postmodern perspectives on restoration and authenticity at the Hill House Box, Scotland, International Journal of Heritage Studies, 28:1, 109-126, DOI: [10.1080/13527258.2021.1883716](https://doi.org/10.1080/13527258.2021.1883716)

Fabbricatti, K., Boissenin, L., & Citoni, M. (2020). Heritage Community Resilience: Towards new approaches for urban resilience and sustainability. City, Territory and Architecture, 7(1), 17. https://doi.org/10.1186/s40410-020-00126-7

Fatiguso, F., De Fino, M., Cantatore, E., & Caponio, V. (2017). Resilience of Historic Built Environments: Inherent Qualities and Potential Strategies. Procedia Engineering, 180, 1024–1033. https://doi.org/10.1016/j.proeng.2017.04.262

Florentin, D. (2010). The "Perforated City:" Leipzig's Model of Urban Shrinkage Management. Berkeley Planning Journal, 23(1). http://escholarship.org/uc/item/97p1p1jx

Fredheim, L. H. & Khalaf, M. (2016). The significance of values: Heritage value typologies re-examined. International Journal of Heritage Studies, 22(6), 466–481. https://doi.org/10.1080/13527258.2016.1171247

Garcia, E. J., & Vale, B. (2017). Unravelling Sustainability and Resilience in the Built Environment. Routledge. https://doi.org/10.4324/9781315629087

Gunko, M., Batunova, E., & Medvedev, A. (2021). Rethinking urban form in a shrinking Arctic city. Espace Populations Sociétés, 2020/3-2021/1. https://doi.org/10.4000/eps.10630

Haase, A., Rink, D., Grossmann, K., Bernt, M., & Mykhnenko, V. (2014). Conceptualizing urban shrinkage. *Environment and Planning A*, 46(7), pp. 1519-1534.

Heinich, N. (2011). The Making of Cultural Heritage. NJA 22. https://doi.org/10.7146/nja.v22i40-41.5203

Herrmann, D.L., Shuster, W.D., Mayer, A.L. & Garmestani, A.S. (2016). Sustainability for shrinking cities. Sustainability 8:911

Hospers, G-J. & Reverda, N. (2014). *Managing population decline in Europe's urban and rural areas*. SpringerBriefs in Population Studies, 100 pp. ISBN 978-3-319-12411-7.

Kirshenblatt-Gimblett, B. (1995). Theorizing Heritage. Ethnomusicology 39, 367–380. https://doi.org/10.2307/924627

Licciardi, G., & Amirtahmasebi, R. (Eds.). (2012). The Economics of Uniqueness: Investing in Historic City Cores and Cultural Heritage Assets for Sustainable Development. The World Bank. https://doi.org/10.1596/978-0-8213-9650-6

Mallach, A. (2011). Demolition and preservation in shrinking US industrial cities. Building Research & Information, 39(4), 380–394. https://doi.org/10.1080/09613218.2011.573743

Mallach, A. (2017). What we talk about when we talk about shrinking cities: The ambiguity of discourse and policy response in the United States. *Cities*, 69, pp. 109-115. doi:10.1016/j.cities.2017.01.008

Martinez-Fernandez, C., Audirac, I., Fol, S., & Cunningham-Sabot, E. (2012). Shrinking Cities: Urban Challenges of Globalization. International Journal of Urban and Regional Research, 36(2), 213–225. https://doi.org/10.1111/j.1468-2427.2011.01092.x

Murthy, M. (2013). HERITAGE AND RESILIENCE Issues and Opportunities for Reducing Disaster Risks.

Neugebauer, C. (2022). Eisenhüttenstadt: Urban Heritage in Transformation. In Post-Utopian Spaces. Routledge.

Pallagst, K., Fleschurz, R., & Said, R. (2017). What drives planning in a shrinking city? Tales from two German and two American cases. *Town Planning Review*, 88(1), pp. 15-28

Silverman, H., Waterton, E. & Watson, S. (Eds.). (2017). Heritage in Action. Springer International Publishing, Cham. https://doi.org/10.1007/978-3-319-42870-3

Olsen, A. (2013). Shrinking cities: Fuzzy concept or useful framework? *Berkeley Planning Journal*, 26(1). Available at: http://escholarship.org/uc/item/9cd585dr [Accessed 10 September 2024].

Podder, A. K., Hakim, S. S., & Bosu, S. P. (2018). Ordinary Heritage. International Journal of Architectural Research: ArchNet-IJAR, 12(2), 334. https://doi.org/10.26687/archnet-ijar.v12i2.1534

Reis, J.P., Silva, E.A., & Pinho, P. (2015). Spatial metrics to study urban patterns in growing and shrinking cities. *Urban Geography*, 37(2), pp. 246-271. doi:10.1080/02723638.2015.1096118

Rottman, E. M. (2011). The Michigan Central Station: Re-Discovering Identity Among Ruins. http://hdl.handle.net/1903/11606

Santangelo, A., Melandri, E., Marzani, G., Tondelli, S., & Ugolini, A. (2022). Enhancing Resilience of Cultural Heritage in Historical Areas: A Collection of Good Practices. Sustainability, 14(9), Article 9. https://doi.org/10.3390/su14095171

Smith, L. (2006). Uses of heritage (Repr). Routledge

Smith, L., & Akagawa, N. (Eds.). (2009). Intangible heritage. Routledge

Schwarz, T. & Hoornbeek, J.A. (2009). Sustainable infrastructure in shrinking cities: Options for the future. Available at SSRN: https://ssrn.com/abstract=2016933 or http://dx.doi.org/10.2139/ssrn.2016933

UNESCO. (2011). Recommendation on the Historic Urban Landscape, Paris UNESCO

Veldpaus, L., Pereira Roders, A. R., & Colenbrander, B. J. F. (2013). Urban Heritage: Putting the Past into the Future. The Historic Environment: Policy & Practice, 4(1), 3–18. https://doi.org/10.1179/1756750513Z.00000000022

Case Study Report

The Social Space Reconstruction of Traditional Villages Based on the Driving of Tourism

A Case Study of Fuling, China

Yiting JIANG, Southeast University, China

Abstract

Traditional villages, as a holistic cultural heritage, face both challenges of protection and utilization. The impact of modernization and urbanization have led to the reshaping of the original social spatial systems. However, the historical cultural space has become an important resource for revitalizing rural area in China. This study takes Fuling Village as an example to investigate the social-spatial reconstruction process around the transformation of village faith heritage under the drive of tourism. The research finds that utilizing traditional culture for cultural promotion and tourism development, Fuling Village has undergone drastic social spatial transformation, gradually evolving from a traditional "rural society" community based on blood relations to a tourism service-oriented community added up by economic interests. The development of tourism has slowed down the process of rural decline in the village and is conducive to rebuilding community resilience. However, it also poses challenges like unstable funding and restored culture to heritage preservation.

Keywords

Rural transformation, Tourism, Traditional culture, Traditional village

1. Introduction

1.1. Chinese Traditional Village: facing challanges

Chinese Traditional Villages, with their rich cultural heritage, well-preserved architectural features, and distinctive local characteristics, are at risk of depopulation and disappearance due to the lack of sustainable livelihoods for villagers(Lapuz, 2023).To address this, the Chinese government has implemented a rural revitalization strategy that emphasizes rural development and has accelerated the reconstruction of these traditional villages. Many villages are developing with their unique characteristics to develop local industries, espetially for tourism (Bramwell & Lane, 2011).

1.2. Tourism: development opportunity

Tourism is a significant opportunity for rural development, particularly with the advancement of network technique and commercial contacts. Rural tourism in China has become a crucial driver for rural restructuring, with the revenue from leisure agriculture and rural tourism reaching 600 billion yuan in 2020, accounting for nearly one-third of the national tourism volume(Yanan et al., 2024). The digital dissemination of information, especially through social media, has significantly influenced rural space layout and tourism promotion. This technological integration has broadened the reach and impact of rural

tourism, offering a path for economic growth and spatial reconstruction in these villages(Komppula, 2014). However, the rapid development of tourism also presents challenges, such us . It is essential to balance economic growth with the preservation of cultural authenticity and the well-being of local communities.

This study focuses on the social space changes and rural culture brought about by the development of tourism. It aims to understand the motivations behind these changes and to reveal their impact on local people and their culture.

2. Project Focus

2.1. Research case

Fuling Village, recognized for its rich cultural heritage and well-preserved architectural features, was officially listed in the fourth batch of traditional village directories by the People's Government of Fujian Province. The village covers an area of 213.11 hectares and has a permanent population of about 1580 people. It is home to cultural relics such as Wuhou Mountain, offering unique religious and scenic tourism experiences.

Since the beginning of the 21st century, village has seen a revival. Traditional ceremonies such as the Belief Festival, attracting believers and tourists, which become the resources of the village's cultural practices. Especially in 2019, the village established a tourism development company, focusing on leveraging social media to attract tourists and highlighting the cultural theme of "fortune" to generate additional income for the village and stimulate industrial development. This strategic move underscores the village's commitment to preserving its cultural legacy while embracing modern tourism strategies to help revitalize local industry.

2.2. Research methods

This research utilizes participant observation and semi-structured interviews to explore the dynamics of rural transformation driven by tourism development. It examines the relationships among residents, the interplay between physical and virtual spaces, and the evolution of cultural forms and connotations. Through interviews with villagers, the study gathers information on current and historical social organization patterns. Combining on-site investigations with online surveys, it captured the subtleties of rural evolution and its effects on social relations and spatial structures. Direct engagement with the community aims to uncover how tourism influences the village, affecting both social dynamics and the reshaping of cultural heritage.

3. Project Results

3.1. Social network

Under the influx of resources, the social structure is undergoing reorganization, leading to changes in the original identities of rural residents(Huang et al., 2020; Sarfo et al., 2024). New social organizations and relationships are emerging, and both internal and external forces are being mobilized. The tourism development company reorganized local villagers, assigning roles based on work titles, ranging from knowledge and capital to management. Fuling village, once defined by blood relations where all villagers shared the same surname and lived in cohesive family units known as "a main stem family", are now facing the challenge of hollowing out as villagers leave in search of work, leaving only those unable to find

employment elsewhere. However, some villagers who have prospered outside have discovered business opportunities in their hometowns and decided to invest in tourism as a way to give back.

With the establishment of new management institutions based on the existing temple board of directors, villagers who remain have transformed their roles to take on responsibilities such as fundraising, daily operations, and historical research (Figure 1), forming social organizations centered around mutual interests. This shift underscores the importance of balancing economic development with the preservation of cultural heritage and the well-being of local communities.

3.2. Virtual and Real Spaces

The transformation goes beyond the superficial changes in the appearance of homes, delving into the commercialization of space. There's been a marked expansion of areas dedicated to services and tourism, causing a considerable rearrangement of the village's conventional spatial configuration. The architecture now showcases a more scattered layout, focusing on unique expressions and designed to appeal to visitors. Simultaneously, the creation of online image has become crucial for attracting tourists; this is achieved through the deliberate crafting and spread of online imagery that promotes local culture, often using symbolic representations to emphasize the area's unique heritage.

In practice, the construction of virtual spaces primarily aims to leverage online platforms for publicity and attract visitors. This approach significantly influences the development of physical public spaces. The goal of creating "unique stories and distinctive spaces" has become a key objective in spatial construction to meet the imagined expectations of outsiders. This shift underscores the importance of narrative and spatial distinctiveness in shaping the appeal of rural areas to tourists and the broader audience (Figure 2).

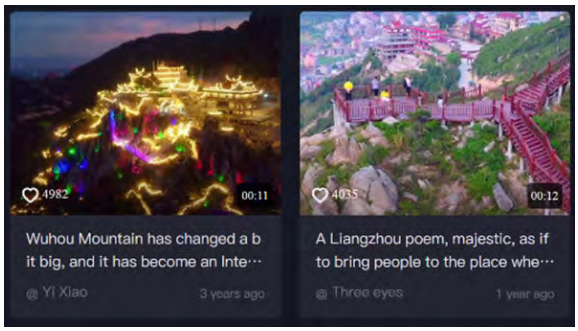


Figure 1 (Left). Villagers were transformed from farmers to tourism managers and operators, etc. Source: *Chinese Traditional Village Archives Survey Form - Fuling Village*.

Figure 2 (Right). villagers were transformed from farmers to tourism managers and operators, etc. Source: https://www.tiktok.com/.

3.3. Heritage protection and tourism development

Cultural customs, once deeply rooted in daily rituals, have seen a decline in practice and fervour under the loss of population and resources. However, large-scale cultural events are experiencing a revival and are being vigorously promoted, particularly in the context of the burgeoning rural tourism industry. Local villagers now annually host major public activities at various temples, along with family ceremonies, which are openly publicized online to attract a greater number of tourists(Liu et al., 2023).

Additionally, more tangible heritages are being collected and displayed in temples, significantly enhancing the cultural pride of the villagers. Despite this, funding, primarily sourced from private sectors, is characterized by short investment cycles, leading to high instability and risk(Wen & Chen, 2020), which slows the progress of many projects.

4. Broader Project Impact

4.1. For community resilience

For community resilience, the commodification of heritage indeed fosters economic development. During the industrial transformation, diverse participants encourage construction, collective discussion, and self-governance. The application of digital technology enhances the community's learning and innovation capabilities, playing a significant role in promoting industrial transformation and community resilience(Güngör & Elburz, 2024; Keyim, 2018).

Tourism development has slowed the weakening of rurality in villages to a certain extent, promoting the restoration of rurality. The development of rural tourism has helped rebuild community resilience.

4.2. For heritage protection

The relationship between rural residents and their environment is undergoing significant changes. The process of consuming heritage through social media has led to the atomization of needs, fragmentation, and mobility, resulting in symbolic spatial production and consumption(Li et al., 2020b).

While large-scale cultural events are being revived and promoted, revitalizing rural tourism, there is a risk of neglecting the needs and participation of local communities. This oversight can lead to the loss of original cultural significance and spiritual value, posing challenges to the long-term sustainable development of heritage sites. The increased reliance on private funding, often characterized by short investment cycles, introduces a high degree of instability and risk, slowing the progress of many heritage protection projects(Tall, 2021).

To address these issues, it is crucial to involve local communities in heritage management, ensuring their cultural heritage is preserved in a way that is sustainable and respectful to their traditions and values(Li et al., 2020a).

4.3. Future Development

The village collective is actively developing and leveraging the natural scenery as a leisure and tourism destination. Following the Wuhou Mountain Scenic Area's elevation to a 2A rating in 2021, there is an increased drive to enhance its construction efforts to meet development demands. The area has introduced investment projects such as slides, elevators, and glass platforms to attract more visitors and boost local economy (Figure 3).

These developments are not only aimed at enhancing the tourist experience but also at preserving the cultural heritage of the village. The integration of modern amenities with traditional elements ensures that the village's unique identity is maintained while catering to the evolving needs of the tourism industry. This approach aligns with the broader trends in rural revitalization strategies that emphasize sustainable development and the protection of cultural legacies.

Figure 1. How to use the command 'Insert Caption'. Source: https://www.tiktok.com/.

5. Acknowledgement

This work was supported by the Postgraduate Research & Practice Innovation Program of Jiangsu Province (Grant numbers: KYCX24_0476).

6. References

Bramwell, B., & Lane, B. (2011). Critical research on the governance of tourism and sustainability Introduction. *Journal of Sustainable Tourism*, *19*(4-5), 411-421, Article Pii 938706798. https://doi.org/10.1080/09669582.2011.580586

Güngör, M., & Elburz, Z. (2024). Beyond Boundaries: What Makes a Community Resilient? A Systematic Review. *International Journal of Disaster Risk Reduction*, 104552.

Huang, Y. F., Hui, E. C. M., Zhou, J. M., Lang, W., Chen, T. T., & Li, X. (2020). Rural Revitalization in China: Land-Use Optimization through the Practice of Place-making. *Land Use Policy*, *97*, Article 104788. https://doi.org/10.1016/j.landusepol.2020.104788

Keyim, P. (2018). Tourism Collaborative Governance and Rural Community Development in Finland: The Case of Vuonislahti. *Journal of Travel Research*, *57*(4), 483-494. https://doi.org/10.1177/0047287517701858

Komppula, R. (2014). The role of individual entrepreneurs in the development of competitiveness for a rural tourism destination - A case study. *Tourism Management*, *40*, 361-371. https://doi.org/10.1016/j.tourman.2013.07.007

Lapuz, M. C. M. (2023). The role of local community empowerment in the digital transformation of rural tourism development in the Philippines. *Technology in Society*, *74*, Article 102308. https://doi.org/10.1016/j.techsoc.2023.102308

Li, J., Krishnamurthy, S., Roders, A. P., & van Wesemael, P. (2020a). Community participation in cultural heritage management: A systematic literature review comparing Chinese and international practices. *Cities*, *96*, Article 102476. https://doi.org/10.1016/j.cities.2019.102476

Li, J., Krishnamurthy, S., Roders, A. P., & van Wesemael, P. (2020b). State-of-the-practice: Assessing community participation within Chinese cultural World Heritage properties. *Habitat International*, *96*, Article 102107. https://doi.org/10.1016/j.habitatint.2019.102107

Liu, Y. L., Chiang, J. T., & Ko, P. F. (2023). The benefits of tourism for rural community development. *Humanities & Social Sciences Communications*, *10*(1), Article 137. https://doi.org/10.1057/s41599-023-01610-4

Sarfo, I., Qiao, J., Lingyue, L., Qiankun, Z., Darko, G., Yeboah, E., Alriah, M. A. A., Gagakuma, D., & Amara, D. B. (2024). Why is rural revitalization difficult to achieve? An in-context discussion of conceptual barriers to China's 2018–2022 strategic plan. *Environment, Development and Sustainability*, 1-36.

Tall, A. (2021). *https://www.worldbank.org/en/news/feature/2021/03/04/unlocking-private-investment-in-climate-adaptation-and-resilience*. Retrieved Oct. 26 from world bank

Wen, T., & Chen, Y. (2020). Integration and development of digital economy and agricultural and rural economy: practice mode, realistic obstacles, and breakthrough path [J]. *Agricultural Economic Issues*, *487*(07), 118-129.

Yanan, L., Ismail, M. A., & Aminuddin, A. (2024). How has rural tourism influenced the sustainable development of traditional villages? A systematic literature review. *Heliyon*.

Research Paper

Embedded Governance and Spatial Response of Traditional Residence Regeneration

A case study of Chenjiapu Village in Songyang County, China

LIU Siqi, School of Architecture, South China of Technology, State Key Laboratory of Subtropical Building and Urban Science, China

HUANG Longyan, Tongji University, College of Architecture and Urban Planning, China

Abstract

Sustainable rural development is of global significance and is conducive to the promotion of equity and well-being. The regeneration of traditional residences is an important element of China's rural revitalisation strategy, which is in essence a dialectical unity of spatial environment and social governance. Embedded governance has been widely used in the regeneration of traditional residences in China to solve the dilemma of the value choice between "demolition" and "retention", but it has resulted in "rehabilitation" and "alienation". Based on two empirical case studies, LIBRAIRIE AVANT-GARDE and Stray Bird, the paper discusses the governance of Chenjiapu Village in Songyang County, Zhejiang Province, China, from the "prototype state", "decay state" to "embedded state". The conclusions show that the evolution of the spatial form of residences is essentially a response to the evolution of the governance structure, and that the problem of authenticity in the conservation of houses implies the problem of the integrity of the social network, and that the effectiveness of the embedded governance should be critically considered.

Keywords

Rural revitalization, Traditional residence, Regeneration, Embedded governance, Chinese experience

Cultural revitalization' is one of the five goals of the rural revitalization strategy, and “protection of traditional residences” has been repeatedly mentioned in the relevant policies issued in recent years (Xinhua News Agency, 2021), and architect Wang Shu even described the countryside as “the last line of defence to protect traditional culture” (Wang S., 2016). Architect Wang Shu even described the countryside as 'the last line of defence for traditional culture' (Wang S., 2016).The essence of 'traditional residence regeneration' is the dialectical unity of spatial environment and social governance, which is beyond the simple material determinism or spatial projection theory, and the scope is broader than 'traditional residence protection'. However, during the period of China's rapid urbanisation, the countryside has experienced the nightmare of 'passive blood loss' for a long period of time, and the increasing hollowing out phenomenon has led to traditional residences in the countryside constantly facing the risk of decay. Due to the lack of financial resources in the countryside, the weakness of the main body, loose organisational structure and other reasons, it is difficult to protect and regenerate the traditional residence solely relying on the strength of the village collectives or the villagers themselves, not to mention the realization of high-quality rural revitalization. The current academic community has

generally agreed that relying on the common action of multiple forces and seeking effective governance in the countryside can keep traditional culture alive in the vast rural areas (Duan J. et al., 2019; Jiang Y. et al., 2019). This research starts from the theoretical perspective of embedded governance, and takes Songyang County Stray Bird as the empirical evidence to explore the realisation path of traditional residence regeneration and its socio-spatial effect.

1. Overview

1.1. The meaning and manifestation of embedded governance

The social governance structure under the market economy system is formed by the intertwining of multiple forces and mutual games. According to Mark Granovetter, an American sociologist, almost all human behaviours are embedded in a specific network of social relations (Williamson, P.J., 1985). Corporatism on the 'embedded governance' for a more in-depth elaboration: in adhering to the government as the strong core (authoritative polity model) under the premise of taking into account the legitimacy and autonomy of the market and the society (Liefferink, D., 2006), and the government can be through a variety of intermediary organisations of the market and the society for penetration, coordination, so as to form a 'vertical governance'. The government can penetrate and coordinate the market and society through various intermediary organisations, thus forming a 'vertically embedded' structure (Feng C. et al., 2018). Embedded governance reveals the integration mechanism of government, market and society during the period of rapid growth in China, and has certain theoretical guidance in promoting the reform of governance modernisation (Yue J. and Deng Z., 2014), and also provides important inspiration for us to examine the social issues of rural governance and the regeneration of traditional residences. Although the specific form of embedded governance varies from place to place and from person to person, the mainstream view is that the core form of embedded governance is 'organisational embeddedness', 'institutional embeddedness' and 'interest embeddedness', which constitute a stable closed loop. The three constitute a stable closed loop that is conducive to flexible governance.

(1) Organisational embeddedness: According to the given governance objectives, the government will send organisational groups with semi-public nature to specific governance units as the medium of communication between the upper and lower levels, inside and outside, so as to avoid, to the greatest extent possible, the conflict between the government's governance intentions and the interests of the governed objects (Li C.i and Zhang H., 2018). For example, the villagers' committee, village sage groups are not only the agent of state power in grassroots governance, but also the common recognition of the villagers as “endogenous authority” (Xu Y. and Zuo D., 2019), playing a central role in rural development affairs.

(2) Institutional embeddedness: Institutional embeddedness is the political guarantee of organisational embeddedness, and its basic logic is the mandatory shaping of organisational carriers and relational networks by governmental will (Chen H., 2018). In the countryside, the endogenous order composed of traditional clan rituals and human relations has a certain degree of stability, but in order to adapt to the modern way of production and life, it is still necessary to clarify the boundaries of the behaviour of each subject through the normative and clear institutional arrangements, and to construct a new order adapted to the modern society.

(3) Interest embeddedness: the framework built by the organisation and the system alone is still not solid, and it is still necessary to promote the implementation of the policy objectives by means of economic compensation or other interest-inducing methods (Feng C. et al., 2018). For example, the household

contract responsibility system and collective land expropriation compensation have used the law of the market to fully mobilise the enthusiasm of the main body of rural development, and to promote the positive interaction between collective interests and individual interests.

1.2. The Use of Embedded Governance in the Regeneration of Traditional Residence

Since the reform of the 'three rights' of rural collective land, there has been a hot practice of residence regeneration, and embedded governance has played an important role in it. Early residence regeneration was mostly led by the government in the form of 'organisation embedding + system embedding', with the lack of market capital's active response, and the countryside's self-blood-supporting ability was quite limited. For example, in the case of Wen village residence regeneration in Fuyang, Zhejiang Province, although the regeneration project has become a high standard in the design industry due to the 'celebrity effect', the hollowing out of the industry and the villagers becoming 'bystanders' in the marketing of the event have been the constraints to the long-term development of Wen village (Figure 1). Figure 1. For example, in the early days of the Longtou Village in Pingli, Shaanxi Province, for the purpose of accelerating the development of tourism, the local government did not hesitate to put the architectural characteristics of Huizhou into the local landscape project, which, due to the large-scale land transfer and the lack of support from the characteristic industry, directly contributed to the loss of population and suspension of the project in the village (Figure 2).

Figure 1. Wen Village Famous Residence. Source: https://www.sohu.com/a/349670002_99949842

Figure 2. Pingli Longtou Village. Source: https://www.sohu.com/a/321391359_120086998

In recent years, the embedded governance model in residence regeneration has become more and more sophisticated, integrating the 'interest embedded' form of market capital, and the participation of a wide range of social organisations has been highly enthusiastic, and the level of residents' self-governance has been improved through trial and error, gradually forming a “co-creation” governance situation. The governance situation of 'common creation' is gradually formed. One of the successful cases is Anding Village in Fuyang, Zhejiang Province, where land transfer and market operation were completed through the establishment of Hangzhou Lianming Tea Culture Co. The cooperation between residents and market capital also provides a solid foundation for residential renewal (Figure 3). For example, Yangjiagou Village in Mili, Shaanxi Province, is a famous historical and cultural village in China, which has preserved the kiln manor of northern Shaanxi Province with the characteristics of Western classicism, and at the same time, the residences in the village have the glorious history of the 'old revolutionary site' during the liberation war period; since the 2010s, Yangjiagou Village has obtained strong policy support from the local

government by virtue of its unique endowment, and has also received a lot of support from the local government. Since the 2010s, Yangjiagou Village, with its unique endowment, has gained strong policy support from the local government and actively introduced market resources, gradually building itself into an important red tourism resort and film shooting base in northern Shaanxi, during which the 'catalyst effect + cyclic effect' has provided useful inspiration for the sustainable development of other old revolutionary areas (Figure 4).

Figure 3. Alpine Tea Garden in An Ding Village

Source: https://m.thepaper.cn/baijiahao_15681522

Figure 4. Yangjiagou Village Shanbei Kiln Cave Manor

Source: https://www.sohu.com/a/505079872_121119253

2. Research hypothesis: embedded governance triggers spatial responses to traditional residence regeneration

According to the above cases, it can be found that the conventional path of contemporary rural residence regeneration practice is: external capital will be idle or decaying traditional residence buildings into cultural tourism theme projects, to achieve the dual purpose of residential building revitalisation and operational income, thus cleverly solving the non-statutory protection of residential 'demolition' and 'retention' choice of difficult problems. The problem of choosing between 'demolition' and 'retention' of non-statutory protected residential buildings can be cleverly solved. In this process, the external forces of the village play a decisive role: the higher level government usually supports the external capital through policy input, departmental liaison, and platform construction; while the village collective and the market entity constitute a de facto interest alliance, and act as an intermediary means for the higher level government to penetrate into the governance of the rural area (Figure 5). The embedded governance model of 'superior government + rural interest alliance' is considered to be an effective path to boost the rural economy (Yin Y. and Li X., 2018), but it is also accompanied by different degrees of negative impacts: for example, rural governance is faced with the weakening of the villagers' main body power (Li Y. and Wang X., 2015), the impact of the rural social network (Xiao L. and Ma C., 2020), and traditional residences are under the ‘coercion’ of capital. traditional residences are 'coerced' by capital, and in the process of regeneration, their cultural kernel is constantly dissolved and reconstructed (Xu D. et al., 2019), and even their originality is seriously damaged (Zhang L., 2021). This research puts forward the basic hypothesis of 'evolution of governance structure - spatial form response', which holds that the newly

embedded governance structure will change the existence state of traditional residence, and the newly embedded governance body will trigger the effects of 'rehabilitation' or 'alienation'. (Figure 6).

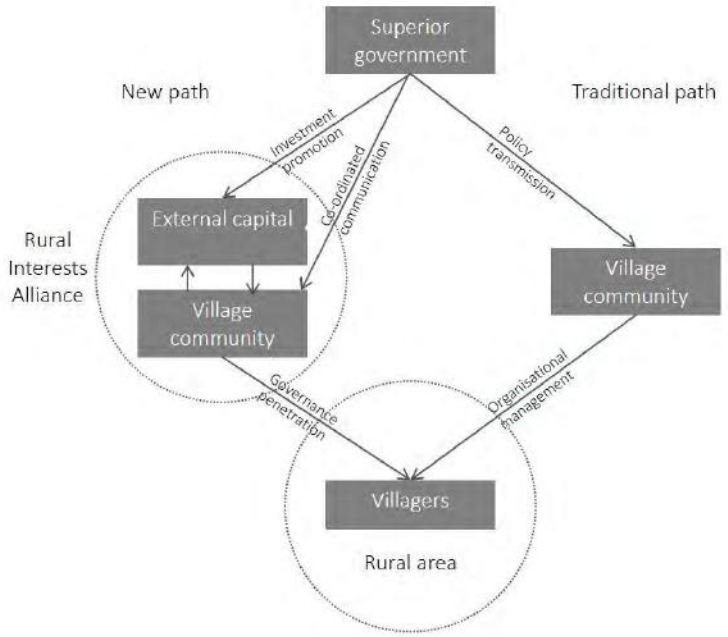


Figure 5. Comparison of New and Traditional Paths of Rural Governance. Source: Author.

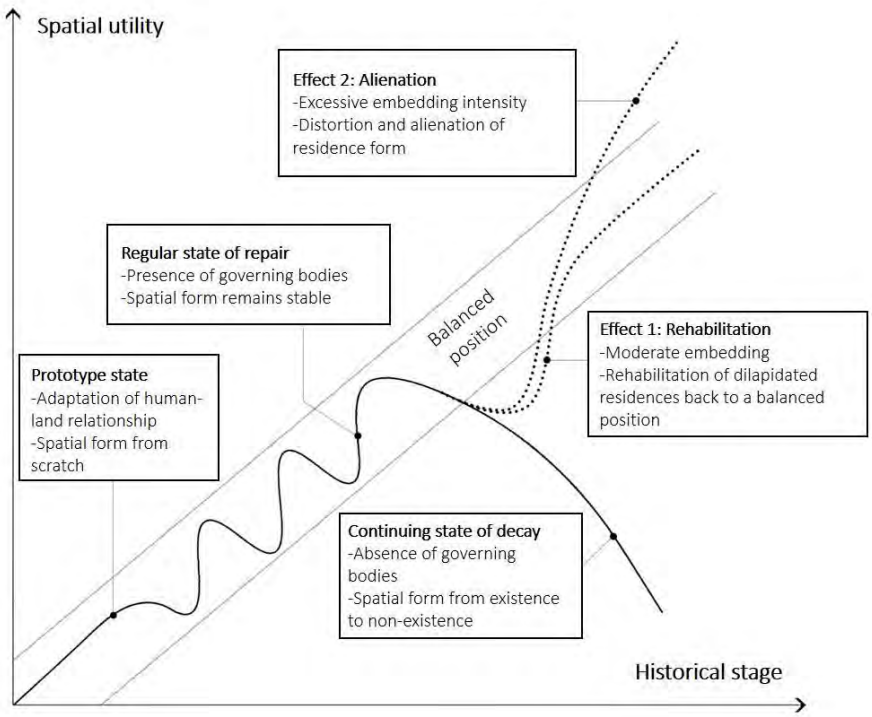


Figure 6. Two Effects of Embedded Governance. Source: Author.

3. Empirical Case: Chenjiapu Village, Songyang County

Chenjiapu Village is located in Sidu Township, Songyang County, Lishui City, Zhejiang Province, with a household population of more than 850, and its establishment can be traced back to the late Yuan and early Ming Dynasties (Zhejiang Provincial Department of Housing and Urban-Rural Development, 2021) . Chenjiapu Village is a typical village with a lot of mountains and little land, and the unique geographical environment has given rise to a distinctive mountainous settlement pattern, and most of the buildings in the village are rammed-earth buildings with the atmosphere of the intermingling of Central Plains and Northern Fujian cultures (Cheng Q., 2010) . Since Chenjiapu Village was sedlected as one of the third batch of Chinese traditional villages in 2014, the village has embarked on the butterfly road of rural revitalization. Chenjiapu Village has completed the protection and regeneration of more than 50 residences with the protection and development of traditional villages as an entry point, and the process of regeneration of its residences responds to the interaction of governance structure and spatial form. In the following, two landmark cases, LIBRAIRIE AVANT-GARDE Bookstore and B&B Stray Bird, are selected and explained according to the changes of their three states: prototype, decay and embeddedness. These two cases are important representative projects of Chenjiapu Village in Songyang County's move towards a diversified rural economy of eco-agriculture, B&B economy, and cultural creativity.

3.1. Prototype state

Songyang County is a famous historical and cultural city in Zhejiang Province, which used to be the economic, political and cultural centre of Chuzhou. And it is one of the areas in East China where the system of famous historical and cultural cities, towns and villages is most completely preserved and where the inheritance of vernacular culture is the best. Songyang County since ancient times to the spectacular southeast of the famous mountains and beautiful water by the literati praised: 'The road to the west is blocked, and the exchange to the south is sparse. This is the only peach blossom garden where there is no other place to go.' Chenjiapu Village in Songyang County Sidu Township, 15 kilometres from the county, more than 850 metres above sea level, surrounded by mountains on three sides, facing the valley, year-round clouds and mist, with the breath of paradise. Chenjiapu Village has a special geomorphology, the height difference of the settlement can be more than 200 metres, the village forefathers built a stepped village in the cliffs according to the local conditions, forming a cliff dwelling settlement form in southwest Zhejiang with great regional characteristics. 600 years, Chenjiapu Village relies on the clan autonomy to form an internal closed system, the public space structure of the village, the ancient stagecoach road and the street and alley system are well-preserved, and the ancestral halls, social temples, the traditional public buildings of the fire halls are well-preserved, with rich types, exquisite shapes and styles, which are well preserved. The traditional residences with rich types and exquisite modelling have also been carefully repaired and maintained by successive generations of villagers.

3.2. Decay state

Since entering modern society, due to the remote location of Chenjiapu Village and the small amount of arable land, during the period of rapid urbanisation, the villagers were keen to pursue the development goal of 'moving the mountains and moving out of poverty'. The villagers either moved to resettlement communities around the county seat or left their hometown to make a living. Due to a lack of resources, the loss of talent and young and middle-aged labour, the village has become hollowed out, with a large number of houses and fields almost abandoned. In addition, the social governance structure of Chenjiapu Village is loose, management funds are insufficient, and the regeneration of infrastructure has long been stagnant. Therefore, during this period, the spatial form of traditional residences was severely damaged,

and even if the villagers repaired them spontaneously, the results were minimal. At the same time, due to the complex land ownership in the village, the ownership and use of a piece of land often involves multiple families, and the cost and profitability of social capital intervention are highly uncertain, so there is little interest. Local government governance, market response, and social mobilisation have not yet formed a synergy in rural development, and the existence of traditional residences is in a precarious state.

Figure 7. Houses in Chenjapu Village. Source: Author.

Figure 8. Roads in Chenjapu Village. Source: https://mp.weixin.qq.com/s/6SzFGkxs6DUM4x97mrLAnQ

3.3. Embedded status

Case 1: LIBRAIRIE AVANT-GARDE BOOKSTORE

LIBRAIRIE AVANT-GARDE Bookstore Civilian Bookstore is the first business introduced by Chenjiapu Village to the outside investment, which is the starting point of Chenjiapu Village rural revitalization.The prototype of the bookstore is the 50-year-old village hall, a public centre with a large floor area and open space. LIBRAIRIE AVANT-GARDE is a company dedicated to the promotion of reading and cultural dissemination, and since its establishment in 1996 it has set up a number of branches nationwide. 2013 saw the start of LIBRAIRIE AVANT-GARDE's Village Bookstore project, with the promotion of rural revitalization and cultural inheritance as a key mission of the company. 2016 saw the start of the renovation of the Old Auditorium of the village, which was carried out by Zhang Lei & Associates Architects. The renovation retains the original building structure and features, and combines the spatial characteristics to preserve the retained exterior dimensions and walls, add single-story volumes and viewing platforms, allowing the building space to strike a balance between a more intimate small library and a more open public space.

The LIBRAIRIE AVANT-GARDE Civilian Bookstore not only provides a space for the sale of books, but also functions as a local library, a cultural and educational base jointly constructed by the embedded organisation and the village collective. In addition to regular books, the bookstore also sets up cultural zones about Songyang's history, folk lodging culture, and literary creation, which serves as an important window for the promotion of local culture. As the bookstore operation moves towards diversified modes, in addition to book sales, LIBRAIRIE AVANT-GARDE Bookstore also carries out local cultural creations, coffee and tea drinks, cultural exhibitions, art incubation and other modes, forming a win-win situation between the corporate brand influence and local cultural influence. For example, LIBRAIRIE AVANT-GARDE imitates the form of 'Artist-In-Residence' and regularly invites writers to stay in the shop to create works, forming a platform for writers to write and exchange ideas. In addition to the LIBRAIRIE AVANT-GARDE Bookstore, in 2020, the Creative Industry Research Centre of Nanjing University established the

Chenjiapu Village Creative Base, also known as the 'LIBRAIRIE AVANT-GARDE Village Creative Space', and the cultural and creative industries have been rising rapidly.

Figure 9. LIBRAIRIE AVANT-GARDE BOOKSTORE UNDER CONSTRUCTION

Source: https://www.thepaper.cn/newsDetail_forward_2227313

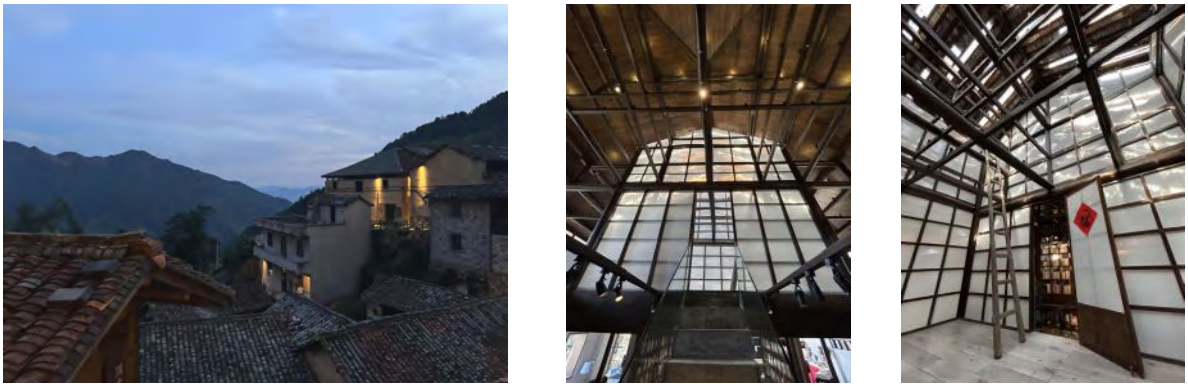


Figure 10. LIBRAIRIE AVANT-GARDE BOOKSTORE after completion

Source: Author

Figure 11 Cultural industries are further incubated in Chenjiapu Village

Photo Credit: Author

Case 2: Stray Bird

The original site of Stray Bird was a residence within the village. The Stray Bird brand and line+ Architects stepped in to participate in the regeneration work, and received the 2018 American Master Builder Award of Merit in the Heritage Architecture category for their ingenious renovation ideas and good social response. The first phase of the Stray Bird B&B originally belonged to a family home, and as the population moved, the house was left with only three sides of rammed earth and one side of a burrstone retaining wall house, in addition to the rough frame. The design intervenes to preserve the basic layout and structure of the residence with rammed earth and burrstone retaining walls, and to renovate and improve the quality of the public space and adapt the living space. The renovation is based on the spatial form and construction characteristics of the vernacular settlement, integrating local traditional construction techniques and modern rammed earth technology to repair and improve the rammed earth walls. At the same time, the dilapidated wooden structure is demolished and a new lightweight steel structure is built using modern assembly technology, which improves the safety of use and reduces the damage to the original rammed earth wall. With the success of the first phase of the project, Stray Bird began the second phase of the construction programme with deeper community engagement. The embedded organisation relies on the construction skills of local villagers, while the subsequent operation of the lodges involves villagers. Stray Bird Phase 2 further added 11 guest rooms, a viewing lobby, a cliff café and a restaurant to form a complete B&B complex. The lodging complex continues to fit into the natural terrain and face excellent views of the natural landscape, adding space for local cultural experiences and displays, and driving more tourism revenue and income for the villagers.

Figure 12. Inside the remodelled residence in Stray Bird

Source: https://mp.weixin.qq.com/s/zKsVpqyveCPEKbGo1aIYsA

Figure 13. Stray Bird Café Tea Room before and after makeover

Source: https://mp.weixin.qq.com/s/sBlZkvZ6c6awtXy_GzfhbA

Figure 14. Inside and Outside of Patchouli Coffee

Source: Author

3.4. Governance effectiveness

Through cooperation with well-known brands such as The LIBRAIRIE AVANT-GARDE Bookstore and Stray Bird, Chenjiapu Village has formed a fusion of ecological agriculture, cultural and creative industries, and

rural lodging. The LIBRAIRIE AVANT-GARDE Bookstore, the Civilian Bookstore, has sparked discussions about 'China's most beautiful bookstore on a cliff' through the Internet, which has greatly boosted the confidence of local village collectives in rural revitalization. The regeneration project of Stray Bird has created a 'high-quality' B&B brand through the Internet, which has attracted more external capital to renovate other traditional residences in the village, and the embedded organisations and the village collectives have gradually explored the idea of 'renting+approval', The embedded organisations and the village collectives have gradually explored innovative governance models such as 'rent + approval', 'village collective assets and resources into shares', 'guaranteed + dividends', and 'joint establishment of operating companies'. The original dried sweet potato industry has re-established industrial cooperatives and cooperated with cultural and tourism brands, expanding production and sales while achieving uniform materials, production standards, quality requirements and pricing, and increasing the income of local villagers.

In 2020, Songyang County Bureau of Culture, Radio, Television, Tourism and Sports issued the Implementation Plan for Songyang County to Create a Pilot Area for the Integration of Culture and Tourism Industries in Zhejiang Province, which affirmed the successful experience of Chenjiapu Village in introducing foreign capital to participate in the village operation, and promoted the development model of ‘ external capital+village collectives+villagers’ to the whole county. Data from Songyang Communist Youth League in March 2024 shows that with the opening of LIBRAIRIE AVANT-GARDE Bookstore Civilian Bookstore, Chenjiapu Village has successively attracted industrial and commercial capital investment of more than 100 million yuan, increasing employment in the village by more than 100 jobs and more than 60 non-local resident entrepreneurial youth. The stationing of the embedded institutions accelerated the village to flow the idle houses and other resources to the village collective, the restored and preserved characteristics of the residence has become the village collective and external capital to carry out in-depth cooperation in the equity resources, effectively revitalising the village collective economy. Driven by the tourism industry, villagers operate food and beverage retail and individual lodgings, effectively sharing the dividends of the common wealth of the village, with per capita income nearly three times higher than five years ago.

Figure 15. Comparison of the village landscape before and after embedding the treatment

Source: https://www.archiposition.com/

4. Discussion

Problems such as a weak economic base, the absence of a governing body and a lack of development tools are all persistent problems that hinder the realisation of the value of rural resources. Without the intervention of external forces in the countryside, Chenjiapu Village could hardly reverse the trend of continuous deterioration in development under the state of natural succession, and traditional residences could hardly escape the end of decay and demolition. In recent years, capital has gradually flowed into the countryside from the city, driven by the power of expanded reproduction, which undoubtedly provides an opportunity for the regeneration and revitalisation of rural residences. The modest embedding of 'superior government + rural interest alliance' into the social structure of the countryside is also conducive to the improvement of the quality of the countryside in a short period of time. Embedded governance can solve the risk of traditional residence decline in the fundamental operation mechanism, which is also the most secure path for the revitalisation of traditional residence.

However, after the new path of 'superior government + rural interest alliance' replaces the traditional path of 'government guidance and rural autonomy', will the capacity of rural autonomy be effectively improved? For village halls, the aging of villages, the loss of population and the decline of ancestral halls represent the gradual failure of the social order of the original villages, which was based on the ties of blood relatives, and whether the civilian bookstores that replaced them, as a spillover of the economic and cultural resources of the city, will have an impact on the social and cultural order of the villages and supplement it? In the case of the traditional residence Stray Bird, the regeneration work is embedded with market interests, and the spatial design inevitably caters to the aesthetic needs of the urban middle class. Will the post-modernist spatial design of these residences have an 'alienation' effect on the authenticity of traditional residences? We are cautious about these questions: can the intensity of market interest embedded in the project be kept within a moderate range, so as to maintain a benign dynamic balance between the interests of the village community, the villagers and the market? Although these debatable questions have not received a positive response from the parties involved, their social significance is worth exploring.

The embedded governance model is based on the weakened capacity of village autonomy, and cannot be regarded as a state of unlimited scope and continuity, where exogenous resources will inevitably be withdrawn, and therefore the village's self-blood-supporting capacity should be cultivated as early as possible. In addition, the resources and architectural space preferences of the newly embedded governance subjects are very different from those of the villagers, which will inevitably lead to the discrepancy between the form of the regenerated residence and the original form, especially in the case of non-statutory protection of traditional residences, and this effect is even more significant. In other words, embedded governance may impact the original social network in the countryside, and the damage to the authenticity of the residence caused by 'embedded regeneration' is in fact the externalisation of the damage to the integrity of the social network. It can be seen that embedded governance can not only 'rehabilitate' the decayed residence, but also may lead to the risk of 'alienation' of the spatial form of the residence due to excessive embeddedness.

5. Summary

The regeneration of traditional residences in the context of rural revitalization reflects, to a certain extent, the increasingly prominent function of rural consumption in the stage of urban-rural integration. The regeneration of traditional residences has a good intention of 'cultural revitalisation', but in the process of concrete practice, it is also accompanied by many problems and risks. While recognising the powerful effect of embedded governance, we should also be wary of the over-exaggeration of nostalgia culture by

external capital and even the systematic destruction of rural governance structures. One of the most undesirable practices is the transfer of residence building management rights, which leads to the passive 'out' of villagers in the governance structure, and the regeneration of residences is eventually reduced to a feast for capital to seize the surplus value of rural space. The future positioning of the countryside should go beyond the purely industrial function of the region, and the path of traditional residence regeneration also needs to reflect more humanistic values. Deepening the interactive mechanism of multiple subjects and realising the organic integration of 'urban and rural capital' is a clear direction for the sustainable regeneration of traditional residences in the countryside.

6. References

Xinhua News Agency. (2021) 'Opinions of the Central Committee of the Communist Party of China and the State Council on comprehensively promoting rural revitalisation and accelerating the modernisation of agriculture and rural areas', *China Farmer Cooperatives*, 3, pp.7-13.

Wang S. (2016) 'Only by rebuilding the earthen stove can the taste of wood-fired cooking be realised', *New Urban and Rural Areas*, (7), pp.42-43.

Duan J., Shao R., Lan W., Liu J., and Jiang Y.g. (2019) 'Spatial gene', *Urban Planning*, 43(02), pp.14-21.

Jiang Y., Shen M. and Zhang J. (2019) 'The evolution of rural social structure and its spatial response: a case study of Dongxian Village in Shantou', *Modern Urban Research*, 34(9), pp.34-41.

Williamson, P.J. (1985) 'Varieties of corporatism: a conceptual discussion', Cambridge University Press.

Liefferink, D. (2006) *The dynamics of policy arrangements: turning round the tetrahedron. In Institutional dynamics in environmental governance.* Dordrecht: Springer Netherlands.pp.45-68.

Feng C., Zhang J. and Chen H.(2018) 'Embedded governance: a study of the spatial development of new towns in China from the perspective of corporatism', *International Journal of Urban Planning*, 33(6), pp.102-109.

Yue J. and Deng Z. (2014) 'Dependence, separation, and embedding: three logics of development of social organisations in China', *Exploration and Contention*, (10), pp.67-70.

Li C.i and Zhang H. (2018) 'Government mobilisation, return of local elites and embedded governance: the logic of action of the return of local elites - a case study of the local elites association in Y town, L city', *Party and Government Research*, (1), pp.101-110.

Xu Y. and Zuo D. (2019) 'Endogenous order in rural governance: evolution logic, operation mechanism and institutional embedding', *Agricultural Economic Issues*, (8), pp.9-18.

Chen H. (2018) 'The conflict and integration of multiple norms in rural governance', *Academic Exchange*, (11), pp.78-89.

Yin Y. and Li X. (2018) 'The development logic and path choice of rural tourism under the background of rural revitalization strategy', *Journal of the National School of Administration*, (5), pp.182-186.

Li Y. and Wang X. (2015) 'Types and mechanisms of conflict of interest in the process of capital going to the countryside', *Zhongzhou Journal*, (10), pp.43-48.

Xiao L. and Ma C. (2020) 'From project embedding to organisational society: new trends and typological studies of village-level collective economic development', *Seeking the Truth*, (3), pp.69-83.

Xu D., Huang Z., Li D., Hong X. and Yu F. (2019) 'Research progress and framework construction of cultural impact of rural tourism destinations from the perspective of coercion', *Human Geography*, 34(6), pp.17-25.

Zhang L. (2021) 'Rural landscape characteristics and planning considerations from a tourism perspective: A case study of Azeke Village in Yuanyang, Yunnan', *Landscape Architecture*, 24(5), pp.87-93.

Cheng Q. (2010) 'A study on the spatial form of residential space in mountainous and hilly areas of Zhejiang Province', *Zhejiang University*.

Zhejiang Provincial Department of Housing and Urban-Rural Development. (2021) 'Songyang County's Chenjiapu Village relies on the growth-oriented homestay economy to create a new model for rural revitalisation', Available at: https://jst.zj.gov.cn/art/2021/9/30/art_1569972_58927785.html. (Accessed: 30 Sept 2021).

Research Paper

Traditional Ecological Wisdom Inheritance and Resilient Urban Planning

Taking Cold City as an Example

Jingxin QI, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, CHINA

Hong LENG, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, CHINA

Abstract

Integrating indigenous ecological wisdom with modernization crucial for revitalizing the resilience of cold cities while honoring human knowledge. Through the lens of traditional ecological wisdom inheritance, this study reexamines the core connotation of resilience in cold cities and delineates the evolution trajectory of ecological wisdom. Ultimately, proposing planning inspirations for the application of traditional ecological wisdom within modern cold cities.

Keywords

Traditional Ecological Wisdom, Resilient City, Climatic adaptation, Cold City

1. Introduction

The IPCC Sixth Assessment Report shows that climate change in all regions will intensify in the coming decades (IPCC, 2019). As a special urban group, cold cities face more unique and diverse climate problems, such as prolonged snowfall and freezing. The intensification of global climate change, significant regional climate background effects, rising temperatures, and increased frequency and intensity of extreme weather events will not only exacerbate the winter climate impact in cold cities, but also bring heat waves, cold waves, droughts, floods, and storms, threatening the health of urban residents and posing increasingly severe emerging risks and challenges to the social ecosystem in cold cities.

Under the dual influence of regional severe cold climate and climate change, it is particularly important to enhance the resilience of cold cities (Zeng et al., 2023). Enhancing the resilience of cold cities can not only alleviate the limitations of the original climate and resist the impact of extreme weather events, but also restore and rebuild the functions of their social ecosystems through flexible response strategies, reducing the impact of new disaster risks caused by climate change. This is of crucial significance for achieving sustainable development of cold cities (Xu et al., 2024). In this process, scientific assessment of the impacts and risks of climate change, based on the economic and social development status and resource and environmental carrying capacity, enhances the comprehensive adaptation capacity of cold region cities to climate change, and requires the establishment of a new climate adaptation strategy system through multi

perspective observation. Traditional ecological wisdom, as a cultural heritage that has been tested over time, provides valuable local practical experience and adaptation strategies. This wisdom stems from long-term observation of nature and interaction with the environment, emphasizing the harmonious coexistence between humans and nature. By exploring and inheriting traditional ecological wisdom, cold region cities can find innovative local solutions in urban planning practices that adapt to climate change, promoting the resilient development of social ecosystems.

This study aims to systematically sort out the basic attributes and core characteristics of cold cities, understand the connotation of indigenous traditional ecological wisdom, and attempt to deduce its evolutionary laws, in order to deeply explore the impact of traditional ecological wisdom on the resilience of cold cities. On this basis, we further propose a modern cold city resilience enhancement strategy based on traditional ecological wisdom. In order to provide support for future cold city initiatives to enhance urban climate adaptation capabilities and resilience planning decisions.

2. The connotation and application of traditional ecological wisdom

2.1. The concept and evolution process of traditional ecological wisdom

2.1.1 Definition of Traditional Ecological Wisdom

Traditional Ecological Wisdom (TEW) refers to the knowledge system developed by indigenous peoples and local communities via long-term natural observations, environmental interactions, and practical experiences. It incorporates wisdom in many areas, including culture, society, and the economics, in addition to understanding of the natural world. TEW emphasizes the harmonious relationship between humans and nature, which is a thinking mode and practical guideline for the survival and development of humans in specific regions in the natural environment. Its function is not only to guide planning actions through social ecological practices, but also to inspire and empower people with tailored approaches in urban systems(Liao and Chan, 2016).

2.1.2 The core characteristics of TEW

TEW has several core characteristics. Environmental adaptation emphasizes human flexibility in response to environmental changes, which is the most important feature of TEW and can help people cope with climate change and natural disasters. By observing temperature and natural phenomena, people in cold cities can use TEW to design buildings and agricultural technologies that adapt to climate change. This requires selecting an appropriate culture, establishing a sound structure, and developing effective resource management plans.

Sustainability places a strong emphasis on social justice and the circular use of natural resources, which are especially important in cold city land use and community involvement. For instance, to deal with the issues of resource volatility and workforce shortages, locals establish a shared tribal government system.

Furthermore, TEW is a distinctive ecological knowledge system that has been established by diverse groups with a range of knowledge based on their particular ecological environment and sociocultural background. Both the substance and the variety of inheritance techniques exhibit this diversity. Many TEW have been passed down through oral transmission, rituals, and practical activities. In the process, many indigenous communities have explored new ecological management methods while maintaining traditional knowledge, combining modern technology and management concepts, and providing new ideas and practical references for modern society.

2.1.3. The evolution process of TEW

TEW have continuously developed and enriched over the course of history. The earliest can be traced back to the primitive worship of the natural environment by humans, when many natural phenomena were intuitively perceived and became the foundation for harmonious coexistence between humans and nature. With the continuous development of productivity, people have accumulated judgments on plant growth, animal behavior, and natural phenomena of climate change through extensive observation and practice (Participants, 2015 and updated in 2017). TEW gradually shifted from pure worship to rational thinking, and people began to analyze natural laws and summarize corresponding survival experiences.

Through repeated practice and intergenerational inheritance, survival experiences such as production technology, climate prediction, and resource management have been continuously refined and refined, gradually forming a systematic ecological knowledge system. TEW is now widely accepted as a natural law and community model (Zhang, 2017).

After entering modern society, cultural ideas, technological means, and coping systems continue to develop, and cold settlements develop into cities. Traditional ecological knowledge is tested in urban construction practice, and traditional knowledge and practical experience with practical feasibility are further developed and utilized in the local geographical environment and social culture(Alexander and E., 1989), Evolved into environmental cognition, resource utilization, production activities, and social organization strategies with rich regional characteristics (Table 1), to adapt to the greater challenges and risks brought by climate change and achieve resilient development of urban planning. This process is consistent with the social learning cycle evolution process proposed by Professor Xiang Weining (Xiang, 2014).

	Indigenous Society	Modern City
Environmental cognition	Nature Worship	Ecological Civilization
Resource utilization	Moderate use of resources	Fully utilize resources and control development intensity
Production activities	Shared agriculture, gathering, fishing, and animal husbandry among tribes	Neighborhood interactive farming and public activities, shared public service facilities, etc.
Social organization	Common decision-making based on the existence of spirits in all things	Age friendly public participation

Table 1. Differences in Key Contents of TEW between Indigenous Societes and Modern Cold City (Source: Compiled information based on references)

In the 1990s, the Inuit Circumpolar Council proposed the concept of integrating Inuit traditional knowledge with Arctic governance values, address the limitations of the region's native cold climate and the risks brought by constantly changing climate conditions. In the 21st century, with the world's environmental problems and climate change becoming more serious.. More and more research shows that TEW can provide valuable solutions for modern society to address climate change, ecological protection, and sustainable development. Especially in urban resilience planning under special climate conditions, the

value of TEW is becoming increasingly prominent, promoting its transformation towards proactive development and sustainable management. This stage emphasizes the combination of modern technology and TEW to form modern ecological wisdom and achieve harmonious coexistence of "human city natural environment" (Figure 1).

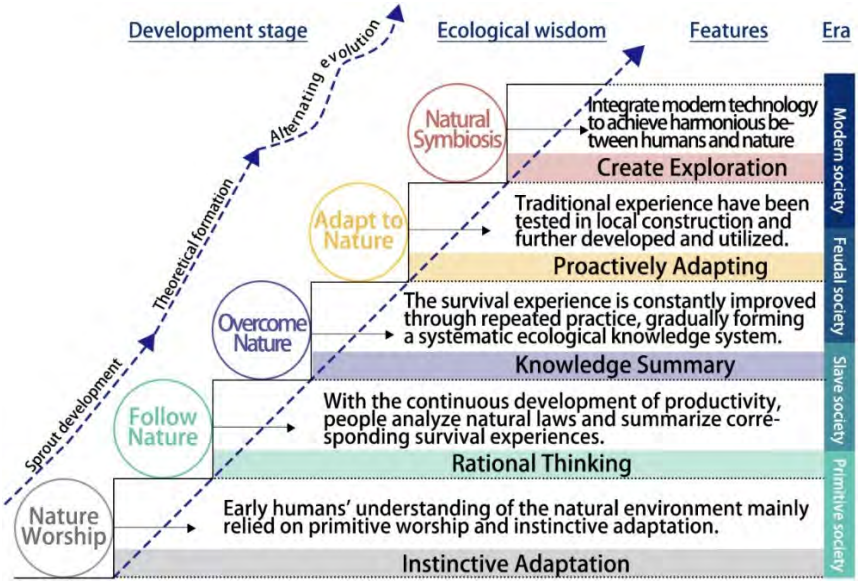


Figure 1. Evolution process of traditional knowledge (Source: Own Draw)

2.2. The impact of TEW on the resilience of cold cities

2.2.1. Cultivation of ecological awareness

The traditional ecological wisdom in cold regions is based on a large amount of understanding of the environment and ecosystem, emphasizing the ecological awareness of identifying, understanding, and responding to environmental changes in extremely cold climate conditions (Folke, 2004). This ecological awareness plays a positive role in maintaining ecological security, and sustainable development of resources in cold cities.

(1) Ecological integrity protection

In cold climate conditions, the overall management and protection of the environment are particularly crucial. Indigenous people in cold regions, represented by shamanism, show respect and care for all elements such as climate phenomena, natural environment, and biology, and have established a natural worship belief characterized by equality and mutual benefit between humans and nature. This kind of nature worship has a distinct purpose, which is to identify and respond to climate and environmental change, and to integrate human activities with the natural environment (Jackson and Holden, 2013). Derived from a series of taboo behaviors, guiding a comprehensive assessment of the local ecosystem, combined with climate change prediction, to achieve ecological integrity and biodiversity conservation.

TEW emphasizes the importance of ecosystem services in addressing climate change risks. Indigenous peoples in cold regions adopt traditional land management models, fully utilizing ecosystem services such as climate regulation and biodiversity maintenance to increase crop yields while enhancing ecosystem resilience, achieving flexible spatial utilization and maximizing public interests.

(2) Sustainable development of resources

In terms of land use, TEW advocates planning in accordance with natural ecological laws, avoiding excessive development and improper use. In Northeast China, Manchu rulers implemented willow edge bans on the black soil, controlling the development of land and forest resources(Chen, 2016). The Sami people follow the efficient resource development principle of "living after prey" to ensure harmonious coexistence between humans and land. TEW also provides effective renewable resource management methods for cold cities. In the barren and limited resource conditions, the ancestors of Changbai Mountain in Jilin Province effectively used natural construction materials, adopted sustainable timber harvesting and transportation methods like "ice release ditches," and used dense forests to create the iconic Jinjiang Wooden House. The Oroqen people support public resolutions and the cooperative use and management of resources (Wang and Sun, 2018). To a certain extent, it has resolved the issue of resource dispersion and fluctuation in cold cities, achieving rational utilization of resources. In addition, the use of cooking waste heat for heating and snow melting to supply energy consumption reflects the profound understanding of traditional ecological wisdom in cold regions in the virtuous cycle of materials (Liu, 2002).

2.2.2. Optimization of survival strategy

(1) Sustainable adaptability construction

In order to adapt to local climate boundaries, early residents developed adaptive building design techniques, rational designed outdoor physical environments, and provided effective climate protection measures (Leng and Yuan, 2004), maintaining the comfort of their living environment.

The dome shaped structure reduces the direct impact of wind and evenly disperses the weight of snow, increasing the stability of the building. In order to minimize indoor heat loss to the greatest extent possible, the ice house is designed with a low and narrow entrance that can successfully prevent cold air from directly entering the space. The layered design of indoor space concentrates heat in higher central areas and provides additional activity areas (Figure 2). Modern cold cities have retained some features such as building orientation and roof shape on the basis of traditional building methods and have also innovated insulation materials.

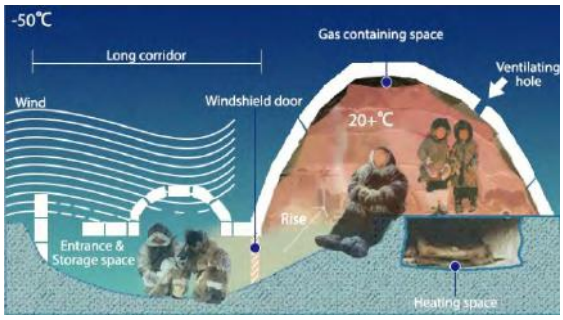


Figure 2. The climate adaptation wisdom of Inuit igloos (Source: Own Draw)

Flexible responses to extreme cold weather and its related climate change challenges are also made possible by TEW's distinct expertise in open space and green space development. Compact layouts in sunny and leeward places are typically chosen for winter camping sites by ethnic groups in colder climates in order to avoid wind and snow while aiming for more sunshine(Liu, 2020). Typically found in the heart of communities, public areas like squares and meeting spots serve as hubs for social interactions. In order to shield locals from severe weather, makeshift shelters like fences are erected concurrently. Native plants that can withstand cold temperatures are frequently used to green landscapes.

(2) Multi party interactive maintenance

Residents in cold climates developed a close-knit cooperative relationship known as "spontaneous co governance" as a result of their early survival instincts. To deal with the challenges of extremely cold weather, the Inuit have created a "winter extended family" by accumulating wisdom and experience. This cooperative concept has developed into systemic governance and community sharing in the present day. assembling native specialists in chilly urban areas and using their traditional wisdom to preserve biodiversity. Through shared public facilities and community services, the local administration has also actively coordinated group efforts to address extreme weather conditions, enhancing the community's capacity to manage the hazards associated with climate change.

3. Enhancing the Resilience of Modern Cold region Cities Based on TEW

3.1. Constructing a climate security spatial pattern based on the TEW behavior path

The modernization of traditional wisdom in cold cities is being implemented through the practice of spatial planning for climate risk prevention and adaptation(Xiang, 2016). Technical assistance for improving spatial resilience governance for climate adaptation is provided by TEW's ecological awareness of comprehensive protection and flexible land use. TEW should be included into the national spatial planning system in a number of ways, including technical standards, implementation oversight, regulatory policies, preparation and approval, and the coordinated execution of general, detailed, and special planning. In particular, the resilience special plan should employ TEW to drive the practice of building resource security spaces, strengthening disaster prevention and warning facility networks through nature-based solutions, and adapting to the cold climate in cold cities. In addition to provide a material carrier for enhancing urban resilience, this will produce a healthy and inclusive spatial pattern for climate security (Figure 3).

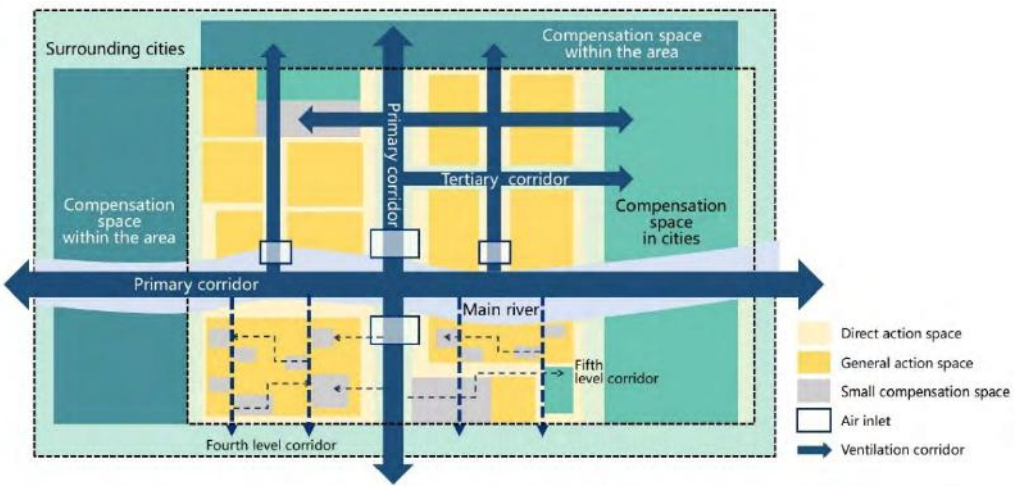


Figure 3. Climate security spatial pattern based on natural solutions (Source: Own Draw)

Referring to the TEW "identification prediction avoidance" behavior path, key basic dimension assessments, climate change scenario simulations, land use safety pattern inspections, etc. are conducted to implement resilience space management and control work, such as urban resilience target positioning design, climate risk mapping, disaster prevention structure and avoidance space division, emergency space reservation, etc., in order to deal with the environmental pressure of cold cities brought on by climate change. This is done while taking into account the original impact of a severe cold climate and the emerging risks of climate change. Therefore, , preserving the natural ecological areas surrounding the city, controlling the climate, lowering the chance of floods brought on by the melting of ice and snow, and creating an ecological security pattern should be prioritized. At the same time, creating vertical vegetation and green roofs at the block level can improve the ecological connectivity and microclimate of the city (Figure 4).

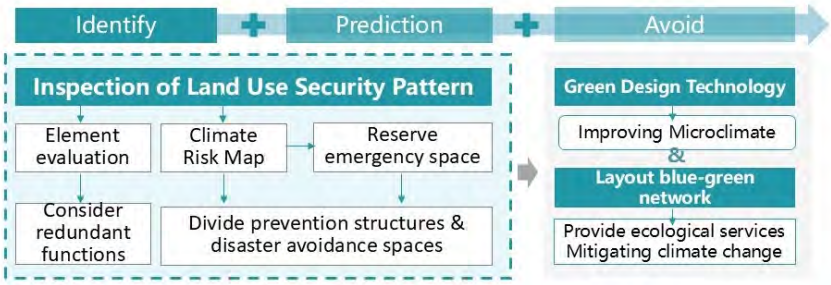


Figure 4. Climate safety spatial planning based on TEW behavior path (Source: Own Draw)

Based on the TEW's sustainable resource management system, cold area cities should build distributed energy systems, actively develop and employ renewable energy, and apply extreme thinking as a guidance. The emphasis is on boosting infrastructure's resilience to cold temperatures, as well as its redundancy and risk management capacities in the face of climate change risks.

3.2. TEW guidance enhances climate adaptation planning technology

In order to improve climate adaptation planning techniques, better identify vulnerable areas, infrastructure, industries, and populations under various types of extreme weather events, and assist cold cities in developing spatial engineering methods that are more suited to severe cold climates, TEW advises cold cities to concentrate on localized needs and scenario analysis in conjunction with modern multi-source data, modern climate models, and multi-departmental support. Prioritize the design of habitable spaces, build shelters for public gathering places, and modify the local microclimate by arranging green plants.

Promote the creation of adaptable, seasonal spaces for winter activities, enhance the way that outdoor public space functions are used collectively, and create urban living spaces that are good for the physical and emotional well-being of people who live in cold climates. Enhance the conventional dome structure throughout the architectural design phase to guarantee the building's security and comfort during inclement weather.

3.3. Innovative Inheritance TEW Resilience Governance Policy

Under the survival principle of multi-party interaction and maintenance, resilience governance based on TEW requires multi-level and cross departmental cooperation and linkage among government departments, civil society, and private sectors. Formulating and issuing relevant policy documents is the primary guarantee for promoting the smooth implementation of resilience planning. It is necessary to appropriately establish resilience planning management departments, strengthen cooperation between governments at all levels, society, institutions, enterprises, and residents, and horizontally coordinate and

collaborate with researchers and government departments at the same level and with different functions. Additionally, the percentage of climate adaptation planning in urban development projects should be suitably raised for cities located in cold climates. To draw the attention of different department levels to this effort, it is advised that the outcomes of climate adaptation planning be incorporated into the assessment system of different department levels.

Drawing on the experience of TEW's efficiency and fairness in responding to extreme weather events, cold region cities should open up cooperation with enterprises and society, establish a multi-party collaborative intelligent emergency command system and grassroots emergency rescue mechanism, integrate urban governance information systems such as the "City Brain", develop a human-machine interactive emergency response decision support system, and provide substantial and effective contingency plan support for emergency response. Focus on improving the climate risk prevention capabilities of vulnerable groups, coordinate social organizations and volunteer resources(Magne Skjelvik et al., 2011), and efficiently and widely mobilize diverse social forces to participate in emergency response to extreme weather events, in order to enhance the city's ability to balance efficiency and fairness in disaster response (Figure 5).

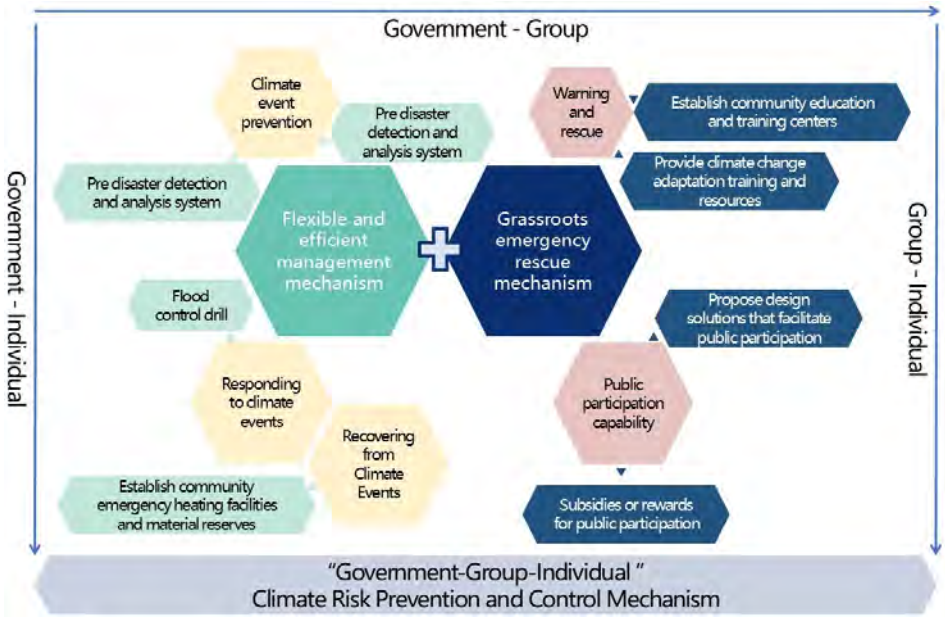


Figure 5. Multi subject collaborative resilience governance mechanism based on TEW (Source: Own Draw)

Cold cities must start with interdisciplinary and participatory research, comprehensively studying and determining local TEW. Secondly, it is necessary to explore the entire value chain and management of TEW in extreme weather events, including intelligent data information, to support the spiral development of urban systems under extreme weather conditions. By forming a virtuous cycle of self-organization and self-learning, we can expand the connotation of traditional ecological wisdom, protect and inherit it.

4. Discussion

We can protect and promote these priceless cultural heritages in the process of modernization through social participation and effective policy guidance, which will also provide substantial support for addressing climate change and resource management. However, despite TEW's profound cultural and environmental roots, the urbanization process often masks this knowledge, especially in extreme weather conditions

where its adaptability is overlooked. Traditional wisdom may ultimately be replaced by the rapid development of modern technology.

To address these issues, governments in cold cities should establish rules that ensure recognition of the value of their traditional ecological knowledge and protect and preserve their heritage. Academic institutions and non-governmental organizations should work together to investigate the use of TEW in the development of modern cold cities for resilience and to promote multi-party participation. Moreover, when traditional ecological knowledge is collected and preserved through digital platforms, more people can learn and apply it. Together they will contribute to the spread of traditional ecological knowledge in cold climates.

5. Conclusion

The inheritance process of TEW includes preparation, perception, adaptation, and learning. It not only maintains ecological awareness, but also continuously optimizes various efficiency- oriented management tools and technologies, guiding the coordinated development of "human technology environment" in cold cities. The purpose of this study is to construct a traditional ecological intelligence network for cold cities and investigate its value in improving the resilience of cold cities. Furthermore, contribute local theories and practical experience to the sustainable development of modern cold cities. In the future, cross-cultural comparative research can be combined to supplement the spatiotemporal background, typical connotations, and modern concepts applied to the evolution of TEW regions.

Reference

ALEXANDER & E., R. 1989. Reviews : Planning in the Public Domain: From Knowledge to Action John Friedmann. Journal of Planning Education and Research, 9, 57-58.

CHEN,Y. 2016. The construction of willow branches in Northeast China and its ecological environment effects: limited to the early Qing Dynasty Journal of Northwest University (Natural Science Edition), 46, 282-286

FOLKE, C. 2004. Traditional Knowledge in Social–Ecological Systems. ecology & society, 9.

IPCC. 2019. Sixth Assessment Report [online]. https://archive.ipcc.ch/index.htm. (23-09-2024).

JACKSON, J. & HOLDEN, M. 2013. Sustainable Development Compromise d in the Planning of Metro Vancouver's Agricultural Lands-the Jackson Farm Case. Sustainability, 5, 4843-4869.

LENG,H.&YUAN, Q.2004. Research on the Planning and Design Concept and Countermeasures of Cold Region Cities Based on "Winter Ecology" Urban Planning Annual Meeting, Beijing, China 56-61.

LIAO, K. H. & CHAN, J. 2016. What is ecological wisdom and how does it relate to ecological knowledge? Landscape and Urban Planning, 111-113.

LIU, W. 2020. Research on the Characteristics of Ancient Human Settlement Site Construction in the Heilongjiang River Basin Based on Archaeological Interpretation Doctor, Harbin Institute of Technology.

LIU X. 2002. Ecological and Sustainable Habitat - Practice of Ecological Residential Communities in Sweden Architecture, 49-52.

MAGNE SKJELVIK, J., BRUVOLL, A. & IBENHOLT, K. 2011. Greening the economy: Nordic experiences and challenges.

PARTICIPANTS, P. 2015 and updated in 2017. Ottawa Traditional Knowledge Principles.

XIANG, W.-N. 2014. Doing real and permanent good in landscape and urban planning: Ecological wisdom for urban sustainability. Landscape and Urban Planning, 121.

XIANG, W. N. 2016. Ecophronesis: The ecological practical wisdom for and from ecological practice. Landscape & Urban Planning, 155, 53-60.

XU, L., FENG, K., LIN, N., PERERA, A. T. D., POOR, H. V., XIE, L., JI, C., SUN, X. A., GUO, Q. & O'MALLEY, M. 2024. Resilience of renewable power systems under climate risks. Nature Reviews Electrical Engineering, 1, 53-66.

WANG,X.&SUN,D. 2018. The contemporary significance of inheriting and promoting the traditional folk culture of the Oroqen ethnic group in the strategy of rural revitalization Heilongjiang Ethnic Series, No. 167, 93-98

ZENG,S., WANG,Q.&TIAN,J. 2023. Research on the theoretical framework and planning response of resilient national spatial planning to address climate change Planner, 39, 21-29.

Research Paper

Heritage as a Driver for Resilience： A Four-Dimensional Historic Urban Landscape (HUL) Approach to Cultural Heritage in Urban Development

Zihui TIAN, Collage of Design and Engineering, University of Singapore, Singapore, Singapore

Abstract

This study presents a systematically constructed four-dimensional theoretical framework that operationalizes the Historic Urban Landscape (HUL) approach in urban heritage documentation, ultimately fostering urban resilience through cultural heritage preservation. Through rigorous analysis of HUL's theoretical foundations and contemporary urban heritage complexities, we have identified four fundamental characteristics inherent in HUL theory: physical integrity, temporal layering, spatial connectivity, and social participation. These characteristics directly inform the development of our four-dimensional framework comprising individual building, area, time, and perception dimensions, and it offers a systematic, mass-oriented way to capturing and analysing these values. With the help of geographic information System (GIS) and digital information technology, this theoretical framework has been transformed into a practical documentation tool, and on the basis of integrating spatial and non-spatial data resources, dynamic updated cultural heritage information management has been realized. The effectiveness of the framework was then substantially validated through an in-depth case study in Singapore. In general, this research approach can be seen not only as a theoretical support for the historical urban landscape (HUL) approach, but also as a structured approach to urban heritage records. Through a heritage-based development strategy, more efficient, dynamic and comprehensive solutions are provided to further enhance the sustainability and resilience of cities.

Keywords

Urban Heritage, Historic Urban Landscape (HUL) approach, Four-dimensional Heritage Map

1. Introduction

In the contemporary context, the rapid pace of urbanization presents novel challenges and opportunities for the conservation and utilization of urban heritage. As the bearer of urban history and culture, urban heritage plays an increasingly crucial role in fostering urban resilience (Bahrami & Samani, 2015; Ginzarly et al., 2019). However, influenced by the context of rapid urban development and the digital age, the

delicate relationship between heritage and its surrounding environment has also changed. (Rey-Perez & Siguencia Ávila, 2017), which necessitates the implementation of new methods. Traditional conservation methods have primarily focused on the protection of individual historical buildings, but experience has shown that this simplistic approach does not work when attempting to integrate heritage into modern cities. These methods often fail to capture the broader urban context and social dimensions, which are increasingly recognized as important components of heritage value(Bandarin & Oers, 2015). For example, in some urban renewal projects, only focus on the restoration of individual buildings, while ignoring the interaction with surrounding communities and the coordination of the overall environment, resulting in poor protection effects, or has lost its heritage value due to excessive commercialization, and community life has disappeared and become a "theme park" (Lowenthal, 2005; Urry, 1996). The Beijing Dashilar Historic District(Tong et al., 2023)， the transformation of Xintiandi in Shanghai (Luo et al., 2022; Zhou et al., 2020), Venice in Italy(Bertocchi & Visentin, 2019; Russo, 2002), and the Old town of Prague(Liu et al., 2022; Soukopová, 2019) all exemplify the aforementioned issues.

In the face of this challenge, the emergence of the Historic Urban Landscape (HUL) approach marks an important turning point in the field of urban heritage conservation. The HUL approach regards heritage as "the result of the historical stratification of cultural and natural values and attributes" (UNESCO 2011, Article 8), , thereby expanding the scope of conservation from the traditional concepts of "historic centers" or "wholes" to broader urban areas and their geographical settings. This approach no longer views heritage as a constraint on urban development, but rather as a potential driving force for a sustainable urban future. However, in practical application—especially in systematically documenting and assessing the complex values of urban heritage—the HUL approach still faces challenges, despite its theoretical framework being widely recognized in academia. To support this conceptual evolution, there is a call for the implementation of "document, understand and present the complex layering of urban areas" (UNESCO 2011, Article 27). However, existing documentation methods often address heritage dimensions in an isolation way: Physical documentation focuses primarily on architectural features, spatial analysis remains limited to defined conservation zones, and social values are frequently treated as supplementary rather than integral components (Jones & Leech, 2015). This fragmented approach fails to adequately capture the interconnected nature of urban heritage highlighted by the Historic Urban Landscape (HUL) approach. Although in recent years, some digital technologies have demonstrated their potential in the field of heritage research(Fortenberry, 2019; Karadag, 2023), but there are still significant gaps: The existing research has not been able to fully construct a theory that conforms to the principle of historical urban landscape (HUL) and at the same time can realize the in-depth excavation and record of the multi-dimensional value of urban heritage, and more importantly, promote the sustainable development of heritage imperceptibly. The central challenge from this perspective is how to develop a documentation approach that captures the physical characteristics, spatial relationships, temporal evolution, and social perception of urban heritage, while at the same time, Maintain theoretical coherence with urban heritage principles (physical integrity, temporal stratification, spatial connectivity, and social engagement) (Bandarin & Oers, 2015).

To bridge the gap between theory and practice, this study constructs a four-dimensional documentation framework. Rooted in the Historic Urban Landscape (HUL) approach, this framework systematically records the tangible and intangible values of urban heritage through four dimensions—individual architecture, regional environment, temporal evolution, and social perception. From the construction characteristics of every brick and tile to the spatial texture of community alleys, from the marks of time’s passage to the living memories of ordinary people, we anticipate that this theoretical framework will offer a practical and feasible methodological guide for the comprehensive documentation of heritage sites.

The significance of this framework lies in its ability to:

1. Systematically transform HUL theoretical principles into practical documentation methods, providing a new practical path for urban heritage conservation.

2. Integrate multiple dimensions of heritage value within a unified analytical structure, thereby achieving a comprehensive assessment and effective protection of urban heritage value.

3. Achieve comprehensive documentation through digital technology, improving the efficiency and accuracy of documentation.

4. Support evidence-based heritage management decisions, providing a scientific basis for the sustainable development of urban heritage.

Through this research, we hope to provide a new perspective and practical method for the field of urban heritage conservation, to cope with the challenges brought by rapid urbanization and to achieve harmonious integration of urban heritage with modern urban life. (Figure 1)

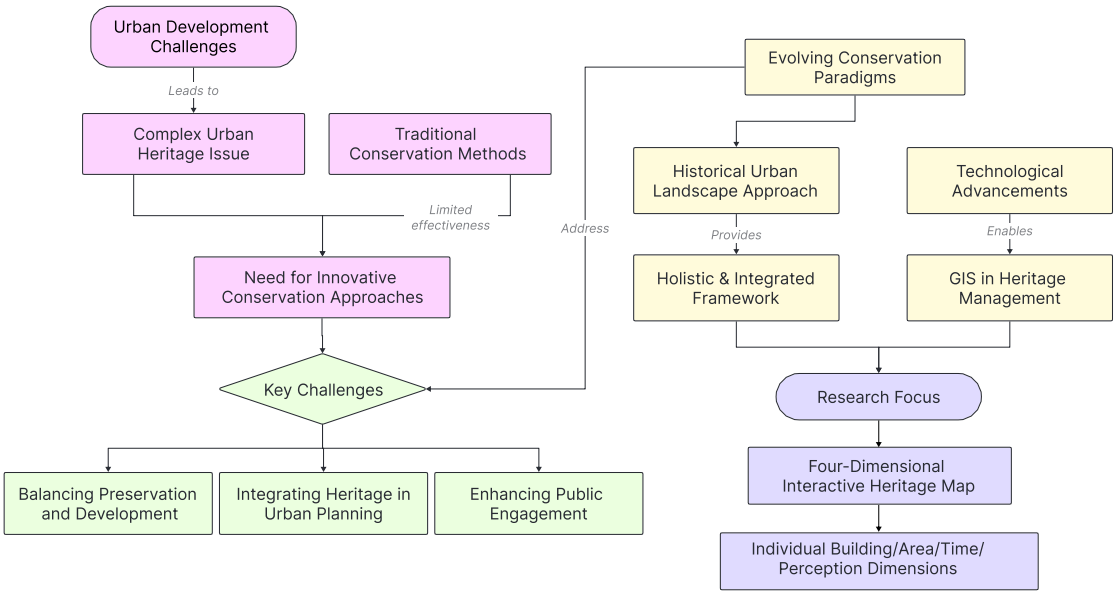


Figure 1. Research Motivation and Methodology Diagram. Source: Authors' own compilation.

2. Theoretical Framework

2.1 Historic Urban Landscape (HUL) approach

The Historic Urban Landscape (HUL) approach recognizes heritage as a potential driver for sustainable urban futures. In November 2011, UNESCO's General Conference adopted the Recommendation on the Historic Urban Landscape (HUL), the first such instrument on the historic environment issued by UNESCO

in 35 years (Figure 2). HUL is defined as "the urban area understood as the result of a historic layering of cultural and natural values and attributes, extending beyond the notion of 'historic centre' or 'ensemble' to include the broader urban context and its geographical setting" (UNESCO, 2011). Rather than replacing existing conservation approaches, the HUL Recommendation serves as an additional tool to integrate heritage conservation into broader urban development goals while respecting diverse cultural contexts. Through the analysis of HUL theory and evolution of heritage regulations, four key characteristics can be identified that guide the development of our four-dimensional heritage mapping framework---Physical Integrity; Temporal Layering; Spatial Connectivity; Social Participation.

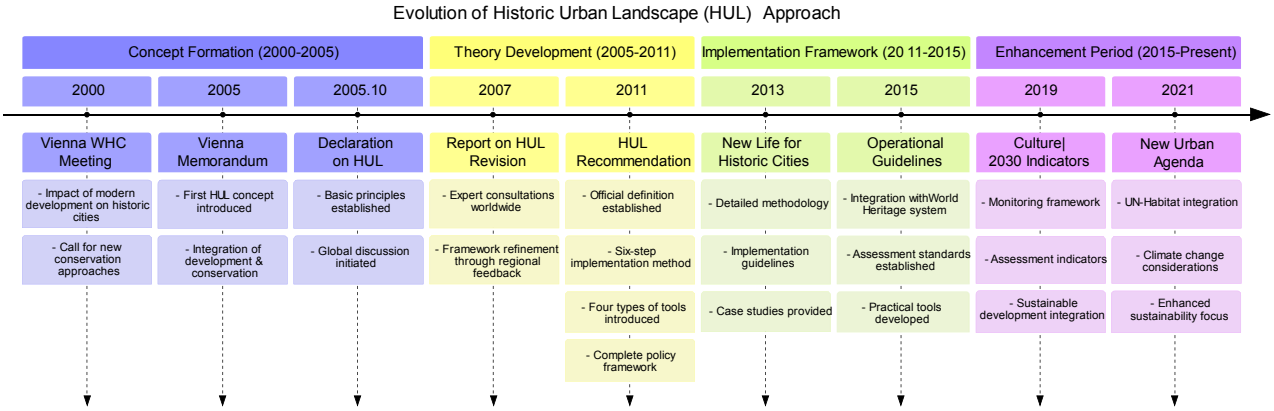


Figure 2. Evolution of Historic Urban Landscape (HUL) Approach. Source: Synthesized from UNESCO's official documents and recommendations. Visualization: Authors.

2.2 Four Key Characteristics of Historic Urban Landscape (HUL) Approach

2.2.1 Physical Integrity

The principle of physical integrity represents a fundamental cornerstone in heritage conservation. This recognition can be traced from the 1931 Athens Charter's initial concern for heritage environments, through Article 6 of the 1964 Venice Charter's clarification of the relationship between heritage and its setting (ICOMOS, 1964), to the 1972 World Heritage Convention's establishment of "integrity" as a core evaluation criterion for World Heritage (UNESCO, 1972), marking the systematization of holistic protection cognition for heritage entities and their environments.

HUL theory inherits and deepens this understanding, specifically emphasizing the holistic characteristics comprising "topography, geomorphology, hydrology and natural features; its built environment... its open spaces and gardens" (UNESCO, 2011). This theoretical development reveals two critical dimensions of physical integrity: first, the protection of authenticity in heritage entities, reflected in the complete preservation of historical information and value carriers; second, the holistic maintenance of environmental elements, emphasizing the inseparability of heritage from its immediate environment. This recognition reflects a basic professional consensus: effective transmission of heritage values must be based on complete physical carriers and their environmental context (Poulios, 2010, 2014).

2.2.2 Temporal Layering

"Temporal layering" emerges as a key characteristic of HUL theory, derived from its fundamental definition of historic urban landscapes as "the result of historic layering." This concept has profound theoretical origins: from the 1964 Venice Charter's emphasis on single-period authenticity, through the 1994 Nara Document's expansion of authenticity understanding, to the 2005 Operational Guidelines' introduction of "cultural continuity," culminating in the 2011 HUL Recommendation's establishment of "historic layering" as a core principle.

"Temporal layering" precisely summarizes this theoretical development, breaking through traditional conservation theory's fixed cognition of specific historical periods and emphasizing cities as organisms continuously accumulating across temporal dimensions. This perspective has gained widespread scholarly support: Bandarin and Van Oers define cities as "continuously evolving organisms"(Bandarin & Oers, 2015) Worthing and Bond emphasize the evolutionary nature of heritage values (Bond & Worthing, 2016)， while Poulios's "living heritage" concept further confirms the continuous nature of culture(Poulios, 2010). This profound understanding of historical cities' temporal dimension not only provides new perspectives for evaluating urban historical and cultural values but also establishes theoretical foundations for contemporary historic city conservation and development, enabling us to support reasonable urban evolution while protecting historical values(Ginzarly et al., 2019).

2.2.3 Spatial Connectivity

Spatial connectivity represents a significant breakthrough in HUL theory. The 2011 Recommendation explicitly extends heritage consideration to include the "broader urban context" and "geographical setting," (UNESCO, 2011) expanding conservation vision to larger regional scales. HUL emphasizes that historic urban landscapes constitute spatial systems comprising natural and cultural elements, tangible and intangible components, requiring understanding beyond the limitations of historic centers.

From a spatial dimension, HUL particularly emphasizes the connectivity between heritage and its regional cultural background, social and natural environment (Panjabi & Winter 2009; Bandarin 2015; Taylor 2015). This connectivity manifests in two aspects: first, the organic connections among heritage elements internally; second, the functional connections between heritage and broader urban systems. This regional perspective necessitates attention to heritage sites' cultural position and function within larger spatial contexts, promoting the expansion of conservation concepts from microscopic places to macroscopic regions. As Jones and Leech emphasize, this multi-scalar understanding necessitates comprehending heritage within broader spatial contexts, grasping the network of spatial relationships from individual sites to regional scales (Jones & Leech, 2015).

2.2.4 Social Participation

The principle of social participation stems from HUL's fundamental recognition that heritage values are socially constructed and maintained rather than predetermined professional judgments. This recognition essentially reflects HUL's emphasis on "public common values." Smith's reinterpretation of heritage nature has profound significance: defining heritage as "a social process" where it is "something that people create and use actively to maintain the connections between themselves and other places." (Smith, 2006)

This definition reveals two fundamental characteristics: first, heritage is no longer static physical carriers but a dynamic process embedded in people's daily life practices (Rey-Perez & Siguencia Ávila, 2017); second, heritage protection objects have broken through traditional limitations of special sites to expand to place environments carrying ordinary people's daily life memories. These two characteristics essentially point to a core transformation: since heritage is defined by daily life practices and carried by ordinary environments, heritage value assessment should naturally be centered on ordinary people who actually use and perceive these places, rather than relying solely on expert academic judgments. This recognition inevitably leads to a fundamental shift in value assessment systems from expert-led to public participation.

2.3 From Theory to Practice: Four-Dimensional Framework

2.3.1 Framework Conceptualization

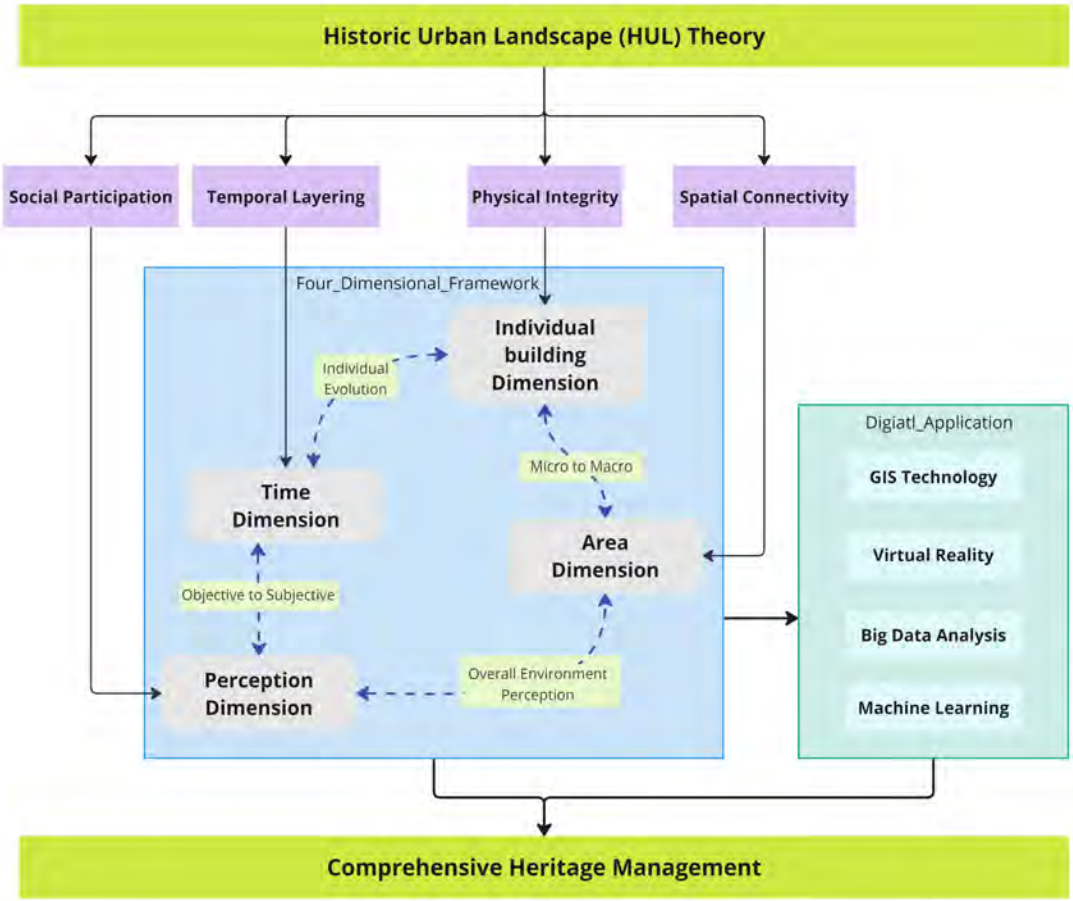


Figure 3. Research Framework Diagram. Source: Authors' own compilation.

The four key characteristics identified from HUL theory provide the theoretical foundation for developing a systematic documentation framework (Figure 3). This framework translates HUL's conceptual principles into operational dimensions while addressing contemporary conservation challenges.

The Individual Building Dimension, derived from “physical integrity” requirements, enables systematic documentation of architectural attributes and material conditions, responding to HUL's requirement of extending "beyond the notion of 'historic centre' or 'ensemble' to include the broader urban context and its geographical setting". The Area Dimension reflects “spatial connectivity” principles by capturing broader

urban contexts and environmental relationships, aligning with what Jones and Leech describe as the necessity to understand heritage within its wider spatial context. The Time Dimension embodies the concept of "temporal layering" by documenting historical evolution processes and cultural continuity, which are "the result of a historic layering of cultural and natural values and attributes" (UNESCO 2011, Article 8). The Perception Dimension implements social participation principles through the integration of stakeholder perspectives and community values, addressing what Waterton identify as the need to democratize heritage practice(Waterton et al., 2006) and aligning with HUL's recognition of the "dynamic character" of urban heritage and its promotion of "social and functional diversity" (UNESCO 2011, Article 11).

While each dimension addresses specific aspects of HUL requirements, their integration creates a comprehensive framework that enables systematic heritage documentation and analysis. This framework provides:

- Systematic recording of physical heritage attributes
- Documentation of spatial-temporal relationships
- Integration of social values and perceptions
- Support for evidence-based conservation decisions

Through this structured yet flexible approach, the framework establishes a methodological bridge between HUL's theoretical principles and practical heritage conservation requirements.

2.3.2 Digital Implementation Strategy

While the HUL Recommendation explicitly encourages the use of information and communication technologies (UNESCO 2011, Article 27), comprehensive digital implementation frameworks remain limited. Smith advocates for digital interactive mapping as a tool for urban heritage conservation, emphasizing its ability to document how "different subcultures may exist in the same physical space in different ways," while Haskins highlights maps' capacity to integrate fragmented heritage content dynamically (Haskins, 2015).

Recent technological advances have significantly enhanced heritage documentation capabilities. Web 3.0 and semantic web technologies have improved historical building interpretation (Amoruso and Manti 2016; Bolici et al. 2017), while digital platforms have democratized heritage documentation through enhanced public participation (Murphy et al. 2016; Widodo et al. 2017). GIS-based modeling and remote sensing technologies provide essential tools for spatial analysis (Agapiou et al., 2015; Robinson et al., 2010; Williams, 2014), and social media integration enables participatory heritage practice (Giaccardi 2012; Liew 2014).

However, most existing studies focus on single aspects of heritage documentation, primarily serving as electronic records rather than integrated analytical tools. The potential for multi-dimensional analysis through the integration of Geographic Information Systems (GIS), Virtual Reality Applications, Big Data Analytics and Machine Learning remains largely unexplored. This research addresses this gap by developing a comprehensive digital platform that leverages these technologies to implement our four-dimensional framework, enabling systematic documentation and analysis of urban heritage values across multiple dimensions.

GIS Technology	Virtual Reality Applications	Big Data Analytics	Machine Learning
Serves as primary platform for spatial data integration	Provides immersive visualization of heritage environments	Processes large-scale perception data from multiple sources	Processes collective perception data through natural language processing
Facilitates temporal data analysis through historical map overlays	Enables detailed documentation of architectural features	Enables pattern recognition in social value assessment	Identifies social value trends from community feedback
Supports creation of interactive heritage mapping interfaces	Supports spatial relationship analysis	Supports temporal trend and multi-modal analysis	Enables systematic analysis of public sentiment and cultural significance
Enables multi-scale documentation from individual buildings to urban contexts	Facilitates stakeholder engagement through interactive experiences	Integrates diverse data types for comprehensive analysis	Analyzes patterns in stakeholder engagement responses

Figure 4. Overview of Digital Heritage Technology Framework. Source: Authors' own compilation.

3. Case Study: Development of Interactive Heritage Mapping Platform Using Four-Dimensional Framework

3.1. Study Area Selection

The research focuses on the northern bank of Singapore River, encompassing significant heritage precincts including Clarke Quay, Fort Canning Park, and Queen's Square. This district, formerly designated as one of six historic conservation districts by the Singapore government in 1986, presents multiple layers of heritage significance through its waterfront landscapes, historic architecture, and evolving urban fabric (Figure 5). Although its conservation status was subsequently modified due to policy changes, the area's rich combination of built heritage, natural elements, and cultural significance provides an ideal testing ground for developing comprehensive digital documentation methodologies.

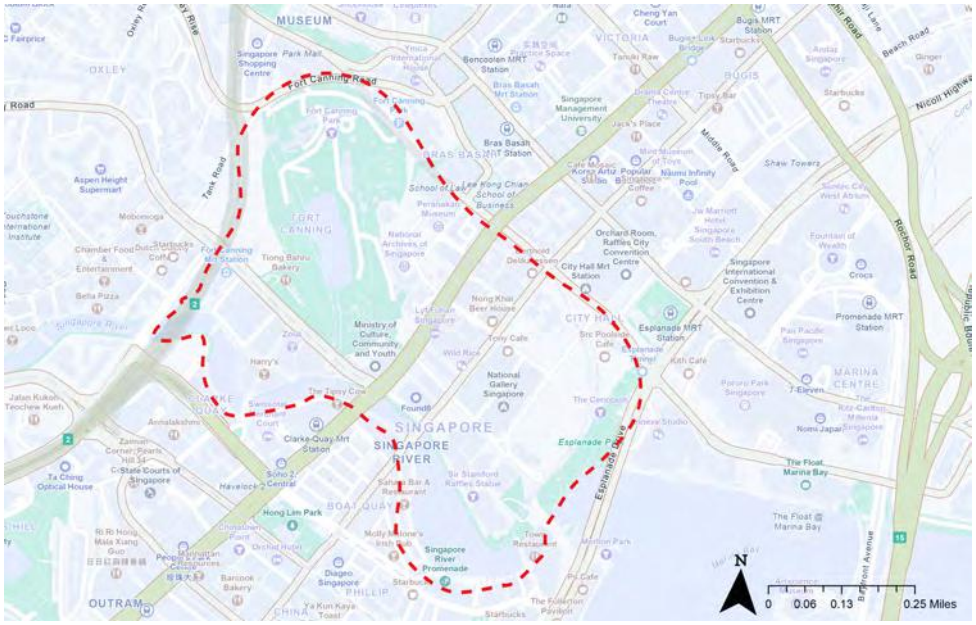


Figure 5. Scope of the research. Source: Authors' own compilation.

3.2 Framework Operationalization

The framework is operationalized through ArcGIS Online and ArcGIS Pro, integrated with Virtual Reality technology, machine learning applications and big data analytics. These platforms are chosen for their capabilities in handling complex spatial-temporal data and supporting multi-dimensional heritage documentation (Figure 6,7). The technical implementation specifically addresses our four dimensions: Individual Building Documentation; Area Documentation; Time Documentation; Perception Documentation.

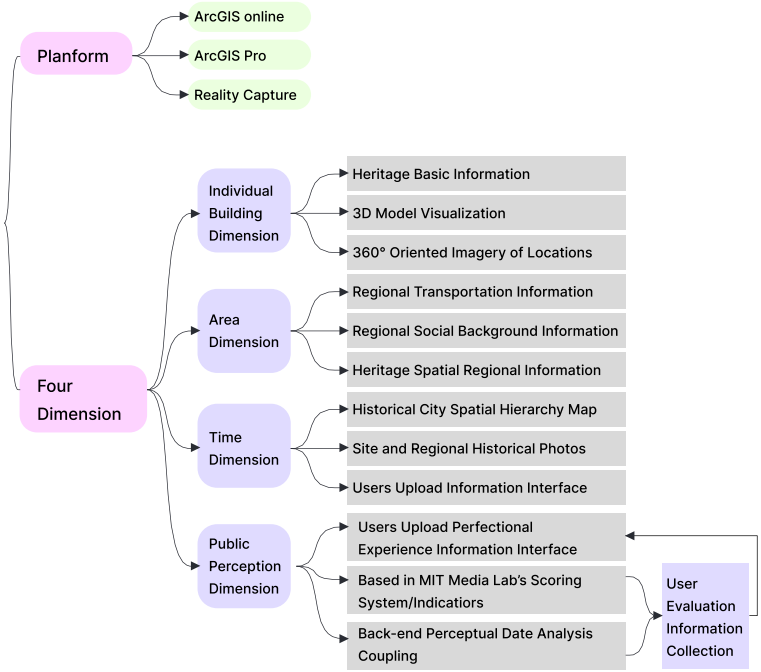


Figure 8. Construction of a Four-Dimensional Framework Interactive Map Using HUL Theory and GIS. Source: Authors' own compilation.

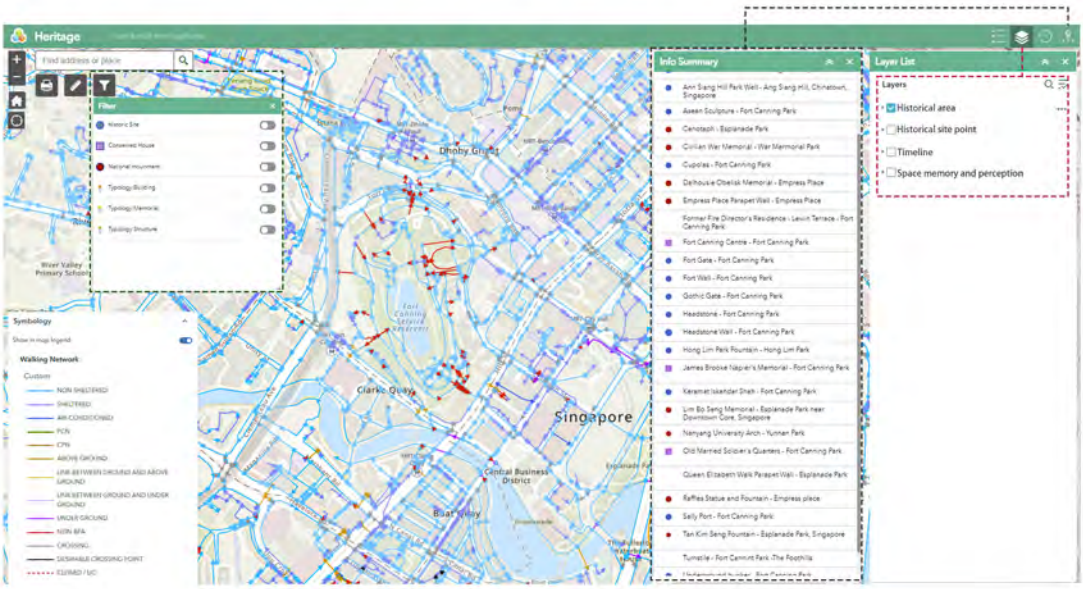


Figure 9. Digital heritage mapping platform of Singapore River North Bank: interface screenshots demonstrating. Source: Authors' own development.

3.2.1 Individual Building Dimension: Establishing Digital Archives of Heritage Sites

The individual building dimension represents the fundamental unit of analysis in implementing the HUL approach, serving as both physical carriers of heritage values and focal points for social meaning construction. While HUL emphasizes comprehensive urban landscape management, the documentation and analysis of individual structures form the cornerstone for understanding layered urban heritage values.

This dimension employs a two-tier documentation methodology that integrates traditional archival research with advanced digital technologies. The foundational tier systematically digitizes conventional documentation, including historical records and basic site information, while the advanced tier utilizes unmanned aerial vehicles (UAVs) and photogrammetry techniques to create precise digital representations. Through specialized photogrammetry software such as Reality Capture and Agisoft Metashape, high-resolution aerial photographs are processed into detailed point clouds and textured three-dimensional models. These models undergo rigorous georeferencing within ArcGIS environment, followed by conversion to SLPK format for integration with ArcGIS Online platform, enabling interactive heritage mapping and three-dimensional visualization capabilities that extend beyond traditional documentation approaches. (Figure 10)

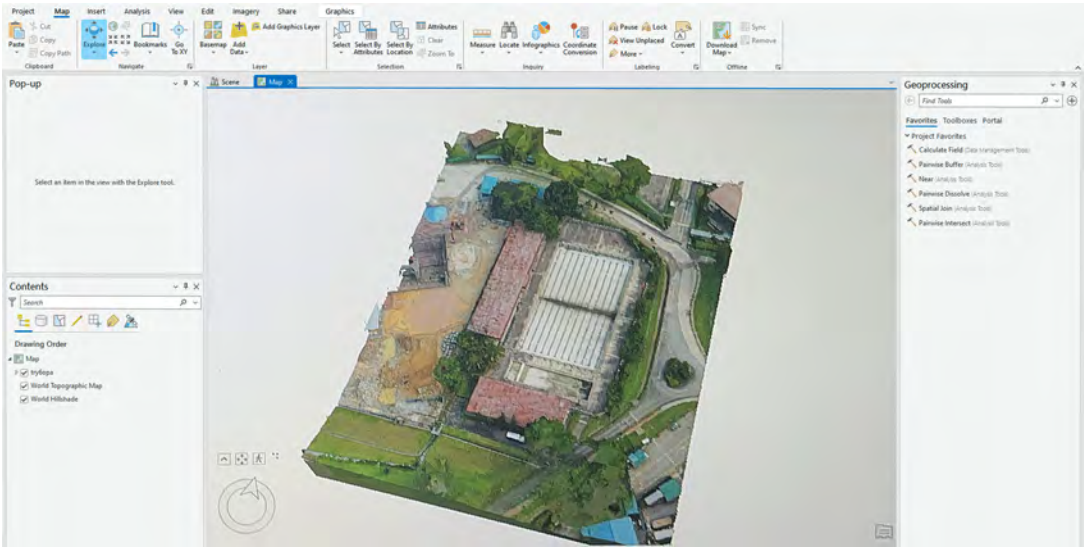


Figure 10. Implementation of heritage 3D documentation: ArcGIS-based visualization interface of Singapore OPA heritage site showing detailed architectural modeling and spatial context. Source: Authors' own development.

The documentation framework is further enhanced through oriented imagery catalogs, implemented via ArcGIS Pro, which systematically capture the contextual relationships of heritage structures. This advanced visualization approach creates interactive 360-degree panoramic views at strategic positions surrounding each heritage site, enabling detailed analysis of visual relationships and spatial patterns. The integration of oriented imagery with the broader digital documentation framework provides an essential layer of contextual information that bridges individual building documentation and area-level analysis, supporting both detailed architectural investigation and broader urban studies. (Figure 10)

Figure 11. Oriented imagery documentation system: 360-degree interactive visualization of heritage sites implemented through ArcGIS platform, enabling comprehensive spatial context analysis. Source: Authors' own development.

3.2.2 Area Dimension: Integrated Spatial-Cultural Documentation

The area dimension operationalizes HUL's holistic conservation principles by establishing a systematic documentation framework that examines heritage preservation from a macro-regional perspective. Through ArcGIS Online's multi-layered visualization capabilities, we developed an integrated platform that extends beyond individual sites and buffer zones to capture comprehensive urban contexts. The platform incorporates multiple data layers including street infrastructure, cultural landscapes, and social patterns. An interactive interface enables users to access contextual information through strategically designed data layers, while embedded linking mechanisms allow stakeholders to contribute cultural narratives, historical photographs, and social memory documentation, enriching the cultural-spatial database through community participation. (Figure 12)

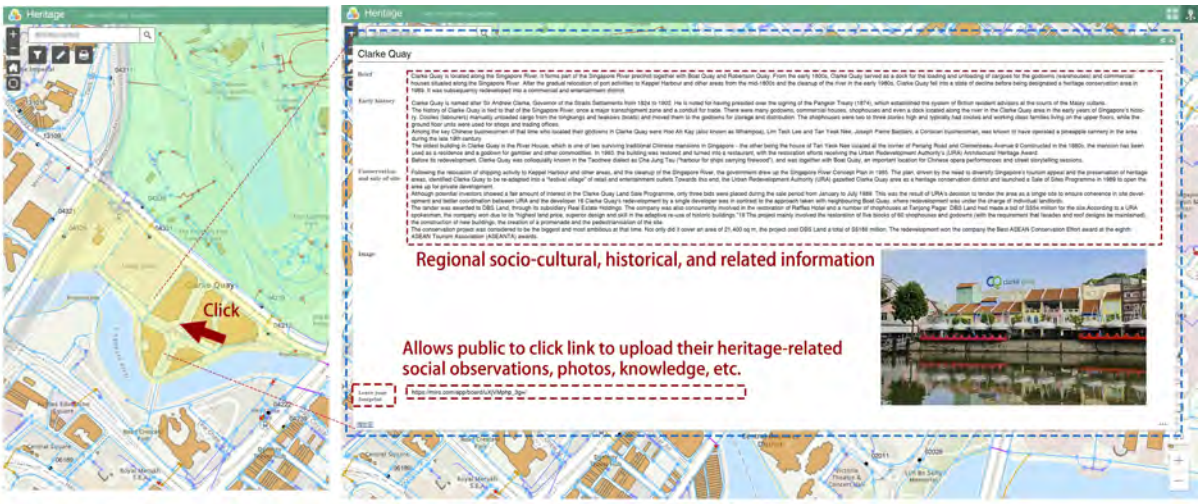


Figure 12. Implementation of the digital heritage documentation framework: interface screenshots showing area-dimensional data integration and visualization. Source: Authors' own development.

3.2.3 Time Dimension: Dynamic Heritage Evolution Analysis

The time dimension systematically documents urban transformation processes, drawing significant methodological inspiration from the Singapore Historical Geographic Information System (SHGIS). The implementation integrates historical maps dating from 1822, providing comprehensive documentation of Singapore's urban evolution over nearly two centuries. At the precinct level, we established detailed chronological documentation capturing the transformation of heritage sites and streetscapes, including records of establishment, restoration, and environmental changes. The temporal database structure enables systematic analysis of both physical evolution and associated social transformations, creating a dynamic framework for understanding heritage sites within their historical contexts.

The establishment of a multi-dimensional framework follows a progressive logic from surface to deep structures. While the individual building and area dimensions represent the fundamental physical layers, the temporal and perception dimensions capture deeper layers of heritage significance. This hierarchical structure enables systematic documentation from tangible attributes to intangible values, reflecting HUL's comprehensive approach to heritage understanding. (Figure 13)

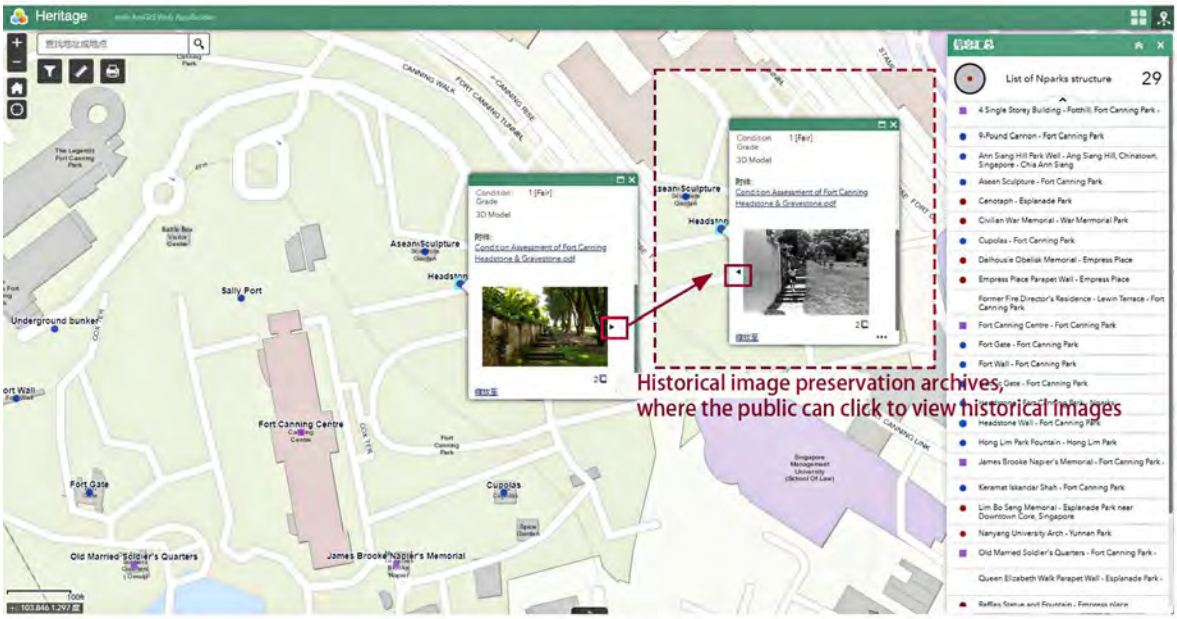


Figure 13. Implementation of the digital heritage documentation framework: interface screenshots showing time-dimensional data integration and visualization. Source: Authors' own development.

3.2.4 Perception Dimension: Quantifying Heritage Experience

The perception dimension advances the public value perspective emphasized by HUL theory through systematic documentation of spatial experience. The implementation methodology involves three key components (Zhang et al., 2023). First, we collected street-view imagery through strategic sampling points identified via OpenStreetMap and accessed through Google Street View API, resulting in a filtered dataset of 1,251 samples. Second, building upon MIT Media Lab's "Place Pulse" framework (Ito et al., 2024), we developed a machine learning-based evaluation system that extends beyond traditional metrics of safety, liveliness, beauty, wealth, depression, and boredom to incorporate heritage-specific indicators. Third, we

integrated an interactive questionnaire system within the digital platform, enabling users to contribute their spatial perceptions and value orientations for locations within the study area. This user-generated data continuously refines our understanding of heritage district perception, aligning with HUL's objective of enhancing public awareness of urban heritage's socio-cultural significance across generations.

In fact, encouraging users to upload and record their own perceptions is consistent with HUL's goal of increasing people's awareness of the social and cultural significance of urban heritage for past, present and future generations. As mentioned by Van der Hoeven in his work, "The storytelling and perceptions on social media are highly relevant to fostering public engagement in heritage conservation, as they reveal residents' emotional and social values associated with the city." (van der Hoeven, 2020) This also indirectly reflects Article 21 of the UNESCO 2011 document, where the HUL theory calls for providing participatory tools to facilitate public dialogue on the core values of urban areas.

4. Discussion

The four-dimensional framework established in this investigation presents a comprehensive paradigm for urban heritage documentation that seamlessly aligns with Historic Urban Landscape (HUL) principles. By integrating physical, spatial, time, and perception dimensions, the framework captures the complexity of urban heritage values and offers a systematic method for their documentation and analysis. In other words, urban heritage values, in their inherent complexity, are captured within this structured approach. The case study of Singapore validates the framework's applicability in urban heritage management.

However, the implementation of the proposed framework encounters several significant challenges, including data collection, stakeholder collaboration, capacity building, and the optimization of visual page presentation. For example, in the terms of data collection, the current integration method combines the recording and uploading of information not only rely on relevant departments but also by the audience themselves. The advantage is that it provides the public with a medium for uploading and greatly enhances the sense of participation. However, at the same time, it also brings certain disadvantages, which may be of uneven quality, resulting in the risk of invalidity. In addition, information from different channels requires a lot of time and energy to clean, organize and verify the data, which also increases the complexity of data management. In terms of Visual Interface, the current platform construction mainly relies on ArcGIS Online. The advantage is that it reduces the technical difficulty and facilitates rapid deployment and use. However, the disadvantage of ArcGIS Online is also evident. As a SaaS (Software as a Service) product, it inherently restricts users' ability to customize and control the system, which, importantly, poses a significant barrier to maximizing the expansion or stimulation of audience interest and engagement. Finally, urban renewal and heritage management involve multiple stakeholders, including government agencies, community residents, experts and scholars, non-governmental organizations and so on. The goals and needs of different stakeholders may be different, and how to maximize the interests of all parties is a complex process, which is also one of the main limitations of existing platforms at the methodological level-- the efficiency of theory and practice transformation.

Future research may be approached from two perspectives. First, the expansion of technological support should be considered. On the backend deployment side, the rationalization of data collection and management methods is essential. Additionally, on the frontend web interface, human-centered design principles should be employed to maximize audience engagement and participation. Second, efforts should be focused on refining the methodology. By establishing a connection between theoretical foundations and practical applications, this approach offers a structured methodology for urban heritage

documentation. Through this systematic framework, urban development strategies can maintain a balance between heritage preservation and contemporary urban requirements.

5. Conclusion

The four-dimensional framework developed in this study is highly compatible with the Historical Urban Landscape (HUL) approach and provides a framework with a solid methodological foundation for the field of urban heritage research. The framework comprehensively captures the complexity and multi-dimensional nature of urban heritage values by integrating physical, spatial, temporal and social dimensions. Its practical application in Singapore shows that the framework can effectively support evidence-based decision-making and promote inclusive estate management practices.

The core value of the framework is to transform the theoretical principles of HUL into practical tools, achieving a close combination of theory and practice：The first level, the four perspectives distilled from the four-dimensional framework, is the fulfillment and validation of the historical urban landscape (HUL) approach. It is based on digital technology, arcgis as the platform media, based on the four-dimensional perspective, based on the establishment of a profound interpretation of the historical urban landscape (HUL) approach, but also practice the theory, for the urban heritage record and sustainable protection to create a new perspective, a multidimensional four-dimensional perspective. The second level, this multidimensional perspective not only integrates the four dimensions of physical, spatial, temporal and social, but also comprehensively captures the complex levels of urban heritage values. It provides a platform to showcase the rich diversity of the city's heritage, further promoting voluntary public heritage knowledge and promoting heritage conservation from the "bottom up". This in turn can further promote the development and implementation of HUL theory.

Overall, the four-dimensional framework based on digital technology is not only a powerful tool for urban heritage experts and planners, but also a powerful medium for the public to actively participate in the sustainable conservation and renewal of urban heritage. Its framework is not only an efficient and comprehensive record of urban heritage changes, its application is also expected to revolutionize urban heritage management practices, promote a comprehensive and inclusive approach to safeguarding our common urban heritage, and enable it to move towards a more efficient and sustainable development model.

6. Acknowledgments

We would like to express our gratitude to the Urban Redevelopment Authority (URA) and National Parks Board (NParks) of Singapore for their valuable data support. We appreciate their collaboration and willingness to share data, which have been instrumental in advancing our understanding of Singapore's urban heritage landscape. For language polishing, Claude (Anthropic, 2023) was used for minor English phrasing suggestions, while all research content and writing were completed by the author.

7. References

Anthropic (2023) 'Claude' [Artificial Intelligence System]. Available at: https://www.anthropic.com/claude. (Accessed: August 2023).

Agapiou, A., Lysandrou, V., Alexakis, D. D., Themistocleous, K., Cuca, B., Argyriou, A., Sarris, A., & Hadjimitsis, D. G. (2015). Cultural heritage management and monitoring using remote sensing data

and GIS: The case study of paphos area, cyprus. *Computers, Environment and Urban Systems*, *54*, 230–239. https://doi.org/10.1016/j.compenvurbsys.2015.09.003

Bahrami, B., & Samani, F. (2015). Reconnecting the landscape in historical cities, conceptual analysis of historic urban landscape approach in iran. *Current World Environment*, *10*(2), 456–466. https://doi.org/10.12944/CWE.10.2.09

Bandarin, F., & Oers, R. van. (2015). *Reconnecting the city: The historic urban landscape approach and the future of urban heritage*. John Wiley & Sons Inc.

Bertocchi, D., & Visentin, F. (2019). "the overwhelmed city": Physical and social over-capacities of global tourism in venice. *Sustainability*, *11*(24), Article 24. https://doi.org/10.3390/su11246937

Bond, S., & Worthing, D. (2016). *Managing built heritage: The role of cultural values and significance* (Second edition). Wiley Blackwell. https://doi.org/10.1002/9781118298718

Fortenberry. (2019). Digital documentation in vernacular architecture studies. *Buildings & Landscapes: Journal of the Vernacular Architecture Forum*, *26*(2), 98. https://doi.org/10.5749/buildland.26.2.0098

Ginzarly, M., Houbart, C., & Teller, J. (2019). The historic urban landscape approach to urban management: A systematic review. *International Journal of Heritage Studies*. https://www.tandfonline.com/doi/abs/10.1080/13527258.2018.1552615

Haskins, E. V. (2015). *Popular memories: Commemoration, participatory culture, and democratic citizenship*. The University of South Carolina Press.

Ito, K., Kang, Y., Zhang, Y., Zhang, F., & Biljecki, F. (2024). Understanding urban perception with visual data: A systematic review. *Cities*, *152*, 105169. https://doi.org/10.1016/j.cities.2024.105169

Jones, S., & Leech, S. (2015). *Valuing the historic environment: A critical review of existing approaches to social value*. https://www.semanticscholar.org/paper/Valuing-the-Historic-Environment%3A-a-critical-review-Jones-Leech/57ce4fb6d5bbc35474b06c55bcdb324aa8166a14

Karadag İ. (2023). Machine learning for conservation of architectural heritage. *Open House International*, *48*(1), 23–37. https://doi.org/10.1108/OHI-05-2022-0124

Liu, F., Kang, J., Wu, Y., Yang, D., & Meng, Q. (2022). What do we visually focus on in a world heritage site? A case study in the historic centre of prague. *Humanities and Social Sciences Communications*, *9*(1), 400. https://doi.org/10.1057/s41599-022-01411-1

Lowenthal, D. (2005). *The past is a foreign country* (12. printing). Cambridge Univ. Press.

Luo, J., Jian, I. Y., Chan, E. H. W., & Chen, W. (2022). Cultural regeneration and neighborhood image from the aesthetic perspective: Case of heritage conservation areas in shanghai. *Habitat International*, *129*, 102689. https://doi.org/10.1016/j.habitatint.2022.102689

Poulios, I. (2010). Moving beyond a values-based approach to heritage conservation. *Conservation and Management of Archaeological Sites*, *12*(2), 170–185. https://doi.org/10.1179/175355210X12792909186539

Rey-Perez, J., & Siguencia Ávila, M. E. (2017). Historic urban landscape: An approach for sustainable management in cuenca (ecuador). *Journal of Cultural Heritage Management and Sustainable Development*, *7*(3), 308–327. https://doi.org/10.1108/JCHMSD-12-2016-0064

Robinson, M. H., Alexander, C. R., Jackson, C. W., McCabe, C. P., & Crass, D. (2010). Threatened archaeological, historic, and cultural resources of the georgia coast: Identification, prioritization and management using GIS technology. *Geoarchaeology*, *25*(3), 312–326. https://doi.org/10.1002/gea.20309

Russo, A. P. (2002). The "vicious circle" of tourism development in heritage cities. *Annals Of Tourism Research*, *29*(1), 165–182. https://doi.org/10.1016/S0160-7383(01)00029-9

Smith, L. (2006). *Uses of heritage* (1st ed.). Routledge. https://doi.org/10.4324/9780203602263

Soukopová, B. (2019). Prague: The national perception of the area. *Prace Filologiczne. Literaturoznawstwo*, *9(12) cz.1*, 111–121. https://doi.org/10.32798/pflit.110

Tong, B., Wang, S., & Zhang, Y. (2023). Analysis of the current situation of cultural continuity in the commercialization of historical and cultural blocks: Take beijing's dashilan commercial and cultural district as an example. In J. Sun, F. P. Chew, I. A. Khan, & C. Jenks (Eds.), *Proceedings of the 2022*

International Conference on Sport Science, Education and Social Development (SSESD 2022) (pp. 4–15). Atlantis Press SARL. https://doi.org/10.2991/978-2-494069-13-8_2

Urry, J. (1996). *The tourist gaze: Leisure and travel in contemporary societies*. Sage.

van der Hoeven, A. (2020). Valuing urban heritage through participatory heritage websites: Citizen perceptions of historic urban landscapes. *Space and Culture*, *23*(2), 129–148. https://doi.org/10.1177/1206331218797038

Waterton, E., Smith, L., & Campbell, G. (2006). The Utility of Discourse Analysis to Heritage Studies: The Burra Charter and Social Inclusion. *International Journal of Heritage Studies*, *12*(4), 339–355. https://doi.org/10.1080/13527250600727000

Williams, T. (2014). Archaeology: Reading the city through time. In F. Bandarin & R. Van Oers (Eds.), *Reconnecting the City* (1st ed., pp. 17–45). Wiley. https://doi.org/10.1002/9781118383940.ch1

Zhou, X., Li, Y., & Cheng, Y. (2020). Neighborhood, community and consumption: Study on the socio-spatial structure during two boosting epochs in shanghai. *Frontiers of Architectural Research*, *9*(2), 419–436. https://doi.org/10.1016/j.foar.2020.01.002

Research Paper

Study on the sustainability of flood control in mountain cities: The Case of Water System Construction in Huizhou Ancient City

Rui Ye, University of Edinburgh, The United Kingdom

Abstract

With the acceleration of urbanization, more and more land is being developed for construction, and suburban areas, mountainous areas, hills and other places have gradually become construction land. However, due to various factors such as historical development problems and modern artificial development, mountain destruction, soil erosion, and ecological imbalance have led to frequent flood disasters in these urban areas. Mountain torrents are characterized by suddenness, high water concentration, large flow, and strong scouring and destructive power. They often cause property losses, interruptions to public utilities, emergency services and transportation, and seriously affect the overall economic situation of a region. Therefore, flood management in mountainous cities is an important issue in modern urban planning.

Faced with the crisis of frequent mountain torrents, some ancient Chinese cities, such as Pingliangtai and Chang'an, were able to coexist with water and achieved remarkable achievements in urban construction and water system construction, some of which continue to this day. This paper aims to provide a perspective on the ancient wisdom of preventing and controlling mountain torrents. This study takes the Huizhou area as an example. The Huizhou area is in the southern part of Anhui Province, China, with an area of 13,870 square kilometers. It is mainly hilly and mountainous and is in the area of Jiuhua Mountain and Huangshan Mountain. Due to its unique geographical location, the Huizhou area is a high-risk area for mountain torrents. Huizhou has a history of more than 500 years, with good disaster prevention awareness and historical experience in successfully managing mountain torrents.

This paper first uses GIS technology to collect watershed information of more than 100 mountain cities in Huizhou, and compares it with the distribution of these mountain cities to find out the common principles of mountain cities in urban construction and site selection; then through literature review, three typical mountain cities in Huizhou: Hongcun, Jixi, and Chengkan are selected for case analysis, and GIS technology is used again to analyze the water system and water circulation system of these three ancient cities to understand the principles of urban flood control projects; field research is conducted in the three ancient cities to deeply understand the attitude of local people towards rainwater management and the lifestyle of coexisting with floods.

According to analysis, the site selection of mountain cities in Huizhou is all above the flood line; the three ancient cities use street networks to become the main flood discharge channels through open channels and culverts to discharge floods to external natural water bodies; at the same time, reservoirs have multiple uses, providing both domestic water and combining with farmland water conservancy.

The results of this study propose a modern mountain city flood and rainwater management planning system, covering three dimensions: blocking external water, draining internal water, and regulating rainwater. Blocking external water focuses on the geographical location of the city, scientifically selecting sites, and avoiding urban

construction in areas below the flood discharge level; draining internal water should give full play to the multifunctional benefits of flood control projects such as regulating and balancing water systems and reducing flood peaks. Regulating rainwater means organically combining urban water systems with farmland water systems, establishing a recyclable and integrated water circulation system, making full use of water resources, and advocating "multiple uses of water".

Keywords

Flooding control, Mountain city construction, Water system construction, GIS.

1. Introduction

In recent years, many mountainous cities around the world have suffered major floods. These floods have resulted in loss of life, property damage and long-term environmental damage (Noji and Lee, 2005). Due to their unique topography, mountain cities are more vulnerable to flooding than plains cities. These cities are often located in areas with steep topography and abrupt elevation changes (Weingartner, Barben and Spreafico, 2003). These features increase surface runoff during heavy rains. Water flows faster, and slopes and valleys channel it into powerful floods that damage infrastructure and communities. Landslides and mudslides often follow, exacerbating the damage caused by flooding (Stoffel, Wyżga and Marston, 2016).

Drainage systems and roads in mountainous cities often fail during heavy rains. These systems are unable to handle large amounts of water, leading to infrastructure damage and traffic disruption (Leszek et al., 2024). Topographical constraints also make it difficult to construct large drainage systems. This reduces drainage capacity and leads to frequent flooding in low-lying areas. Floods inundate roads, houses and public facilities, threatening the safety and livelihoods of residents.In 2014, heavy rainfall in Hiroshima Prefecture, Japan, led to widespread flooding and mudslides. The city's mountainous terrain and rugged rivers exacerbate disaster risk. The local government constructed disaster prevention facilities and focused on vegetation restoration to reduce risk.

In 2018, Belluno in northern Italy suffered severe flooding following heavy rains. The floods damaged roads and power lines, isolating the community from the outside world and causing significant damage. Large numbers of trees were washed away and sediment clogged the rivers, adding to the environmental damage. 2022 Floods in Pakistan's Swat River basin caused extensive damage. The valley's steep slopes and sparse vegetation allowed the floodwaters to flow rapidly, destroying buildings, infrastructure and farmland. More than a million people were left homeless (UN, 2023).

In summary, flood disasters in mountainous cities have multifaceted impacts, causing widespread and deep-seated damage to infrastructure, residents' lives, and the ecological environment. To address these challenges, mountainous cities urgently need to explore effective flood prevention and management measures to enhance resilience and adaptability in the face of floods. This paper aims to provide a perspective on ancient wisdom in preventing and controlling mountain torrents. Taking Huizhou as an example, we learn from the good disaster prevention awareness and historical experience of successful mountain torrent control and propose a modern mountain city flood and rainwater management planning system.

This paper is organized into five sections. Following this introduction is a literature review that examines theories and models related to flood prevention in mountainous cities, summarizes past experiences, identifies research gaps, and introduces three specific case study cities: Hongcun, Jixi, and Chengkan. The second section details the research methodology, which uses GIS technology to analyze water system data

from hundreds of cities in the Huizhou region and assesses the water systems and circulation of the three ancient cities to understand site selection and flood engineering principles in mountainous areas. The third section presents research findings, including geographic information on topography and rainfall in the Huizhou area and flood risk analysis maps for the case study cities. This is followed by the discussion section, which connects findings to the literature review, elaborates on major discoveries, and proposes recommendations for flood prevention in mountainous cities. The paper concludes with a summary of key points.

2. Literature review

2.1. Progress in Sustainable Research on Flash Floods in the World

Globally, flood control construction in mountainous cities has received widespread attention from various countries and organizations. As early as 1964, the European Forestry Commission of the United Nations Food and Agriculture Organization (FAO) established a Working Party on Mountain Watershed Management, which regularly hosts the “Mountain Disaster Prevention Conference” in Austria. This conference primarily serves as a forum for European countries to exchange experiences on managing mountainous torrents (European Forestry Commission Working Party, 2023).

In 1885, the Mississippi River Commission in the United States implemented a "levees-only" policy, based on the theory that building levees would force floodwaters to scour the riverbed, deepening the channel sufficiently to carry floodwaters directly to the sea. Proposals for artificial reservoirs, drainage outlets, and spillways were repeatedly rejected. Over the next 40 years, the commission adhered strictly to this policy, refusing to build any artificial drainage outlets and actively closing many of the river’s natural outlets. This “levees-only” approach, which resisted using flood reservoirs, channelization, and retention areas, remained the main flood control policy until the Great Mississippi Flood of 1927. The disaster significantly changed the U.S. government’s perspective on relying solely on levee systems (American Experience, n.d.).

In Asia, Japan introduced a new policy titled “Resilience and Sustainability in River Basin Management through Community Participation.” This policy adopts a comprehensive approach that includes flood prevention, exposure reduction, proper evacuation, response, and recovery. It aims to enhance disaster resilience and sustainability through the collaborative efforts of all stakeholders (Toshio, 2021). In Russia, flood management in mountainous regions focuses on prevention and soil erosion control, emphasizing non-structural engineering measures. This approach advocates the use of biotechnological methods for river management (Perov et al., 2017).

Research on urban flood management in mountainous areas has expanded in recent years. During the Italian Renaissance, Leonardo da Vinci suggested the use of a network of open channels and culverts in streets and alleys to prevent standing water and litter. In modern times, researchers such as Faryad Ebrahimi, Atabak Feizi and Taher Baher Talari (2022) applied advanced tools to study urban flooding. They used SWMM software to identify flood-prone channels and areas in Ardabil, a mountainous city in Iran, while evaluating the use of Low Impact Development (LID) techniques to reduce flooding in cities such as Ardabil.

2.2 Progress in Mountain Flood Prevention Research in China

The increased frequency of extreme weather events, the increased risk of flash floods in mountainous areas, and the critical importance of effective flood management to combat climate change and promote sustainable development have attracted great attention from Chinese scholars.

In 2004, Wang Senqiang's book Hongcun Water Veins explored the evolution, structure and human-water relationship of the ancient water system in Hongcun. The village's strategic layout followed natural topography and water flow, improving the environment and demonstrating a harmonious relationship with water.

Modern research has explored innovative approaches to urban flood protection in mountainous areas.2021 Wang Guangpeng and colleagues used Fuzzy Hierarchical Hierarchy Analysis (FAHP) and Geographic Information Systems (GIS) to assess the flood risk of a metro system under subsidence conditions. They found that ground subsidence has a significant effect on the flood risk of the metro. The researchers recommended measures such as raising station entrances, installing waterproof barriers and adding flood gates to reduce future flooding. This study is particularly relevant to the Beijing metro system and provides a theoretical basis for flood risk assessment in other cities.

2.3 Flood Control in Ancient Chinese Mountain Cities

Historically, many mountainous cities in China have developed unique water systems to cope with flooding. Cities such as Pinggiantai and Chang'an successfully coexisted with water, and their achievements in urban and water conservation are still relevant today. These historical practices provide valuable lessons for modern urban planning.

In Pinggongdae, the inhabitants built a ‘triple flood defence’ system. They built dykes and flood walls around the city to keep out external floodwaters. In addition, they developed an internal drainage network to channel rainwater away from the city through outfalls. They also raised the foundations of important buildings such as granaries to protect them from flooding (Li, 2023).

In the Huizhou region, ancient mountainous cities demonstrated a deep understanding of flood prevention in their urban design and water systems. These cities followed the principle of ‘building for the land and living by the water’. Historic towns such as Jixi, Hongcun and Chengkan integrated flood control with the living environment. Their innovative water systems reflect a harmonious balance between urban life and flood control (Qi, 2015). Studies of ancient water systems in Huizhou have revealed effective water use, flood control and disaster management strategies.

Previous studies have focused on specific regions, often using computational simulations to analyse flood data for individual cities. However, systematic studies covering multiple cities are rare. Wyoming flood management studies usually emphasise the historical context and multifunctionality of ancient hydraulic systems. Future studies could synthesise the flood control practices of individual cities. This approach will deepen the understanding of historical flood management and provide guidance for planning modern mountain cities.

3. Research Methodology

This study adopts a mixed-method approach combining macro-level data analysis and micro-level field investigation, incorporating GIS technology and on-site observations to systematically examine flood prevention practices in Huizhou’s mountainous cities.

- **GIS Data Collection and Watershed Analysis**

The study begins by using GIS technology to collect watershed information from over a hundred mountain cities in the Huizhou region. Through precise spatial mapping and analysis, we positioned and examined the geographical environment and watershed distribution of ancient mountain cities in Huizhou. This data reveals the common principles underlying the geographic placement and water system layout of these cities. GIS technology not only provides detailed data support but also allows for the visualization of urban siting and flood adaptation strategies across different geographical settings, laying a foundation for understanding the overarching characteristics of these mountain cities.

- **Literature Review and Selection of Representative Cases**

Building on previous studies on water systems and flood prevention strategies in Huizhou, a systematic literature review was conducted. From this review, we selected three representative mountain cities—Hongcun, Jixi, and Chengkan—for in-depth analysis. These cities exhibit diverse water system structures and flood control designs within mountainous environments, making them ideal case studies to uncover both the commonalities and differences in flood prevention among mountain cities. Detailed case analysis of these cities provides valuable insights into water system planning in Huizhou, offering practical reference points for other mountainous urban areas.

- **Case Analysis with GIS Technology**

After identifying the three typical mountain cities, we applied GIS technology to conduct detailed analysis of their water and drainage systems. By mapping the distribution of water bodies and the layout of flood control infrastructure in each city, we assessed the level of flood risk and the role of flood prevention facilities within the urban landscape. GIS technology made it possible to visually highlight the effective water management strategies in these cities, providing scientific evidence to support flood prevention design in mountainous urban environments.

- **Field Investigation**

The author conducted field investigations in Hongcun, Jixi, and Chengkan, focusing on residents' attitudes towards rainwater management and their everyday interactions with water. Information was gathered on how residents respond to flood events, as well as how they manage and utilize rainwater in daily life. This phase of the research, through the perspectives of residents, enriched the study by adding insights on flood management practices rooted in daily habits and cultural identity, making the findings more closely aligned with practical realities.

In summary, this study combines macro-level analysis with micro-level investigation to provide a holistic view of flood prevention in mountainous cities in the Huizhou region. From a technical perspective, we explore the principles behind flood management systems, while from a socio-cultural perspective, we examine residents' flood awareness and practices. This approach highlights the uniqueness of Huizhou's water system and flood protection measures, and provides practical suggestions for improving flood protection strategies in other mountain cities.

4. Results and Discussion

An analysis of the ancient mountain city of Huizhou using GIS technology reveals common principles of urban construction and site selection. The analyses focused on urban distribution, slope, topography, water flow and rainfall patterns. A key finding is that many of Huizhou's famous cities and towns were

located at higher elevations to reduce flood risk. This ‘upland siting’ strategy is an important flood prevention measure that allows cities to naturally avoid flood-prone areas (Figures 1 and 2).

The results emphasize the importance of considering the geographical environment scientifically in the initial stages of urban planning. By carefully selecting city locations with a focus on natural defences against floods, the ancient planners of Huizhou managed to mitigate flood risk from the outset. This approach serves as a valuable reference for modern flood prevention in mountainous urban areas, highlighting the role of site elevation and topography as proactive measures against flooding.

Figure 1. Huizhou slop map. Source: Author’s work.

Figure 2. Huizhou elevation map. Source: Author’s work.

On the other hand, situating cities on the elevated edges of basins is one of the most common layout strategies in Huizhou's mountainous urban planning (Figures 3 and 4). Located at the confluence of rivers within mountain basins and valleys, this placement provided villages with ample space for growth and development. The relatively flat basin areas offer extensive catchment areas for water, which fosters the

gradual development of rivers that shape the basins and valleys. Over time, these river systems deposit rich and fertile soil layers in the middle and lower reaches, making the land highly suitable for agriculture.

By selecting high ground along the basin edges, ancient Huizhou settlements could avoid the direct impact of floods while preserving flat and fertile basin plains for farming. This strategic placement allowed for a balance between flood protection and agricultural productivity, demonstrating an adaptive approach that leverages both topography and water management to create sustainable mountain cities.

Based on the literature review and analysis, three ancient mountain cities in Huizhou - Hongcun, Jixi and Chengkan - are selected as representative cases of flood control. As examples of Huizhou mountain cities, these ancient cities reflect the wisdom of the ancients and are compatible with the local topography and climate conditions.

Figure 3. Huizhou water flow map. Source: Author's work.

The ecological wisdom of ancient Huizhou is thus demonstrated as these measures not only improve the convenience of residents' daily lives, but also reduce the risk of flooding. They emphasise the sustainable balance between human and natural environments and provide valuable insights into flood resilience in modern mountain urban planning.

A detailed study of three case cities, Hongcun, Jixi and Chengkan, reveals similarities in their urban and water system designs. Each city was built near a river source with upstream water flowing from a deep valley. Huizhou's ancestors often chose to settle in areas surrounded by mountains and streams, usually locating their villages downstream. The complex mountainous terrain created many tributaries that formed a stable network of rivers that supported agriculture and community life. These downstream areas also provided important natural resources (Yang et al., 2022).

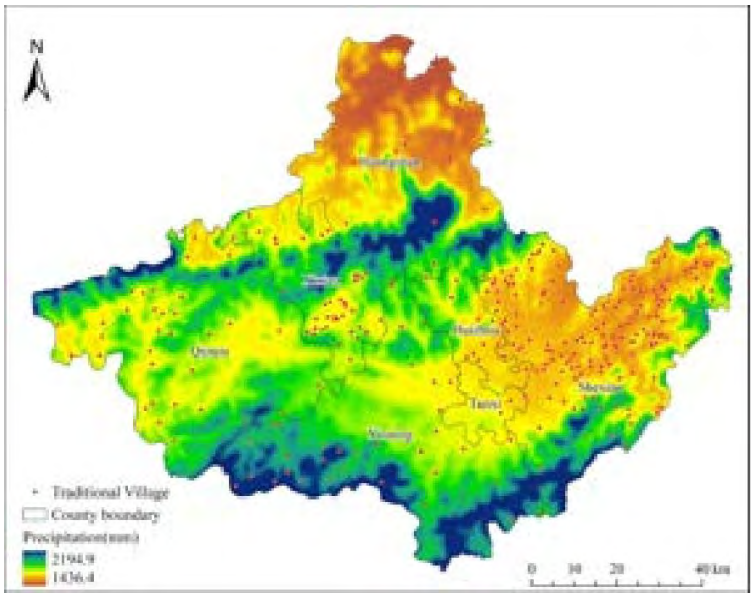


Figure 4. Huizhou precipitation map. Source: Author's work.

Figure 5. Picture of Hongcun, Jixi, Chengkan. Source: Anhui province government, 2019. 'Polar Bears in the Arctic'[Image]. Available： https://www.ah.gov.cn/ [Accessed 13 September 2024].

Using GIS technology to analyse the flood risk levels of these cities, it was found that the risk levels were generally low to medium (Figures 6, 7 and 8), indicating that the integration of water facilities and drainage systems in the road network in Huizhou area has effectively improved the city's flood resilience. At the same time, these designs also balance the efficient use of water resources with the maintenance of regional water ecosystem stability.

In the Huizhou region, the cities of Hongcun, Jixi, and Chengkan have ingeniously integrated their street networks with flood drainage systems. Through the use of both open and underground channels, they effectively direct excess floodwater to external natural bodies of water (Figure 9), creating an efficient urban drainage network. This street-based drainage system not only meets daily water discharge needs but also allows for rapid diversion during flood events, significantly reducing the risk of urban flooding and waterlogging. Furthermore, the reservoir facilities in these cities serve multiple functions; they not only provide a reserve of potable water but also connect to the surrounding agricultural irrigation systems, ensuring the rational allocation of water resources for agriculture.

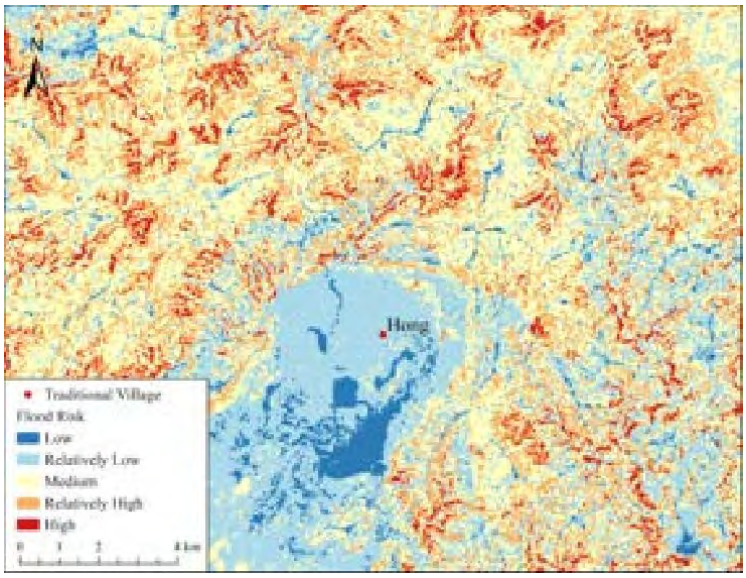


Figure 6. Hongcun Flood Risk map. Source: Author's work.

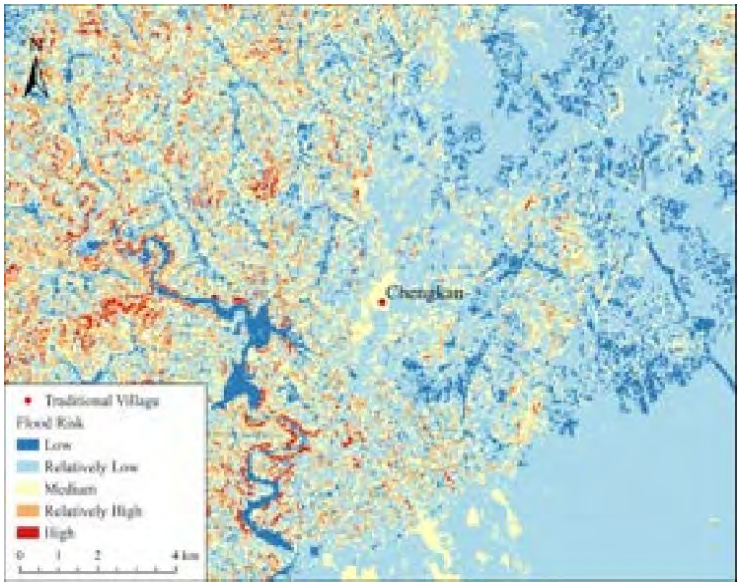


Figure 7. Chengkan Flood Risk map. Source: Author's work.

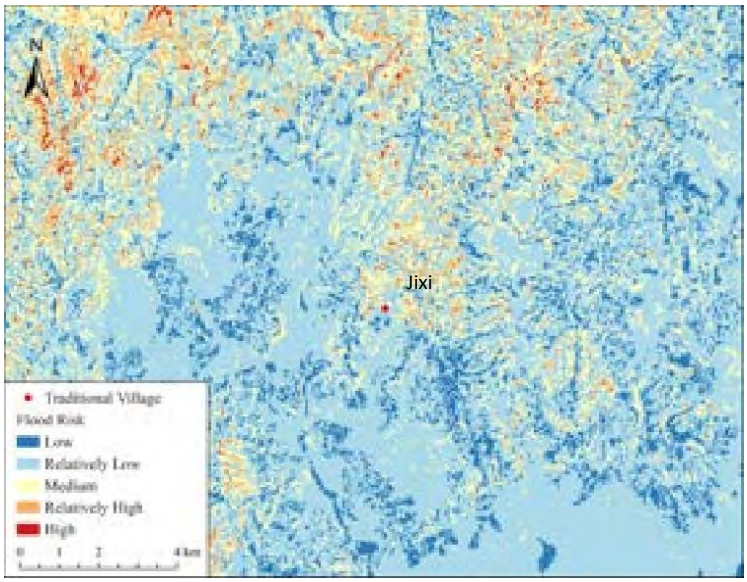


Figure 8. Jixi Flood Risk map. Source: Author's work.

Figure 9. Rainwater management. Source: Li (2013:53) .

5. Conclusion

The aim of this study is to investigate modern stormwater management systems for sustainable mountain cities, focusing on three key aspects: 'external water retention, internal drainage, and stormwater storage and regulation'. This approach aims to address the unique flooding challenges faced by mountain cities.

First, external water storage emphasises the integration of urban geography with hydrological conditions. Cities should be sited to avoid areas of high flood risk, such as areas below the flood discharge level. This proactive approach helps to reduce the threat of flooding and ensure safer urban development.

Secondly, internal drainage management focuses on maximising the use of existing flood protection infrastructure. Flood levels are reduced to protect urban safety by optimising the regulatory balance of the water system. Peak flood pressures are reduced through multi-layered drainage networks and overflow channels.

Finally, the rainwater storage and conditioning component includes collection, storage, conditioning and multiple uses. It contributes to the reduction of urban flooding, improves the management of rainwater resources and promotes water recycling and ecological sustainability.

In summary, the combination of the three water systems management will greatly improve the flood resilience of mountainous cities. It will reduce the disaster risks associated with extreme rainfall events and provide an efficient, green, and sustainable pathway for water environment governance in these

areas, thereby offering robust support for ecological safety and improving living conditions in mountainous urban environments.

6. References

American Experience (no date) The Mississippi River Commission and the Army Corps of Engineers. Available at: https://www.pbs.org/wgbh/americanexperience/features/flood-control/ (Accessed: 22 October 2024).

Anhui province government, 2019. Picture of Hongcun, Jixi, Chengkan. [Image]. Available：https://www.ah.gov.cn/ [Accessed 13 September 2024].

Ebrahimi, F., Feizi, A. and Talari, T.B.(2022)'Investigation of the Potential Threat of Urban Flood at Mountainous Areas through Low Impact Development Techniques (Case Study: Ardabil City)', *Journal of Hydraulic Structures*,8(2), pp. 52-67.

European Forestry Commission Working Party (2023) Working Party on the Management of Mountain Watersheds. Available at: https://www.fao.org/forestry-fao/37705/en/ (Accessed: 20 October 2024).

Leszek, G., Bogusława, B.Z. and Wojciech, Z. (2024) 'Flash Floods Hazard to the Settlement Network versus Land Use Planning (Lublin Upland, East Poland)', *Applied Sciences (Switzerland),* 14(18), pp. 1-23.

Li, P.Y. (2023) The earliest known pottery drainage system in China was unearthed at the Pingliangtai ancient city site, dating back about 4,000 years. Available at: https://www.chinanews.com.cn/cul/2023/08-15/10061281.shtml (Accessed: 20 October 2024).

Li, T.J. (2013) 'Ancient Study on water system construction and flood control design in Huizhou villages and towns', Master thesis. Hefei University of Technology, p. 53.

Noji, E.K., Lee, C.Y. (2005) 'Disaster Preparedness' in Frumkin, H.(ed.) *Environmental health: from global to local*. 1st edn. San Francisco: Jossey-Bass, pp. 745–780.

Perov, V., Chernomorets, S., Budarina, O., Savernyuk, E. and Leontyeva, T.(2017)'Debris flow hazards for mountain regions of Russia: regional features and key events', *Natural Hazards*, 88, pp. 199-235.

Qi, M.N. (2015) 'Enlightenment of water resource utilization in traditional Huizhou villages on modern residential planning', *City Construction*, 5(10), p.1.

Stoffel, M., Wyżga, B., Marston, R.A. (2016) 'Floods in mountain environments: A synthesis', *Geomorphology*,272, pp.1-9.

Toshio, K. (2021) 'Evolution of Japan's flood control planning and policy in response to climate change risks and social changes', *Water policy,* 23 (S1), pp.77–84.

Tullos, D., Byron, E., Galloway,G., Obeysekera, J., Prakash, O. and Sun, Y.H. (2016) 'Review of challenges of and practices for sustainable management of mountain flood hazards', *Natural Hazards*, 83, pp. 1763-1797.

United Nations（2023） Guterres: Pakistan floods a 'litmus test' for climate justice. Available at: https://news.un.org/zh/story/2023/09/1122342 (Accessed: 26 October 2024).

Wang, G.P., Liu, Y., Hu, Z.Y., Zhang, G.M., Liu, J.F., Lv, Y.L., Yu, G., Huang, X.C., Zhang, Q.Y., Liu, L.Y.(2021) 'Flood Risk Assessment of Subway Systems in Metropolitan Areas under Land Subsidence Scenario: A Case Study of Beijing', *Remote Sensing,* 13(4), pp. 1-33.

Wang, S.Q. (2005) *Water vein Hongcun*. Nanjing: Jiangsu Fine Arts Publishing House.

Weingartner, R., Barben, M., Spreafico., M. (2003) 'Floods in mountain areas—an overview based on examples from Switzerland', *Journal of Hydrology*, 282(1-4), pp. 10-24.

Wu, Q.Z. (1995) *Research on Flood Control in Ancient Chinese Cities*. Beijing: China Architecture & Building Press.

Yang, M., Chen, D.K., Shi, L.Y., He, J., Liu, L.Y., Shang, X.Q. (2022) 'How do construct a sponge city that can improve residents' satisfaction? Evidence from a suburb of Huizhou City, China', *Ecological Indicators,* 142, pp.1-17.

Zhao, G., Pang,B., Xu, Z.X., Yue, J.J. and Tu, T.B.(2018)'Mapping flood susceptibility in mountainous areas on a national scale in China', *Science of The Total Environment*, 615, pp.1133-1142.

Research Paper

Green Infrastructures, Monumental and State-Owned Assets: The Role of Tratturi in the Southern Italian Landscape

Francesco ZULLO, Department of Civil, Construction-Architectural and Environmental Engineering – University of L'Aquila, Italy

Annamaria FELLI, Department of Civil, Construction-Architectural and Environmental Engineering – University of L'Aquila, Italy

Chiara CATTANI, Department of Civil, Construction-Architectural and Environmental Engineering – University of L'Aquila, Italy

Abstract

The ancient Tratturi, once crucial for southern Italy's transhumance economy, saw their role diminish by the early 20th century. Today these routes have become important cultural heritage and laid the basis for economic initiatives in slow tourism, especially in lowly developed Apennine regions of Italy. The Tratturi may also serve as green infrastructures, however, the knowledge about their ecological roles and the present condition of these protected lands is minimal. This research deals with the aspects of the ecological dimensions of the main Tratturi network, especially with the importance of the green linkages to the protected areas and the network of the Natura 2000 along the Apennines. Through indicators of anthropogenic disturbance, ecological integrity, habitat quality, and proximity to protected sites, the study evaluates each route's ecological contribution. One of the findings of this study shows that the successful implementation and improvement of Tratturi can become the basis of sustainable development only if eco-tourism and local economies are properly supported. Treating Tratturi as strategic eco-tourism infrastructure can maintain biodiversity and the linking of ecosystems. The present study identifies the activities of conservation and tourism as those which bring to the fore the cultural and natural heritage of the areas, whereas the advised methodology is capable of being a mode of taking care of and running other ecological networks sustainably.

Keywords

Tratturi, Cultural heritage, Sustainable development

1. Introduction

For centuries, the Tratturi (from the medieval Latin *tracturus*, meaning "path" or "ditch")—ancient transhumance routes—have been essential in the economy of southern Italy. These routes served not only transhumance but also as critical connectors for the movement of herds and goods [Zullo, 2023]. Transhumance was a pastoral practice based on the traditional use of natural resources and ecosystem services, marked by seasonal migrations of herds between mountain pastures in summer and plains in winter. This practice shaped and maintained the landscape over centuries [Mastronardi et al., 2021], and it continues to impact the urban structure of the towns it passes through. In Italy, the Tratturi consist of grassy paths that mark the routes used by herds during these seasonal movements [Mastronardi et al.,

2023; Petrocelli, 2011]. These routes formed a network (Figure 1) of main and secondary paths, stretching about 3,000 km through Abruzzo, Molise, and Puglia, with parts in Campania and Basilicata [Mastronardi, 2000; Zullo, 2023]. The main routes had a length of 236 km (*L'Aquila-Foggia*), 207 km (*Pescasseroli-Candela*), 189 km (*Celano-Foggia*), and 35 km (*Lanciano-Cupello*), with a maximum width of about 110 m. The main tracks extended from north to south, while the smaller ones (the so-called *tratturelli* and *bracci*) from east to west, creating a dense network [Cialdea, 2007; Mastronardi et al., 2023]. Today, most of these have disappeared throughout Europe. Many paths have been lost due to agricultural abandonment, natural reforestation, and urbanization. This decline began in XX century, when transhumance began to desappear. For this, the Italian state introduced protective decrees to preserve and reintegrate the Tratturi. Currently, Tratturi lands are protected as monuments under Legislative Decree 42/2004. They are also state-owned, which creates complex management challenges. To date, the lands of the Tratturi are protected by Legislative Decree 42/2004. However, there are some that are also state-owned, creating difficult land management. Various regulations and regional initiatives were amended to relaunch economic and tourist development by enhancing the archaeological, cultural, environmental, and landscape value of the Tratturi. However, the landscapes linked to these routes have changed significantly [Mastronardi et al., 2023]. In 2019, UNESCO recognized transhumance as an intangible cultural heritage [UNESCO, 2019]. This recognition underlines the importance of these routes for both local culture and global heritage. Recently, initiatives have been intended at restoring and promoting the Tratturi for local economic growth, for example through slow tourism. Although national regulations recognize the cultural and historical value of the Tratturi, their ecological importance remains little studied. This study introduces a methodology to evaluate whether the Tratturi, given the current anthropogenic pressures and their geographical conformation, can function as ecological connectors. The analysis includes their link to protected areas, current land cover and levels of surrounding land degradation, using indicator engineering techniques developed for this purpose.

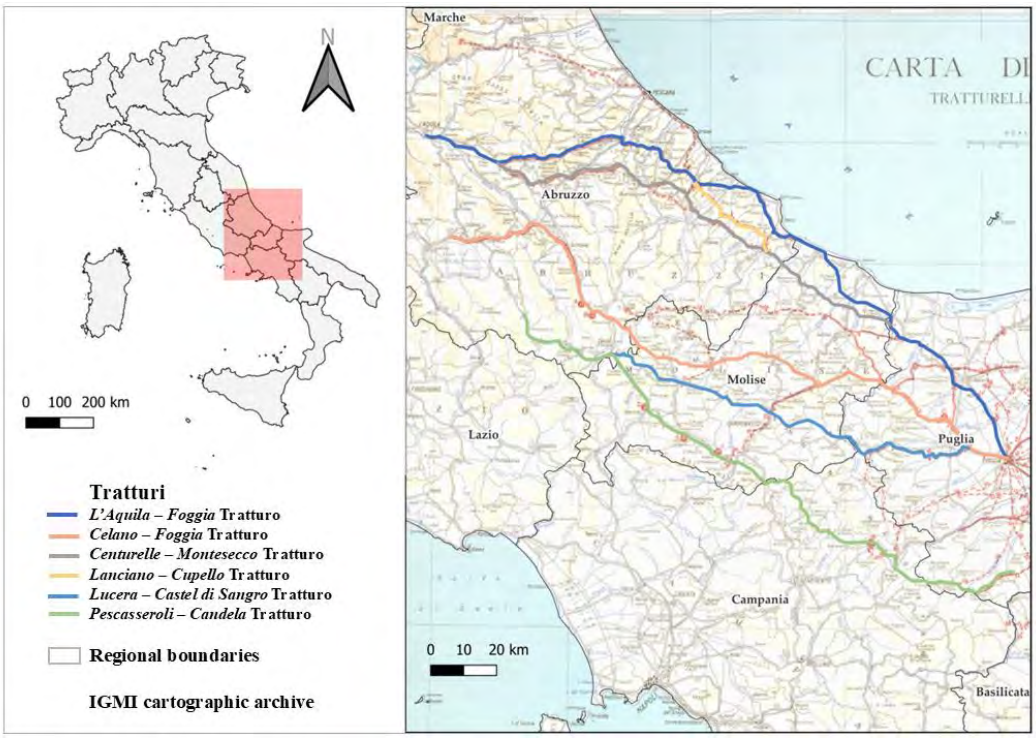


Figure 1. Map of the Tratturi. Source: IGMI cartographic archive and authors' elaboration.

2. Study background

2.1 Historical Evolution and Current State of the Tratturi

The Tratturi have been important for the culture of local communities and for the landscapes that have characterized the regions of southern Italy for centuries, in particular Abruzzo [Staffa, 2020; Violante, 2016]. When transhumance declined in the early 1800s, people began to use these lands for agriculture, and later urbanization began near populated areas. This trend was strong in regions like Abruzzo, where development pressures starting in the 1950s significantly changed the Tratturi landscape [Zullo et. al., 2024]. Figure 2 shows the historical evolution of the Tratturi.

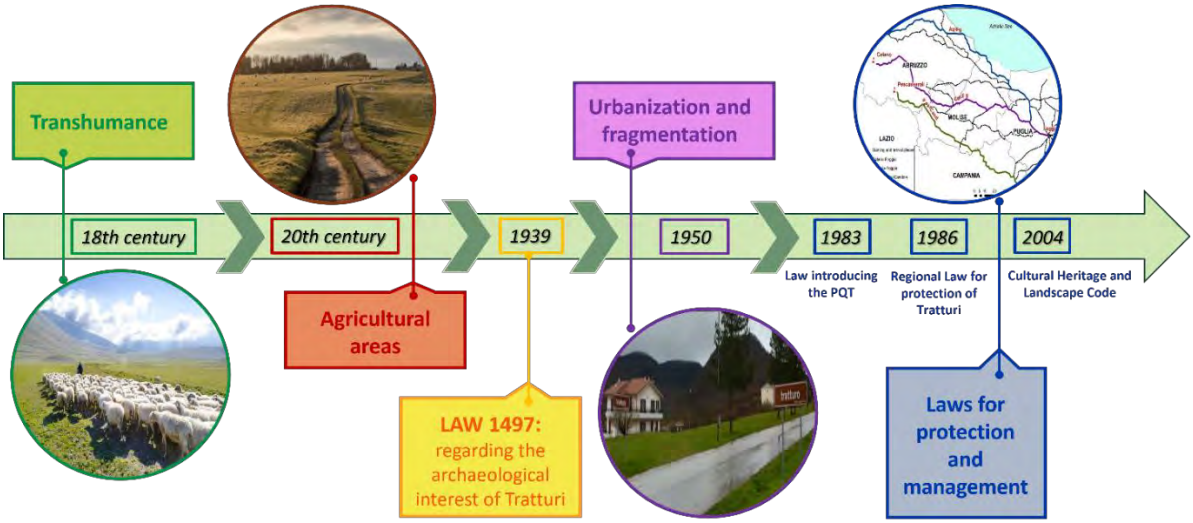


Figure 2. Historical evolution of the Tratturi. Source: Authors' elaboration.

Until the 18th century, laws protected transit and grazing rights to support the economic importance of sheep farming. However, by the end of the century, regulations allowed for different uses, such as agriculture, leading many minor Tratturi to be converted into roads in response to increasing demand for land [Mastronardi et al., 2021]. As a result, significant portions of Tratturi were sold, especially in Abruzzo and Puglia. In the early 20th century, only the main Tratturi (L'Aquila-Foggia, Celano-Foggia, Pescasseroli-Candela) remained available for herding and grazing, while others were sold or converted to agricultural use. To protect the routes from uncontrolled urbanization, Italy approved the Bottai Law (Law 1089/39) in 1939, recognizing the Tratturi as archaeological assets, declaring them inalienable for their cultural value [Meini et. al., 2014; Minotti et. al., 2018; Pellicano et. al., 2008; Pierucci, 1988; Zullo, 2023]. Since then, the Tratturi have had a dual role as both state-owned and archaeological assets, which creates difficulties to their management and protection [Cazzani et. al., 2021; Centofanti et. al., 2008]. In the 1970s, the responsibility for managing these state-owned assets was passed to the regions, while the Ministry for Cultural Heritage and local Superintendencies retained authority over preservation and acceptable uses. The building boom throughout Italy was also reflected on the land of the Tratturi, causing a considerable loss of soil and impact on the surrounding landscape. To protect the Tratturi, Molise (in 1976) and Abruzzo (with the Ministerial Decree of March 1980) have introduced a new planning tool, the Tratturi Framework Plan (PQT). This tool is mandatory for municipalities crossed by Tratturi, yet about 50% of Abruzzo's municipalities have not yet implemented it. The creation of the knowledge framework necessary for the FPT is complex: this creates technical and administrative challenges in verifying building titles and prior land sales. Over time, various regional laws and broader projects have leveraged the identity that Tratturi create for local communities and landscapes, aiming to revitalize these areas and bring renewed economic activity to the regions they cross. Walking routes and slow tourism are some of the main themes

promoted by these initiatives. Recently, however, projects like the one in Molise have also highlighted the ecological role Tratturi could play as potential connectors between areas with different levels of natural preservation. While the historical, cultural, and archaeological value of Tratturi is widely recognized and supported by various national and regional laws, the idea of their role as ecological corridors still requires extensive evidence and scientific support.

2.2. The Ecological and Cultural Role of the Tratturi

The cultural role is clear. Ecosystems, ecosystem services, and ecological networks are key aspects to be assessed, requiring specific data and verifications. The ecological role of the Tratturi depends on different factors such as their proximity to protected areas, the degree of soil sealing and the ecosystem services they provide. Each Tratturo has unique characteristics that vary from region to region but also from municipality to municipality and therefore must be evaluated individually. The morphology of the territory and the proximity to the various urban centers has played an important role to define the future of these lands. Often, areas adjacent to major urban centers or settlements encouraged urban expansion over Tratturi, while segments passing through the internal Apennine areas experienced a return to nature, with landscapes transformed by natural vegetation development. Recent studies [D'Ottavio et. al., 2016; Mastronardi et al., 2021; Plieninger et al., 2016; Rivieccio et al., 2017; Sallustio et al., 2018] on the ecological potential of these paths show that while some cross areas with ecological value, others are heavily urbanized, with disturbance levels making ecological connectivity challenging. In Abruzzo, for example, only a limited portion of the Tratturi crosses protected areas or Natura 2000 sites, and human disturbance levels vary significantly (Figure 3).

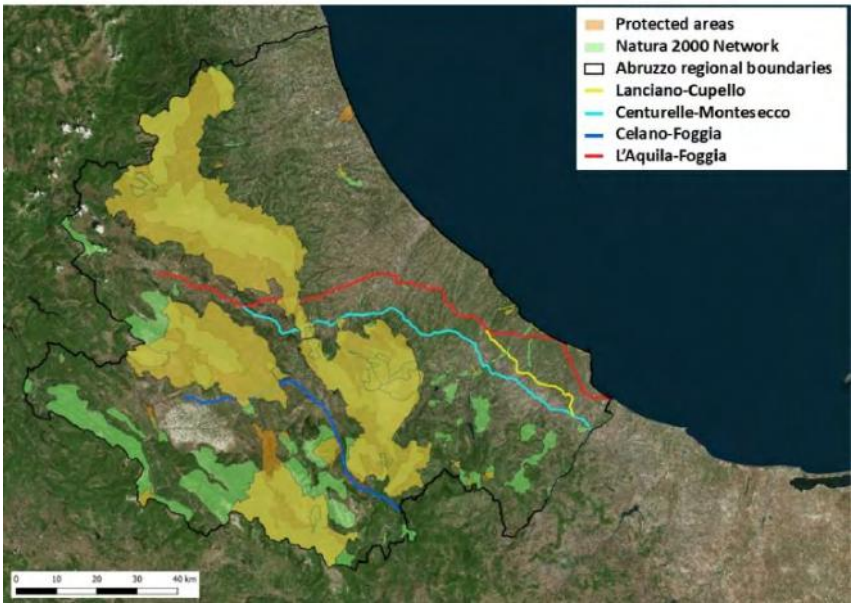


Figure 3. Map of Protected areas, Natura 2000 Network and the Tratturi in Abruzzo. Source: Zullo, 2023.

Infrastructure and urbanization have compromised much of their ecological integrity, making policies and interventions on these issues more difficult [Zullo et al., 2022; Zullo et al., 2024]. Urban sprawl [Romano et al., 2017] and intensive agriculture [Van Vliet et al., 2015] were the main factors that transformed the landscape, also influenced by demographic dynamics [Dupras et al., 2015]. In addition, political, institutional and cultural factors, together with agricultural policies, have had a strong impact on changes in land use [Mastronardi et al., 2021; Plieninger et al., 2016]. In Italy, recent phenomena include the abandonment of agricultural areas, with consequent forest expansion and natural regrowth in marginal

areas, and the urbanization of plains, coasts and easily accessible areas [Mastronardi et al., 2021; Sallustio et al., 2018]. Intensive agriculture, with the conversion of pastures to intensive crops such as cereals, has reduced natural habitats. Hedgerows were eliminated and the use of fertilizers and pesticides increased. This has led to a decline in the cultural ecosystem services needed to improve the Tratturi [Schirpke et al., 2013], especially in favorable agricultural areas [Pinto-Correia and Kristensen, 2013]. This intensification has led to strong land use [Rivieccio et al., 2017] and the homogenization of landscapes, with the loss and fragmentation of natural areas [Pinto-Correia et al., 2006]. Meanwhile, urbanization has damaged ecosystems and landscape sustainability [Brunori et al., 2016], creating landscapes with simplified forms and functions [Romano et al., 2017]. Today, the condition of Tratturi lands is highly complex and varied. Assigning them an ecological role, as mentioned, requires consideration of multiple significant aspects. Promoting slow tourism and connecting these routes to the paths requires a good knowledge of the territories crossed. Elements such as road crossings, the presence and arrangement of accommodation facilities, integration with other historical-cultural assets, or significant species along the route are essential to establishing such pathways. The same approach applies to their potential as ecological corridors, which necessitates thorough technical evaluations.

3. Methodology

In order to understand the potential of the Tratturi as ecological corridors, it is necessary to analyze a wide range of variables that must be interpreted through different keys and different territorial scales. The first output is the number of municipalities crossed by the Tratturi (Table 1). In Molise, 50% of the municipalities are crossed by these, whereas the final destinations of transhumance activities, Campania and Puglia, have increasingly less Tratturi. The knowledge of Tratturi and protected areas (National Parks, Natura 2000 Network), and the status of land transformation on their trajectories is essential to characterize the current states of Tratturi [Zullo, 2023].

Regions	No. Of Municipalities with Tratturi	Total Municipalities	(%) of municipalities with Tratturi compared to the total number of regional municipalities
Abruzzo	93	305	30,5%
Campania	15	550	2,7%
Molise	57	136	41,9%
Puglia	23	257	8,9%

Table 1. Number of municipalities crossed by the Tratturi. Source: Authors' elaboration.

As visible in Figure 4, the traces of the Tratturi overlap with the system of protected regional areas. These findings highlight how many protected areas and Natura 2000 sites are crossed by the Tratturi, as well as the ecological role of these historic routes as important ecological corridors, albeit varied across the regions of southern Italy. Redirecting now to Abruzzo, the Tratturi cross very significant portions of National Parks and Special Protection Areas, amounting to roughly 73% and 70% of the areas involved, respectively. This makes the value of the Tratturi for the protection of biodiversity in Abruzzo clear. Tratturi are mainly proposed in the Special Areas of Conservation (SCI) areas, a protected status which covers more than 70% of the areas of Molise planned for planting, whereas they are running through the rest of the SACs/SPAs. The role of the Tratturi as ecological corridors is emphasized, given their importance for the conservation of biodiversity and as viable protected areas in an area with limited protected areas such as Puglia and

Campania. This fact shows that these ancient paths are only weakly associated with the protected territories of Puglia and Campania region. The data referring to Abruzzo and Molise presents quite the opposite situation that characterizes The Tratturi, not only cultural and historical roads, but also important green belts for biodiversity and ecological linking of natural spaces. These similarities of interests are strongly expressed in the regions and interest in the prospects of the continuity of the well-known Apennine ecosystems.

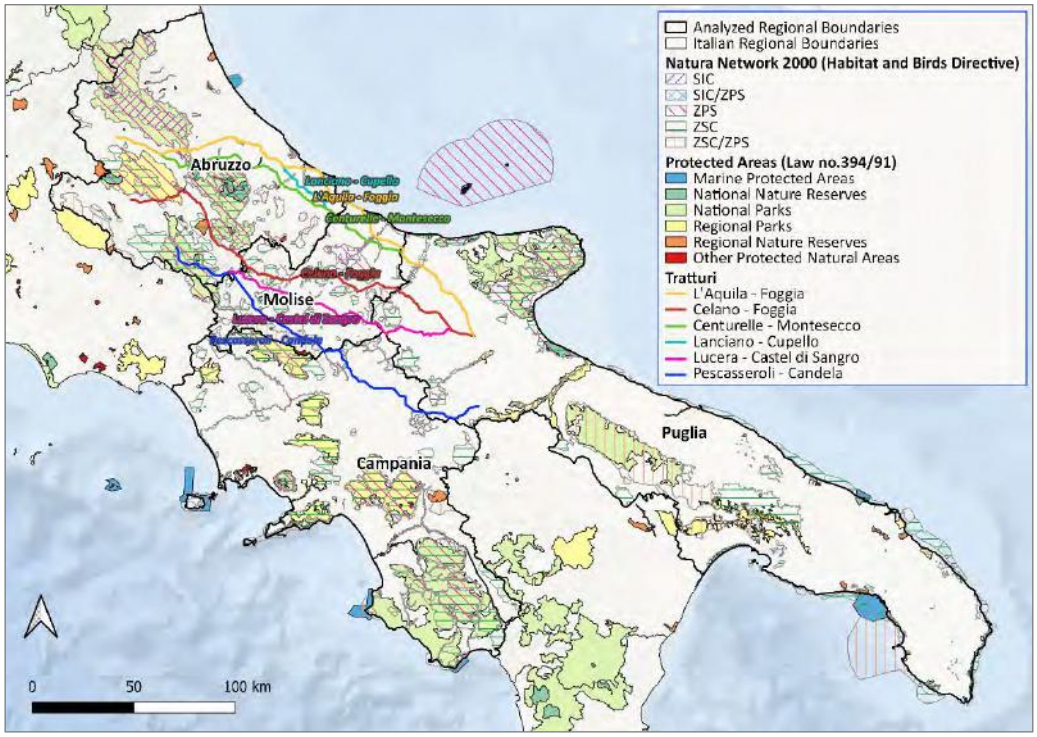


Figure 4. Map of Protected areas, Natura 2000 Network, and the Tratturi in Abruzzo, Campania, Molise, and Puglia. Source: Authors' elaboration.

The analysis can be done using Geographic Information Systems (GIS) based mapping of the areas involved, by sectoring the Tratturi, through defining measures of urban pressure, and by defining the areas of ecological value and connectivity. From 1956 up to 1997 urbanized areas were evaluated using IGMI and regional maps and comparisons were made with current data from the Civil Protection pertaining to building aggregates. The DU (Urbanization Density) indicator indicates the extent to which the urban pattern has compromised or fragmented the original path, deterring the restoration and ecological function of the original path. As illustrated in Fig. 5, the percentage of land use (% DU) adopted along sections of six main Tratturi in southern Italy has been attribtue on a regional basis (Abruzzo, Molise, Campania and Puglia) and two reference years, 1950 and 2000. There are substantial divergences between between the regions which also shows diverse pressure on the land and might influence the ecological and cultural richness of the Tratturi. The DU 50 graph indicates that the distribution of Abruzzo and Molise is fairly similar in terms of land uses in almost all Tratturi, with spikes of approximately 1.5–2%. On the contrary, Campania records lower values, except for the Regio Tratturo Pescasseroli-Candela that wins around 1%. Puglia maintains low percentages in this period, with the exception of the Regio Tratturo Pescasseroli-Candela where it exceeds 2%, which is already an index of growing pressure. What did change was the DU 2000 desk and other sources what also brought large land use percentage numbers especially

in Puglia. Specifically, in Puglia, the contents of the Aquila-Foggia, Celano-Foggia, Lanciano-Cupello, and Pescasseroli-Candela Tratturi are greater than those of DU 50, exceeding even 10%. Notably, Abruzzo and Molise maintain their high percentages, especially for the Aquila-Foggia, Celano-Foggia and Centurelle-Montesecco Tratturi, while Campania is marginal, excepted for a few routes such as the Pescasseroli-Candela Tratturo. At the same time, these data also show a significant increase in land use along the Tratturi in the regions of Abruzzo, Molise, and Puglia, with more than 4% increase of DU 2000 along the Tratturi axis. This trend might suggest more anthropogenic and urban pressure that might impact the ecological function and historical value of these ancient routes. Indeed, with reference to Puglia, such growth data from DU 2000 may reveal important variations in territory-dynamics, of significance with respect to conservation of the Tratturi and development of soft tourism, ecological connectivity and sustainability. In summary, the analysis of the land use along the Tratturi in the studied areas highlights the different levels of the territorial pressure between the three regions, where Abruzzo, Molise and Puglia find the highest values of pressure. This trend emphasizes the need for specific planning interventions aimed at the conservation of the ecological and historical-genetic sensibility of the Tratturi, with particular regard to the heaviest territorial pressure regions.

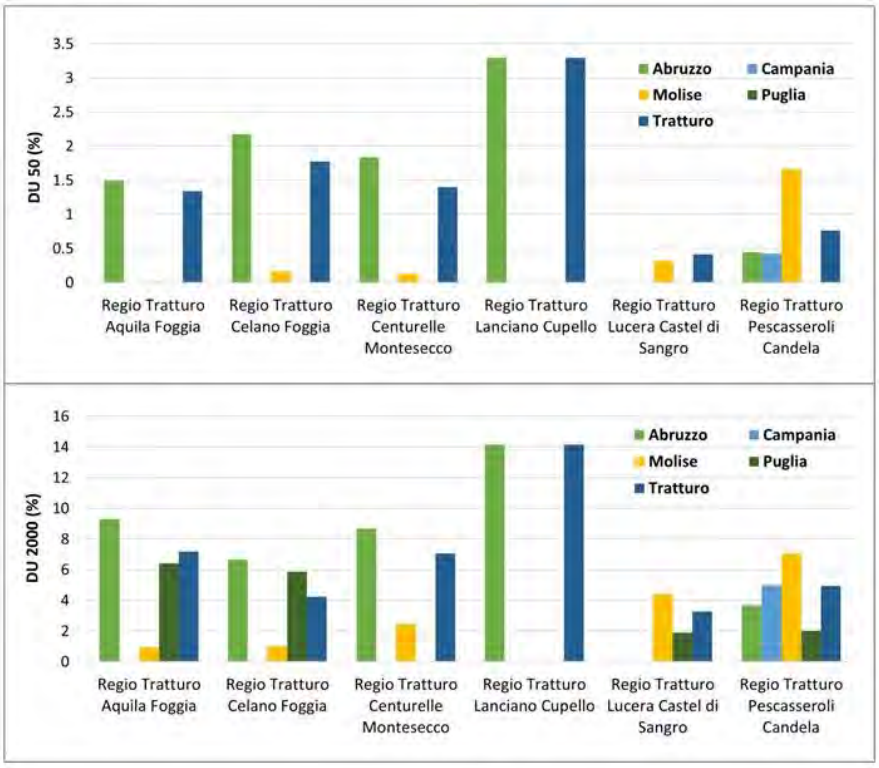


Figure 5. Urbanization Density (%) in 1950 and 2000. Source: Authors' elaboration.

The system density (DIn) gives an idea of how much infrastructure in relation to the reference area [Zullo, 2023]. For the calculation, Open Street Map (OSM) serves as the database, as it delivers more complete data compared to aggregates of regional sources, including service roads and agricultural access roads. DIn is therefore an useful metric for quantifying the fragmentation in an ecological graph and to locate those novelties to tackle measures for connectivity improvement. Recent infrastructures have cut to pieces the Tratturi, limiting their efficiency as biodiversity corridors or tourist routes. Figure 6 presents the kilometers of different infrastructure types along six major Tratturi in southern Italy,

offering understandings about the level and nature of development across the regions.

	Infrastractures (km)									
	Highway	*State road*	*Railways*	*Roads in residential areas*	*Regional and provincial roads*	*Service roads*	*Municipal roads*	*Roads for agricultural areas*	*Unclassified roads*	*Total*
Regio Tratturo Aquila Foggia	9.02	48.39	11.13	25.97	27.47	35.81	67.81	60.69	31.86	318.15
Regio Tratturo Celano Foggia	6.09	19.86	4.61	10.84	18.27	19.24	20.30	68.20	25.84	193.24
Regio Tratturo Centurelle Montesecco	0.48	7.31	0.44	14.68	5.41	10.31	30.88	38.81	23.77	132.09
Regio Tratturo Lanciano Cupello	0.10	0.00	0.15	5.66	2.42	4.57	14.49	8.63	7.03	43.05
Regio Tratturo Lucera Castel di Sangro	2.77	7.41	0.34	6.16	5.15	3.90	10.86	52.75	7.44	96.78
Regio Tratturo Pescasseroli Candela	3.38	11.55	1.60	7.31	2.32	9.64	13.16	26.87	21.24	97.06

Figure 6. Infrastructure Endowment Index in the Tratturi. Source: Authors' elaboration.

The Regio Tratturo Aquila-Foggia, Celano-Foggia, Centurelle-Montesecco, Lanciano-Cupello, Lucera-Castel di Sangro and Pescasseroli-Candela are among the Tratturi listed. The Aquila-Foggia and Celano-Foggia sheep tracks have a higher infrastructural diversification than the others, with abundant presence of state, municipal and agricultural roads. This structure shows a higher level of urbanization and good integration with regional networks promoting access locally and in rural zones. The latter, however, are mainly composed of agricultural and unclassified roads, with a low degree of urbanization. That configurational preservation might reflect a preservation of the historical and rural character of these areas. Lastly, the Lanciano-Cupello Tratturo, the one having the least infrastructural development overall, widespread municipal and agricultural roads, due to the few regional interconnections. Contrasting with this, less completed tratto, as Lucera-Castel di Sangro, Pescasseroli-Candela and Lanciano-Cupello, have retained a mostly rural function that to preserve in the territory cultural and environmental backgrounds. This analysis reveals significant variations in the distribution of infrastructure across the Tratturi which correspond to their differing functions. Tratturi where this percentage is higher (e.g., Aquila-Foggia and Celano-Foggia) could thus be important arteries for local communities, as well as for agricultural carrying on, thus more easily in sight of urban development pressures. Dotted around the Tratturi with its vast stretch of roads or minor unclassified roads like the Lanciano-Cupello that benefit from a conservation standpoint has remained a better choice from an ecological and historical point of view. As– related information provides the bases of developing sustainable development and conservation strategies for the respective regions. This implies that for lesser developed tracts of Tratturi, focus would lie with each regional plannner ensuring ecological continuities and protection of culture, should any development be allowed while the opposite would apply to highly developed areas. Urban proximity and degree of urbanization will need to be analyzed and factored into determining ecological quality of these lands. Land of finale: Since Tratturi enters into a buffer zone here, the description can help spatial analyse when compared with adjoining urban settlements. Upon this foundation, it becomes possible to consider some parameters intended to imposed as regards whether Tratturo continues to practice ecological asset in its primary function, that being the reduction of pollution, increase of biodiversity and so on and so forth. This provides an analysis that helps identify what sections still provide these and what is impacted by built environments and urban planning. Abounding ecological sustainability of Tratturi regions, the methodology contributes to decision making processes for Tratturi protection, protection and enhancement. This is still a nascent process, but it will be crucial in grasping the spatial and ecological significance of the routes.

4. Revitalizing Tratturi: Challenges and Opportunities

The lack of resources and infrastructure along the Tratturi does not allow these paths to be simply transformed into green infrastructures for tourism and ecosystems. Many of these paths cross economically and demographically disadvantaged areas in the Italian Apennines, where local administrations often lack the funding to invest in tourism infrastructure or ecological restoration. Slow tourism, however, offers a good approach to encourage the rediscovery of these places, creating local economies by initiating positive cycles [Fistola et. al., 2018; Gaeta et. al., 2019]. The "La via del Tratturo" project in Abruzzo and Molise [La Via del Tratturo, 2020], which spans 112 kilometers across six stages, shows how Tratturi can support trekking and experiential tourism. With this route, people can renew their bond with the land and its cultural and natural heritage, making the most out of the ecosystem services. A master plan for the restoration of the Molise Tratturi was introduced in Molise in March of 2024. This plan focuses on revitalizing historical transhumance routes by integrating them with the cultural and tourism landscape of Molise's historic villages. The main goal is to bring these paths back to life, increasing their accessibility, but also, by coiling history into a spiral, showing village connections, and turning the Tratturi into biodiverse and ecologically competitive corridors. This approach creates local synergies that are important for the regional economy and the infrastructure that declines each year. The policies that are in line with the necessities of the region are the key to success in implementing projects like the Special Territorial Plans. These ancient itineraries require a comprehensive network of strenuous trails, as well as basic services, such as parking, the latter of which is vital to the tourism industry and the local economy in general. In the aftermath of these consequences, it is evident that the current initiatives reach only the local level which in turn leads to the non-fulfillment of the projects. The communities concerning the local Superintendencies are more secure and can render appropriate infrastructure for the implementation of projects because they have a good history and a detailed survey of the routes. One of the most apparent goals of these projects is to have an up-to-date mapping of the paths to make the project planning phase easier and already a map [Ulisse et.al., 2024].

5. Conclusions

The Tratturi in Southern Italy at the moment are on the crucial cusp of a turning point. These ancient roads, whose past existence was of great importance for the transhumant movement and the local economy, are now being transformed into green infrastructures with the ability to accelerate long-term sustainability in these rural areas. Though, to maximize their role as important ecological corridors, as well as the resources which can be derived from them as objects of cultural and tourism, a few major issues need to be resolved: information voids, infrastructure deficiencies, unproductive territorial management, and lack of attention from the local planning authorities. The work presented here indicates that the identification of an ecological function for the Tratturi and the development of slow tourism require targeted action laid down at the regional or Tratturi-wide scale, complemented by science-based and numerical data. The survey reveals that biodiversity conservation and the economic potential go hand in hand with the proper use of technology. Their ability to protect biodiversity and bring about sustainable economic growth depends on integrated planning and using new tools and techniques for effective monitoring and control activities. Adding the Tratturi to slow channels of mobility provides one avenue to conserve and develop cultural and natural heritage but entails a full understanding of their present state and related problems. Accurate and up-to-date data are the key components of sustainable interventions that retain the intrinsic value of these landscapes. In short, Tratturi conservation is an emerging sector but still affected by social (especially economic) processes and policies, requiring tailored interventions according to land use and the morphological nature of routes (Fig. 1; Table 4). Without a corridor through degraded areas they will be lost to the urban environment, so this is critically important. Intensive farming [where the same product is

grown in cycles, or multiple crops are grown on the same piece of land] is exacerbated by the regular hype of economies to re-encourage the farm owners, more than is required, further stressing them, while to help the case of the same will be more than businesses often resetting for growing crops and joining the local tourism sector. The good policies should be in the spirit of their initial intent, that is, the rehabilitation of old unspoiled tracks and the viability of compatible uses. The first step to take is an action plan established jointly with a local authority, a number of volunteers, farmers and a land management program. Through joint management mode of the reclaimed lands apprenticeships of the workers, identification with local cultural environment, the promotion of local tradition and sustainable development of the rural localities is as follows. On the other hand, the recognition of Transhumance as a World Intangible Cultural Heritage by UNESCO makes it not only historically relevant, and significant, but also from the point of view of local and international development. Only in this way, it will be possible to ensure a sustainable recovery of the economy of the entire area, involving local authorities, tour operators, and environmental institutions as a key element of the synergistic and multidisciplinary approach adopted. The Tratturi are state-managed archaeological assets of primary and extraordinary importance. However, the situation is difficult since many Municipalities in the area do not have the specific master plans of their Tratturi networks (PQT) while many of them have not organized their GIS rooms for relative access. The 1983 decree was approved which added the obligation of drafting PQT but did not specify any deadline, so many towns and cities, however continuous their demands for these plans, have been and remain behind. The delay originated from this and also from the transparent procedure that does not respect the regulation and created in this way many administrative problems and consequently it did not allow the proper evaluation of the condition of the land of the Tratturi. To improve management, it should be make an integrated SIT with the Territorial Information System to make the processing of permits and planning clearer and efficiency of the management and many of these processes should be online. The PQTs will have to be digitized, and all the municipalities will have to have the software to do that.

1. References

Brunori, G., Galli, F., Barjolle, D., Van Broekhuizen, R., Colombo, L., Giampietro, M., ... & Touzard, J. M. (2016). *Are local food chains more sustainable than global food chains? Considerations for assessment.* Sustainability, 8(5), p. 449.

Cazzani, A., Boriani, M. (2021). *The Role of Historic Roads to Preserve and Valorize the Landscape*. In: Pileri, P., Moscarelli, R. (eds) Cycling & Walking for Regional Development. Research for Development. Springer, Cham, pp. 85-103.

Centofanti M., Brusaporci S., (2008), *Topos/Antropos – Le vie della transumanza e il sistema insediativo storico nel territorio tra il Gran Sasso ed il Sirente*. In Atti del convegno Le Vie dei Mercanti – Rappresentare il Mediterraneo, La scuola di Pitagora, Napoli, pp. 495-500.

Cialdea, D. (2007). *Le tipologie di coinvolgimento del territorio intorno al tratturo Pescasseroli-Candela*. In Il Molise terra di transito. I Tratturi come modello di sviluppo del territorio. ArtiGraficheLaregione, pp. 51-107.

D'Ottavio, P., Francioni, M., Trozzo, L., Sedic, E., Budimir, K., Avanzolini, P., ... & Toderi, M. (2016). *Methods and approaches used for assessing ecosystem services provided by grazing systems*. OPTIONS, 51.

Dupras, J., & Alam, M. (2015). *Urban sprawl and ecosystem services: A half century perspective in the Montreal area (Quebec, Canada).* Journal of environmental policy & planning, *17*(2), pp. 180-200.

Fistola, R., La Rocca, R. A. (2018). *Slow mobility and cultural tourism. Walking on historical paths*. Smart planning: sustainability and mobility in the age of change, pp. 301-322.

Gaeta, L., Curci, F. (2019). *Prospettive di recupero della transumanza e dei percorsi tratturali nell'Italia meridionale*. In Atti della XXI Conferenza Nazionale SIU. CONFINI, MOVIMENTI, LUOGHI. Politiche e progetti per città e territori in transizione, Firenze 6-8 giugno 2018, Planum Publisher, pp. 25-31.

LA VIA DEL TRATTURO. https://viadeltratturo.it/ Accessed 12 Feb 2022

Mastronardi, L. (2020) *Tratturi, luoghi della transumanza e sviluppo locale*. Fondazione Architetti Chieti-Pescara (a cura di), Un paesaggio senza confini: il tratturo. Atti di Seminari di Studi e Catalogo della Mostra itinerante, Edizioni Menabò, Ortona, pp. 62-66

Mastronardi, L., Cavallo, A., Romagnoli, L. (2023). *A new governance model for the conservation and enhancement of Italian ancient transhumance routes*. Journal of Environmental Management, Volume 341, 118086, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2023.118086.

Mastronardi, L., Giannelli, A., Romagnoli, L. (2021). Detecting the land use of ancient transhumance routes (Tratturi) and their potential for Italian inner areas' growth. Land Use Policy

Meini, M., Adducchio, D., Ciliberti, D., Di Felice, G., (2014). *Landscape conservation and valorization by satellite imagery and historic maps. The case of Italian transhumance routes*. European Journal of Remote Sensing 47, pp. 375–387.

Minotti, M., Giancola, C., Di Marzio, P., & Di Martino, P. (2018). *Land use dynamics of drove roads: The case of tratturo castel di Sangro-Lucera (Molise, Italy)*. Land, 7(1), 3.

Pellicano, A. (2007). *Geografia e storia dei tratturi del Mezzogiorno: ipotesi di recupero funzionale di una risorsa antica*. Aracne, p. 84.

Pellicano, A., Zarrilli, L. (2008). *I toponimi della transumanza nell'Abruzzo aquilano tra retaggio storico e persistenze socioculturali.* In Toponomastica Italiana. L'eredità Storica e le Nuove Tendenze, Società Geografica Italiana, Roma, pp. 213-231.

Petrocelli, E. (2011). *Itinerari: sulle vie della transumanza: Abruzzo, Molise, Campania, Puglia, Basilicata*. Touring editore.

Pierucci, P. (1988). *Le Doganelle d'Abruzzo: struttura ed evoluzione di un sistema pastorale periferico*. Mélanges de P'école française de Rome - Moyen Age Temps modernes, 100-2, pp. 893-908. DOI: https://doi.org/10.3406/mefr.1988.2994.

Pinto-Correia, T., & Kristensen, L. (2013). *Linking research to practice: The landscape as the basis for integrating social and ecological perspectives of the rural*. Landscape and Urban Planning, 120, pp. 248-256.

Pinto-Correia, T., Gustavsson, R., & Pirnat, J. (2006). *Bridging the gap between centrally defined policies and local decisions–Towards more sensitive and creative rural landscape management*. Landscape ecology, 21, pp. 333-346.

Plieninger, T., Draux, H., Fagerholm, N., Bieling, C., Bürgi, M., Kizos, T., Kuemmerle, T., Primdahl, J., Verburg, P.H. (2016). *The driving forces of landscape change in Europe: A systematic review of the evidence*. Land Use Policy, Volume 57, pp. 204-214.

Plieninger, T., Draux, H., Fagerholm, N., Bieling, C., Bürgi, M., Kizos, T., ... & Verburg, P. H. (2016). *The driving forces of landscape change in Europe: A systematic review of the evidence*. Land use policy, 57, pp. 204-214.

Rivieccio, R., Sallustio, L., Paolanti, M., Vizzarri, M., & Marchetti, M. (2017). *Where land use changes occur: Using soil features to understand the economic trends in agricultural lands.* Sustainability, *9*(1), 78.

Romano, B., Zullo F., Fiorini, L., Ciabò, S., Marucci, A. (2017). *Sprinkling an approach to describe urbanization dynamics in Italy*. Sustainability, 9(1), p. 97

Sallustio, L., Pettenella, D., Merlini, P., Romano, R., Salvati, L., Marchetti, M., Corona, P. (2018). *Assessing the economic marginality of agricultural lands in Italy to support land use planning*. Land Use Policy, Volume 76, pp. 526-534

Schirpke, U., Timmermann, F., Tappeiner, U., & Tasser, E. (2016). Cultural ecosystem services of mountain regions: Modelling the aesthetic value. Ecological indicators, 69, pp. 78-90.

Staffa, A.R., (2020). *La transumanza in Abruzzo fra tarda antichità e medioevo*, PCA - Post Classical Archaologies, 10, pp. 401-448.

Ulisse, C., Fico, R., & Marucci, A. (2024). *Territorial Regeneration in the Crater Municipalities After the Earthquake of L'Aquila: Social Challenges and Innovative Approaches*. In International Conference on Computational Science and Its Applications. Cham: Springer Nature Switzerland, pp. 302-314.

UNESCO. https://www.unesco.it/it/ItaliaNellUnesco/Detail/820, Accessed 22 Mar 2022

Van Vliet, J., de Groot, H. L., Rietveld, P., & Verburg, P. H. (2015). *Manifestations and underlying drivers of agricultural land use change in Europe*. Landscape and Urban Planning, 133, pp. 24-36.

Violante, F. (2016). *Agricoltura e allevamento transumante nella Puglia medievale: alcune osservazioni sul governo della mobilità rurale*. MEFRA: Mélanges de l'École française de Rome: antiquité: 128, 2, pp. 329-340.

Zullo, F. (2023). *La pervasiva diffusione urbana nelle reti della transumanza*. L'Aquila, Aracne.

Zullo, F., Cattani, C., Montaldi, C., & Marziali, E. (2024). *Scenari trasformativi nei contesti ad alto pregio culturale ed ambientale. Analisi lungo le antiche vie della transumanza*. Atti della XXV Conferenza Nazionale SIU "Transizioni, giustizia spaziale e progetto di territorio"

Zullo, F., Cattani, C., Montaldi, C., Di Pietro, G. (2022). ARMENTIS: Abruzzo Region's Management of an Enhanced Tratturi Information System. In: Borgogno-Mondino, E., Zamperlin, P. (eds) Geomatics for Green and Digital Transition. ASITA 2022. Communications in Computer and Information Science, vol 1651. Springer, Cham. https://doi-org.univaq.idm.oclc.org/10.1007/978-3-031-17439-1_25

Case Study Report

Renewal of the City Centre İzmir Çankaya Case Study

H. Meryem NALBANT, İzmir Democracy University, Türkiye

Assoc. Dr. Gizem ERDOĞAN AYDIN İzmir Democracy University, Türkiye

Abstract

This study explores urban renovation strategies with a focus on the İsmet Kaptan Neighborhood, a historically significant commercial area in Izmir, Turkey. Urban centers, which reflect the physical, social, cultural and economic richness of city life, often face deterioration due to their restricted capacity to meet the changing needs. Challenges faced—such as physical decay, infrastructure deficiencies and declining economic vitality—pose crucial need to implement measures for the sustainability and vibrancy of city centers.

The research employs a broad approach, incorporating literature review through the snowball technique with urban morphological, typo-morphological, and spatial sequence analyses to assess the study area. Through on-site observations and data analysis, intervention zones were identified, and urban renewal strategies were proposed. Findings underline that urban revitalization and rehabilitation tools are fundamental to preserve the historical identity and economic functionality of the region while ensuring sustainable development.

The study named "Renewal of the City Center; İzmir Çankaya Case Study" presents a theoretical foundation and practical strategies for urban renewal while also suggesting tools to enhance the physical and cultural integration of declining urban areas. It also provides an outline of the future directions for research, underlining the importance of holistic urban design in improving the quality of life in city centers.

Keywords

Urban revitalization, Urban rehabilitation, Urban morphology, Urban renewal, City centre,

Space syntax

1. Introduction

City centers are dynamic living spaces that play a critical role in the establishment and development of civilizations. The cities are described as living organisms to which the past has great impact on. Thereby, it can be argued that the cities are shaped by history, kneaded with time and then take their present form. The cities are shaped by their own characteristics and physical, cultural, socio-economic, historical and formal elements. Urbanites, on the other hand, constantly change the cities with their lifestyles (Hayta 2016). City centers have an important place both in the history and identity of cities as places that represent the identity of a city and provide functions.

Witnessing many historical events, city centers have undergone great changes in the 21st century as they have been used as means of capital accumulation and, hence the increase in the economic importance of cities. The materials used in buildings have diversified in design and new designs have emerged with the opportunities brought by digitalization. These political, social and economic changes in social life also caused city centers to lose their characteristic of being a democratic space (Akman 2020). While historical city centers have been replaced by shopping and business centers that have started to form with the modern world order, it is also seen that most of them have been losing their value for different reasons, especially physical, although their attribution as being the centre of the city continue.

The spatial structure of cities, which are constantly changing and developing, may lose its power in many physical, economic, ecological and technological areas over time. In this process, interventions in accordance with the conditions and needs are necessary to make cities more livable and urban systems more sustainable (Alfuqhar & Aysu, 2022). The interventions to be made should provide these areas with qualities that can meet new needs without harming the natural and identity elements of the areas that need to be renewed. This approach forms the basis of the concept of urban renewal. Bearing the traces of history and witnessing many periods in time, urban centers have been formed through various phases of change and development in environmental, spatial, social, economic, demographic and administrative terms. Obsolescence in these centers has led to loss of livability and attractiveness, economic stagnation, social problems and environmental problems. Therefore, urban renewal works, and sustainable development strategies are of great importance for a healthy settlement.

Urban centers experiencing rapid and unchecked growth due to migration are increasingly prone to physical, spatial, socioeconomic, and ecological degradation. Such growth has spurred population increases and expanded settlements, often resulting in deteriorated and depressed areas within city cores. These declining conditions prompt various issues that are physical, social, economic, ecological, and political highlighting the crucial need for intervention. Through revitalization and rehabilitation, it is possible to renew and stabilize the foundational urban fabric and identity without compromising the city's essence.

To revitalize the city and shape the built environment, forms of urban intervention are often applied (Huang et al., 2023). At the same time, strategic planning and development initiatives also contribute significantly to the regeneration of urban areas. The planned regeneration of the city centre creates dynamic, mixed-use areas and sustainable modern (Lousada A., 2021). In addition to physical repair, urban areas designed this way can boost economic growth, enhance the social environment, expand the user base, strengthen business commitment, and enhance prosperity.

The purpose of the study is to reveal through which sustainable urban revitalization and sanitation tools the decline and deterioration of city centers can be prevented. In line with the aim of the study, Konak district, which is seen as the central business area of Izmir city, has been examined by selecting a sub-area in Çankaya district. In this study, the study area consisting of building islands with predominantly commercial building function in the northern part of Çankaya district in Konak district of İzmir province, where the use of commercial areas is intensely seen in the traditional urban fabric (framed by Fevzipaşa Boulevard in the south, Gazi Osman Pasa Boulevard in the west, Gazi Boulevard in the north, Gazi Boulevard in the east and Anafartalar Street in the east) is examined in the context of the renewal of the city centre. The research was guided by the research question: "Which urban revitalization and sanitation tools can be used to stop the decline and deterioration of the city centre?". The hypothesis that the decline and deterioration of the city centre can be stopped by using urban revitalization and sanitation tools was tested within the scope of the study.

2. Urban Renewal

In the historical process, the increase in production has brought about a population increase that continues with the diversification in the lines of work and the increase in the number of workers. In the mid-19th century, cities, which were the settlement areas of the population, developed towards new settlement areas starting from places close to production areas. In addition to new constructions, old, obsolete buildings were also rehabilitated and renovated. At the end of the 19th century, with this process, which can be called 'Industrial Urbanization', the process of improvement and renewal of the old urban fabric remained and concurrently the modern city started to form. Physical, technical, social and infrastructural changes were made to improve the quality of life, and they continued as urban renewal interventions until the 20th century and beyond. While this process has been intensively influential in European countries, it has also strengthened its place in urban planning discipline (Yiğitcanlar 2001).

Urban renewal (Cordeiro, et al., 2024) is discussed as a approach which underlines strategies for the revitalization of a city and the success of the related initiatives (Richards, 2014, p. 6867). Urban renewal can also be defined as all the economic, social, physical or environmental decisions, strategies and actions taken for the improvement and development of old or degraded urban fabric (Ünal 2021). In another definition, urban renewal is defined as 'a series of plans and interventions aimed at enhancing distressed or deteriorated neighborhoods and run-down areas. By focusing on the physical dimensions of urban deterioration, the studies address these problems. (Ergen and Peker 2022) The process of reorganizing areas of urban space that have lost their physical, economic, functional and social functionality and transforming them into different functions is called urban renewal. The urban renewal process is applied through many methods to make urban functions efficient. Urban renewal application methods include clearance of the area, redevelopments, revitalization, sanitation and gentrification.

In their publications on advanced planning capacity in urban renewal (Cordeiro, et al. 2024) discuss urban renewal as necessary to meet the increasing urbanization and settlement needs. This urban renewal process considers economic, social and environmental responsibilities while addressing matters such as environmental degradation, poverty and access to services. A multi-criteria methodology is an ideal approach to develop efficient and transparent strategies for urban regeneration planning.
When the historical definitions (Sadioğlu & Ergönül, 2020) of urban renewal in the literature are analyzed, it can be said that it is the process of socio-economic improvement of urban areas that are physically worn out and require simple, medium and major repairs and fitting them to today's needs.

Urban revitalization and sanitation tools can be used as auxiliary tools in this process.

3. Purpose, Scope and Methodology of the Study

3.1. Project Focus

The study aims to examine urban intervention methods in detail, to examine their suitability for the determined study area and to present suggestions by evaluating the positive and negative aspects of the data obtained.

Figure 1. Registered Building.
Source: Author Attraction

Figure 2. Telephone Bazaar.
Source: Author Attraction

Figure 3. Communication Bazaar.
Source: Author Attraction

Figure 4. Study Area.
Source: Author Attraction

Figure 5. Study Area.
Source: Author Attraction

Figure 6. Study Area.
Source: Author Attraction

3.2. Project Methodology

This study highlights that Çankaya City Centre, located in Konak district of Izmir, preserves its identity as a historical, cultural and commercial centre, while its desirability has decreased with the changes it has experienced. The study examines the role of urban revitalization and sanitation tools in preserving the identity of this centre and adapting it to modern needs. The study examines the scope through discussing urban intervention methods in detail, examining their suitability to the determined study area and presenting suggestions by evaluating the positive and negative aspects of the data obtained. The following steps were followed within the scope of the methodology:

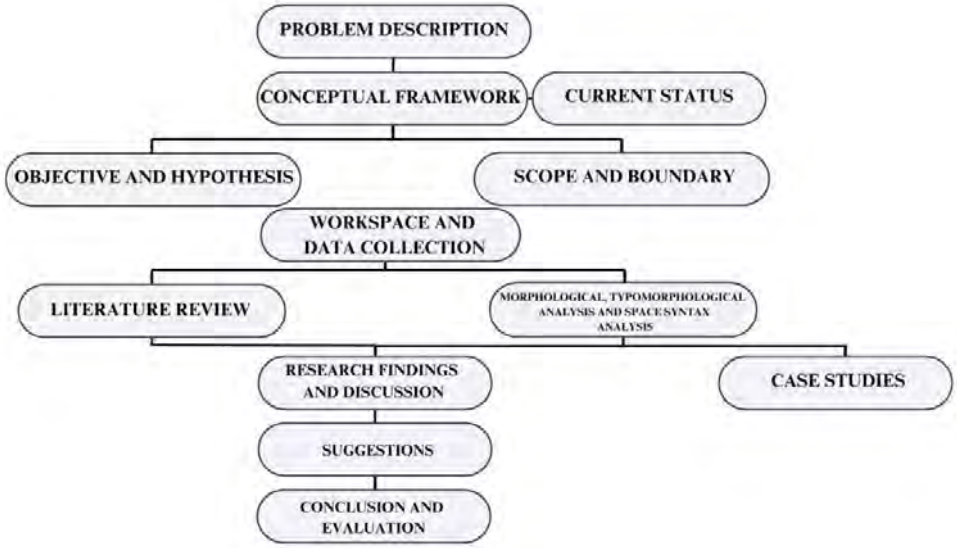


Figure 7. Methodology. Source: Author

For these purposes;

According to the findings and parameters of the literature review, natural structure analysis and spatial analysis were made for the study area. In addition to this, a space syntax analysis was carried out to establish a connection with pedestrian mobility and accessibility level.

Figure 8. Study Area Surroundings. Source: Author

Figure 9. Study Area. Source: Author

The determining factors in the selection of the study area were the suitability of the area in terms of urban renewal, rehabilitation and revitalization works, its impact on urban identity, its being a city centre, experiencing physical aging and wear and tear problems due to its high intensity of use and location, and the absence of any urban work for the study area, although there are many urban renewal/revitalization works in the surrounding area.

4. Project Results

4.1. Results of the Analysis

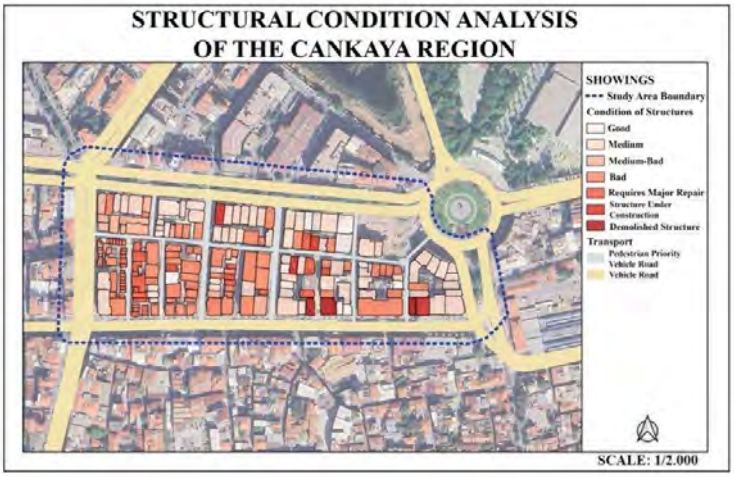


Figure 10. Structural Condition Analysis. Source: Author

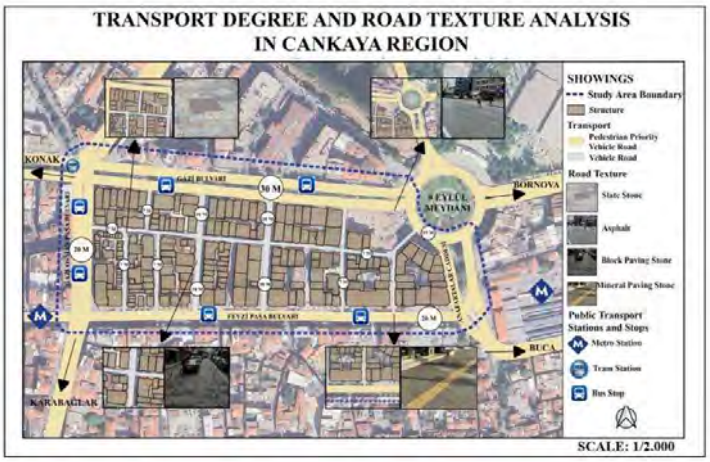


Figure 11. Transport Degree and Road Texture Analysis. Source: Author

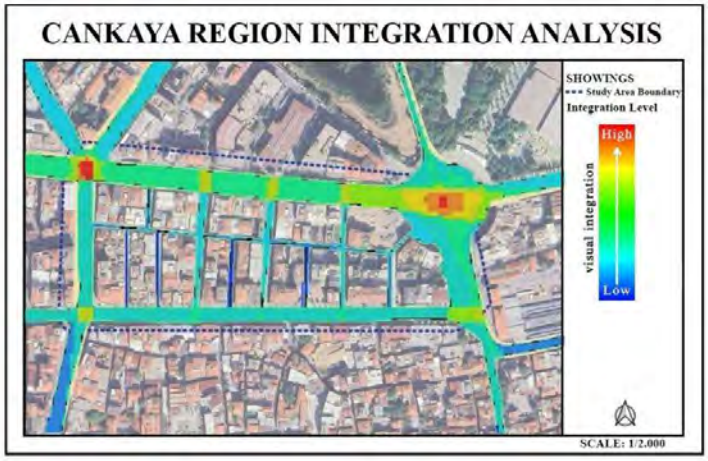


Figure 12. Space Syntax Integration Analysis. Source: Author

The assessments of Çankaya District reveal that the area faces issues such as physical deterioration, irregular settlement, uncontrolled population growth, and related security problems. Considering its commercial identity, historical texture, and strategic location, urban renewal efforts will contribute to the socioeconomic revitalization of the area by improving the buildings in terms of functionality, aesthetics, and safety. It is important to take into consideration the user needs during the renovation process and create a stronger urban center through sustainable planning, while preserving the cultural heritage.

The analyses conducted in the study showcased varying degrees of physical deterioration in the Çankaya area, prompting a staging study to prioritize interventions based on the levels of physical deformation (See some of the analysis given above as examples.). As a result, tailored renewal, revitalization, and rehabilitation strategies were developed for different parts of the district. Dangerous buildings are identified for urgent renovation, moderately damaged buildings for partial repair and facade improvements, while slightly deteriorated buildings will undergo rehabilitation and facade arrangements. This staged approach ensures that further works can be carried out in a more planned and efficient manner.

5.Conclusion And Evaluation

The renewal of urban areas revitalizes both the physical environment and the socio-economic structure of the community through environmental improvement. (Saha, et al., 2017) The rapid loss of valuable textures, individual preferences in the renewal process and the emergence of vague targets for the historical centers of the cities generate more importance for the need for urban renewal. In this process, the necessity of preserving and renewing historical and spatial layers also comes to the fore (Chahardowli and Sajadzadeh 2022). As can be seen from the analyses conducted in the study area, the area has both positive and negative values.

It is predicted that the fact that the area has the power to support economic, cultural and tourism will increase its effect with the renovation works to be carried out. Examining similar studies offers a reference for recommended methods and approaches in the field.

In the Çankaya district, the obsolescence of buildings, loss of functional identity, socio-economic decline and the formation of depressed areas have been observed. In the study, the methods and findings of the sample studies conducted with the literature review snowball technique were examined. Morphological analyses were carried out to ensure the physical, social, cultural, economic and environmental integrity of the area. Typo-morphological analyses were conducted at the building and street scale and contributed to the evaluation of the current situation. In addition, the level of urban mobility and access was analysed using the Space syntax method, and the problems and potentials of the area were identified in consideration of the findings supported by field observations. Six intervention areas have been established according to urgency situations as can be seen from the Figure 13.

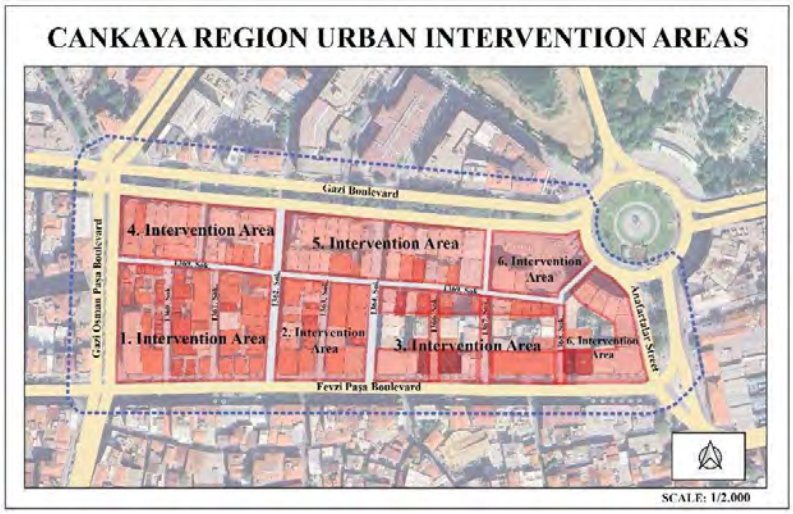


Figure 13. Çankaya Region Urban Intervention Areas. Source: Author

Six key intervention areas were identified within Çankaya, each requiring different levels of action. For instance, the historic Telephone Bazaar will be preserved with facade improvements and the addition of socio-cultural spaces. Other areas, suffering from decay and cramped use of space, will undergo facade rehabilitation, renewal, and more substantial interventions to improve their condition.

- **Intervention area 1** is the area known as the telephone bazaar. The building registered as an historic reservation building will be preserved by improving the facade and adding socio-cultural features, while other buildings that have become dysfunctional will be renovated.
- **Intervention area 2** includes buildings in need of major repair and in poor condition. The irregular number of uses of the apartments as a warehouse and cramped use of the buildings indicate the need for facade rehabilitation and renewal works.
- **Intervention area 3** renewal and facade rehabilitation works are proposed for buildings that require major repairs and are in poor condition.
- **Intervention area 4** is where the facade modifications are proposed for buildings in moderate and moderate-poor condition, and sustainable urban rehabilitation is targeted by using renewable energy sources.
- **Intervention area 5** is an area where the buildings are in bad condition and in need of substantial repair. Renewal and facade arrangement works are proposed in this area.
- **Intervention area 6** is where the single building in the north holds great potential for urban renewal, while missing areas will be improved with sustainable systems. In the south, regulation and renewal works are recommended due to dense signage and facade pollutants.

Consequently, renewal strategies tailored to regional needs were developed, with revitalization and rehabilitation identified as the most suitable methods for urban renewal.

6. Broader Project Impact

The renewal of Çankaya city centre could serve broader purposes and implications for Izmir as a whole. To create a comprehensive urban renewal strategy, the work could be integrated with other projects in the region, such as the pedestrianization of the coastline, the renewal and rehabilitation of Mimar Kemalettin Street, the urban regeneration areas in and around Kemeraltı, and the revision of Kültürpark. This would not only improve the socio-economic structure of the region, but also increase Izmir's cultural and economic potential and strengthen its visibility and competitiveness on a global scale.
Finally, we have defined the need for urban renewal in Çankaya as both necessary and beneficial for Izmir's sustainable development. The district's buildings are obsolete, and the area has lost its functional identity. By implementing targeted renewal strategies, we can revitalize the area while preserving its functional identity & cultural heritage. For future works in urban development in Çankaya, resilience interventions and data collected at the neighborhood and building scale that can support long-term holistic plans should be taken into consideration.

''In this study, Artificial Intelligence powered DeepL translation tool was benefitted from for translation purposes on some parts (DeepL, 2024).''

7. References

Akman, K., 2020. The Importance and Changing Function of City Squares. Journal of Academic Thought, 26 March, pp. 17 - 33.

Alfuqhar, I. & Aysu, M., 2022. Sustainable Urban Renewal of the Old City of Mosul. AL-Rafdain Engineering Journal, September, pp. 21-27.

Chahardowli, M. & Sajadzadeh, H., 2022. A Strategic Development Model for The Regeneration of Urban Historic Cores: A Case Study on The Historic Fabric of Hamedan City. Land Use Policy, January, pp. 2-13.

Cordeiro, T. A. A. A. et al, 2024. Enhanced planning capacity in urban renewal: Addressing complex challenges using neutrosophic logic and Dematel. Cities.

DeepL (2024) DeepL Translator. Köln: DeepL SE. Available at https://www.deepl.com (Accessed: 20 October 2024)

Ergen, M. & Peker, Ü., 2022. Urban Transformation Process Analysis in Turkey; The Case of Istanbul/Gaziosmanpaşa. Journal of Agricultural Biotechnology, 3 (2), pp. 101-116.

Hayta, Y., 2016. Urban Culture and Changing City Concept. Bitlis Eren University Journal of Institute of Social Sciences, December, pp. 165-184.

Lousada A., Ferreira F., Meidutė-Kavaliauskienė I., Spahr R., Sunderman M., Pereira L., 2021. A sociotechnical approach to causes of urban blight using fuzzy cognitive mapping and system dynamics. Cities-The International Journal of Urban Policy and Planning. Volume 108, pp. 1-13.

Richards, R. (2014). Urban renewal. In A. C. Michalos (Ed.), Encyclopedia of Quality of life and well-being research. Dordrecht: Springer. pp.6867

Sadioğlu, U. & Ergönül, E., 2020. Meaning, Actors and Objectives of Urban Transformation in Turkey. Ideal City Journal, Issue 30, Volume 11, pp.878-908.

Saha, D., Ahmed, S., Shahriar, A. T. & Mithun, S. M. N. H., 2017. A Journey through the History:Introduction to Heritage Tourism and Tourist Trails for the Renewal of Old Dhaka. American Journal of Civil Engineering and Architecture Vol. 5, No. 3, pp. 98-107.

Ünal, A. T., 2021. An Approach for Sustainability in Urban Renewal Regions-Antalya Balbey Example, Antalya: Akdeniz University Institute of Science and Technology.

Yiğitcanlar, T., 2001. Urban Renewal Phenomenon and Development Process. Planning, pp. 55-58.

Research Paper

Relationship between climate change risk perception, mental health, and differences in urban environments

Ang QU, School of Architecture and Design, Harbin Institute of Technology;Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

As climate change intensifies, the risks associated with climate change are increasingly affecting the mental health of residents through their perceptions. Understanding the relationship between climate change risk perception and residents' mental health, as well as the differentiation of this relationship in different built environments, can help reduce the negative impacts of climate change risks on urban residents, improve their mental health, and encourage them to take positive bottom-up adaptation behaviors to reduce the health risks posed by climate change. In this paper, we used a questionnaire survey to collect data, and geostatistical methods to discuss the relationship between residents' climate change risk perceptions and mental health in different urban built environments. The results show that each dimension of the CCRP has a different degree of influence on different aspects of residents' mental health, which is mainly manifested in the differences between old and new urban areas and between urban centries and suburbs. It was also found that higher green space coverage, lower sky view factor (SVF), and building density were associated with lower mental health, and that there were regional differences in the mental health of residents living in different urban built areas.

Keywords

Climate change risk perception, Mental health, Urban environments

1. Instruction

1.1. Background

The impact of climate change on residents' health is a topic of great concern, and the main scope of discussion is the impact of climate change on residents' physical health and physical activity, with relatively little discussion of the impact on mental health, while the impact of climate change on residents' mental health is mainly obtained through the residents' perception of climate change risk, which includes direct impacts, indirect impacts, and substitution impacts and other pathways. The impacts of climate change on mental health are mainly obtained through residents' perception of climate change risks, including direct, indirect, and vicarious impacts.

The direct impacts of climate change phenomena, such as increasing precipitation, rising temperatures, and extreme weather events, which are experienced by residents living in urban areas, can have a direct impact on mental health, mainly in the form of post-traumatic stress disorder, anxiety, and depression. Studies have shown that psychological stress following extreme weather events is associated with increased rates of suicide and mental health problems.[1][3][5]

Indirect impacts are caused by unequal access to resources for combating the adverse effects of climate change due to unbalanced development and gentrification of living environments, which means that lower socio-economic groups, women, and the elderly are more likely to be affected by the adverse effects of climate change. Alternative impacts are those in which urban residents do not feel the impacts of climate change, but through community organisations, the internet, and communication with friends and family, they learn about the experiences and attitudes of others towards the adverse impacts of climate change, and in the process form their own judgements about the risks of climate change.[2][4][6]

According to existing research, climate change risk perception is an important factor in urban residents' perception of the impacts of climate change, and climate change risk perception is also an important perceptual component of climate change impacts on residents' mental health, and climate change risk perception is affected by a variety of factors, including the individual's level of education, level of income, worldview, access to climate change-related information and the amount of climate change-related information, and even affected by Race, geography, and political affiliation. Environmentalists and those with higher levels of education and access to information are more likely to believe in climate change and feel the impacts of climate change, and studies have shown that people who live in cities longer are less likely to be affected by climate change, and that older people have lower levels of climate change risk perceptions than younger people. In general, people with higher levels of climate change risk perception are more likely to take proactive adaptation measures. [9][10][11] [12][13]

1.2. Literature Review

Differences in geographic location and socio-economic level not only result in significant differences in the spatial scale of climate change risk, but also in the perception of climate change risk by people of different socio-economic status in different urban spaces. Due to the rapid development of cities, their internal spaces have become gentrified, e.g. newly built high-grade neighbourhoods tend to have a higher quality built environment, a higher proportion of green and permeable areas, and more convenient access to infrastructure. The inhabitants of these neighbourhoods are mainly high-income and well-educated, and are relatively more capable of coping with the impacts of climate change. Older neighbourhoods, on the other hand, tend to have lower quality built environments, more crowded living environments, a higher proportion of hardened land, a lack of access to nature and outdoor space, and poorer accessibility to various types of infrastructure. However, residents tend to have lived there for a longer period of time, and are mostly low-income and elderly people, who are also more vulnerable to the risks posed by climate change. Spatial heterogeneity in geographic space can lead to climate injustice in cities, making vulnerable populations more susceptible to the impacts of climate change. [7][14] In addition, while there is still a gap in understanding between urban dwellers and climate-related experts, this gap is now narrowing as a result of easier access to information. [15][16]

Urban residents' perception of climate change risk can have an impact on residents' mental health in the following ways. Affective response play a critical role in shaping perceptions of climate change risk, which is the first reaction of residents to climate change risk, with fear of climate change dominating. Affective response can lead to positive adaptive actions based on the experiences that residents have gained from experiencing climate change. Residents whose means of production are closely linked to climate change tend to be more vulnerable to the effects of climate change on their mental health. [17]

Adaptation intentions is another important aspect of climate change risk perception. Adaptation intentions refers to an individual's willingness and behaviour to take measures to mitigate the effects of climate change risks. People who are more likely to be willing to undertake positive adaptation tend to have higher levels of income to afford their adaptation behaviour and higher levels of climate change awareness.

Cognition can also have a significant impact on climate change risk perception. Cognition includes understanding of climate change knowledge, risk assessment and awareness of its causes. Differences in the level of awareness come mainly from individual residents, including their ideology, political stance, etc., which mainly influences whether residents can adopt rational adaptive behaviours to cope with climate change, and to a certain extent affects their psychological expectations of climate change, and influences the mental health of the residents. [18][19]

Self-efficacy is also an important aspect of climate change risk perception; self-efficacy refers to an individual's confidence in his or her ability to perform a specific task or achieve a specific goal. It determines whether individuals are able to adopt adaptive behaviours that are within their capabilities, and is more of a practical guide, and is therefore often regarded as one of the key psychological factors in the response to climate change by individual residents. [20]

The above studies show that climate change risk perception is affected by the built environment and social support, which are highly sensitive to spatial changes in the city, and that socioeconomic status also influences residents' choice of residence to a certain extent. Existing research on climate change risk perception is mainly at the mathematical level, which is different from the reality and does not reflect the real perception of residents, and fails to discuss the impact of climate change risk perception on mental health. The lack of in-depth discussion of the relationship between climate change risk perception and mental health in terms of geographic distribution and differences between built environments in different cities also makes it difficult to plan and guide policy.

This study examines the relationship between climate change risk perception (CCRP) and residents' mental health, and the differences in the role of the urban environment in this relationship. The risks posed by climate change are not just objective risks, but also health risks to the human body, including psychological trauma. And the spatial differences in this affective relationship are elaborated, providing a theoretical basis for more in-depth research in the future, and a new perspective for improving the research on climate change risk perception.

The objectives of this research are as follows: 1) To analyze the impact of affective responses, adaptation intentions, and cognition within climate change risk perception on different dimensions of residents' mental health; 2) To explore how factors such as urban green coverage, Sky View Factor (SVF), and building density mitigate mental health issues among residents; 3) To investigate regional differences in mental health levels among residents in various urban built areas and examine the potential causes of these disparities.

2. Materials and Methods

2.1. Research Area

Harbin is a representative of China's cold cities, in the past two decades, Harbin's annual average temperature, seasonal average temperature, and monthly maximum temperature have shown an upward trend, and the annual average temperature increase is, per decade, 0.37 ℃, due to the influence of rapid urbanisation, the city centre tends to warm up more seriously.

The study area is selected as the main built area of Harbin, including Daoli District, Nangang District, Daowai District, Xiangfang District, which includes the old city centre and the newly developed city centre, and covers the main types of built environment and architectural characteristics of Harbin. To ensure the accuracy of the experimental results, data collection was conducted at the community level to improve precision.

The study's methodology and approach are illustrated in Figure 1.

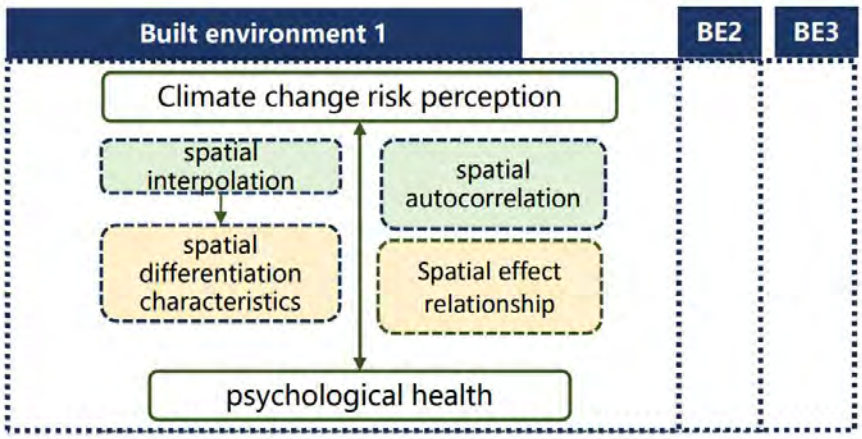


Figure 1. The spatial distribution of various dimensions of climate change risk perception. Source: drawn by the author.

2.2. Data Sources

In conducting the dimensional screening process, the indicators used in this study were identified and categorised under each dimension by using the previous research literature as a basis and by selecting their recurrent indicators in conjunction with the existing research questions. The four dimensions of climate change risk perception are Affective Response (3 indicators), Adaptation Intentions (4 indicators), Cognizance (3 indicators), and Self-efficacy (2 indicators). Socioeconomic data collected included age, educational attainment, income (in RMB), gender (male = 1, female = 2), past experience, and occupation. A 1-4 Likert scale was used to measure all indicators of climate change risk perception, with scale points ranging from very low (1), low (2), high (3), to very high (4). After finalizing the indicators, a survey questionnaire was developed. The first part of the questionnaire covers basic socioeconomic factors, including age, income, gender, and educational level.

The survey data used in this study was collected from March to November 2023 through a climate change risk perception survey using a mixed-method approach of online and offline research. Respondents were recruited from 134 communities across the main urban areas of Harbin, including Daoli District, Daowai District, Nangang District, and Xiangfang District, resulting in a total of 752 participants. After excluding incomplete responses, individuals under the age of 12, and those who did not acknowledge the existence of climate change, 551 valid respondents remained. To ensure the geographical representativeness of the sample, a stratified multi-stage sampling method was employed. The geographical location of respondents was determined based on the community name they provided.

Regarding mental health, the WHO-5 Well-Being Index (1998 version) was used, which measures five dimensions: active and vigorous, calm and relaxed, fresh and rested, cheerful and in good spirits, and filled with things that interest. These dimensions were used to assess different aspects of residents' mental health.

Finally, the main urban areas of Harbin were divided into 500m fishnet grid cells, and spatial connections were established with the respective data for further analysis.

3. Result

3.1. The spatial distribution of climate change risk perception

There are clear spatial differences in perceptions of climate change risk within cities, which are closely linked to gentrification of urban development. Residents' socio-economic status and income influence their choice of place of residence, and areas with higher quality built environments tend to have more favourable climatic conditions. As a result, residents in these areas are relatively less exposed to unfavourable urban environmental conditions, and conversely, those in more vulnerable cities are rather more exposed to unfavourable urban environmental conditions.

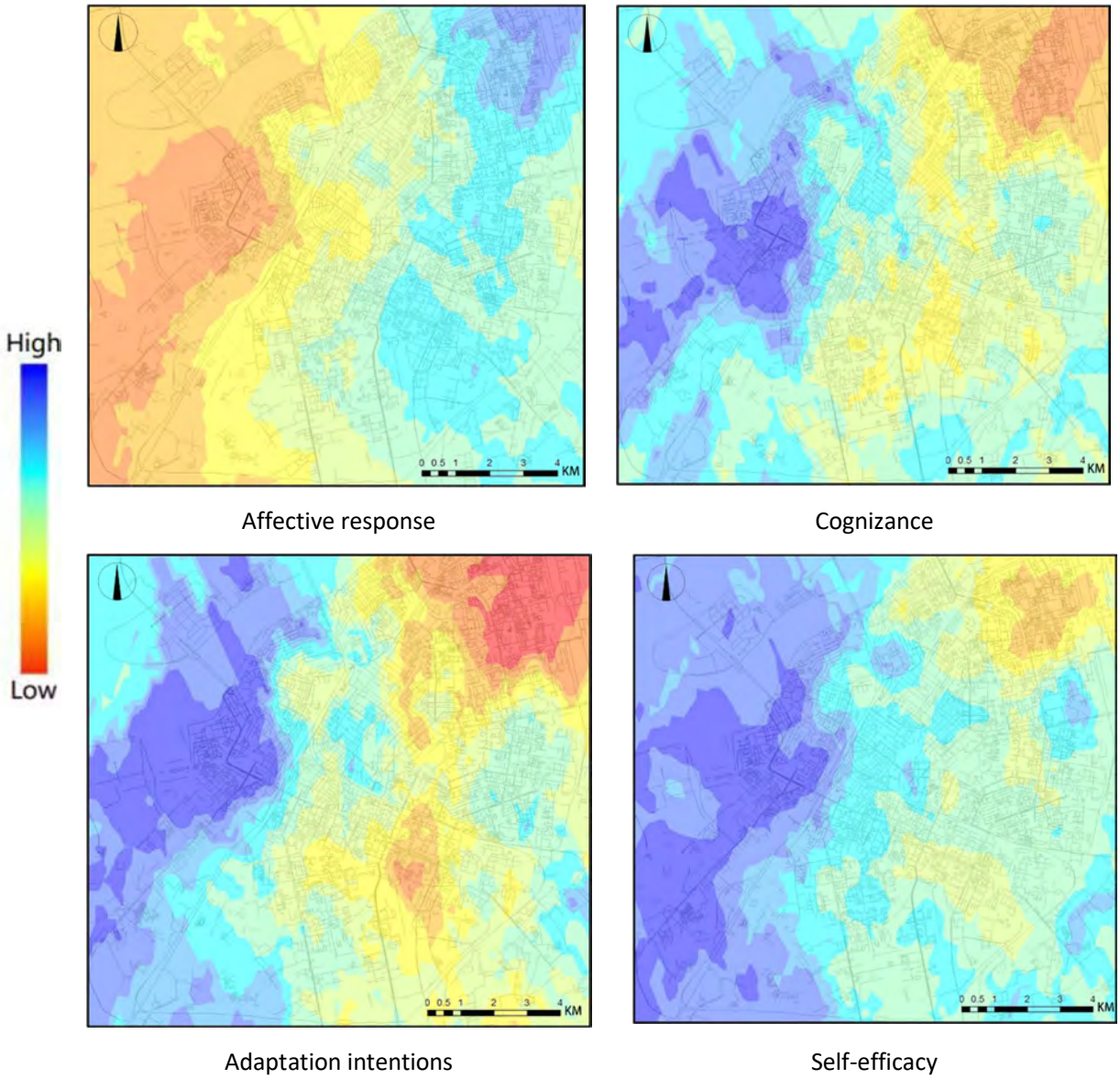


Figure 2. The spatial distribution of various dimensions of climate change risk perception. Source: drawn by the author.

In Figure 2, the distribution of CCRP varies across different dimensions. The low-value point for Affective Response is located in Daoli District, a built area of Harbin known for its relatively high economic status,

high construction quality, and higher housing prices. Residents in this area generally have higher income levels, giving them more time and resources to cope with the risks associated with climate change. Consequently, their Affective Response is relatively low. In contrast, in the older parts of Harbin, where infrastructure is poor, buildings are aging, and residents have lower income levels, the ability to cope with climate change is weaker, and the fear of climate risks is greater.

In the dimensions of Cognizance, Adaptation Intentions, and Self-Efficacy, the distribution is the opposite of Affective Response, with low values mostly appearing in outlying areas and high values concentrated in the central areas. Although there are some variations in hotspot distribution, the overall trends are similar. This suggests that individuals with higher socioeconomic status have greater access to climate change knowledge, are more willing and able to take action, and possess a deeper understanding of climate change.

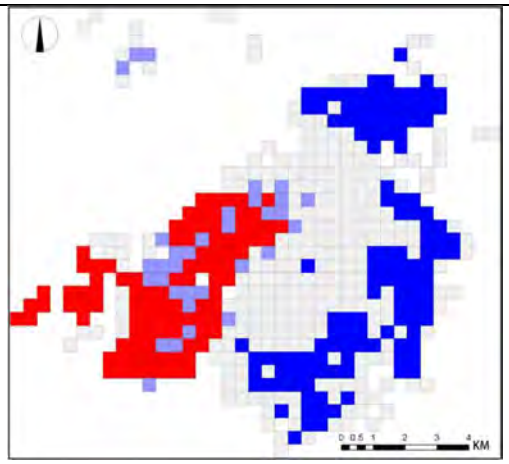
In the dimension of Adaptation Intentions, there is also a low-value hotspot in Xiangfang District, which is near several universities. This may be linked to the activity habits of university students, who often study or engage in entertainment indoors, relying on the cool spaces provided by buildings to avoid extreme weather. Their adaptation behaviors tend to be passive, influenced by factors beyond their control, such as university regulations. For instance, students cannot install air conditioning in dormitories without permission, even in extreme heat. Additionally, studies suggest that while many students have a basic understanding of climate change, they lack knowledge of specific adaptation measures and the concrete impacts of climate change. In addition, it has been shown that as age decreases, more and more college students are more inclined to be less active outdoors, especially in the winter and summer months, even though college students have some level of knowledge about their climate change situation.

3.2. The spatial distribution of climate change risk perception

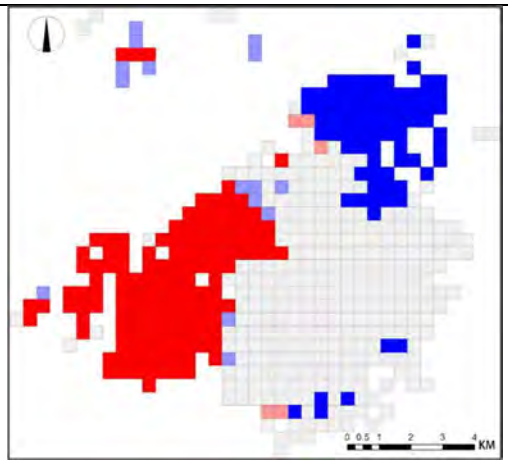
In Figure 3, the spatial distribution pattern of the impact mechanism of climate change risk perception and built environments appears generally stable. Similar trends were observed in the dimensions of Adaptation Intentions, Self-Efficacy, and Cognizance. The high-value (H-H) areas for each dimension of climate change risk perception are primarily concentrated in Daoli District. This indicates that residents with higher socioeconomic status possess a better understanding of climate change and are more willing to invest time and resources in responding to climate-related situations, leading to a higher level of climate change risk perception. Consequently, residents in this area are less affected by the mental health impacts of climate change.

Conversely, the low-value (L-L) areas are mainly found in Daowai District, Nangang District, and parts of Xiangfang District (near the city suburbs). This suggests that residents with lower socioeconomic status often lack the time or awareness to consider climate change, resulting in a lower level of climate change risk perception and greater vulnerability to the mental health impacts of climate change.

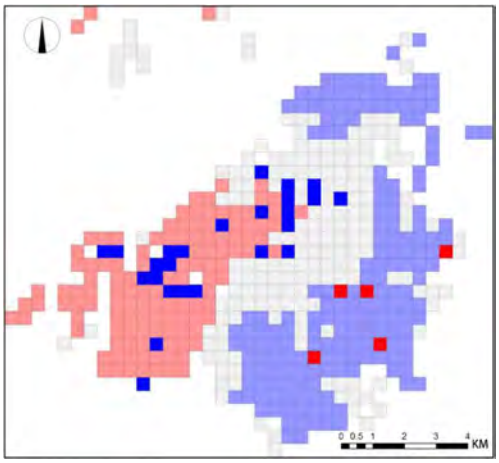
Mental Health and Adaptation Intentions



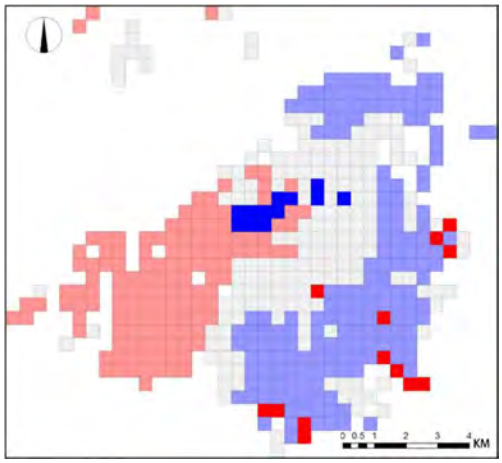
Active and Vigorous



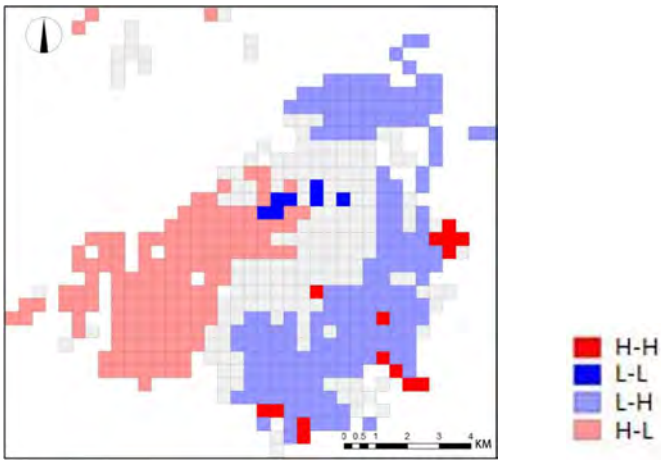
Calm and Relaxed



Fresh and Rested



Cheerful and in Good Spirits



Filled with Things that Interest

Figure 3.1 Spatial autocorrelation between Adaptation Intentions and residents' mental health. Source: drawn by the author.

Mental Health and Self-efficacy

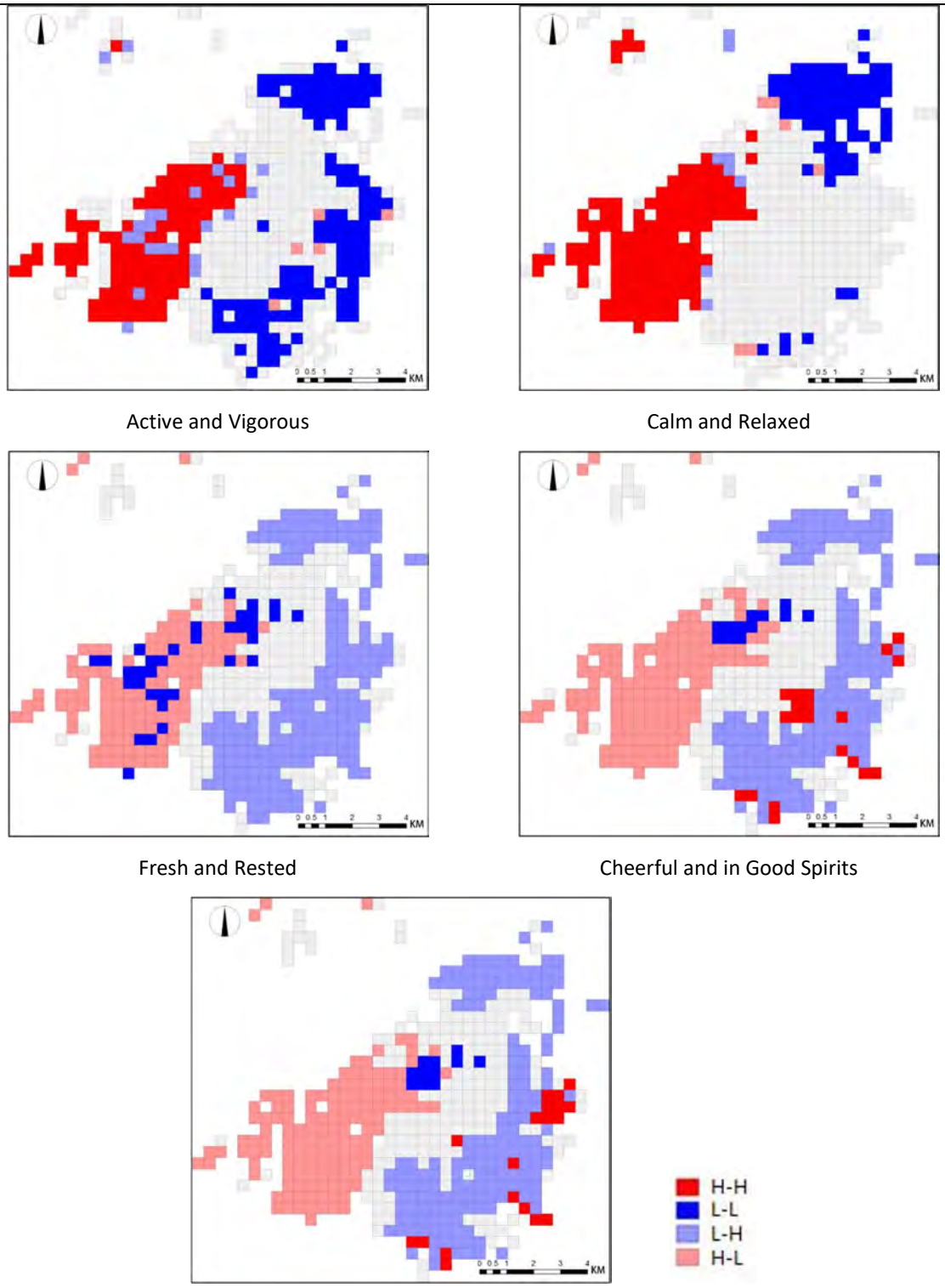


Figure 3.2 Spatial autocorrelation between Self-efficacy and residents' mental health. Source: drawn by the author.

Mental Health and Cognizance

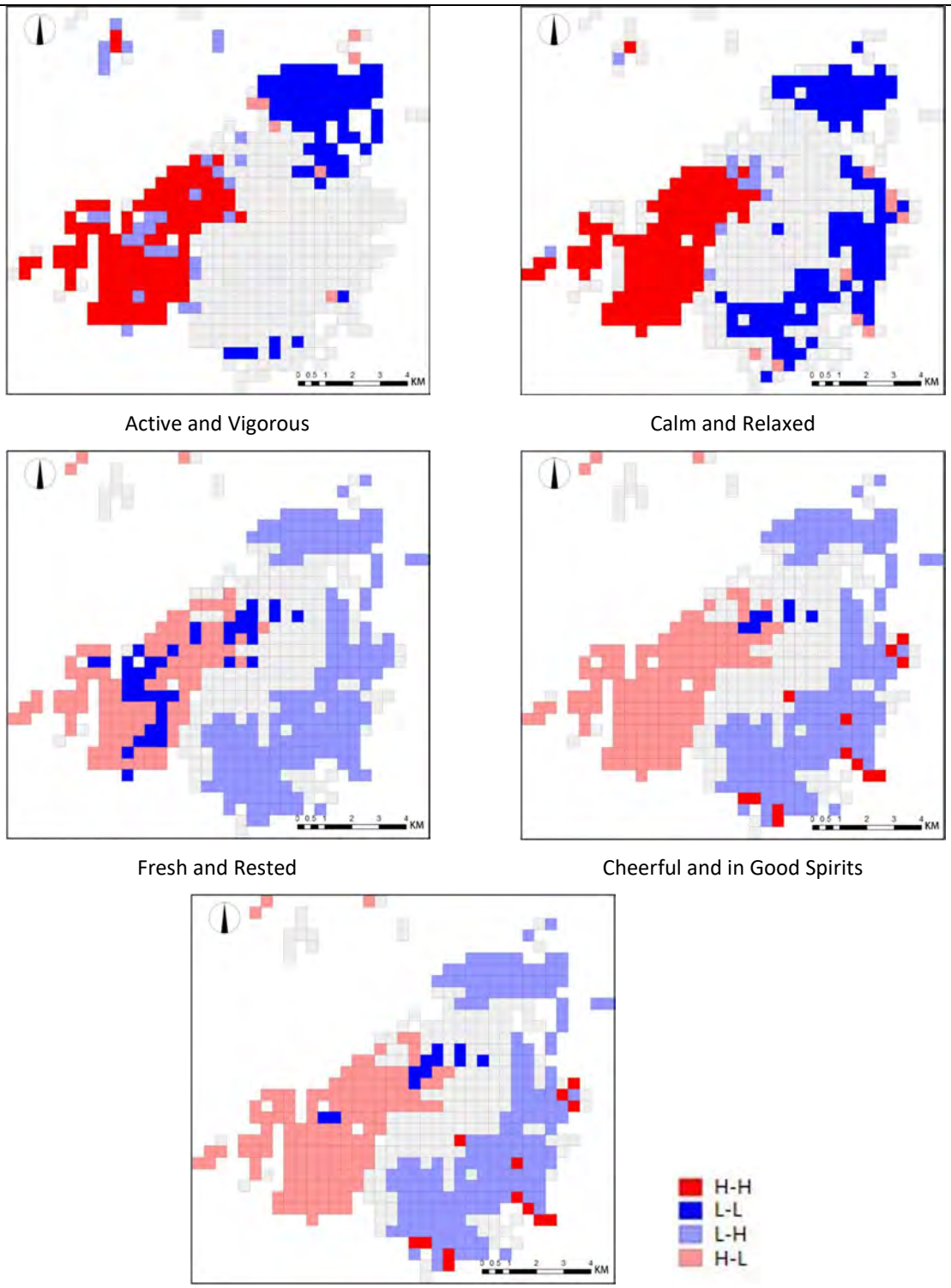


Figure 3.3 Spatial autocorrelation between Cognizance and residents' mental health. Source: drawn by the author.

Mental Health and Affective Response

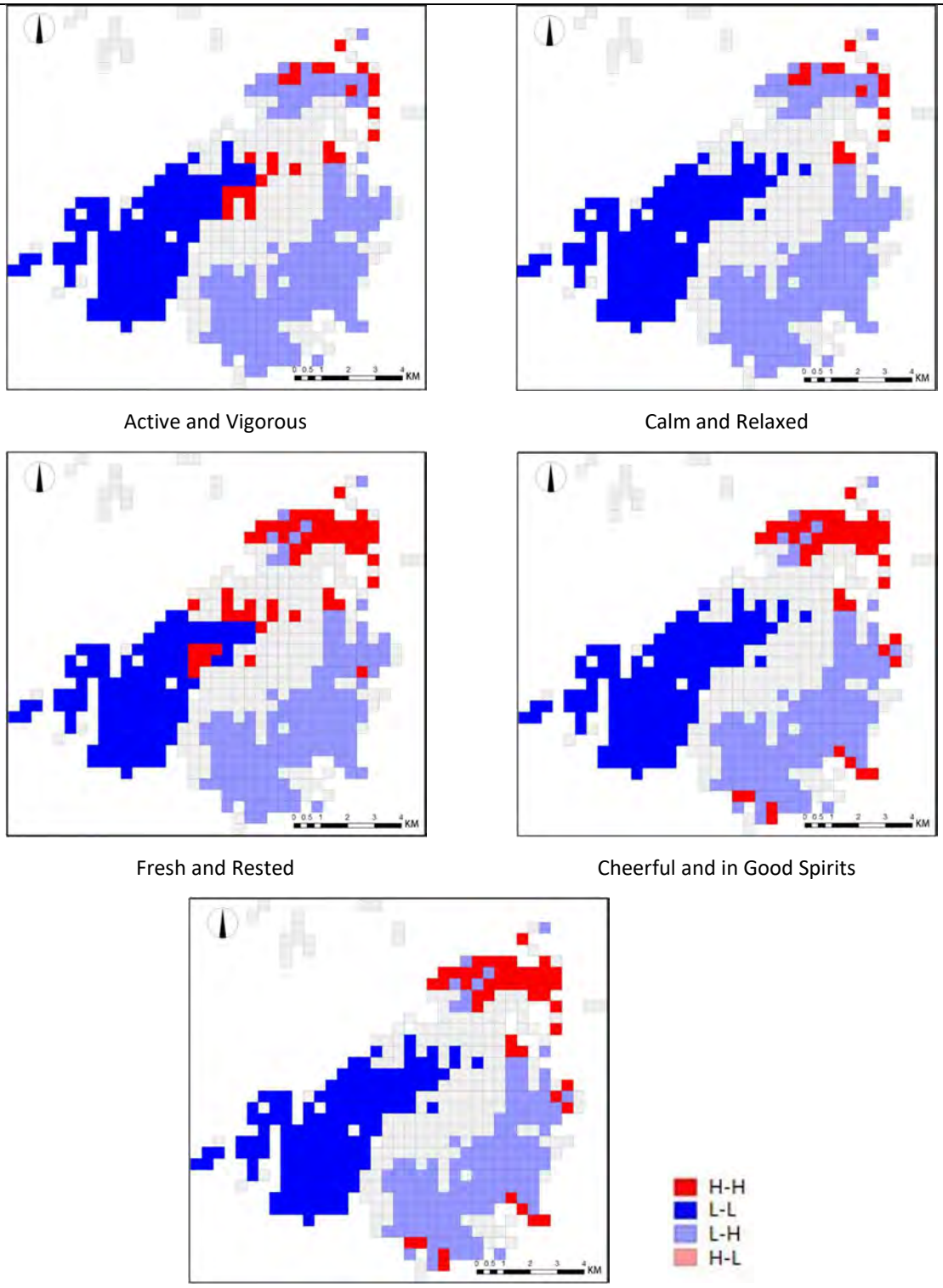


Figure 3.4 Spatial autocorrelation between Affective Response and residents' mental health. Source: drawn by the author.

The Affective Response dimension is the opposite of the first three dimensions, as it reflects the negative experiences of urban residents in response to climate change. The Sky View Factor (SVF) and building height exhibit low-high (L-H) value aggregation in certain areas of Daowai, Nangang, and Xiangfang, while high-low (H-L) value aggregation is observed in Daoli District.

In Figure 3, it is evident that, due to the impact of climate change, the dimensions of mental health—specifically "Active and Vigorous" and "Calm and Relaxed"—in Daoli and Daowai Districts of Harbin City are generally positively correlated with climate change risk perception. In contrast, other dimensions of mental health also show positive correlations with climate change risk perception. However, in Nangang District, Xiangfang District, and other areas, most dimensions exhibit negative correlations in the Affective Response dimension, although a few dimensions are not statistically significant. The distribution characteristics of these areas are generally consistent with those of Daoli and Daowai Districts.

This indicates a significant relationship between climate change risk perception and residents' mental health, characterized by high spatial autocorrelation. The degree of this correlation varies across different regions of the city, highlighting the need for further research tailored to the characteristics of the populations in these areas. Such research could help identify the impact patterns for different groups of urban residents and propose targeted strategies.

3.3. Strategy

The impact of climate change risk on urban residents has not been fully clarified, and at this stage, most of the relevant studies have used climate change risk perception as a moderator variable to express the impact of climate change risk on residents, to explore its impact on the physical, psychological, and behavioural aspects of the residents, which has not yet been established, and there is not a set of standard paradigm based on a set of effective, and the current research are The current research is based on the selection of indicators according to the focus of the research. In this paper we focus on the impact of climate change risk perceptions on the mental health of the population and the differentiation of this impact across built environments, but physical health and adaptive behaviours, for example, can be characterised in the same way, and there may be spatial differences in impacts between them. Such differences and support are often created through differences in built environments within communities as well as community support, which may be significantly related to an individual's social network as well as social interaction activities, but unfortunately none of the above conjectures were tested in this paper.

Future research that explores the pathways of climate change risk perceptions on urban residents in a relatively complete manner will allow for the development and implementation of comprehensive policies and targeted programmes, with the necessary assessment and monitoring, and the regulation of the allocation of needed resources, which could be of great significance for climate justice in urban areas, thus further reducing the overall climate health risks of the population.

Special support should be given to vulnerable groups in cities, such as women, outdoor workers, low-income groups, etc., to protect women and vulnerable groups, who are often more susceptible to the risks posed by climate change than the rest of the population, causing deeper psychological stress. Public awareness-raising and knowledge dissemination should also be carried out to estimate, through publicity and education, that urban residents will respond positively to climate change and actively prepare for long-term climate change events in order to alleviate climate anxiety.

4. References

[1]Alibudbud, R. (2023) 'Mental health service, training, promotion, and research during typhoons: Climate change experiences from the Philippines', *Asian Journal of Psychiatry*, 86. Available at: https://doi.org/10.1016/j.ajp.2023.103673.

[2]Ansah, E.W. *et al.* (2024) 'Climate change, urban vulnerabilities and adaptation in Africa: a scoping review', *Climatic Change*. Springer Science and Business Media B.V. Available at: https://doi.org/10.1007/s10584-024-03711-8.

[3]Arya, B. and Kumar, H. (2023) 'An Investigation of Climate Change, Eco-Anxiety and Risk Perception in The Context of Theory of Planned Behaviour', in *IOP Conference Series: Earth and Environmental Science*. Institute of Physics. Available at: https://doi.org/10.1088/1755-1315/1279/1/012020.

[4]Bourque, F. and Cunsolo Willox, A. (2014) 'Climate change: The next challenge for public mental health?', *International Review of Psychiatry*, 26(4), pp. 415–422. Available at: https://doi.org/10.3109/09540261.2014.925851.

[5]Brody, S.D. *et al.* (2008) 'Examining the relationship between physical vulnerability and public perceptions of global climate change in the United States', *Environment and Behavior*, 40(1), pp. 72–95. Available at: https://doi.org/10.1177/0013916506298800.

[6]Charlson, F. *et al.* (2021) 'Climate Change and Mental Health: A Scoping Review', *Public Health*, 18, p. 4486. Available at: https://doi.org/10.3390/ijerph.

[7]Cianconi, P., Betrò, S. and Janiri, L. (2020) 'The Impact of Climate Change on Mental Health: A Systematic Descriptive Review', *Frontiers in Psychiatry*, 11. Available at: https://doi.org/10.3389/fpsyt.2020.00074.

[8]Deng, X. *et al.* (2023) 'Spatiotemporal evolution patterns of urban heat island and its relationship with urbanization in Guangdong-Hong Kong-Macao greater bay area of China from 2000 to 2020', *Ecological Indicators*, 146. Available at: https://doi.org/10.1016/j.ecolind.2022.109817.

[9]Doherty, T.J. and Clayton, S. (2011) 'The Psychological Impacts of Global Climate Change', *American Psychologist*, 66(4), pp. 265–276. Available at: https://doi.org/10.1037/a0023141.

[10]Ebi, K.L. *et al.* (2025) 'Extreme Weather and Climate Change: Population Health and Health System Implications', *Annual Review of Public Health Downloaded from www.annualreviews.org. Guest (guest* [Preprint]. Available at: https://doi.org/10.1146/annurev-publhealth.

[11]Evans, G.W. (2018) 'Projected Behavioral Impacts of Global Climate Change', *Review in Advance first posted on* [Preprint]. Available at: https://doi.org/10.1146/annurev-psych-010418.

[12]Gao, Y., Zhao, J. and Han, L. (2022) 'Exploring the spatial heterogeneity of urban heat island effect and its relationship to block morphology with the geographically weighted regression model', *Sustainable Cities and Society*, 76. Available at: https://doi.org/10.1016/j.scs.2021.103431.

[13]Hayes, K. *et al.* (2018) 'Climate change and mental health: Risks, impacts and priority actions', *International Journal of Mental Health Systems*, 12(1). Available at: https://doi.org/10.1186/s13033-018-0210-6.

[14]Hussein, A.K., Dosh, R.J. and Abojassim, A.A. (2023) 'Using of a Moran's I and Hot Spot Analysis to Identify of Thoron in Najaf City using GIS Software', *Pollution*, 9(3), pp. 1140–1149. Available at: https://doi.org/10.22059/poll.2023.354568.1768.

[15]Kabisch, N. *et al.* (2024) 'Monitoring and perception of allergenic pollen in urban park environments', *Landscape and Urban Planning*, 250. Available at: https://doi.org/10.1016/j.landurbplan.2024.105133.

[16]Kjellstrom, T. and McMichael, A.J. (2013) 'Climate change threats to population health and well-being: The imperative of protective solutions that will last', *Global Health Action*, 6(1). Available at: https://doi.org/10.3402/gha.v6i0.20816.

[17]Majumder, S. *et al.* (2023) 'Multiscale GIS based-model to assess urban social vulnerability and associated risk: Evidence from 146 urban centers of Eastern India', *Sustainable Cities and Society*, 96. Available at: https://doi.org/10.1016/j.scs.2023.104692.

[18]Newberry Le Vay, J. *et al.* (2023) 'Integrating mental health into climate change education to inspire climate action while safeguarding mental health', *Frontiers in Psychology*, 14. Available at: https://doi.org/10.3389/fpsyg.2023.1298623.

[19]Obradovich, N. *et al.* (no date) 'Empirical evidence of mental health risks posed by climate change'. Available at: https://doi.org/10.7910/DVN/OVQY76.

[20]Reyes-Riveros, R. *et al.* (2021) 'Linking public urban green spaces and human well-being: A systematic review', *Urban Forestry and Urban Greening*. Elsevier GmbH. Available at: https://doi.org/10.1016/j.ufug.2021.127105.

[21]Salas Reyes, R. *et al.* (2021) 'A Research Agenda for Affective Dimensions in Climate Change Risk Perception and Risk Communication', *Frontiers in Climate*, 3. Available at: https://doi.org/10.3389/fclim.2021.751310.

[22]Villacis, A.H., Alwang, J.R. and Barrera, V. (2021) 'Linking risk preferences and risk perceptions of climate change: A prospect theory approach', *Agricultural Economics (United Kingdom)*, 52(5), pp. 863–877. Available at: https://doi.org/10.1111/agec.12659.

[23]Zeren Cetin, I., Varol, T. and Ozel, H.B. (2023) 'A geographic information systems and remote sensing–based approach to assess urban micro-climate change and its impact on human health in Bartin, Turkey', *Environmental Monitoring and Assessment*, 195(5). Available at: https://doi.org/10.1007/s10661-023-11105-z.

[24]Zhou, M., Wang, R. and Guo, Y. (2024) 'How urban spatial characteristics impact surface urban heat island in subtropical high-density cities based on LCZs: A case study of Macau', *Sustainable Cities and Society*, 112. Available at: https://doi.org/10.1016/j.scs.2024.105587.

Research Paper

Cultural Heritage and Urban Transformation: The Role of Festivals in Enhancing Public Spaces and driving Development

Case of Durga Puja in Kolkata

Priyanka KUREEL, Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur, West Bengal, India

Prof. Joy SEN, Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur, West Bengal, India

Dr Arkopal K. GOSWAMI, Ranbir and Chitra Gupta School of Infrastructure Design and Management, Indian Institute of Technology Kharagpur, West Bengal, India

Abstract

This study examines the role of cultural festivals, specifically Kolkata's Durga Puja, in enhancing urban spaces and promoting tourism and economic growth. Recognized by UNESCO in 2021, Durga Puja represents an intangible cultural heritage celebrated since the 18th century, transforming the city through temporary structures called 'pandals' that reinvent public spaces. Using GIS mapping and network analysis, this research analyzes over 70 pandals, exploring the scale of activity, facility distribution, and the influence of urban patterns on accessibility. The findings highlight a hierarchy in facility provision, where basic amenities like fire safety and water are standard across all pandals, but advanced facilities, such as food stalls and toilets, are concentrated in larger pandals connected to key transit nodes. Cluster analysis reveals that high-density, well-connected areas support greater facility access, while on-street pandals vary in scale and resources. The study identifies gaps in permanent facilities, that are supplemented by temporary provisions. By proposing pandal clusters as units for facility planning, this research underscores the potential of cultural festivals to activate public spaces, fostering a model for urban regeneration and development.

Keywords

Cultural Festivals, Temporary Transformation, Facilities, Network Analysis

1. Introduction

UNESCO refers to intangible cultural heritage also known as 'living heritage' as "the practices, representations, expressions, knowledge and skills handed down from generation to generation" (UNESCO, 2003). This intangible cultural heritage passed down through generations, is continuously revitalized by communities and groups as they adapt to their environment, interact with nature and reflect on their history. It provides a sense of identity and continuity, encouraging respect for cultural diversity and the expression of human creativity(UNESCO 2003). Cultural events, particularly festivals, are also part of the

intangible cultural heritage, which plays an important role in enhancing the city's image(Huang et al., 2010) and as a result, cities and regions worldwide apply festival branding, due to the growing importance of cultural industries within the contemporary economy (Ashworth & Kavaratzis, 2009). They have notable spill-over effects, by employing people in the cultural professions and raising awareness and consumption of arts locally, and through increased earnings in the hospitality sector, etc.(CER, 2013) apart from creating opportunities for tourism promotion, commercial outcomes and increased inward investment in host regions, facilitating urban regeneration (Getz, 2007). However, they also create a temporary surge in demand for public services and infrastructure, requiring careful management and supervision by the authorities. These implications can depend on the scale of the festivals. The festivals which are mega scale demand new appropriate approaches.

1.1. Cultural Festivals and its implications on urban public spaces

Worldwide, researchers have characterized mega-scale cultural events and festivals not only as instruments for promoting tourism, driving economic growth, shaping city image, and fostering social cohesion(Blesic et al., 2014; Casero et al., 2018) but also catalysts for urban regeneration and revitalization (Liu, 2014). The temporary increase in infrastructure demand often shifts resource allocation priorities, potentially disrupting the city's normal operations and causing short-term but significant challenges and negative impacts on the urban environment(Kammeier, 2002).

1.2 Festivals and Urban Transformation

Cultural events and festivals are marked by the temporary transformation of urban spaces (Chatterjee & Khanna, 2023; Quinn & Wilks, 2017). (Falassi, 1987) highlights a multitude of defining features inherent to festivals, beginning with a valorization ritual, where ordinary spaces are officially claimed and transformed into festival spaces. Using Durga Puja as a case study—a mega cultural festival in Kolkata, India, celebrated at the community level since the 18th century that evolved into a global socio-cultural public art festival and inscribed on the UNESCO Representative List of the Intangible Cultural Heritage of Humanity in 2021, this study explores the relationship between cultural events and festivals, tourism, and urban public spaces.

Firstly, this study aims to understand the seasonal transformation of the city and evaluate existing permanent and additional temporary facilities. Additionally, it seeks to identify gaps in the provision and optimal distribution of these facilities, as well as assess visitor accessibility to them at a perceivable scale.

The paper introduces the scholarly literature related to Mega-scale events and temporary infrastructure along with the identification of associated challenges and critical variables. Literature based on GIS Network analysis in the context of spatial distribution and coverage of tourism facilities has also been presented. This is followed by the methodology including the description of the case study, data collection methods, and GIS Network analysis approach that leads to the results and findings of the study. Lastly, the paper concludes with a practical discussion regarding the relevance of the study in policy development for tourism and events.

2. Background Research

The literature has been broadly reviewed under two major heads: the first aspect includes a description of the challenges related to the cultural events and festivals and their infrastructure aspect including temporary infrastructure. The second part focuses on the existing studies that employ GIS Network analysis for spatial distribution and coverage of tourism facilities.

Figure 1 explains that a mega-scale or pulsar event is characterized by distinctive supply and demand dynamics. As highlighted by Kammier, both permanent and temporary supply strategies are implemented to accommodate the peak demand generated during such events. Hence, these events require special operational arrangements and management, leading to modifications in urban planning processes and the city's lifecycle.

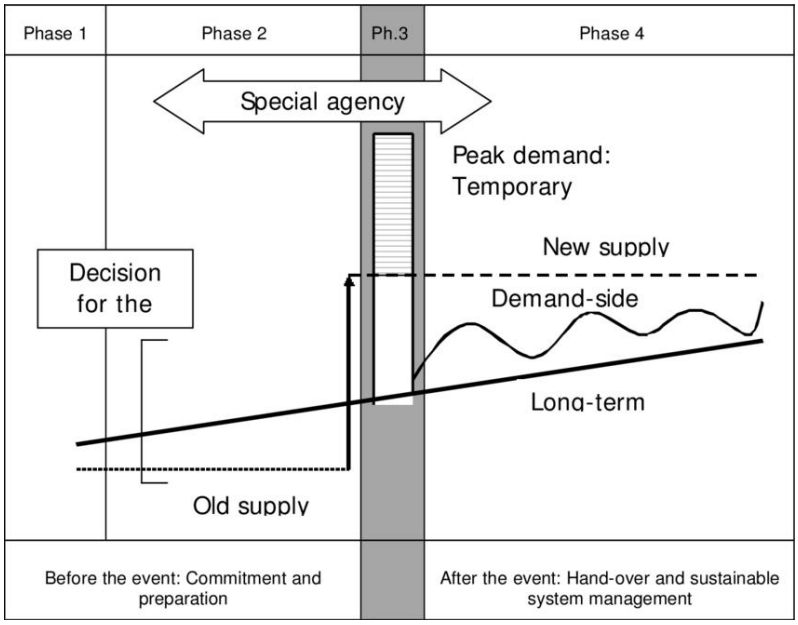


Figure 1: Supply side and Demand side aspects of Infrastructure during Pulsar events, Kammeier, 2002

In the year 2002, 38th ISOCARP Congress focused on the theme "The Pulsar Effect: Urban Planning and the Pulsar Effect: Coping with Peaks, Troughs, and Repeats in the Demand Cycle." It addressed the challenges of providing urban services, facilities, and infrastructure during pulsar events, which represent some of the most significant issues confronting modern urban planners and managers (Colman, 2002).

Table 1 summarizes several studies about various cultural events from different countries and their challenges related to urban infrastructure.

Author	Country	Urban infrastructure issues
Mansfed, 2003	Israel	Distribution/ concentration of accommodation and tourist facilities, Adequacy of accommodation facilities, State of safety and security
Kruger & Saayman, 2012	South Africa	Parking arrangement adequacy, Adequate seats in the grounds, Access to entry gates, Clean and hygienic toilet facilities, Adequate safety measures, Provision of proper information
Lee, Lee, & Park, 2014	South Korea	Availability of food and beverage, Availability of clean toilets, Availability of adequate accommodation, Safety, Access to parking space, Availability of easy-to-understand information, Affordability, Quality of events and exhibits, Acceptance by locals
Novitasari, 2017	Indonesia	Alternative land transport services within the destination, Accommodation service (Hotel), Cleanliness of toilets, Availability of large parking area, Restaurant service, Availability of experienced Tour guide, Presence of souvenir shops
Sorrentino, Fu, Romano, Quintano, & Risitano, 2020	Italy	Hospitability of local people, Adequacy of restaurants, Adequacy of hotels, Quality of tourism attractions and activities in the event location
Njoroge & M., 2021	Kenya	Destination attractiveness, Adequate public space and circulation area, Maintenance of venues, Easy to secure accommodation, Hospitality and

	friendliness, Reasonable pricing of services, Variety of shopping centres, readily available food outlets

Table 1: Summary of studies about various countries' cultural events and their infrastructural challenges

2.1. Temporary infrastructure

Cities of the Global South encounter significant challenges associated with informality and insurgency, where a large portion of the urban population navigates daily life through alternative practices and occupations related to urban spaces(Miraftab, 2012). Limited planning capacities and resource limitations further add to these challenges(Andres et al., 2021). As described in various studies, there is a need for approaches that transcend traditional 'planning' to address the complexity and diversity of such urban environments. This includes recognizing the role of temporary and informal dynamics as viable alternatives, particularly in contexts struggling to establish, implement, and enforce formal planning processes, as seen in the case of mega-scale festivals and cultural events.

Other forms of Mega events such as the Olympics typically drive large amounts of investments in permanent infrastructure, such as stadiums, housing, and other urban renewal projects. However, these investments often spark debates as they offer minimal benefits compared to the extensive public expenditure as they lead to underutilization and high cost of maintenance of legacy infrastructure(Stewart & Rayner, 2016). Temporary form of facilities, on the other hand, offer a cost-effective alternative, eliminating post-event maintenance costs associated with underused or excessively large structures(Müller, 2015). Urban public spaces undergo a temporary transformation during large-scale festivals and often reflect a degree of informality, enhancing the dynamic, vibrant, and spontaneous character of cultural mega-events. As noted by studies, in cities across the Global South, informality has historically been integral to religious festivals and recurring cultural events(Chatterjee & Khanna, 2023). The temporary infrastructure is typically developed through informal collaborations among varied stakeholders, such as community groups, organizations, urban local bodies, and other agencies, contributing to the enhancement of event-related facilities.

2.2. GIS Network analysis for spatial distribution and coverage of tourism facilities

In urban settings, network analysis is commonly employed to assess the current spatial distribution of services, examining aspects such as their functional reach and accessibility, and identifying underserved areas (Mohammadi et al., 2017). Researchers have also applied this method to explore social inequalities within cities, aiming for an equitable distribution of urban services (Harvey, 2010; Mitchell, 2003). It has also been used in suitability assessments, service-area evaluations, and location-allocation analyses to support land-use planning and management, essential for fostering sustainable urban development (Nguyen et al., 2015; Scholten & Stillwell, 2013). Hence it can be said that researchers have utilized GIS-based accessibility analysis, including network analysis tools, to evaluate and enhance the distribution and coverage of public services.

In the context of tourism, (Zheng & Zhao, 2023) have analyzed the accessibility of public service facilities in the context of multiple groups of tourist destinations based on the distribution and accessibility of facilities, particularly catering and shopping facilities by carrying out an evaluation of the facility configuration from the microlevel perspective. Additionally, authors have also used network analysis in an attempt to model shortest path and closest tourist facilities such as hospital, shopping centre, market areas and universities (Nicoară & Haidu, 2014; Prameshwori et al., 2021) done on the basis of estimate travelling time and

distance in terms of time through a network. However, the studies in the tourism context using GIS network analysis to evaluate urban infrastructure and facilities are limited.

By drawing on the literature, variables of tourism facilities were identified and compiled in the next section. Using these variables, the surveys were conducted in the case study area. This study contributes by offering spatial renditions by mapping the distribution and accessibility to cultural-tourism-driven facilities during a mega cultural event using GIS network analysis, taking the case study of Durga Puja in Kolkata.

3. Methodology

This study employs the case study approach, taking the case of Durga Puja in Kolkata, India. The festival drives the seasonal transformation of the city with the creation of 'Durga Puja Pandals,' temporary structures housing the idol of Goddess Durga with extravagant themes.

Kolkata is the capital city of West Bengal, India with a large population size of 4.5 million and an area of 206 square kilometers. Durga Puja in Kolkata has been the first festival in Asial to be inscribed on UNESCO's Representative List of the Intangible Cultural Heritage (ICH) of Humanity. During the 5 day festival of Durga Puja, Kolkata experiences a substantial increase in visitors, leading to increased occupancy across airways, trains, buses, and metro services. Also, special trains and additional coaches are introduced to accommodate this surge, while traffic from nearby towns rises significantly, resulting in peak passenger volumes on metro rail. In 2019, approximately 14.87 lakh passengers were estimated to have traveled to Kolkata during the festival(*Mapping the Creative Economy around the Durga Puja*, 2019).

The festival transforms Kolkata into a city-wide public art gallery, with thousands of pandals located in various parts of the city. These Pandals are temporary structures, built using bamboo frameworks and adorned with colorful fabric drapes, house the idol of Goddess Durga. Featuring extravagant themes and intricate artwork, the pandals involve the traditional knowledge as well as the contemporary style of thousands of artists, from idol-makers to lighting designers. As the focal points of the festival, these pandals draw crowds who interact with and marvel at the art and craftsmanship surrounding them. Hence, they have been taken as the activity nodes for the study.

The Kolkata Municipal Corporation area has been selected for the study. The facility variables taken for the data collection include fire safety, medical aid, security personnel, CCTV, Wheelchairs, drinking water facilities, food and dining facilities, and toilet facilities.

3.1 Questionnaire and Collection of Data

The data was collected through a primary Survey during the Durga Puja 2023 from 12th October 2023 to 21st October 2023, on visitor facilities of Durga Puja pandals in the KMC area to assess the temporary and permanent infrastructure present during the festival. Data collection was carried out through visual observations and interviews with pandal committee members using structured questionnaires. A strategically assigned survey team of four conducted primary surveys across selected pandal clusters. Information was gathered from over 62 pandals of different scales, distributed across 12 clusters within the Kolkata Municipal Corporation (KMC) area. An inventory of pandals was created to track their locations, scale, and the availability of facilities. Facilities were grouped by classification, and organizing into different hierarchy for clearer analysis and visualization. These facilities were then mapped based on their type and location, providing insights into their spatial distribution and reach.

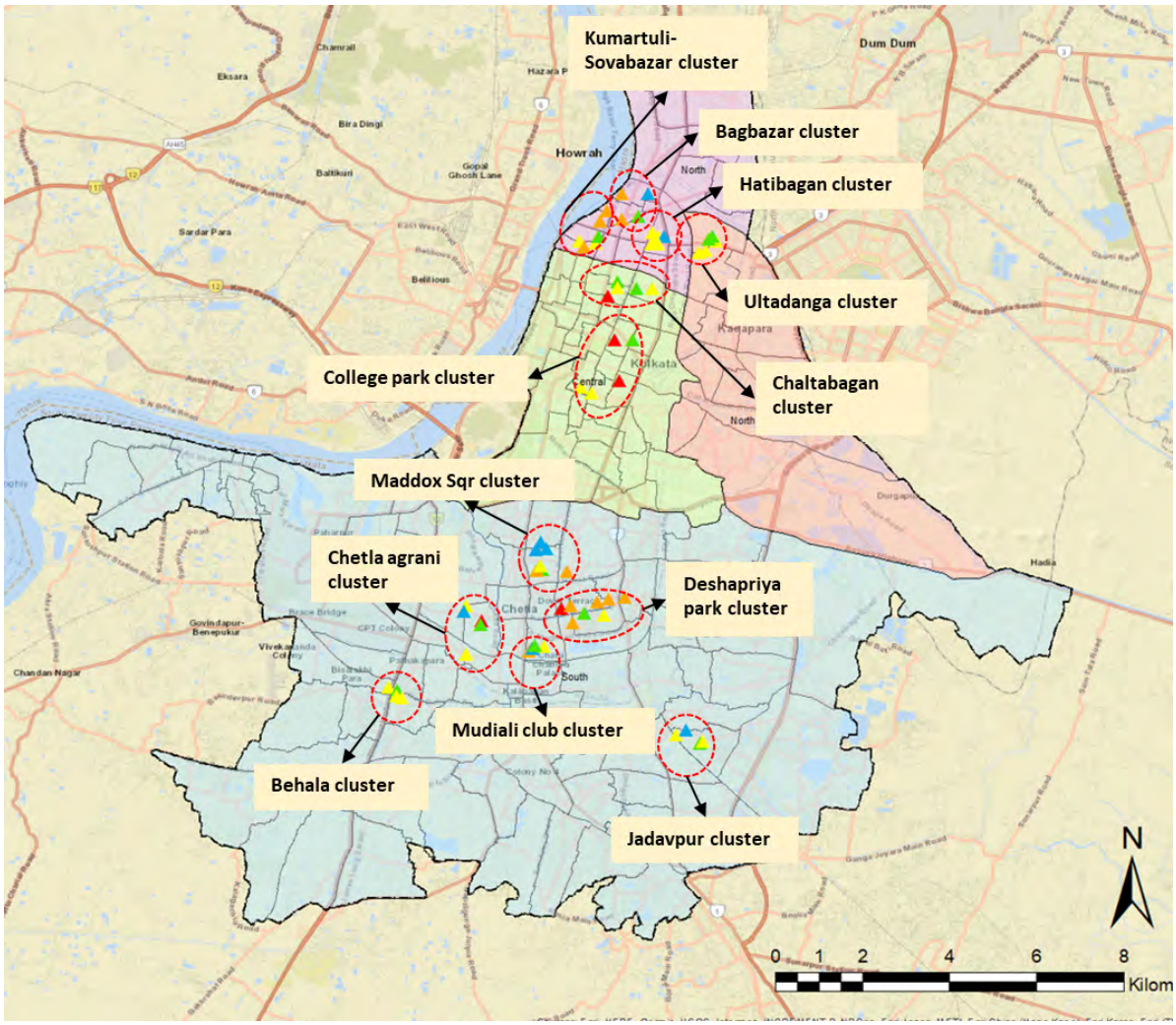


Figure 1: Surveyed Pandal Clusters in Kolkata Municipal Corporation Area

Taking the budget of the Pandals as the criteria, 62 surveyed pandals have been categorized into five scales varying from small to super mega. Surveyed across the four zones of the KMC i.e. north, central, south and north-east, the data from these surveyed pandals of different scales has been compiled in table 2.

Zone/ Scale of Pandal	*Small*	*Medium*	*Large*	*Mega*	*Super Mega*	*Total*
North	2	2	6	5		15
Central	3	4	5	2	3	17
South	3	5	9	6	2	25
North East		2	3			5
Total	**8**	**13**	**23**	**13**	**5**	**62**

Table 2: Pandals surveyed during Durga Puja 2023 scale wise and zone wise

The distribution of facilities that included permanent as well as temporary facilities is governed by the scale of the pandals within a pandal cluster. Since the pandals are not visited in an isolated manner but in the form of clusters that are located near to each other, it is imperative to look at the facility distribution and their access at a perceivable scale. Taking a representative cluster of pandals as an evaluation unit from each zone, the distribution and access to basic and advanced facilities are examined using GIS mapping and network analysis.

3.2 GIS Network Analysis

GIS Network Analysis involves using ArcGIS 10.8.2's Network Analyst tool to evaluate network datasets, covering aspects like service coverage, shortest routes, drive-time zones, and optimal facility locations (ESRI, 2021). Analyses require connecting a network layer to a geodatabase or shared network dataset, either through local datasets (e.g., from OSM) or online sources via ArcGIS Online. Key network features such as connectivity, adjacency, and incidence support this process, which involves digitizing routes, adding details like route lengths, traffic directions, and one-way or two-way data. Although network dataset preparation is time-intensive, ArcGIS offers ready-to-use online datasets to streamline the process. In this study, the ArcGIS Open Street Network Dataset was utilized for service area analysis. First, the analysis type was selected, and the network dataset was prepared and integrated into GIS software. The network analysis layer (e.g., service area) was then created, and relevant network analysis features were applied.

Analysis parameters such as drive time, walking time, or distance were set following literature standards. Finally, service area analysis was performed on each facility to identify the gaps in accessibility. The routing solvers within the ArcGIS Network Analyst extension namely the Route, Closest Facility, and OD Cost Matrix solvers—are based on the well-known Dijkstra's algorithm for finding shortest paths. Each of these three solvers implements two types of path-finding algorithms.

Degree to which visitor facilities can be used by the tourists within a range of ideal walkable distance is evaluated on the basis of two aspects:

a. Facility availability – sparsely distributed or concentrated or not present.
b. Facility accessibility – number of facilities that can be reached within a certain range from the starting point.

The following assumptions have been taken for the GIS mapping and network analysis in Pandals clusters:

- Starting point of the visitors is a transport node- Metro station or railway station or a major bus terminal
- Pandals are covered on foot and visitors cover all the pandals in a cluster.
- Visitors can access the nearest facility present in pandals along this route.
- Visitors follow the shortest route to visit the pandals
- Pedestrian walkable distance is taken as 1.2 km for transport nodes (metro station and railway station) and 400m for catchment area of facilities (Li et al., 2019; Pitot et al., 2006).

4. Findings and Results

Across all pandal scales, the majority of facilities provided are temporary, with the distribution of both permanent and temporary facilities varying according to the scale of the pandals. The majority of facilities found in pandals of all scales are temporary while permanent facilities that are least prevalent are primarily found in larger-scale pandals. The facilities observed in the pandals broadly have been categorized into 'Safety and Security' and 'Cultural Tourism Driven' according to their functionality. Figure 3 illustrates the detailed classification of the facilities. Mandatory facilities for safety and security such as fire extinguishers and first aid are present in almost all the pandals. Discretionary facilities for safety and security are further classified into basic such as CCTVs and Wheelchair which are present in 80-90% of pandals and moderate such as medical booths and fire safety booths are present in 50-80% of the pandals. Similar distribution pattern are observed in basic and moderate cultural tourism facilities that are also temporarily arranged during the event. On the other hand, permanent facilities most of which are present in Mega and Super Mega scale pandals are of higher order and are present in less than 30% of pandals mostly located in parks or squares.

4.1 Category of facilities

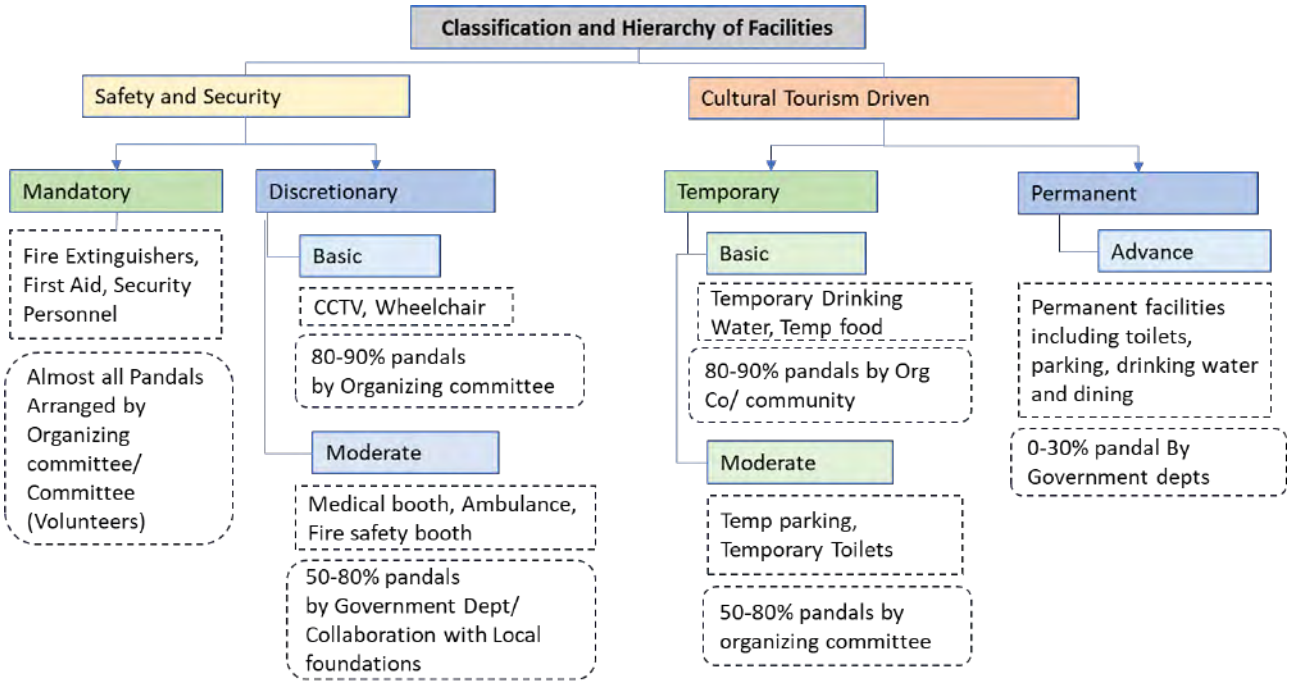


Figure 3: Categorization of Visitor facilities

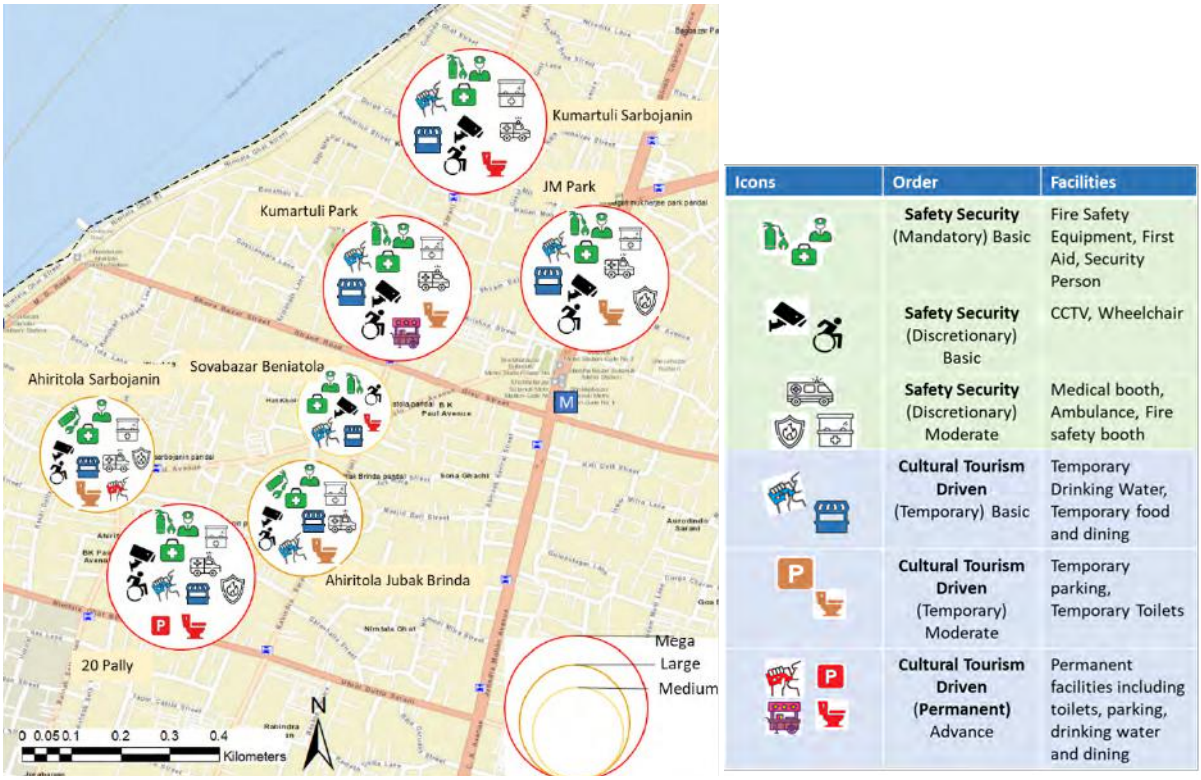


Figure 4: Kumartuli Park Cluster for Service Area Analysis

4.2 Network analysis results

Kumartuli park pandal clustered has been taken as the first cluster for cluster-level analysis which has been included in this report. The pandal cluster is present in the north zone and comprises of seven pandals ranging from medium to mega-scale, namely Kumartuli Park, Kumartuli Sarbojanin, Jogot Mukherjee park and 20 Pally pandal are of mega-scale, Ahiritola Sarbojanin and Ahiritola Jubak Brinda of large scale, and Beniatola Sarbojanin of medium scale. This cluster is in the proximity of Sovabazar metro station. Overall, the cluster is well accessible by public transport via metro and bus routes and comprises temporary facilities and very few permanent facilities. These facilities have been mapped on the pandal cluster (Figure 4).

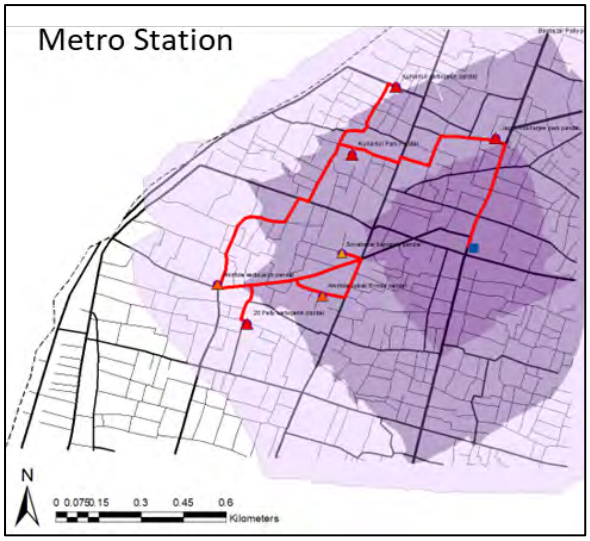


Figure 5: Shortest route starting from Transport node covering all the pandals (activity nodes)

Taking metro station as a starting point (for instance), first an optimal route has been calculated covering all the clusters in a pandal which is approximately 4 km long (Figure 5). The objective here to evaluate the distribution of facilities and their coverage along the optimal route covering the pandals of a cluster.

Accessibility of the activity nodes i.e. pandals from the transport node (Metro station) has been assessed based on the calculated service area of the metro station taking the walkable distance of upto 1.2 km (Li et al., 2019). It has been found that all the pandals fall within the serviceable area of the metro station.

Secondly, the service area of the mapped facilities have been assessed taking the walkable distance of 400m for each facility (Pitot et al., 2006). This has been done for different categories of facilities.

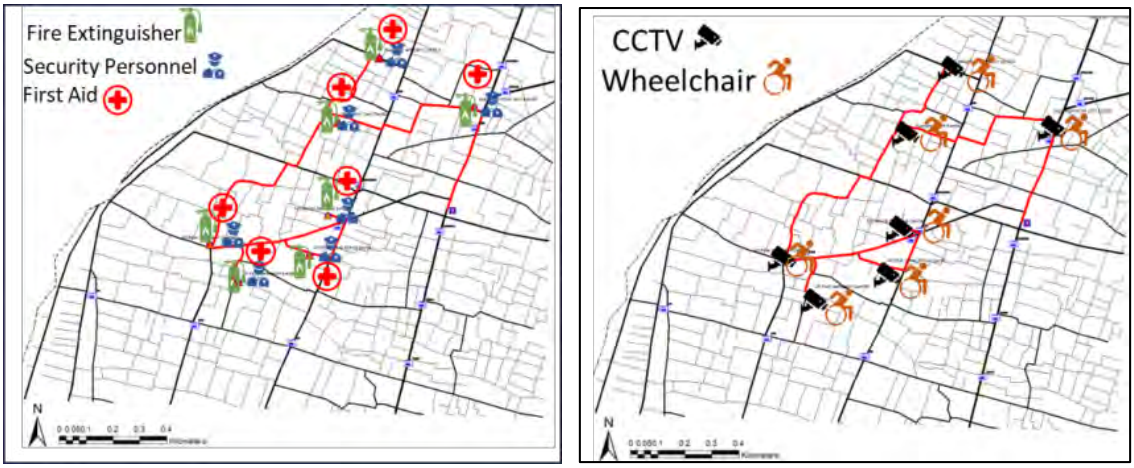


Figure 6: Distribution of Mandatory and Basic facilities

Figure 7: Distribution and service area of Moderate facilities

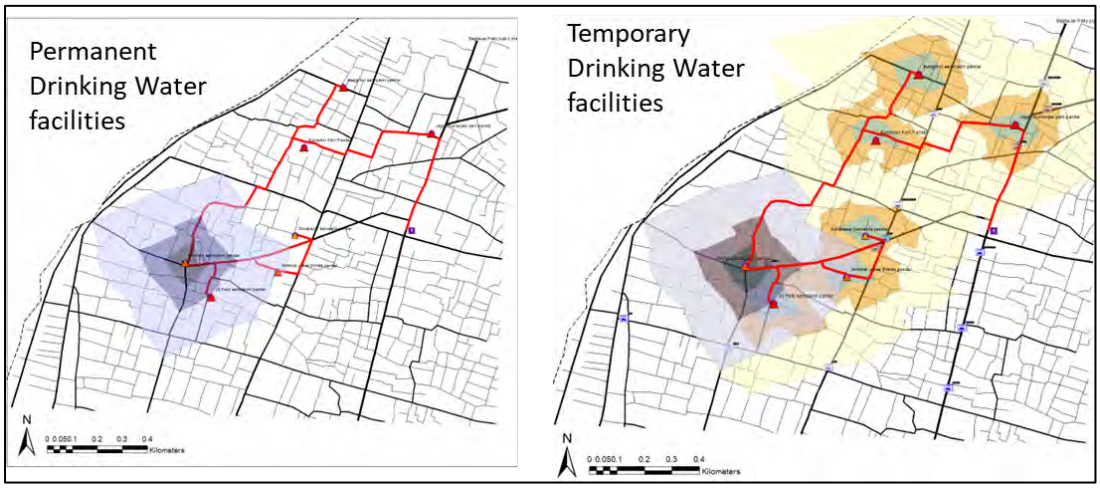


Figure 8: Distribution of Temporary and Permanent drinking water facilities

Mandatory as well as basic safety and security-related facilities are present in all the pandals (Figure 6). Moderate level safety and security facilities such as Ambulance and medical assistance booth although missing in one medium scale pandal are within the walkable distance along the route. Fire safety booth is present in only 3 out of 7 pandals and 50% of the route is not within it's walkable distance.

Figure 9: Distribution of Temporary and Permanent food and dining facilities

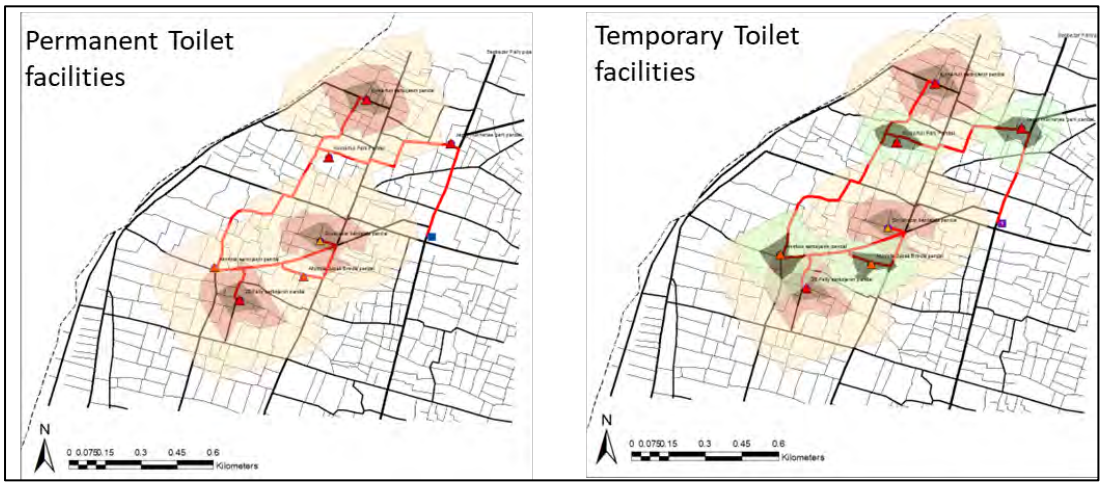


Figure 10: Distribution of Temporary and Permanent toilet facilities

The network area analysis presents some gaps in the provision and access to the present facilities in a cluster of pandals. Basic cultural tourism driven facilities such as temporary drinking water stalls and food stalls are present in all the pandals. Moderate level Safety and security facilities including ambulance and medical assistance booths are distributed uniformly and are accessible within walkable range. Fire safety booths distribution has gaps in accessibility within walkable distance specifically in almost all clusters evaluated. All safety and security facilities are temporary given the seasonal requirement of mitigation of risk during large gatherings.

On the other hand, permanent drinking water and food and dining is limited and only two pandals are within their walkable distance. Permanent toilet facilities are present in few mega scale pandals and the gaps in the walkable service area of the permanent facility are bridged by the distribution of and temporary toilet facilities. Permanent facilities being limited, provision and distribution of temporary facilities have the main role in ensuring that all visitors have access to facilities while moving along the route. Some of the gaps in the permanent facilities are fulfilled by the provision of temporary facilities by the Pandals committee. Among the permanent facilities, permanent toilets are more prevalent than drinking water and dining in all the clusters considered. This is due to the preference of users.

5. Discussions and Conclusions

The study gives an insight into the phenomenon of cultural festivals invigorating the 'invisible city' through the transformation of public spaces that are not only used as stages but enhanced as environments to be reactivated, rediscovered, and experienced differently. It also suggests considering clusters of closely located pandals as units for facility planning and highlights the existing gaps in facility provision and distribution based on activity scale and development patterns. Further, the study offers a framework for understanding the spatial distribution and accessibility of facilities, specifically in the context of pandals as temporary structures. By mapping transport nodes and assessing the spatial attributes, we evaluated the influence of public transportation, major streets, and urban parks on the accessibility and scale of these facilities.

Mega/Super Mega Pandals function at the Structural Network level, attracting huge number of visitors and requiring connectivity with major transport nodes and their organization demands coordination with citywide infrastructure, and coordination with multiple stakeholders, including city authorities and

emergency services. Continuous maintenance is essential, particularly during peak visiting hours, to ensure visitor safety and manage large crowds effectively.

On the other hand, Small, Medium, and Large-Scale Pandals operate mainly within the Local Network, these pandals are designed to serve neighborhood or district-level populations. They rely on smaller transport nodes or are accessible by foot, reducing the need for extensive logistical coordination with the broader city infrastructure. They are often managed by local community volunteers. Maintenance efforts are focused on ensuring cleanliness and safety within a smaller space, with limited coordination needed with external agencies.

This study underscores the importance of integrating both **Structural** and **Local Networks** to optimize the accessibility and distribution of urban facilities, especially temporary structures like pandals.By identifying the pattern of transformation during the festival and discerning gaps in integrating cultural festivals with facility planning, the study foresees development guidelines to utilize cultural festivals for overall urban development. By understanding the operational distinctions between pandal scales and network layers, planners can more effectively allocate resources and manage crowd dynamics. The integration of real-time data and GIS tools into this two-layered framework could further enhance adaptability, allowing for dynamic adjustments in urban spaces.

4. References

Andres, L., Bakare, H., Bryson, J. R., Khaemba, W., Melgaço, L., & Mwaniki, G. R. (2021). Planning, temporary urbanism and citizen-led alternative-substitute place-making in the Global South. *Regional Studies*, *55*(1), 29-39. https://doi.org/10.1080/00343404.2019.1665645

Ashworth, G., & Kavaratzis, M. (2009). Beyond the logo: Brand management for cities. *Journal of Brand management*, *16*, 520-531.

Blesic, I., Pivac, T., Dordevic, J., & Stamenkovic, I. (2014). Cultural events as part of cultural tourism development. Case study: Sombor and Apatin (Serbia). *Acta geographica Slovenica*.

Casero, G. G., Jara, C., Beltran, F., & Nogueras, J. (2018). Cultural Events: Case Study of a Theatre Festival as an Element of Tourist Attraction. *Mediterranean Journal of Social Sciences*, 177-185.

CER. (2013). Conference on Europe's growth strategy and the World Economy. Oxforshire.

Chatterjee, D., & Khanna, K. (2023). Planning Temporariness: Unpacking Time–Space Planning and Its Socially Just Applications in and Around Kolkata. *Urbanisation*, *8*(2), 117-142. https://doi.org/10.1177/24557471231196586

Colman, J. (2002). Urban Planning and the pulsar effect: Coping with peaks, troughs and repeats in the demand cycle. In ISOCARP (Ed.). Athens, Greece: ISOCARP.

Falassi, A. (1987). Festival: Definition and morphology. *Time out of Time: Essays on the Festival*, *1*.

Getz, D. (2007). Event studies: Theory, research and policy for planned events. *Elsevier*.

Harvey, D. (2010). *Social justice and the city* (Vol. 1). University of Georgia press.

Huang, Z., Li, M., & Cai, L. (2010). A model of community-based festival image. *International Journal of Hospitality Management - INT J HOSP MANAG*, *29*, 254-260. https://doi.org/10.1016/j.ijhm.2009.10.010

Kammeier, H. D. (2002). Coping with 'pulsar effects': Towards a conceptual framework. Urban planning and the 'pulsar effect': Coping with peaks, troughs and repeats in the demand cycle- 38th ISOCARP Congress, Athens.

Li, S., Yang, H., Zhang, G., Ling, Z., Xiong, Y., & Li, Y. (2019, 14-17 July 2019). What is the best catchment area of a metro station? A study based on station level ridership modeling. 2019 5th International Conference on Transportation Information and Safety (ICTIS),

Liu, Y.-D. (2014). Cultural Events and Cultural Tourism Development: Lessons from the European Capitals of Culture. *European Planning Studies*.

Mapping the Creative Economy around the Durga Puja. (2019).

Miraftab, F. (2012). Small-Town Transnationalism: Socio-Spatial Dynamics of Immigration to the Heartland. In K. W. Stefan Kratke, and Stephan Lanz (Ed.), *The Transnationalism and Urbanism* (pp. 220-231). The Transnationalism and Urbanism.

Mitchell, D. (2003). *The right to the city: Social justice and the fight for public space*. Guilford press.

Mohammadi, A., Tavakoli Naghmeh, M., Abbasi, S., & Talkhab, A. (2017). Spatial analysis of urban services using network analyzer in the GIS environment (case study: Babolsar City). *Journal of Urban Social Geography*, *4*(1), 111-130.

Müller, M. (2015). The Mega-Event Syndrome: Why So Much Goes Wrong in Mega-Event Planning and What to Do About It. *Journal of the American Planning Association*, *81*(1), 6-17. https://doi.org/10.1080/01944363.2015.1038292

Nguyen, T. T., Verdoodt, A., Van Y, T., Delbecque, N., Tran, T. C., & Van Ranst, E. (2015). Design of a GIS and multi-criteria based land evaluation procedure for sustainable land-use planning at the regional level. *Agriculture, Ecosystems & Environment*, *200*, 1-11.

Nicoară, P.-S., & Haidu, I. (2014). A GIS based network analysis for the identification of shortest route access to emergency medical facilities. *Geographia Technica*, *9*(2), 60-67.

Pitot, M., Yigitcanlar, T., Sipe, N., & Evans, R. (2006). Land use and public transport accessibility index (LUPTAI) tool: the development and pilot application of LUPTAI for the Gold Coast. In C. Grainger (Ed.), *Proceedings of the 29th Australian Transport Research Forum* (pp. 1-18). Planning and Transport Research Centre (PATREC). https://eprints.qut.edu.au/214591/

Prameshwori, T., Wangshimenla, J., Surjit, L., & Ramananda, L. (2021). GIS-Based Route Network Analysis for Tourist Places: A Case Study of Greater Imphal. *International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET)*, *8*(2), 233-238.

Quinn, B., & Wilks, L. (2017). Festival heterotopias: Spatial and temporal transformations in two small-scale settlements. *Journal of Rural Studies*, *53*, 35-44. https://doi.org/https://doi.org/10.1016/j.jrurstud.2017.05.006

Scholten, H. J., & Stillwell, J. (2013). *Geographical information systems for urban and regional planning* (Vol. 17). Springer Science & Business Media.

Stewart, A., & Rayner, S. (2016). Planning mega-event legacies: uncomfortable knowledge for host cities. *Planning Perspectives*, *31*(2), 157-179. https://doi.org/10.1080/02665433.2015.1043933

UNESCO. (2003). Convention for the Safeguarding of the Intangible Cultural Heritage. Text of the Convention for the Safeguarding of the Intangible Cultural Heritage, Paris.

Zheng, X., & Zhao, D. (2023). Evaluating the accessibility of public service facilities to tourists and residents in island destinations: Evidence from the Changhai County [Original Research]. *Frontiers in Public Health*, *10*. https://doi.org/10.3389/fpubh.2022.1090341

Research Paper

Spatial heterogeneity in the impact of traditional mountainous urban patterns on retail industry location

A case study of Chongqing historic district

Ziqi WU, Chongqing University, China
Xiliu HE, Southeast University, China
Heping LI, Chongqing University, China

Abstract

The objective quantification of urban patterns' influence on industrial location has always been an important issue in urban geography. As the most crucial component of urban service activities, retail industry's location choice and spatial expansion are seen as significant outcomes of urban pattern shaping. Yuzhong District, as Chongqing's mother city, best exemplifies the mountainous urban characteristics of Chongqing. It concentrates ancient Chongqing's historical and cultural heritage and is also where retail businesses are most densely clustered. Different urban spatial cultural types determine consumer types and scale, forming consumption characteristics that shape urban regional features. Exploring retail distribution characteristics in mountainous urban districts and analyzing their interaction mechanisms with historical spatial elements helps form culturally distinctive urban imagery through location preference and spatial layout strategies, thus playing a fundamental role in guiding urban commercial space development and reviving Chinese traditional mountain city culture.

This study takes China's most typical traditional mountain city region - the Two Rivers Junction area of Chongqing's Yuzhong District as an example. Based on the latest POI data, combined with kernel density, local hotspot analysis, spatial correlation analysis and natural language processing methods, it explores the distribution characteristics, industry correlation characteristics and consumption symbolic characteristics of retail consumption space in Chongqing's historical district from a historical and cultural perspective. The study finds that the retail consumption space pattern in the Two Rivers area is "mainly concentrated in the eastern historical city wall area, with dual-core aggregation and multi-point dispersion coexisting", showing close association with historical resource elements and reflecting the local cultural characteristics of "openness, freedom, diversity and inclusiveness", providing scientific basis for mountain city planning and construction and shaping urban cultural imagery.

Keywords

Mountain city, Retail consumption space, Spatial characteristics, Historical district, Consumer culture, Urban morphology

1. Introduction

1.1. Interaction Between Retail Commercial Space and Urban Morphology

With China's rapid economic development and accelerating urbanization process, retail industry has entered a period of rapid growth, and many cities have gradually transformed from "production-oriented cities" to "consumption-oriented cities" (Zhou, 2014). Under the development background of "consumption-oriented cities", a city's success or failure largely depends on its advantages in the consumption sector (Glaeser, 2006). For instance, in terms of urban economic development, consumption has gradually become the mainstay of economic growth. In terms of urban commerce, commercial space patterns, business development models, and residents' daily consumption behaviors also change with urban morphology transformation, thereby giving rise to more diverse consumption demands such as scenario-based, experiential, and interactive modes (Cao, 2019).

Retail business behavior serves as the "capillaries" of urban commercial activities. China's retail commercial space research has yielded abundant results, covering multi-scale characteristics of retail commercial layout from national and urban to community levels (Hao, 2019). As the historical inheritance subject of urban development, historical districts have traditionally concentrated large amounts of urban internal flows of people, goods, information, and capital, making them important components of cities (Wang, 2018). Chongqing is China's youngest municipality directly under the central government. Its main urban district's retail enterprises started early, with large quantities, complete business formats, and comprehensive varieties (Liu, 2021). Its commercial circle spatial structure is influenced by specific urban spatial structures, differing from China's traditional plain cities' band-type spatial patterns. Based on ground level and extending three-dimensionally underground and skyward, it exhibits typical mountain city characteristics (Chen, 2012). Mountain cities are complexes of natural geographical units such as mountains, hills, rivers, and bays, thus urban morphology has an even greater impact on commercial space layout (Tu, 2019). Studying the relationship between mountain city morphology and retail commercial space helps grasp mountain city location selection patterns and enriches relevant theories of urban geography and location theory. Additionally, it can guide mountain city planning and construction by mapping urban spatial structure and functions through retail industry's spatial patterns and structures, promoting positive spatial interactions between retail layout and urban space.

1.2. Impact of Urban Cultural Space on Consumption Characteristics

Compared to newly developed urban districts, historical districts represent past urban forms and play a crucial role in contemporary urban development (Nyseth, 2013). From a historical perspective, historical districts are relatively old parts of cities with stable socioeconomic structures and rich customs and cultural habits (Wang, 2009), requiring reasonable protection and renewal to revitalize. Culture, as the soul and temperament of cities, leads people toward nobility, courtesy, self-respect, and fulfillment (Wu, 1997). When cities face opportunities or crises, revitalizing urban space from a cultural dimension is the true and lasting path of urban development (Huang, 2010). Examples like Birmingham's Brindley Place, Liverpool's Albert Dock, Chengdu's Kuanzhai Alley, and Hangzhou's Southern Song Imperial Street are all demonstrative cases of urban space cultural revival strategies (Huang, 2006). Cities must have their own cultural spirit and cultural symbols, allowing residents and tourists to clearly grasp urban images and spiritual connotations, forming their own urban brands (Wang, 2017).

The transition from traditional material consumption to modern service-oriented experience has become a basic characteristic of retail enterprise development (Liu, 2021). Experience is a memorable activity where sellers use services as stages and goods as props, existing within consumers' minds and involving their physical, emotional, and intellectual participation (Schmitt, 1999). Similarly, the cultural experience generation process in retail commercial spaces uses spatial layout, architectural form, and landscape environment as experiential media, and business format composition and activity settings as activity experience media, which can be seen as the process of experiencing urban spatial cultural characteristics (Hu, 2015). Urban space is a functional space for human activities, and different urban spatial cultural types determine the types and scale of consumers (Tu, 2019), forming consumption characteristics and thereby shaping urban regional features, reflecting the combination of traditional historical culture and modern urban space quality requirements (Chen, 2019). Taking British cultural and creative industries as an example, since 2005, these industries have grown at twice the rate of overall GDP growth for eight consecutive years, creating enormous job opportunities, promoting urban residents' cultural education, and spatially creating a series of impressive cultural tourism routes and districts (Gao, 2018). In the postmodern context, culture and consumption have become inseparable concepts (Wang, 2017). Urban space, as the physical spatial carrier of culture and consumption, when given certain historical significance, its spatial consumption changes will profoundly impact urban culture and urban spatial structure.

1.3. Regional Characteristics of Retail Space in Historical Districts

Yuzhong District is Chongqing's mother city and the birthplace of Ba-Yu culture, best reflecting Chongqing's mountainous city characteristics (Pei, 2017). The Yangtze River and Jialing River converge here, traditional commerce originated here, and the city's embryonic form was nurtured here, concentrating ancient Chongqing's historical and cultural heritage. Its main body is the Huguang Guild Hall - East Water Gate historical and cultural district, where merchants gathered and shops lined the streets, being Chongqing's most prosperous commercial district from ancient times to present, and the most densely concentrated area for retail enterprises (Liu, 2021). With numerous historical residences like Hu Zi'ang's former residence and Xie Family Mansion, alleys full of urban life such as Banana Garden Lane, Xiahong Study Lane, and Drum Lane are scattered throughout, containing old Chongqing's spirit and soul. Meanwhile, it is also one of Chongqing's CBD financial centers (Wang, 2017), producing leading economic, political, and cultural central effects.

Yuzhong District is built on a "peninsula" mainly consisting of Pipa Mountain and Goose Hill. "Mountains" are the objective material elements that constitute Chongqing's urban fabric, serving both as carriers for urban development and as organic components of the city. Ancient Chongqing's urban construction adapted to the natural terrain, organically distributed among mountains and waters, forming popular mountain-water cultural characteristics shaped through residents' interactive settlement practices. Both Chongqing's urban spatial form and architectural style demonstrate prominent characteristics of "following natural timing and taking advantage of geographical conditions", which is inseparable from the creative play of "human harmony", and shows Chongqing culture's openness and inclusiveness (Wang, 2005). In recent years, Yuzhong District has vigorously promoted the inheritance and renewal of historical culture, continuously advancing the integration of culture, commerce, tourism, industry, city and landscape. It has proposed three development goals: restoring the historical appearance of "Old Chongqing", enhancing the cultural tourism quality of the "New Mountain City", and developing "Most Chongqing" cultural tourism industry. The scale of cultural and tourism

industry in Yuzhong District continues to grow, forming cultural creative development clusters and a diversified industrial spatial pattern with historical districts, parks, bases, and buildings as carriers. The actual operational benefits of cultural tourism hotspots have risen rapidly overall, with obvious advantages in areas like Hongyadong and Eighteen Steps.

Retail enterprises, as important players in urban commercial activities, are the main platform for connecting with residents' consumption needs and powerful assistants in optimizing urban spatial planning (Liu, 2021). Therefore, exploring the distribution characteristics of retail industry in mountainous urban districts and sorting out its influence mechanism with historical spatial elements is to summarize and form urban image associations with cultural characteristics from location selection preferences and spatial layout strategies, to guide urban commercial space development. This provides decision-making reference for maintaining local culture and cultural diversity, creating new driving forces for urban development in the post-industrial era. Urban space is the material carrier of culture and plays an important foundational role in the revival of Chinese urban culture. The era of economic development as a single development goal has ended, while multiple development goals highlighting cultural value, ecological value, and social value have become the main direction of future urban development (Wang, 2017). Urban spatial culture should provide ethical, aesthetic and poetic nurturing to the people, and all memorable people, events and places should leave respectable cultural footprints. The consumption spatial form of historical urban districts should reflect the cultural personality of the mountain city, become the spatial discourse of the mountain city, and display urban spirit and symbols (Huang, 2010).

Therefore, taking China's most typical traditional mountainous urban area - Chongqing's Yuzhong Two Rivers Confluence Area as an example, this study explores the distribution characteristics, industrial correlation characteristics and consumption symbol characteristics of retail consumption space in Chongqing's historical urban district from a historical and cultural perspective, based on the latest point of interest data, combined with kernel density, local hotspot analysis, spatial correlation analysis and natural language processing methods, to provide scientific basis for mountainous urban planning and construction.

2. Research Data and Methods

2.1. Study Area and Data Sources

The Two Rivers Confluence Historical District is located at the confluence of the Yangtze River and Jialing River in central Chongqing, covering an area of approximately 13.36 square kilometers. It extends north to the Chaotianmen Yangtze River Bridge, south to Nanbin Road, west to the Hongyan Village Bridge (bounded by the western edge of the Eighth Route Army Chongqing Office Site - Hongyan Village No. 13 construction control zone), and east to Tushan Road.

This study uses Point of Interest (POI) data as its basic dataset, sourced from the open-source data provided by the Amap Open Platform, collected in December 2022. The retail consumption space data is categorized into four types: Food & Beverage, Hotel & Accommodation, Shopping & Consumption, and Leisure & Entertainment (Table 1). After data cleaning and coordinate correction, a total of 10,663 POI data points were extracted (Figure 1).

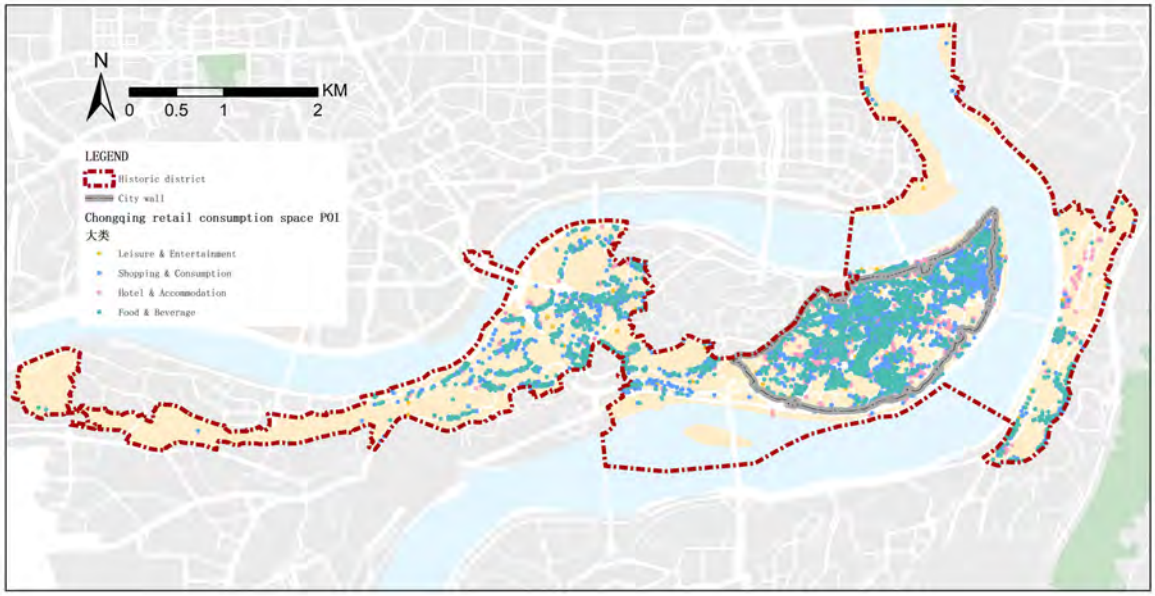


Figure 1. Study area and data. Source: Authors.

Table 1. Types of retail consumption space. Source: Authors.

2.2. Research Methods

2.2.1. Kernel Density Analysis

Kernel Density Analysis calculates the value per unit area using a kernel function based on point features. It estimates the degree of spatial point feature clustering using a regularly moving quadrat, reflecting the relative concentration degree of element spatial distribution. This is a commonly used research method for identifying spatial aggregation (Yu et al., 2016).

2.2.2. Average Nearest Neighbor Analysis

The Average Nearest Neighbor Analysis calculates the nearest neighbor index based on the average distance between each feature and its nearest neighboring feature and the expected average distance under random distribution. This determines whether point features exhibit clustered or uniformly dispersed distribution patterns, quantifying the degree of clustering.

2.2.3. Local Spatial Autocorrelation Analysis

Local Spatial Autocorrelation Analysis determines the correlation between data at adjacent spatial locations by defining research scale, constructing spatial weight matrices, and calculating spatial autocorrelation indicators such as Moran's I. This can be used to detect hot and cold spot clusters of various retail consumption spaces.

2.2.4. Spatial Correlation Analysis

Spatial Correlation Analysis is based on the Pearson correlation coefficient model to analyze POI elements that may have correlations, exploring the degree of spatial correlation between different types of POIs. This study conducts spatial correlation analysis after normalizing grid cell sizes to eliminate density differences caused by point feature quantities (Zhang et al., 2022).

2.2.5. Text Analysis Based on Jieba and Wordcloud

For cultural scene analysis, we employ Python-based natural language processing tools. Jieba, a Chinese word segmentation tool, is used for text analysis and processing, while Wordcloud is utilized for visualization of word frequency analysis. The combination of Jieba word segmentation and Wordcloud visualization enables a comprehensive analysis of important keywords, revealing the characteristics of retail consumption spaces from a cultural perspective.

3. Case study

3.1. Distribution Characteristics of Retail Consumption Spaces

Overall, there is a high number of POIs with dense distribution and diverse categories. From a spatial perspective, the retail consumption spaces demonstrate an evident east-west differentiation, with concentration in the eastern historical district and relatively sparse distribution in the western area of the Two Rivers Confluence District. This distribution pattern closely follows the city's mountainous topography and shows a clear correlation with the Yangtze and Jialing river systems, reflecting the unique characteristics of the mountainous urban form.

The kernel density analysis (Figure 2a) reveals a spatial pattern characterized by "dominance of the eastern historical city wall area, dual-core aggregation coexisting with multi-point dispersion." The distribution is primarily concentrated in the historical city wall area, centered around two traditional commercial districts: "Jiefangbei-Qiaogoukou" and "Chaotianmen-Xiaoshizi." These areas, which include major commercial landmarks such as Dacheng Department Store, Chongqing Department Store, and Guotai Arts Theatre, form significant commercial nodes with distinct spatial clustering characteristics.

Different types of retail consumption spaces exhibit varying spatial structures:

1. Shopping consumption (c) and leisure entertainment (e) display a "dual-core" spatial structure, with cores at "Jiefangbei-Qiaogoukou" and "Chaotianmen."
2. Food and beverage establishments (b) show a "main core + radiation area" pattern, with the core concentrated in the "Jiefangbei-Qiaogoukou" district and forming connected radiation zones.
3. Hotel accommodation (d) exhibits a more dispersed "scattered points" spatial structure without obvious core areas.

This differentiated distribution pattern reflects the historical evolution of Chongqing's urban form and the influence of its unique mountainous topography on retail space development. The spatial organization demonstrates how different retail functions have adapted to and been shaped by the city's natural and historical urban patterns, creating a complex and layered commercial landscape that characterizes the Two Rivers Confluence Historical District.

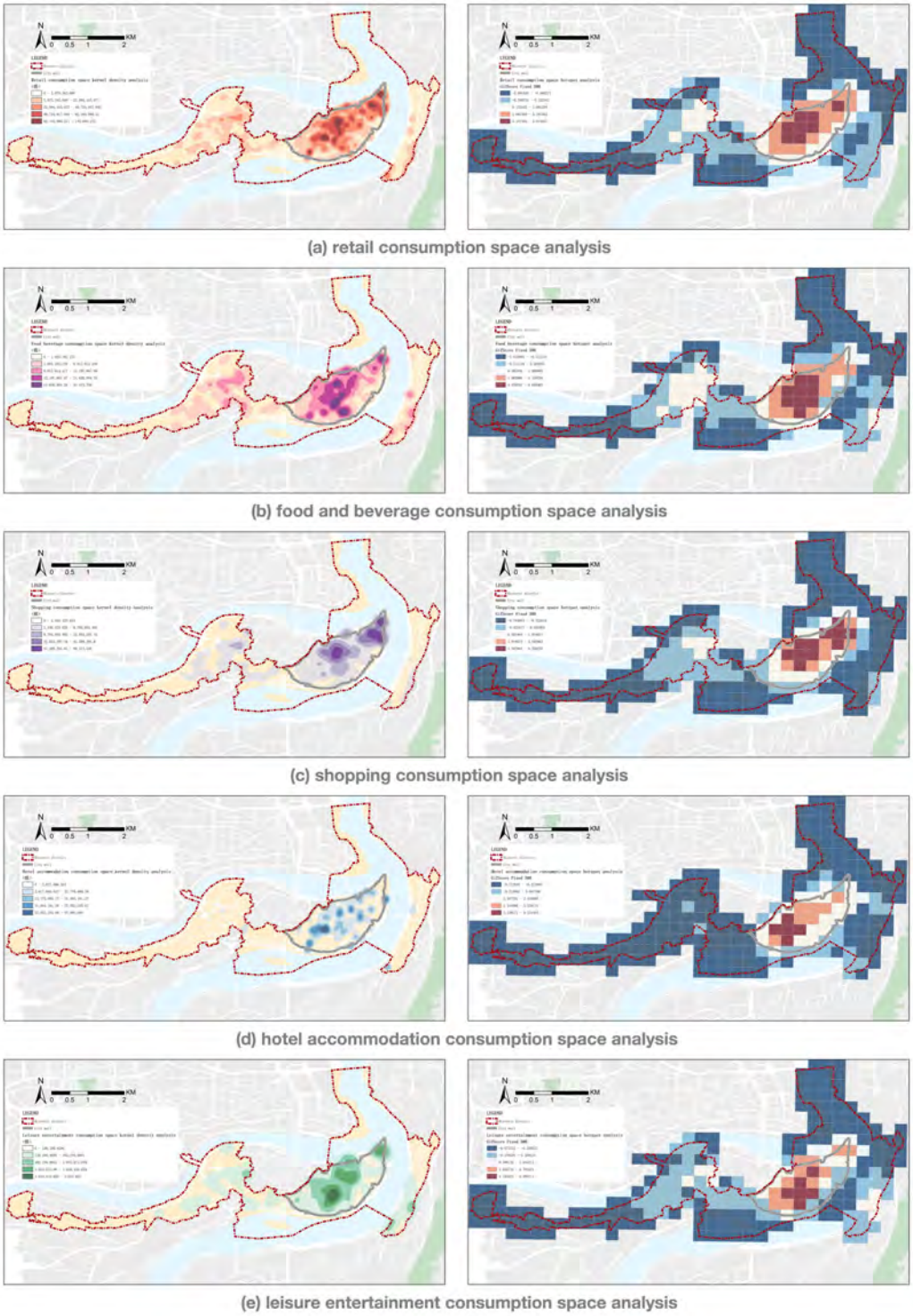


Figure 2. (a) Kernel density analysis and hotspot analysis. Source: Authors.

Further analysis of spatial aggregation patterns through the nearest neighbor index calculation reveals distinct clustering characteristics among different retail categories (Figure 3).

In terms of aggregation degree, from highest to lowest, the order is hotel accommodation (0.23), food and beverage (0.25), shopping consumption (0.26), and leisure entertainment (0.47).

The analysis of POI quantities combined with kernel density and hotspot analysis demonstrates that food and beverage, hotel accommodation, and shopping consumption not only have relatively large numbers of establishments but also exhibit high degrees of aggregation. This finding is particularly noteworthy as these three categories, while representing basic and daily retail consumption spaces in the city, maintain relatively concentrated distributions within the historical urban area without showing obvious dispersion trends. In contrast, leisure entertainment facilities show both fewer numbers and lower aggregation characteristics, with an observed average distance of 63.98 meters and an expected average distance of 137.06 meters, indicating a more scattered distribution pattern compared to other retail categories.

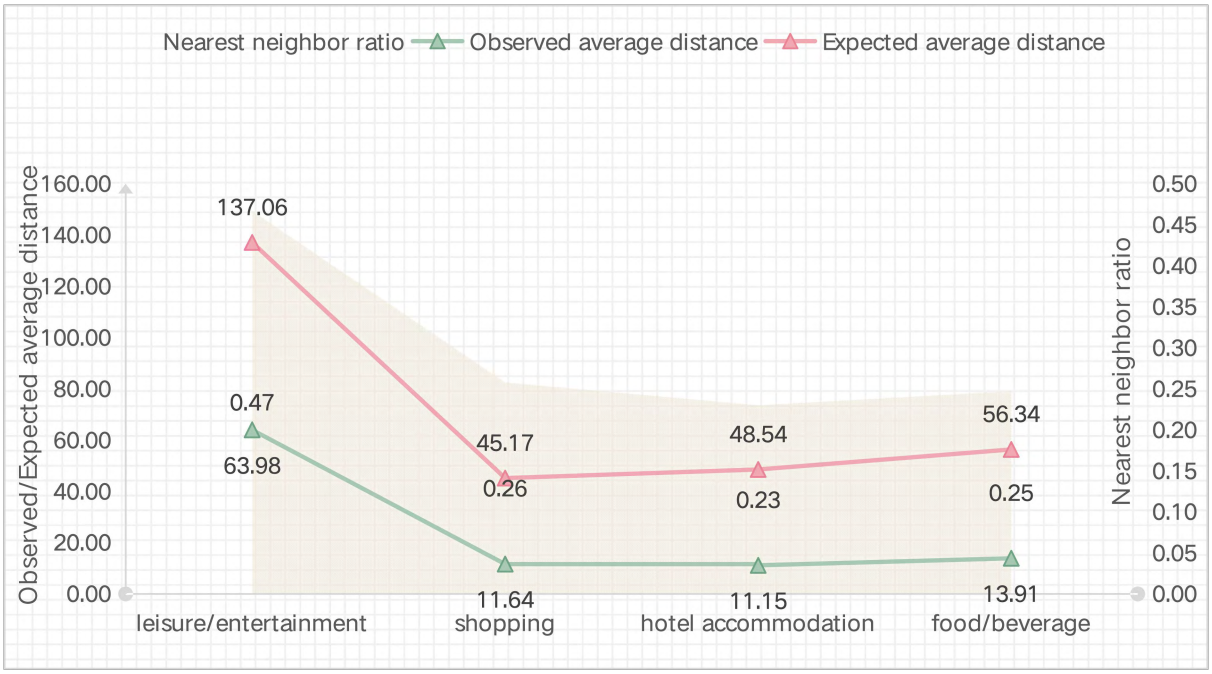


Figure 3. Nearest neighbor index analysis. Source: Authors.

3.2. Retail Consumption Spatial Correlation

Following the analysis of distribution characteristics, we examined the spatial correlations between different types of retail consumption spaces. After normalizing the grid cell sizes of each facility type, correlation coefficients were calculated based on the Pearson correlation model, resulting in a correlation matrix for the four types of retail consumption spaces in Chongqing's historic urban area (Table 2). Generally, correlation coefficients can be categorized into four levels: 0-0.09 (no correlation), 0.09-0.3 (weak correlation), 0.3-0.5 (moderate correlation), and 0.5-1.0 (strong correlation).

The analysis reveals that strong correlations dominate between facility types, with most correlations significant at the 0.01 level. The strongest correlation is observed between

food/beverage and leisure/entertainment facilities (0.850), indicating their close spatial proximity and functional complementarity. In contrast, the weakest correlation exists between shopping consumption and hotel accommodation (-0.005), showing only moderate spatial interdependence.

Food and beverage facilities demonstrate particularly strong correlations with all other types (ranging from 0.534 to 0.850), suggesting their widespread distribution and high interdependence with other facilities. This pattern indicates that food and beverage establishments serve as fundamental retail consumption spaces in the district, acting as anchors that support and attract other retail categories. Their extensive spatial distribution reflects their role in providing daily consumer services while also integrating with various commercial functions.

Hotel accommodation facilities show relatively weaker correlations with other retail types (coefficients ranging from 0.418 to 0.534). This pattern can be attributed to the distinct nature of hotel services, which primarily cater to non-local populations. Unlike other retail consumption spaces that prioritize local community needs and commercial synergies, hotel location choices are more influenced by factors such as accessibility to tourist attractions and business districts.

	Food/beverage	shopping	leisure/entertainment	Hotel accommodation
Food/beverage	1	0.702**	0.850**	0.534**
shopping	0.702**	1	0.625**	0.418**
leisure/entertainment	0.850**	0.625**	1	0.511**
Hotel accommodation	0.534**	0.418**	0.511*	1

Table 2. Spatial correlation coefficients of retail consumption space. Source: Authors.

3.3. Consumption Scenario Analysis Based on NLP

To explore the urban cultural symbols and consumption phenomena behind the retail and consumer spaces in Chongqing's historical district, text segmentation statistical analysis of retail consumer space POI names was conducted using Jieba and Wordcloud modules. The font size was adjusted according to the frequency of occurrence, as shown in Figure 4.

The word frequency statistics results of various retail consumer spaces show distinct Chongqing characteristics. For food and beverage retail spaces, the most frequent words are "Traditional Hotpot," "Hotpot," "Teahouse," "Coffee," "Noodle House," and "BBQ Restaurant." "Hotpot" reflects Chongqing people's preference for hotpot cuisine, while "Teahouse" and "Coffee" reflect Chongqing's unique leisure consumption culture.

For shopping and retail spaces, the most frequent words are "Convenience Store," "Supermarket," "Groceries," "Apparel," "Tobacco and Liquor," and "Jewelry." "Convenience Store" and "Supermarket" reflect the typical spatial forms of shopping consumption in Chongqing's historical district, while "Groceries," "Apparel," "Tobacco and Liquor," and "Jewelry" reflect diverse shopping consumption orientations.

For hotel and accommodation spaces, the most frequent words are "Apartment," "Guesthouse," "River View," "High-rise," "Mountain City," "Jiefangbei," and "Hongyadong." "Apartment" and "Guesthouse" reflect the large number of flexible, small-scale capital investments in short-term rental markets through guesthouses and apartment-style accommodations. "River View" and "Mountain City" reflect the unique Chongqing landscape's competitiveness in the hotel market. "High-rise" reflects how Chongqing's vertical residential building forms as a mountain city attract numerous tourists. "Jiefangbei" and "Hongyadong" reflect popular hotel location choices, which corroborates with the kernel density and hotspot analysis results.

For leisure and entertainment spaces, the most frequent words are "Bar," "Karaoke," "Board Games," "Entertainment Room," "Mahjong," and "Dance Hall." These words reflect the diverse types of leisure and entertainment consumption spaces and a lifestyle that emphasizes entertainment.

As physical spatial carriers of culture and consumption, retail consumer spaces represent the coupling of urban culture and spatial consumption, while also mapping urban cultural symbols different from other regions. The word frequency statistics results of various retail consumer spaces in Chongqing's historical district demonstrate the area's primary consumption characteristics and reflect the urban consumption culture Chongqing presents to both local residents and tourists. Among these, the mountain city pattern and leisurely lifestyle are Chongqing's most attractive consumption cultural symbols.

Figure 4. (a) food and beverage NLP analysis; (b) shopping NLP analysis; (c) hotel accommodation NLP analysis; (d) leisure entertainment NLP analysis. Source: Authors.

4. Conclusion and Discussion

4.1. Research Findings and Contributions

4.1.1. Distribution Characteristics

Our GIS analysis revealed that retail consumption spaces in Chongqing's historic district are numerous, densely distributed, and diverse. The spatial pattern shows a distinct concentration in the eastern historical area, characterized by dual-core aggregation and multi-point dispersion. The four consumption sub-categories (dining, shopping, accommodation, and leisure) displayed distinct spatial distributions with high correlation. The analysis identified two major commercial cores - "Jiefangbei-Qiaogoukou" and "Chaotianmen-Xiaoshizi" - which serve as primary nodes in the retail network, while different retail categories demonstrated varying degrees of spatial clustering and dispersion patterns.

4.1.2 Consumption Scenario

Natural language processing of consumption scenarios highlighted Chongqing's unique urban consumer culture. The analysis revealed distinct characteristics across different retail categories, from food and beverage establishments reflecting local culinary traditions to leisure spaces embodying social interaction patterns. Notably, the mountainous urban layout and leisurely lifestyle emerged as key cultural symbols, demonstrating how geographical features and local culture interweave to create unique consumption spaces. These findings underscore the complex interplay between urban geography, consumer behavior, and local culture in shaping retail spaces in mountainous cities.

4.2 Research Limitations and Future Directions

Our study has certain limitations, primarily in terms of data and methodology. The current analysis relies on limited data sources and precision levels, which may affect the comprehensiveness of our findings. Methodologically, there is room for improvement in our natural language processing techniques, particularly in capturing more nuanced cultural patterns.

To address these limitations and advance this line of research, we propose several future directions. We plan to utilize more diverse and high-precision data sources to enhance the accuracy and depth of our analysis. Furthermore, we intend to employ more advanced natural language processing models to gain deeper insights into consumer behavior and cultural patterns.

5. References

Iosifidis, P. (2011). ‘The public sphere, social networks and public service media’, *Information, Communication & Society*, 14(5), 619-637.

Simonofski, A., Fink, J., & Burnay, C. (2021). ‘Supporting policy-making with social media and e-participation platforms data: A policy analytics framework’, *Government Information Quarterly*, 38(3), 101590.

Zhou S.H.,Hao X.H., &Liu L. (2014).‘Validation of spatial decay law caused by urban commercial center's mutual attraction in polycentric city:Spatio-temporal data mining of floating cars' GPS data in Shenzhen’, *Acta Geographica Sinica*, (12), 1810-1820.

Cao Q.M. (2019).'Research on Spatial Distribution Change of Commercial Network in Old District and Its Influencing Factors: A Case Study of DapingArea, Chongqing(Master's thesis, Chongqing University)', *Master*, https://link.cnki.net/doi/10.27670/d.cnki.gcqdu.2019.002512doi:10.27670/d.cnki.gcqdu.2019.002512.

Glaeser, E. L., & Gottlieb, J. D. (2006). 'Urban resurgence and the consumer city', *Urban studies*, 43(8), 1275-1299.

Hao F.L.,Yang Y.X.,Li J.L., Li Y.L.,&Wang S.J. (2019).'Characteristics of Commercial Centers in Changchun from the Perspective of Retailing', *Economic Geography*(12),138-146.doi:10.15957/j.cnki.jjdl.2019.12.016.

Liu G.S.,Zhang Y.,&Cao X. (2023).'Research on the Influencing Factors of Spatial Distribution and Location Choice of Retail Enterprises in Chongqing Main Urban Area', *Urban Geotechnical Investigation & Surveying*(06),44-49.

Wang X.M.,Wang J.,&Zhu Q. (2018).'Identification of Hollowing Phenomenon in Commercial Space of Six District of Beijing Based on Checking-in Data', *Urban Development Studies*(02),77-84.

Chen D.J. (2012).'A Study on The Spatial Structure ofCommercial District inChongqing Main City(Master's thesis, Chongqing University)', *Master*, https://kns.cnki.net/kcms2/article/abstract?v=gpYlZH45TFmp_gB-PfzHAANf0a7dFshDdKytGm98udi-QC_GXzcYju7vL4Tmcl8jPo1xL_NK1msfkswqJzuYfu9XeKw_oiux6MK4KMbCFQHdh-dNCWOD3qooGscKOW9ZbFbhkrs4Lr1T5T_ApCuA0StRWoAcNfEAxp6puNUypKJdNypWnwsPSOoknnoh0gfyx_Ezfs2ypA8=&uniplatform=NZKPT&language=CHS

Wang Y.,Wang X,O.,&Zhang S.S. (2009).'A system dynamics model of urban renewal', *Journal of Shenzhen University(Science and Engineering)*(02),169-173.

Nyseth, T., & Sognnæs, J. (2013). 'Preservation of old towns in Norway: Heritage discourses, community processes and the new cultural economy', *Cities*, 31, 69-75.

Tu J.J.,Tang J.J.,Zhang Q.,Wu Y., &Luo Y.C. (2019). 'Spatial heterogeneity of the effects of mountainous city pattern on catering industry location', *Acta Geographica Sinica*(06),1163-1177.

Wu T.H. (1997). 'Pursuing the soul of the city', *City Planning Review*(03),25-28.

Huang L. (2010).'A Study on Cultural Structure of UrbanSpace with the Case Study of Cities inSouthwest China(Ph.D. Dissertation, Chongqing University)', *Ph.D.*, https://kns.cnki.net/kcms2/article/abstract?v=gpYlZH45TFni2rJD5Sdp92yT8zaL2DDkdP9DyB5KPk7yY0DnZbjy60YHTXyyTqOgRjLFdkrb_ECtoczFs4OUtkGwUQSuA1Dl5zD6d17vAYs6HcbUn5JwEVTFW1UZVdXhU46C2mfGq8Lq9gcTVet3386Qn3j2S2Oe6FFhwXu6l35xNRXcyB8CBwsy0N2aW2EX&uniplatform=NZKPT&language=CHS

Huang H. (2006).'Cultural-policy-led Urban Regeneration: Experience and Inspiration of Development of Western Cities Based on Cultural Resources', *Urban Planning International*(01),34-39.

Wang C.F. (2017).'Research on the Optimization of urbanCultural Spatial Structure under theBackground of Cultural Consumption——A case of the main city of

Chongqin(Master's thesis, Chongqing University)', *Master*, https://kns.cnki.net/kcms2/article/abstract?v=gpYlZH45TFlAMA7jBLPtsEYCHBeNTk7drzwvBvhULEVzjKK0QPbhDIukzR00Ks8d_zX1NLLZZUnjcRel6yq1ZMsqqe89Y_JCcpnPkdZyUbaUJr_wFOWbA-PhX8KQrxTAORQ9TA53TIFPL2mU7WtsAN8hiud2ECDFXQnV8EY-ly1H3pPCDWrbTDUZ5F98JdNZvuaNE7GUQIE=&uniplatform=NZKPT&language=CHS

Gao L.(2018).'Public Participation in London City Planning: A Home for All Londoners', *Urban Planning Forum*(01),124-125.

Chen D.J.(2019).'Characteristics and Gene Analysis of SpatialMorphology Types in Historic District ofChongqing——Based on The Scale of Blocks And Building(Master's thesis, Chongqing University)', *Master*, https://link.cnki.net/doi/10.27670/d.cnki.gcqdu.2019.001752doi:10.27670/d.cnki.gcqdu.2019.001752.

Schmitt, B. (1999).'Experiential marketing', *Journal of marketing management*, 15(1-3), 53-67.

Hu Y.T.(2015).'Cultural experience of ChongQingpedestrian commercial streets(Master's thesis, Chongqing University)', *Master*, https://kns.cnki.net/kcms2/article/abstract?v=gpYlZH45TFnDI5HwAI9orICL7HAlyvZy-PbruQrXNhEW_i3ImpKGa-azTQ2RTSEIe2YAAyuKmDvah4W00u6r18ElCwmWVm5GTA1DQNWXKLyBhbgmt1_lIYADSAA_V3vYSUjZEMtPfSvAckErde1loZsgrNuRwiBpBK-ZGxTzBimuGz9hdaZsvbdkI0qWinDwrAFMqbwaeyU=&uniplatform=NZKPT&language=CHS

Pei Y.X.(2017).'The Structure, Features and Evolution of theimage of Chongqing Yuzhong Peninsula(Master's thesis, Chongqing University)', *Master*, https://kns.cnki.net/kcms2/article/abstract?v=gpYlZH45TFltephl4vsj6fMpAbtRf2a6JFGsiImJ0lPxOtayG9eEGdSrluynonV-h4XFU_mNqV2N8xaFyGh_FwpfoZEosMbry05n5Nd7t8oBc4lp1IQod-XT8lkNUjTVniMxFB21NYZDyQttK5kyj2WiNcW1xcRCHHcJVfOov3wACN9xjwLIelqKCOpYFCoZ7TgOHPATpjA=&uniplatform=NZKPT&language=CHS

Wang Jiwu.(2005).'Study on Urban Space Form with View ofRegional Culture(Ph.D. Dissertation, Chongqing University)', *Ph.D.*, https://kns.cnki.net/kcms2/article/abstract?v=gpYlZH45TFlmrdudOYX6GiT53poZtEOWzpTHSrIhMHDnyuN4MBRcItFhCzZR51ZTrLPvuxXWYu7aEqspjd3lGP84wEnsfSpDKeknyjPIjasiD7H3Gh-rlsHIBVEaVp9fV0nthy9EZ8vjt76E3wtoCqXyfxdZlTqzUqLfmUsgUl-5Vl2uhwB_4yi5ouglvZkQ&uniplatform=NZKPT&language=CHS

Yu W.H.,Ai T.H.,Yang M., & Liu J.P.(2016).'Detecting"Hot Spots"of Facility POIs Based on Kernel Density Estimation and Spatial Autocorrelation Technique', *Geomatics and Information Science of Wuhan University*(02),221-227.doi:10.13203/j.whugis20140092.

Zhang J.Q.,Liu Y.N., & Song B.B.(2022).'Study on the spatial distribution characteristics of life service industry in the main urban area of Zhengzhou city based on POI data', *World Regional Studies*(02),399-409.

Shen Q.X.,Li C.G., & Liu Q.(2017).'Urban Spatial Structure by Service Facilities Distribution:A Case in Main Districts of Changchun', *Economic Geography*(03),129-135.doi:10.15957/j.cnki.jjdl.2017.03.017.

Gan Q.Q.(2021).'Series connection and optimization of cultural touristroutes in Yuzhong District of Chongqing Based on spatialvitality(Master's thesis, Southwest University)', *Master*, https://link.cnki.net/doi/10.27684/d.cnki.gxndx.2021.002129doi:10.27684/d.cnki.gxndx.2021.002129.

Huang G.Y.(2005).'ECOLOGICAL THINKING OVER SPATIAL STRUCTURE OF HILLY CITY', *City Planning Review*(01),57-63.

Duan Y.M.,Liu Y.,Liu X.H., & Wang H.L.(2018).'Identification of Polycentric Urban Structure of Central Chongqing Using Points of Interest Big Data', *Journal of Natural Resources*(05),788-800.

Zhang L.J.(2019).'Study on spatial pattern characteristics anddriving factors of catering industry inChongqing main urban area based on GISspatial analysis(Master's thesis, Chongqing Normal University)', *Master*, https://kns.cnki.net/kcms2/article/abstract?v=gpYlZH45TFl3iG9YOPNhnlAiD4VvAMzIj8zZ-slVef-ubHw7wQZUMmB-hBNf5obJawohkqgXh6VOEkP5MWJlGZWoRBsAJFYe8rgJfaxrfTC4midnbyhMtAW7fBNQljB4MPfR_uY1H2fnnD8NV6V-SqBE3KrrFP2l92x8qh666BNPQrncAyJo0XpfCrM5EDSV9XJ0ZOpReU4=&uniplatform=NZKPT&language=CHS

Shu S.Y.,Wang R.,Sun Y.W.,Liu J., & Xiao L.S.(2012).'Spatial Distribution of Urban Catering Industry and Its Influenced Factors: A Case Study of Xiamen City', *Tropical Geography*(02),134-140.doi:10.13284/j.cnki.rddl.001590.

Yang F.,Xv J.G., & Zhou L.(2016).'Cluster Identification and Spatial Characteristics of Catering in Guangzhou based on DBSCAN Spatial Clustering', *Economic Geography*(10),110-116.doi:10.15957/j.cnki.jjdl.2016.10.015.

Chen L.Q.(2011).'Urban Culture:the Inner Driving Forces of Urban Development', *Journal of Xihua University(Philosophy & Social Sciences)*(01),108-114.doi:10.19642/j.issn.1672-8505.2011.01.021.

Zhan Y.S.(2021).'Research on the cultural image of Chinese citiesbased on multi source data(Master's thesis, Tianjing University)', *Master*, https://link.cnki.net/doi/10.27356/d.cnki.gtjdu.2021.003241doi:10.27356/d.cnki.gtjdu.2021.003241.

Ning Y.X.(2015).'Optimization Research on Urban PublicSpace of High-density Mountainous Cities——Take Yu Zhong peninsula of Chong Qing as anExample(Master's thesis, Chongqing University)', *Master*, https://kns.cnki.net/kcms2/article/abstract?v=gpYlZH45TFkOztdu_oRr8VA4pzM2cY5g1cu5gQu2IJsv6_ugBtKPAL1KC22nDS4KSh5Te27HpNH7JuhrJWRJOp3DtL-cmMcjBRrUKrGXNWHMOC0_wVFtaEECKYqCoJJrjfMkE9ldyMs47tQMB3xlLOAfgQYm6FZRdB9rf480u9io0Ndy0f3qw2Akovm9Z_YH7AMQsAvsdpY=&uniplatform=NZKPT&language=CHS

Luo J.L.(2016).'Geographical Names andUrban Morphology——Exploring the Culture Connotation、Inheritanceand Evolution of Urban Morphology throughGeographical Names of Chengdu and Chongqin(Master's thesis, Chongqing University)', *Master*, https://kns.cnki.net/kcms2/article/abstract?v=gpYlZH45TFklx0tjIOB4Ko6ImrvekenAeGa-doXoQz73gQalNunyN12IKhpXN72D-

LG_7mXTaEZwixJLwy3EJ3aV3Nc1K4ScYLW9iSr9FtU9LUzHgFQx7Dz1-PWW_JaXox6c7uJ8duJvF25qIoBjNDTa8vX9PlN3rssKFKejEqynIUMtX1Aveigo_tAdUPoeRd71OIPNETU=&uniplatform=NZKPT&language=CHS

AI Methodological Note:

When translating and polishing the paper, advanced artificial intelligence language model Claude 3.5 was used to assist with data analysis, content structuring, and language refinement. Artificial intelligence tools help improve the clarity and coherence of case studies by generating initial drafts and suggesting organizational frameworks. However, all final explanations, conclusions, and editorial decisions are made by the authors to ensure the accuracy and completeness of the research. Careful monitoring was conducted on the use of Claude 3.5 to meet research objectives and maintain the quality of research results.

Research Paper

Investigating Past, Present, and Emerging Research Trends on Public Spaces for Cultural Heritage, Social Cohesion, and Safety

Vuyiswa LETSOKO, University of Johannesburg, South Africa

Mhlalisi MNDZEBELE, University of Johannesburg, South Africa

Trynos GUMBO, University of Johannesburg, South Africa

Abstract

Public spaces play a crucial role in fostering cultural heritage, promoting social cohesion, and ensuring safety in urban environments. This study employs a bibliometric analysis to map the evolution of research on public spaces as key sites for cultural heritage preservation, social cohesion, and safety. The research systematically searched Scopus using specific keywords to find 3218 relevant articles. By analysing this comprehensive dataset of scholarly publications, the research identifies dominant trends, influential authors, prominent journals, and core research clusters within this multidisciplinary field. The analysis highlights how scholarly interest has shifted over time, from foundational studies in urban sociology and architecture to recent, technology-driven approaches focused on digital heritage, participatory design, and data-informed safety planning. Emerging themes include the role of public spaces in community resilience, the integration of cultural narratives into urban landscapes, and the use of public spaces for promoting inclusivity and social interaction. This bibliometric approach provides a nuanced understanding of how academic discourse on public spaces has adapted to contemporary challenges, offering critical insights for researchers, urban planners, and policymakers invested in designing public spaces that foster cultural vitality, social cohesion, and urban safety. The findings underscore the importance of interdisciplinary collaboration and the potential for new research frameworks that address evolving societal needs.

Keywords

Public spaces, cultural heritage, social cohesion, urban safety, bibliometric analysis, Scopus

1. Introduction and background

In this increasingly urbanized world, public spaces are critical platforms for the promotion of cultural heritage, social cohesion, and community safety. These public spaces, ranging from parks and plazas to cultural institutions and community centers, are central to maintaining the rich tapestry of cultural identities and histories that constitute our societies. They are social hubs, centres of cultural exchange, and civic participation that can contribute to the general welfare and quality of life of citizens (Lopes et al., 2020; Gürer et al., 2017). Furthermore, available and well-managed public spaces can encourage a sense of community, facilitate social interaction, and enhance interpersonal relationships (Hutomo & Fuad, 2020 ; Amirjani & Zarghami, 2014). Researchers have been studying different facets of public spaces, design, use, and effect on the immediate community. Amidst growing research on public spaces and their importance, design, use, and effect on cities and immediate communities, there is a knowledge gap regarding the intricate dynamics and new trends in research in this area.

This discovery is significant in formulating pragmatic policy and design solutions that are realistic and responsive to real situations. As matters of public space, the research objective was to conduct a bibliometric literature review that will provide an overall overview on the past, current and future trends and issues that are emerging and developing between public space and three main fields: cultural heritage, social cohesion, and safety. Through a study of the intersections of these three axes based on a bibliometric analysis, the study will present insights needed into the general publication trends so that researchers, policymakers, and urban planners interested in planning public space are aware of the dominant research topics in studying such spaces (Smith et al., 2021).Public space in the context of this paper is defined as urban environments that are accessible to the general public and serve as shared spaces for social interaction, cultural activities, and community engagement (Carvalho and Carvalho, 2021). There are various typologies of public spaces which are all considered in this study parks, plazas, streets, squares, and other open areas. Public spaces have also been considered as contributing to social cohesion which si understood as being The degree to which individuals in a community feel connected, supported, and integrated. It involves a sense of belonging, trust, and shared values among community members (Putnam,2000). Accessible, inclusive, and properly maintained public spaces not only provide a sense of security for residents but also play a role in preventing crime and reducing social tensions (Nguyen & Roberts, 2019). Therefore, indicating their role in improving safety which is the perception and reality of freedom from harm or danger. It includes physical safety, such as protection from crime and violence, as well as psychological safety, such as feeling secure and comfortable in public spaces (Nguyen, and Roberts, 2019). Urban public spaces are not merely physical entities, but rather multifunctional domains that hold profound social, political, and cultural significance (Silva & Costa, 2016). As cities continue to grow and evolve, the preservation of cultural heritage within public spaces has become increasingly vital. These spaces serve as tangible reminders of a community's past, fostering a sense of identity and belonging. Moreover, the preservation of cultural heritage in public spaces can contribute to the sustainability of urban development, enriching human life with meaning and emotion, and raising the quality of life as a key component of sustainability.

3. Methodology

A bibliometric analysis was applied in the study in order to explore the research landscape of public spaces with a focus on the role they play in cultural heritage, social cohesion and safety. This type of analysis was best suited for the study because it provides a thorough and quantitative approach to map the intellectual structure of the research field, identify key trends, and uncover emerging patterns (Merigó and Yang, 2017). The main aim of this technique is to grasp the interconnections that occur among citations from journals in order to identify key research topics and emerging trends (Jia & Mustafa, 2022). By analysing a large dataset of scholarly publications, this method allows researchers to gain valuable insights into the evolution of research topics, the contributions of leading scholars, and the impact of specific studies (Khan et al., 2020). The Scopus database was chosen as the main source for this research due to its wide coverage of peer-reviewed literature on subjects such as urban planning, architecture, sociology, and cultural studies (Bass et al., 2020). Subsequently, the powerful indexing and citation analysis offered by Scopus makes it an established basis for bibliometric research. In addition, since the focus of the database is on quality and relevance, this complements the specific aims of the current study ensuring the analysis contained within is grounded on high-quality. ChatGPT was also employed to guide the researchers in their analyses of the network maps, providing insights into patterns, relationships, and key themes emerging from the data.

3.1. Selection criteria

On August 31, 2024, a Scopus database search was conducted to access and evaluate the body of research on public spaces, cultural heritage, social cohesion, and safety. To ensure a comprehensive review, no specific time frame was imposed. The search terms included "public space AND cultural heritage," "public space AND social cohesion," and "public space AND safety." The inclusion criteria focused on English-language publications from any country and any year up to 2024, encompassing articles on social cohesion, cultural heritage, and safety in public spaces. Exclusion criteria eliminated editorials, errata, letters, notes, short surveys, publications with unidentified authors and books, book chapters, reviews, and conference papers not published in English. To ensure rigorous selection, titles and abstracts were screened to confirm eligibility, guided by the PRISMA protocols. PRISMA is a well-established method for systematically reviewing literature, reducing bias, enhancing the validity of findings, and presenting results in a clear and coherent manner (Selcuk, 2019; Page et al., 2021).

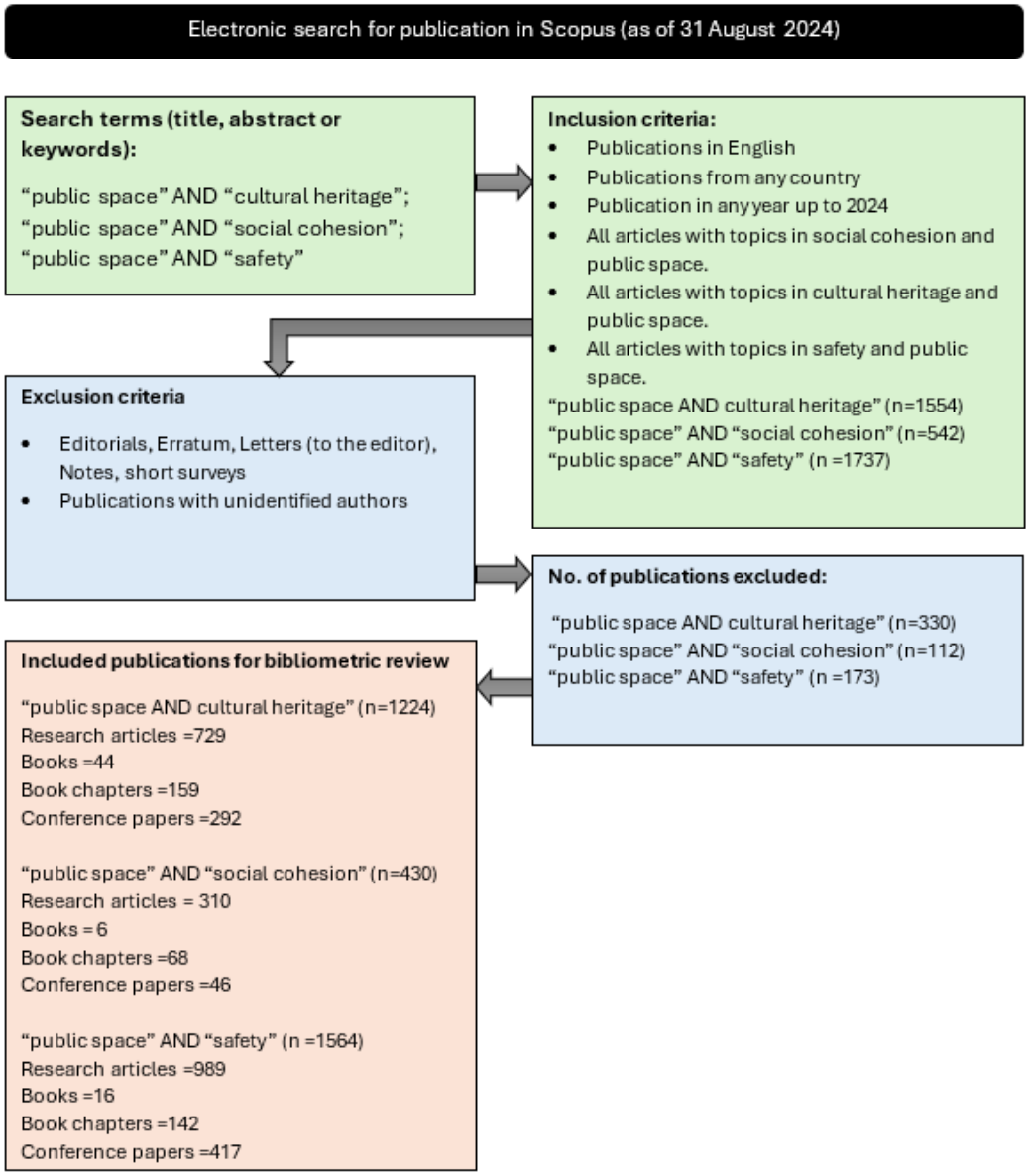


Figure 1: PRISMA flow diagram (Adapted from Moher et al. ,2016)

The initial search yielded 1554 publications on public space and cultural heritage, 542 on public space and social cohesion, and 1737 on public space and safety. After applying the inclusion and exclusion criteria, 1224, 430, and 1564 publications were respectively excluded, leaving a total of 3218 eligible documents. VOSviewer was utilized to conduct the bibliometric analysis, as outlined in the figure below (Van Eck & Waltman, 2014). VOSviewer is a software tool that visually analyzes literature reviews, identifying trends, research foci, and key areas (Zhang et al., 2021; Soegoto et al., 2022). While other analysis tools like Citespace have been used in other studies, VOSviewer remains the preferred choice due to its ability to handle large datasets and produce reliable results (Kalaoane et al., 2024).

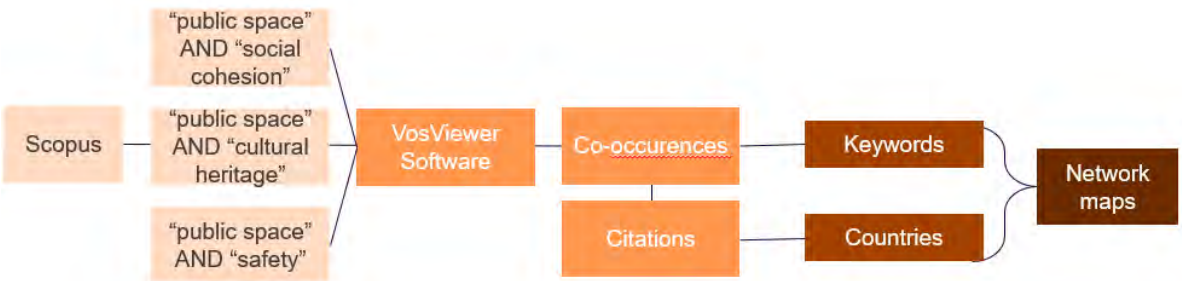
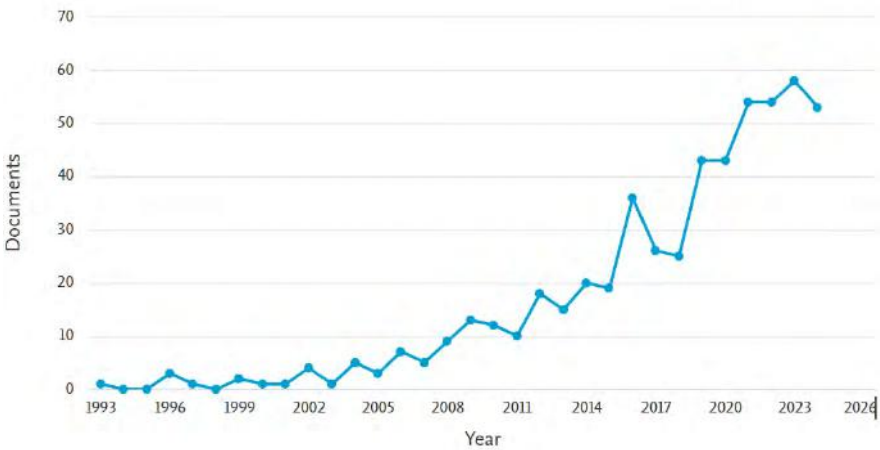


Figure 2: Bibliometric analysis process (Adapted from Kalaoane, 2024)

4. Results and discussions of the bibliometric analysis

4.1 Publication trends

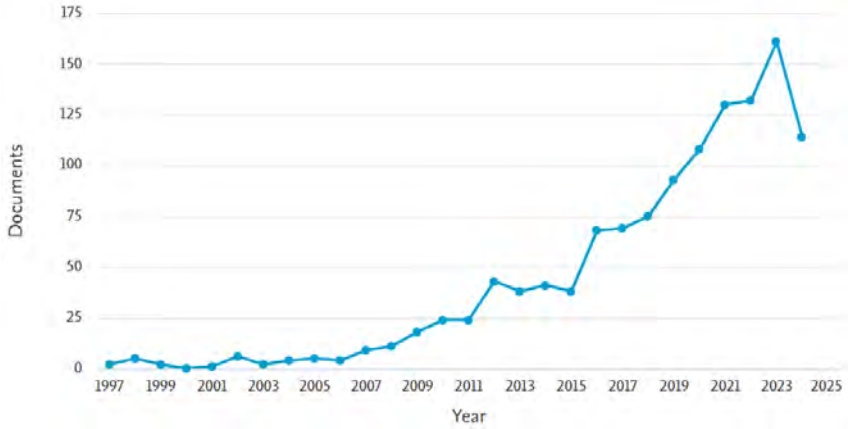
Between 1993 and 2024, there has been a noticeable rise in the number of publications on public space and social cohesion. As can be seen in the figure below, initially, research activity in this area was scarce since there were few and fluctuating publications in the beginning years. But from 2005, a slow increase in publications can be seen, which reflects growing interest in the topic. This trend rises rapidly after 2014. There is a significant rise in research activity, which may be due to several factors, including urbanization trends, increasing social inequality, and growing recognition of the importance of public spaces in enhancing community well-being. In general, the graph reveals the rising significance of public spaces for social cohesion and points to the growing number of studies focusing on this area.



Graph 1: Publication trends for research on public space and social cohesion

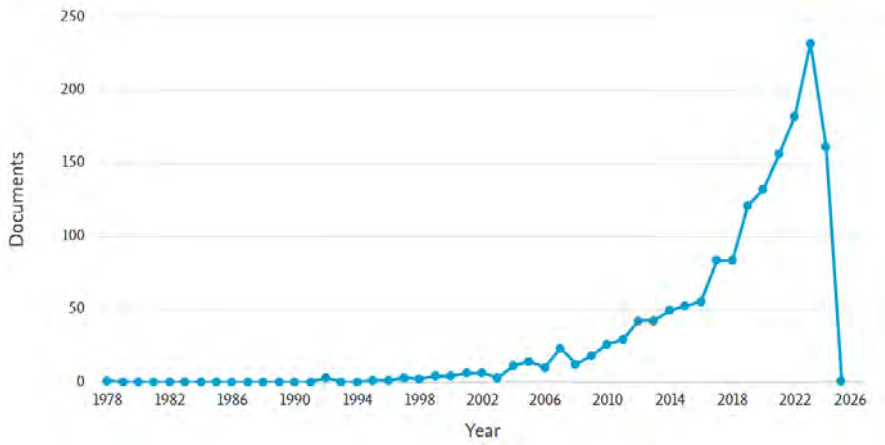
Research into the issues of public space and cultural assets has received great impetus in recent years, as depicted by Graph 2 on the trends in publication between 1997 and 2025: In the initial period, the number of documents published was rather modest to demonstrate sufficient academic attention to the problem.

However, from the year 2005 onwards, a sudden increase in publications reflected an increase in awareness of the value of public places for maintenance of cultural assets. This upward slope became more pronounced after 2014, reflecting a big increase in research activities. This could have been attributed to many factors that include increased urbanization, the influence of globalization, and an improved understanding of the ways in which public space engenders cultural identity and civic well-being.



Graph 2: Publication trends for research on public space and cultural heritage

The graph 3 on publication on public space and safety depicts a clear upward trend in the number of documents published on public space and safety over the period from 1978 to 2026. This indicates a growing interest and research focus on this topic within the academic community.



Graph 3: Publication trends for research on public space and safety

The graph reveals a modest number of publications in the early years, suggesting limited research activity in this area. However, from the mid-2000s onwards, a gradual increase in publications is observed, indicating a growing recognition of the importance of public spaces in promoting safety. This trend accelerates significantly after 2014, suggesting a substantial rise in research activity. The surge in publications may be attributed to various factors, including increased urbanization, terrorism threats, and a heightened awareness of the role of public spaces in fostering community security. Interestingly, the graph shows a sharp decline in publications in 2026. This could be due to various factors, such as a shift in research priorities, changes in funding, or methodological limitations. Further analysis would be needed to determine the specific reasons for this decline. Overall, the graph demonstrates a clear and sustained increase in research on public space and safety, albeit with a recent downturn. This trend suggests that

public spaces will continue to be a significant focus of academic inquiry, with a particular emphasis on safety and security issues.

4.2 Keyword Analysis

A co-occurrence network analysis for research on public space and social cohesion shows that research on social cohesion and public space spans across urban planning, health, environmental factors, and social demographics, with a strong focus on policy, sustainability, and inclusivity. Four dominate clusters are visible in the network analysis below. The different clusters and keyword density indicate popular research areas and reveal how themes intersect.

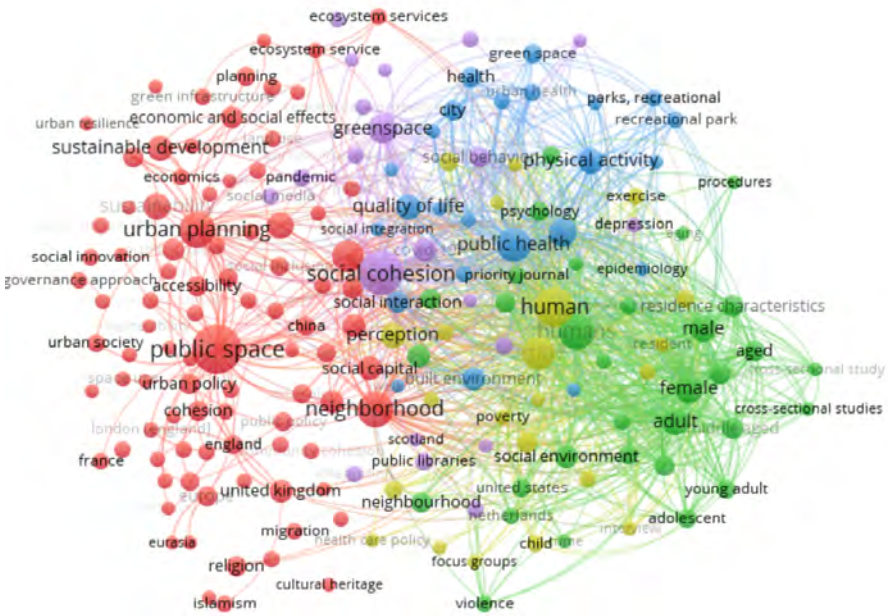


Figure 3: A co-occurrence network analysis of keywords on public space and social cohesion research.

The red cluster focuses on urban planning and public space, with terms like "accessibility," "urban policy," and "sustainable development," indicating a strong emphasis on spatial design and governance for inclusivity and environmental goals. The green cluster centers on health and demographic characteristics, including terms like "public health," "social environment," and specific age and gender groups. This suggests that many studies examine how public spaces impact physical and mental health across different demographics, with keywords like "depression" and "physical activity" highlighting connections to well-being. The blue cluster emphasizes the link between public spaces and physical health, as seen in terms like "physical activity," "exercise," and "quality of life," focusing on the role of green spaces in promoting active lifestyles. Meanwhile, the purple cluster addresses environmental and economic aspects with terms like "greenspace," "ecosystem services," and "economic effects," indicating research interest in the environmental benefits and economic impacts of public spaces. From this analysis, one is able to deduce that key themes in public space and social cohesion research include the role of public spaces in fostering social interaction and engagement, as well as promoting physical and mental health. Inclusivity is a priority, with studies examining demographic-specific experiences to create cohesive environments. Emerging areas explore cultural and religious inclusivity, supporting diverse practices for social integration. Governance and policy are also significant, with interest in innovative, inclusive models. Geographic mentions indicate that national contexts impact approaches, showing cross-country differences. Overall,

this interdisciplinary research highlights public spaces' vital role in enhancing community bonds and quality of life.

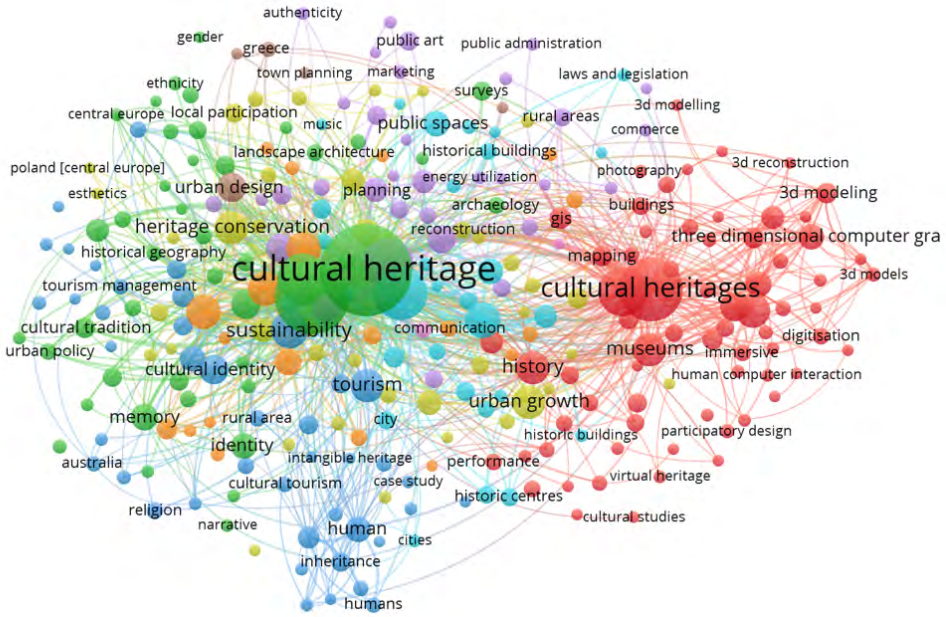


Figure 4: A co-occurrence network analysis of keywords on public space and cultural heritage research.

The analysis of research on cultural heritage and public space research shows a broad and interconnected research field around cultural heritage and public space, where traditional themes like urban planning, conservation, and identity intersect with modern concerns about technology, sustainability, and digitalization. The green cluster focuses on "cultural heritage," "sustainability," and "heritage conservation," highlighting research efforts to preserve cultural heritage within sustainable urban planning frameworks. Terms like "urban design," "cultural identity," and "memory" suggest a commitment to maintaining heritage sites in ways that respect both ecological and cultural values, emphasizing the role of heritage in shaping social identity within communities. The red cluster highlights technological integration in heritage preservation, with terms like "3D modeling," "digitisation," and "immersive media" suggesting a shift toward using digital tools like GIS and immersive media for public engagement and documentation of heritage sites. This reflects a growing trend towards digital and participatory approaches in heritage studies. The blue cluster focuses on tourism and urban growth, with keywords like "tourism," "urban growth," and "cultural tourism" indicating the economic impact of heritage sites on urban expansion and identity formation. This cluster underscores the importance of tourism-driven heritage sites in city planning, balancing preservation with economic benefits. Meanwhile, the purple cluster addresses public spaces and policy, with terms like "public administration" and "town planning" underscoring the regulatory role in managing heritage sites within urban spaces.

Key themes across these clusters include cultural identity and community engagement, as seen in terms like "cultural identity," "local participation," and "authenticity," emphasizing the importance of community involvement in heritage preservation. Technology and heritage visualization are also prominent, with "3D modeling" and "digitisation" highlighting digital tools' role in both preserving and making heritage sites more accessible. Sustainability and conservation remain central, reflecting a need to balance heritage protection with urban development needs. The economic impact of tourism is another important focus, showing that heritage sites serve as both cultural symbols and economic assets. Geographic mentions like "Greece," "Australia," and "Central Europe" indicate that cultural heritage research often considers local

and regional contexts, showcasing diverse approaches to heritage preservation. Overall, this analysis demonstrates the interdisciplinary nature of cultural heritage research, incorporating urban planning, technology, sustainability, and tourism to enrich the role of heritage in modern urban spaces.

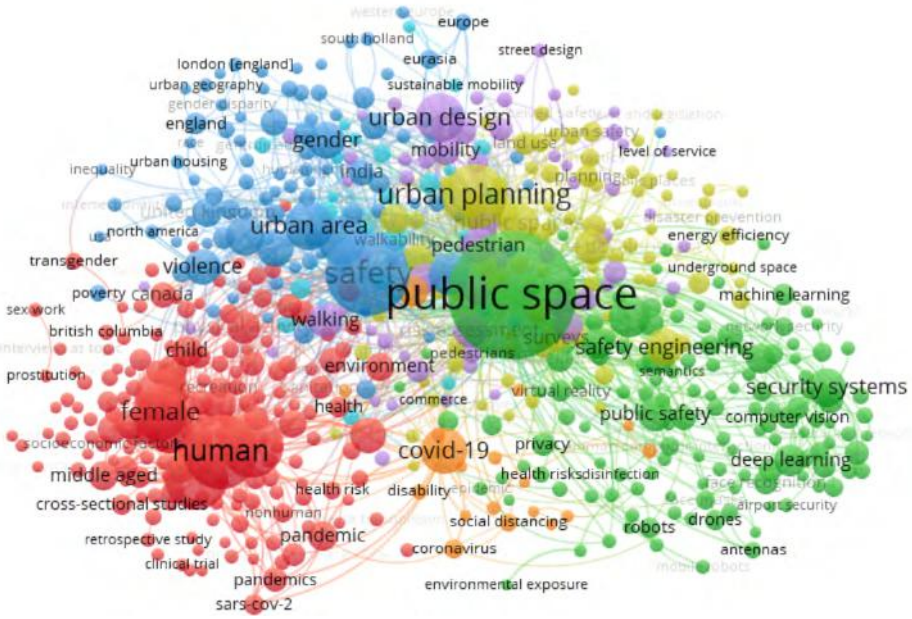


Figure 5: A co-occurrence network analysis of keywords on public space and safety research.

This keyword co-occurrence network on research on public space and safety shows a comprehensive analysis of themes in research on public space and safety, revealing several interconnected clusters around topics such as urban planning, health, security, and social dynamics. The green cluster focuses on safety technology, featuring terms like "safety engineering," "security systems," "deep learning," and "machine learning," reflecting an increasing interest in using advanced technologies such as AI, drones, and computer vision to enhance public safety. Meanwhile, the yellow cluster emphasizes environmental health and safety, with keywords like "environmental exposure," "air pollution," and "energy efficiency," showing a focus on the role of urban planning in mitigating environmental risks to promote public well-being. The blue cluster highlights urban planning and mobility, centered around terms like "urban design," "mobility," "walking," and "sustainable mobility." This indicates an emphasis on designing walkable, pedestrian-oriented spaces that prioritize safety and accessibility. The red cluster addresses social issues impacting public space safety, including terms such as "violence," "gender," "poverty," and "health risk." The prominence of COVID-19 and pandemic-related terms in this cluster underscores how health crises have influenced public space safety discussions, reshaping perceptions and priorities around accessibility and safety.

Finally, the purple cluster focuses on governance and policy, with terms like "urban policy," "laws and legislation," and "public administration" pointing to the role of policy in shaping safe and accessible public spaces. This highlights the importance of government intervention and regulatory frameworks in ensuring urban safety. Overall, this analysis shows that research on public space and safety is highly interdisciplinary, integrating urban design, technology, health, social issues, and policy. Key themes include the use of advanced technologies for public safety, the impact of environmental and health risks, especially in light of COVID-19, and the importance of urban design in creating pedestrian-friendly spaces. Social factors such as gender, poverty, and violence also play a significant role, emphasizing the need for inclusive safety measures that address diverse experiences. Governance and policy appear crucial for maintaining safe

public spaces, revealing a complex interplay of design, technology, health, and social equity in urban safety research.

4.1 Top countries publishing in public space research on cultural heritage, social cohesion and safety

The analysis of the top ten countries contributing to public space research reveals a complex interplay of historical, cultural, and socio-economic factors. Anglophone countries, particularly the United States, the United Kingdom, Canada, Australia, and South Korea, dominate the rankings, reflecting a strong emphasis on urban planning, architectural design, and social sciences within these nations. These countries have a long history of urban development and a deep-rooted understanding of the role of public spaces in shaping urban life. However, the emergence of China, Indonesia, and Mexico as significant contributors to public space research is noteworthy. These countries are experiencing rapid urbanization and social change, leading to increased attention on the role of public spaces in addressing challenges such as congestion, pollution, and social inequality. The focus on public space and social cohesion in these countries reflects a growing awareness of the importance of public spaces in fostering community resilience and promoting social justice. The diverse geographic distribution of research underscores the global significance of public spaces. By sharing knowledge and experiences, researchers from different countries can identify best practices and innovative solutions to common challenges. Furthermore, the findings can inform policymakers and urban planners in developing evidence-based strategies for creating and managing public spaces that are inclusive, safe, and culturally relevant.

Rank	Country	Public Space & Cultural Heritage	Public Space & Safety	Public Space & Social Cohesion
1	United Kingdom	128	165	165
2	United States	128	265	265
3	Canada	40	126	126
4	Australia	41	68	68
5	Sweden	18	81	81
6	Hong Kong	11	54	54
7	Russia	33	72	72
8	South Korea	19	22	22
9	Indonesia	22	16	16
10	Mexico	16	79	79

Table 1: Top Countries in research on the interconnections between public space, cultural heritage, safety, and social cohesion

While the analysis reveals a global interest in public space research, it is notable that African countries are underrepresented in the top 10 list. This lack of representation may be attributed to various factors, including limited research funding, inadequate infrastructure, and a scarcity of skilled researchers. Additionally, historical and colonial legacies may have shaped research priorities and institutional capacities in many African countries (Lawson, 2019). The underrepresentation of African perspectives in public space research has significant implications. Firstly, it limits our understanding of the diverse ways in which public spaces are used and experienced in different cultural and socio-economic contexts. Secondly, it hinders the development of context-specific design guidelines and policy interventions that address the unique challenges and opportunities faced by African cities. Thirdly, it may perpetuate a global discourse

on public space that is dominated by Western perspectives, potentially overlooking the valuable insights and innovative practices that may exist in African contexts (Moyo, 2021). To address this issue, it is crucial to invest in research capacity building in African institutions, encourage international collaborations, and promote the dissemination of knowledge on African public spaces. By fostering a more inclusive and equitable research landscape, we can better understand the role of public spaces in shaping the future of African cities.

Conclusion and recommendations

In conclusion, the bibliometric analysis has provided a comprehensive overview of the academic discourse on public spaces as crucial sites for cultural heritage, social cohesion, and safety. Over the past few decades, research has increasingly recognized public spaces as vital components of urban life, with trends showing a shift from traditional urban planning and architecture toward technology-driven approaches that integrate digital heritage, participatory design, and data-informed safety measures (Qi et al.,2024). Through the lens of cultural heritage, social cohesion, and safety, the analysis emphasizes the role of public spaces in fostering inclusivity, resilience, and social interaction, underscoring the importance of public spaces in the well-being of communities. The findings reveal key themes and emerging areas, such as the role of public spaces in promoting community resilience, the integration of cultural narratives into urban landscapes, and the use of public spaces for fostering inclusivity and social interaction. These insights offer a valuable reference for urban planners, policymakers, and researchers working to create public spaces that respond to societal needs and challenges. Furthermore, the underrepresentation of African countries in the research on public spaces calls attention to a global knowledge gap that limits diverse perspectives on public space utilization and design. Addressing this imbalance is crucial for developing a comprehensive understanding of public spaces' roles across varied socio-cultural contexts.

Key recommendations could be considered for policy, practice and research. These are outlined below:

- Encourage multidisciplinary and collaborative research: Given that the study of public space encompasses several subjects, including urban planning, technology, health, and social dynamics, future research must be truly inter-disciplinary. Collaboration in research between architecture, urban sociology, public health, and digital technology will thus be critical to gaining a comprehensive knowledge of the role of public space in urban living (Lee et al., 2024).
- Inclusion of Underrepresented Regions: Expanding research in currently underrepresented regions, particularly African countries, which face unique challenges in public space management and its intersections with cultural heritage, safety, and social cohesion (Landman and Makakavhule, 2021). This will be done to bring varied viewpoints and context-specific insights into public. This would be done to incorporate varied viewpoints and context-specific insights into public space design and use. International collaborations, capacity-building efforts, and knowledge-sharing platforms can help to close this gap.
- Integrate advanced technology with public space management: With a growing scholarly interest in digital tools for public space research, cities should implement technologies such as GIS, 3D modeling, and AI-powered safety systems to construct accessible, resilient, and secure public places. Such technologies allow for more informed planning and better meet the dynamic demands of urban populations (Sepe, 2024).
- Emphasize Policy and Governance for Inclusive Public Spaces: Policymakers should consider regulatory frameworks that prioritize inclusivity, safety, and cultural preservation in public spaces.

Policies should address social issues such as gender safety, environmental health, and inclusivity to ensure public spaces serve the needs of all community members equitably.

- Prioritize Community Engagement in Public Space Planning: Local communities should be involved in public space planning, design, and management, aligning with participatory design approaches described in this study. Community engagement encourages a sense of ownership, promotes social cohesiveness, and guarantees that public places represent inhabitants' cultural values and requirements (Gearin and Hurt, 2024).

By implementing these recommendations, cities can foster public spaces that enhance quality of life, preserve cultural heritage, and promote social cohesion, ultimately contributing to sustainable and resilient urban futures.

References

Baas, J., Schotten, M., Plume, A., Côté, G., & Karimi, R. (2020). Scopus as a curated, high-quality bibliometric data source for academic research in quantitative science studies. *Quantitative Science Studies*, 1(1), 377-386. https://doi.org/10.1162/qss_a_00019

Carmona, M. (2010). Public places – urban spaces: The dimensions of public space. Routledge.

Dahae Lee, P. F., Unger, L. (2024). Co-production, co-creation or co-design of public space? A systematic review. *Cities*, 154, 105372. https://doi.org/10.1016/j.cities.2024.105372

Gearin, E., & Hurt, C. S. (2024). Making Space: A New Way for Community Engagement in the Urban Planning Process. *Sustainability*, 16, 2039. https://doi.org/10.3390/su16052039

Jia, C., & Mustafa, H. (2022). A bibliometric analysis and review of nudge research using VOSviewer. *Behavioral Sciences*, 13(1), 19. https://doi.org/10.3390/bs13010019

Khan, M. A., Ali, I., & Ashraf, R. (2020). A bibliometric review of the special issues of psychology and marketing: 1984–2020. *Psychology & Marketing*, 37(9), 1144–1170. https://doi.org/10.1002/mar.21393

Landman, K., & Makakavhule, K. (2021). Decolonizing Public Space in South Africa: from conceptualization to actualization. *Journal of Urban Design*, 26(5), 541–555. https://doi.org/10.1080/13574809.2021.1880885

Lawson, T. (2019). Rethinking Public Space in African Cities: The Impact of Colonial Legacies. *Urban Studies*, 56(12), 2587-2604.

Merigó, J. M., & Yang, J. (2017). A bibliometric analysis of operations research and management science. *Omega*, 73, 37–48.

Moyo, S. (2021). African Perspectives on Public Space: A Critical Review. *Journal of Urban Design*, 26(2), 187-205.

OpenAI (2024) *ChatGPT* (January 2024 version). Available at: https://openai.com (Accessed:24 January 2025).

Qi, J., Mazumdar, S., & Vasconcelos, A. C. (2024). Understanding the Relationship between Urban Public Space and Social Cohesion: A Systematic Review. *International Journal of Community Wellbeing*, 7, 155–212. https://doi.org/10.1007/s42413-024-00204-5

Retsepile Kalaoane, Walter Musakwa, Alain Kibangou, Trynos Gumbo, Innocent Musonda, et al. (2024). Bibliometric analysis of quality of service in public transportation: current and future trends. *Scientific African*, 23 (March), e02059.

Sepe, M. (2024). New Technologies and Public Spaces: Supporting Sustainable Urban Policies. In: Bisello, A., Vettorato, D., Bottero, M., Kolokotsa, D. (eds) *Smart and Sustainable Planning for Cities and Regions*. Green Energy and Technology. Springer, Cham. https://doi.org/10.1007/978-3-031-39206-1_9

Silva, M. M., & Costa, J. P. (2016). Flood Adaptation Measures Applicable in the Design of Urban Public Spaces: Proposal for a Conceptual Framework. *Multidisciplinary Digital Publishing Institute*, 8(7), 284-284. https://doi.org/10.3390/w8070284

Smith, A., Vodicka, G., Colombo, A., Lindström K., McGillivray, D. and Quinn, B. (2021). Staging city events in public spaces: an urban design perspective . *International Journal of Events and Festival Management*. 12 (2), pp. 224-239. https://doi.org/10.1108/IJEFM-10-2020-0063

Van Eck, N. J., & Waltman, L. (2014). Visualizing Bibliometric Networks. In Y. Ding, R. Rousseau, & D. Wolfram (Eds.), *Measuring Scholarly Impact* (pp. 10.1007/978-3-319-10377-8_13). Springer, Cham.

Research Paper

Exploring the Extraction and Innovation Path of "Canal Genes"

Taking the southern section of the Grand Canal in China as an example

Juan GUAN, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, CHINA
Shan WANG, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, CHINA
Jiujiu GUO, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, CHINA

Abstract

The Beijing-Hangzhou Grand Canal carries rich historical and cultural elements. Over time, the precious resources left have become a typical lineal or serial cultural heritages. This paper introduces the genetic concept of biology, and takes the Beijing-Hangzhou Grand Canal (Cangzhou Section) as the research object to extract its unique cultural value and spiritual connotation. Through the all-round collection of 268 examples, three types of gene-property are classified into natural ecology, history and humanities, and characteristic innovation. This paper combines the characteristics of the space along the canal to build a 'Canal Gene Bank'. And then, according to the idea of"the river is the line, the city is the bead, the bead is connected with the line, and the line drives the surface", a spatial layout of the protection and development of the canal with the Grand Canal as the main axis and the distribution of resources as the clues will be constructed.

Keywords

Canal gene, Extraction and innovation, The Beijing-Hangzhou Grand Canal, South Cana,

1. Research Background

The 18th National Congress of the Communist Party of China in 2012 emphasized "cultural self-confidence" and put forward new requirements for the inheritance, protection and promotion of Chinese culture.

In May 2021, the Central Committee for Comprehensively Deepening Reform put forward the "Several Opinions on Strengthening the Protection and Inheritance of History and Culture in Urban and Rural Construction". Manage an effective urban and rural historical and cultural protection and inheritance system.

On May 22, 2022, the General Office of the Central Committee of the Communist Party of China and the General Office of the State Council issued the "Opinions on Promoting the Implementation of the National Cultural Digital Strategy". To form an online and offline integration and interaction, three-dimensional coverage of cultural service supply system.

The excavation and connection of the Beijing-Hangzhou Grand Canal represent the wisdom of the ancient Chinese people, the product of their constant struggle with nature and ultimate harmony with it prior to the advent of industrialization. It serves as a significant and precious corridor of material and cultural heritage for China and even the world. On the one hand, it has maintained its vitality through more than

2,500 years of dynastic changes; on the other hand, it spans five major river systems, three major plains, and four provinces and two municipalities in China, nurturing numerous historic and cultural cities along its route. It is truly a "living" and distinctive super-large linear cultural landscape heritage, possessing both temporal and spatial dimensions. The successful application for World Heritage status of the Beijing-Hangzhou Grand Canal marks the international recognition and affirmation of this unique large-scale linear water conservancy heritage, the canal basin culture, and the giant living cultural landscape. It also reflects the appreciation and respect for China's water conservancy achievements from ancient to modern times, as well as for Chinese culture.

The Beijing -Hangzhou Grand Canal is a cultural display gallery that runs through the north and south. Each paragraph has a unique personality, but most of them stay in the analysis of culture, and not have completed the" Digitalization of cultural industry and industrialization of digital culture". In this context, while actively responding to national policies, we have conducted in-depth research on the characteristic culture of the South Canal (Cangzhou Section) of the Beijing-Hangzhou Grand Canal with the purpose of Unearthing, Inheriting, and Innovating Traditional Culture to Build Regional Characteristics: The Need to Further Enhance the Extraction and Application of Characteristic Culture by the “Canal Gene Bank”

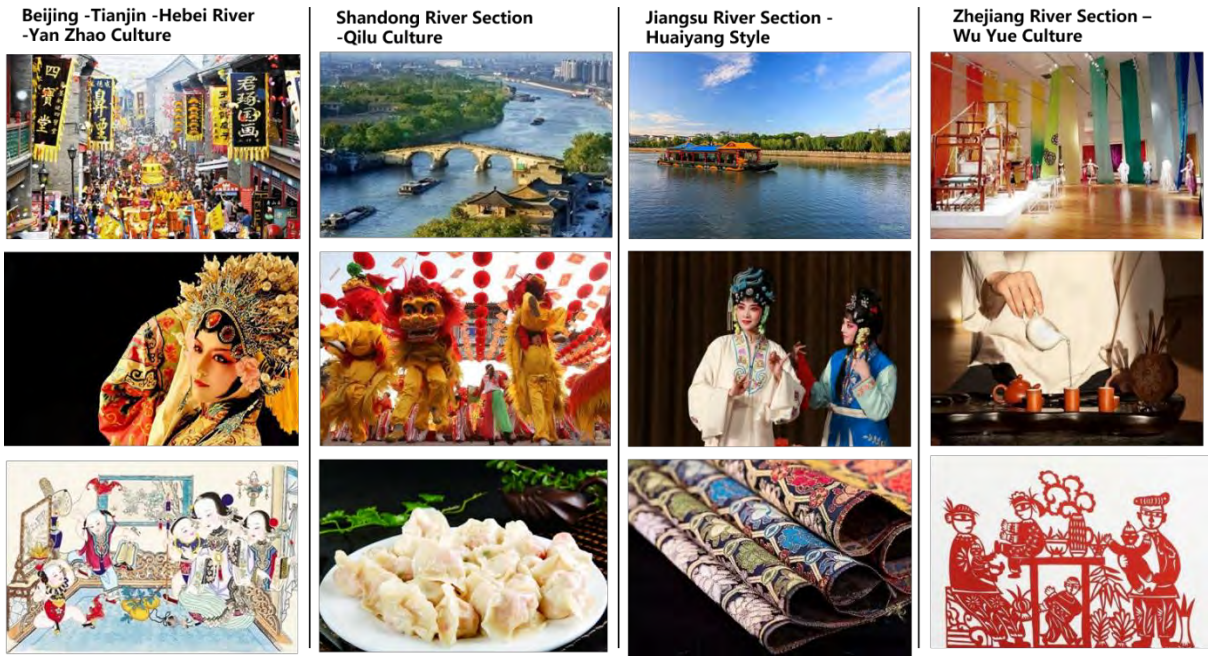


Figure 1. Illustration of Segmented Cultures along the Beijing-Hangzhou Grand Canal. Source: Authors.

As an important corridor for the exchange between the north and south of China, the Grand Canal in Cangzhou has promoted the economic and cultural development of its surrounding areas through material exchange, giving birth to a rich cultural heritage and diverse cultural landscapes. Protecting and inheriting the cultural heritage of the Grand Canal in Cangzhou can effectively advance the local tourism industry. At present, China has achieved some success in protecting historical and cultural heritage, but there are still issues such as limited public cultural awareness, insufficient local resource development, and homogenized development models. Therefore, it is imperative to further enhance public cultural protection awareness and fully explore local cultural resources, and explore diverse development models. Guided by rich theoretical knowledge, we must genuinely excel in the preservation and transmission of the cultural heritage of the Grand Canal in Cangzhou.

2. Research Methods

Based on an example of the elements of the Beijing-Hangzhou Grand Canal South Canal (Cangzhou section), the concept and expression of biological genes are introduced. The instance is regarded as the body, and the instance database group is comprehensively constructed according to the instance type. Secondly, the instances are decomposed into corresponding cultural element proteins, and the cultural element proteins are reversely translated and reverse transcribed to form cultural genes. Then through multiple instance gene extraction, the canal gene pool is formed. Then, through the orderly utilization of the canal gene bank, the genes required for the canal project will be recombined in an orderly manner to form a soulful canal project bank. Finally, through the injection of projects, taking the overall development layout of the town as the guide, the Grand Canal as the main axis and the resource distribution as the clue, "the river is the line, the city is the bead, the line is beaded, the bead belt surface" to build a space for the protection and development of the canal The layout will drive the socio-economic and cultural development of the Beijing-Hangzhou Grand Canal South Canal (Cangzhou section).

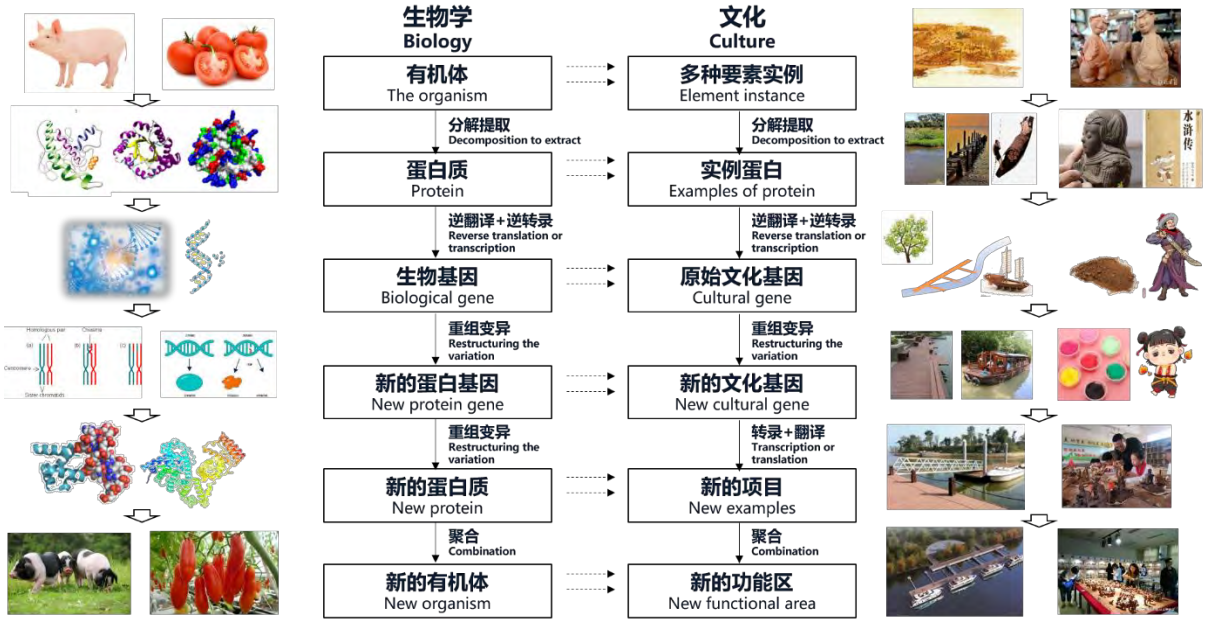


Figure 2. Diagram for Concept Expression of Biological Genes. Source: Authors.

3. Implementation Path

3.1. Establishment of instance database group

First, build the instance database index directory. According to the characteristics of instance elements, instances are divided into three categories according to natural ecology, history and humanities, and characteristic innovation elements. According to the composition of the natural ecosystem (a relatively stable ecosystem maintained by the ability of natural regulation within a certain time and space), the natural ecological elements are subdivided into two categories: "certain spatial environment" and "biological groups" and several sub-categories; according to the division principle of cultural heritage, the historical and humanistic elements are subdivided into two middle categories of "material culture" and "intangible culture", as well as several sub-categories; according to the innovation type of characteristic innovation, the characteristic innovation The elements are subdivided into two middle categories, "product innovation" and "technical innovation", as well as several subcategories.

Secondly, collect the instances of the Beijing-Hangzhou Grand Canal South Canal (Cangzhou section), and decompose the collected instances into three major element classes, which correspond to the subdivision catalogues.

Finally, by decomposing 268 instances, the canal instance database group is finally formed.

3.2. From feature instance database to gene database

First, build the index directory of the "Canal Gene" database. According to the case database group, the "canal gene" is divided into three categories according to natural ecology, history and humanities, and characteristic innovation elements. According to the characteristics of natural ecology, it is divided into two middle categories and several sub-categories according to "space environment characteristics" and "biological group characteristics"; and "external appearance composition" is divided into three middle categories and several subcategories; according to the characteristic innovation characteristics, it is divided into two middle categories and several subcategories according to "product identification" and "technical process".

Secondly, based on the instance database group, the elements of natural ecology, history and culture, and characteristic innovation are decomposed to obtain the corresponding element proteins. Then, by extracting the characteristics of the natural ecological element protein, the natural ecological gene is obtained; the abstract analysis of the historical and humanistic element protein is carried out to obtain the historical and humanistic gene; the symbol extraction of the characteristic innovation element protein is carried out to obtain the characteristic innovation gene.

Then, the gene categories obtained by the analysis are corresponding to the gene database index directory, and the gene database group of canal is finally formed by extracting genes from 268 instances.

Finally, the canal gene database is gradually improved, and the database implements the dynamic adjustment and update mode. Repair excellent genes that are in line with current values, but are not expressed or are rarely expressed today. For the excellent genes that are in line with today's values and are well inherited today, build a test area to guide their mutation and innovation. Keep records of genes that are inconsistent with current values, so that the latter can learn from them.

3.3. From gene database to project database

First, build the canal project library index directory. According to the type of project, the projects are divided into "improvement and improvement of coastal villages and environment", "conservation and promotion of traditional culture of the canal", "improvement of traffic construction around the canal", "infrastructure renovation and improvement projects on both sides of the canal", "canal agricultural and cultural projects". Tourism-Industry Integration Development Project" and "Reconstruction and Utilization of Low-Effective Land along the Line" are six categories and several subcategories.

Secondly, for existing projects, we can use the project as a carrier to call high-quality genes from the "Canal Gene" database to embed them in each project, making them the spiritual core of the project and optimizing the humanistic attributes of the project. For projects yet to be constructed, appropriate genes can be selected from the "Canal Gene" database as the spiritual core, and the projects can be modified and improved according to the actual situation.

Finally, establish a data connection channel between the canal project library and the canal gene library, and build a soulful canal project library.

3.4. From the project database to the overall spatial layout of the town

Guided by the overall development layout of cities and towns, with projects as supporting conditions, the construction of the spatial layout of canal protection and development takes the Grand Canal as the main axis and resource distribution as the clue, "the river as the line, the city as the bead, the line is stringed with beads, and the bead belt surface".

"River as the line": This emphasizes the canal's role as a link in maintaining ecological balance. Through comprehensive ecological and cultural assessments, a deeper understanding of the canal's current state can be achieved, and areas requiring human intervention can be identified to ensure that its ecological stability is not affected by development activities.

"City as Pearl": Relying on the “canal gene”, urban construction activities can be carried out to create cultural nodes along the canal, including “one city, five counties and seven towns”. Counties and towns can serve as cores for cultural protection, integrating the canal gene into urban development to provide a unique cultural identity for local development.

"Line Beads": Using wind corridors and river channels as carriers, linear ecological landscapes can be shaped, and a canal tourism road system of “three verticals and two horizontals, connecting lines into loops” can be constructed. Relying on these linear spaces, a regional landscape network of the canal can be created to ensure seamless access for tourists to various attractions and destinations along the canal.

"Pearls Stringing into a Surface": By leveraging urban-rural integration projects, the gap between urban and rural areas can be gradually narrowed, promoting coordinated regional development and integrating the primary, secondary, and tertiary industries. This will enhance the economic and social environment in rural areas.

Commonwealth Project—— "Entrepreneurship Service Complex, Agricultural Tourism Complex, Pastoral Tourism Complex".

Urban-rural linkage—— the extension of three "roads", connecting urban and rural areas.

Four-level synergy——big beads with small beads, parks with villages.

Integration of Three Industries—— "Based on Agriculture, Supported by Manufacturing, and Linked by Cultural Tourism", to Achieve Interactive Development Among the Primary, Secondary, and Tertiary Industries.

Three districts are built together—— define "new communities, industrial parks, and ecological parks" to achieve differentiated and interactive development of the three districts.

4. Conclusion

The Grand Canal in Cangzhou, with its long history and rich cultural heritage, holds significant regional value. To fully realize its potential, it is essential to focus on the unique local culture, deeply explore regional cultural resources, and highlight the canal's cultural significance. In this process, avoid blindly following trends; instead, develop scientific plans, integrate exploration efforts, and select culturally significant elements, such as Cangzhou's casting culture, acrobatic traditions, and scholarly respect. Strengthen cooperation between government and private sectors to identify resource utilization opportunities and create regional cultural industries, ensuring the active development and rational allocation of heritage resources.

5. References

Arjo, K., M. (1997) *The value of culture: on the relationship between economics and arts*. Amsterdam: Amsterdam University Press.

Blackmore, S. (1999) *The meme machine.* Oxford: Oxford University Press.

Chen, G.M. 'Views on two classification methods of cultural heritage along the grand canal', *China Famous Cities*, 2010(1), p27-30.

Gao, J.J. 'The cultural Implications of canal folk customs and their influence on the contemporary era', *Journal of Jining Teachers' College*, 2001(2), p7-12.

Jing, Y. and Zhang, J.C, Baidu (2017) Baidu terms of service. Availsble at: https://zj.cnr.cn/hzbb/20171030/t20171030_524005102.shtml (Accessed: 16 May 2024)

Liu, B.S. and Fang, H. 'A brief discussion on the cultural research of the cangzhou section of the grand canal', *Journal of Cangzhou Normal University*, 38(2), p18-21.

Liu, S.L. 'An initial exploration of the cultural pattern of cities along the grand canal', *Journal of Nantong University*, 2008(1), p2-4.

Liu, S.L. (2014) 'The grand canal and the history, society, and culture of Chinese cities', *China Culture Daily*, 26 April, p3-5.

Lv, J. 'The "genes" of Chinese culture', *Journal of the Party School of Ningbo Municipal Committee of the CPC*, 37(1)

Needham, J. (1971) *Science and civilization in China.vol. 4:physics and physical technology,patr III: civil engineering and nautics.* Cambridge: Cambridge University.

Prieto, R. (2005) *Analytic schemes for the territory of the cultural routes and their settings, towards the standardization on the methodology.* Xi'an: Xi'an World Publishing Corporation.

Randall, M. (2000) *Assessing values in conservation planning: methodological issues and choices. assessing the values of cultural heritage*. Los Angeles: The Getty Conservation Institute.

Richard, B. (1997) *Viruses of the mind: The new science of the meme*. California: Hay House Inc.

Shi, P.Y. 'Research on the development path and countermeasures of characteristic cultural industries along the grand canal in Cangzhou', *Cultural Studies*, 2019(10), p35-38.

Shan, J.X. '"Living heritage": innovations in the protection of the grand canal', *China Famous Cities*, 2008(02), p4-6.

Green, T.J. (2004) *Cultural resource management(CRM): conservation of cultural heritage*. Amsterdam: Elsevier Press.

Xie, Q.T. 'The grand canal of China as a linear cultural heritage and Its comparative study', *Studies in Culture and Art*, 2008(6)

Yan, C. (2022) 'A study on the uniqueness of intangible cultural heritage along the grand canal from the perspective of cultural routes', *Journal of Northeast Normal University*, 2022(05), pp, 78-86. doi: 10.16164/j.cnki.22-1062/c.2022.05.011.

Yao, H.Y. (1998) *History of the Beijing-Hangzhou grand canal.* Beijing: China Water & Power Press.

Zhang, B.F. 'Research on the interactive mechanism between the protection of intangible cultural heritage and tourism development along the Beijing-Hangzhou grand canal', *Academic Journal of Zhongzhou*, 2019(08), p91-96.

Rapporteurs:
- ***Giuseppe Pace**, CNR-Institute for Research on Innovation and Services for Development, Italy*
- ***Olusola Olufemi**, Independent Consultant, Canada*

1. Introduction

The "Cities of/for Tomorrow" theme explores innovative approaches to urban development aimed at creating inclusive, sustainable, and resilient cities. This report synthesizes insights from Track 2, which includes six sub-themes and identifies key challenges, findings, and recommendations for urban planning and governance. Presented abstracts, research contributions, and country-wide experiences provide a comprehensive outlook on the future of urban development, addressing issues of equity, technological integration, sustainability, and community engagement.

2. Core Objectives

Track 2 focuses on five primary objectives that are crucial to the future evolution of urban spaces:

1. **Enhancing Urban Mobility and Efficiency** – Improve transportation systems to optimize urban connectivity and accessibility, aiming for a more efficient and sustainable urban environment.
2. **Discovering Innovative Solutions for Urban Revitalization** – Focus on revitalizing cities and metropolitan areas to enhance economic vibrancy and social inclusiveness.
3. **Promoting Equity and Inclusiveness through Urban Planning** – Implement spatial planning that fosters fairness, inclusivity, and collaboration within diverse urban communities.
4. **Implementing Technological Advancements for Urban Modernization** – Explore digital innovations for urban management, enhancing service delivery and supporting smart city infrastructure.
5. **Supporting Sustainable Urban Development** – Encourage planning practices that align with environmental sustainability and efficient use of resources.

3. Sub-Themes

To better manage these objectives and contextualise concepts and case-studies, six sub-themes have been defined:

1. **Sustainable Urban Mobility and Accessibility**
   This sub-theme emphasizes innovative solutions for urban mobility, including smart transportation, sustainable transit systems, green infrastructure, and the integration of emerging technologies. Addressing challenges in mobility is essential for reducing urban congestion, decreasing pollution, and promoting more sustainable lifestyles.
2. **Resilient Urban Planning and Sustainable Transitions**
   Resilience is a key aspect of sustainable urban development, focusing on cities' adaptability to changing environmental, social, and economic conditions. This sub-theme highlights strategies for resilient urban planning, including adaptive reuse of buildings, climate action, and strategies for ensuring that urban development supports both current and future needs.
3. **Digital Innovative Transformation and Smart Cities**
   The role of digital technologies in urban transformation is critical to smart city development. This sub-theme explores the integration of smart technologies to improve urban management, service efficiency, and the overall quality of urban life.
4. **Inclusive Urban Design and Social Innovation**
   This area of focus involves creating urban spaces that promote social inclusiveness, equity, and community cohesion. Innovative urban design aims to create therapeutic, accessible, and liveable environments for all citizens, including marginalized communities. This approach promotes spatial justice by ensuring that urban benefits are equitably distributed.
5. **Collaborative Governance and Community Engagement**
   Collaborative governance models foster stronger partnerships between governments, the private sector, and communities. This sub-theme investigates strategies to enhance citizen engagement, support public-private partnerships, and develop transparent governance systems, leading to more democratic urban planning and management.
6. **Restorative Urbanism and the Modern City Legacy**
   This sub-theme addresses the balance between innovation and heritage preservation, exploring how cities can modernize while retaining their unique identity and historical character. Maintaining a city's legacy enhances its cultural significance and supports tourism while adapting to contemporary needs.

4. Data Summary

Out of 148 abstracts presented, 131 were accepted, including 19 for the posters exhibit. 87 participants registered, covering ten sessions under six sub-themes. Research contributions represented 27 countries, among them Australia, Australia, Bangladesh, China, Denmark, Finnland, Israel, Italy, Japan, South Africa, Turkey, the United Kingdom, and the United States, highlighting diverse perspectives on urban challenges.

5. Key Findings

Identified issues include urban polarization, marginalization of rural areas, population shrinkage, high urban service demands, fragmented governance, and the impacts of climate change. In particular, from the presentations emerged the following key findings:

- **Enhanced Urban Accessibility and Connectivity**
  Improved connectivity contributes to urban liveability and highlights the need for behavioural changes in travel habits. Proximity services and clean, soft mobility options can support sustainable urban living.
- **Territorial Equality and Local Potential**
  Addressing urban overload by promoting territorial equality and unlocking local potential reduces disparities between urban and rural areas. Leveraging local resources and cultural heritage strengthens community identity and cohesion.
- **Public Space Utilization**
  Public and green spaces play multi-dimensional roles, providing areas for social interaction, walking, and relaxation, which promote mental well-being and community engagement.
- **AI for Public Safety and Urban Liveability**
  AI can enhance public safety and liveability by improving surveillance, optimizing traffic flow, and providing data-driven insights for urban planning. However, data quality remains a key challenge, emphasizing the need for robust data collection and management practices.
- **Collaborative Governance and Citizen Engagement**
  Collaborative governance models that involve co-creation and co-production with communities ensure inclusive urban development. Place-based approaches encourage local engagement, making urban spaces more resilient and adaptable to change.
- **Energy Efficiency and Sustainable Consumption**
  Segmenting energy consumption and pro moting low-cost, sustainable energy solutions can reduce cities' ecological footprints. This includes innovative practices like "ethanol urbanism," which combines ecological and social sustainability.

6. Identified Challenges

- **Urban Polarization and Marginalization**
  Inner and rural areas often face marginalization, while core urban areas attract most innovations. This polarization limits equal access to urban opportunities and services.
- **Population Shrinkage and Innovation Space Disparity**
  Shrinking populations and a concentration of innovation in specific areas can create economic and social imbalances. Broadening innovation efforts across regions can reduce this disparity.
- **Mobility Obstacles and Limited Data Quality**
  Challenges in mobility, poor data quality, and difficulties in adapting the built environment to change hinder urban efficiency and inclusivity.
- **Fragmented Governance and Top-down Approaches**
  A fragmented governance structure and top-down approaches can restrict community participation, limiting citizens' influence on urban development.
- **Climate Change and Urban Vulnerability**
  Cities are increasingly vulnerable to cli-

mate change impacts, and spatial justice challenges make it difficult to address differentiated levels of vulnerability across communities.

7. Recommendations

- **Policy Support for Green and Public Spaces**
  Reconnect cities by reactivating urban public spaces while avoiding redundancy in nature-based solutions. Cities should focus on making urban areas more walkable and encouraging community-centric activities.
- **Develop Innovative Urban Mobility Solutions**
  Transnational strategies for sustainable mobility and toolkits for urban mobility design are essential. Empowering urban planners with new design strategies can lead to improved accessibility.
- **Promote Participatory Planning and Community Engagement**
  Incorporate participatory tools to amplify the voices of underrepresented communities in urban planning. This includes using community data collection and fostering a collaborative approach in decision-making.
- **Integrate Spatial Justice in Planning Education and Practice**
  Educate future planners on spatial justice by engaging them with marginalized communities and NGOs. Emphasize a participatory approach that includes communities in the planning process.
- **Long-term, Inclusive Urban Strategies**
  Embrace long-term planning perspectives over short-term projects, using collaborative governance and citizen participation as foundational principles for sustainable urban development.

8. Conclusion

Track 2 outlines a comprehensive framework for developing cities of the future, emphasizing sustainability, inclusivity, and resilience. By focusing on mobility, revitalization, digital transformation, inclusivity, governance, and heritage, cities can address contemporary urban challenges while preparing for future growth. Implementing these insights and recommendations can support cities in evolving into environments that are equitable, efficient, and responsive to both human and environmental needs.

Case Study Report

Reviving River Corridors for Sustainable Mobility and Urban Regeneration in Bandung, Indonesia with CARE Approach

Erlangga BASKARA, Pandega Desain Weharima, Indonesia
Widasari Yunida PUTRI, Pandega Desain Weharima, Indonesia

Abstract

This case study explores the possibilities & potentials of revitalizing the Cikapundung River corridor in Bandung, Indonesia, as a catalyst for sustainable urban regeneration and improved mobility. Once the backbone of the city of Bandung, the river is now overlooked due to uncontrolled urbanization and stricken by environmental degradation. To address the problems, the project proposes a full-scale approach that utilizes the CARE principles of re-Connect, re-Activate, Revive, and re-Establish. Through a common application of these principles, this case study shows how revitalization in the Cikapundung River corridor can lead to urban regrowth and more sustainability and resilience for residents and visitors of Bandung. Proposing a solution for bettering public space, environment quality for sustainable mobility, and many more to ultimately flourish through urban issues, this model would represent a good way to think of urban regeneration in other cities perceived to be solving the same issue of how innovative urban planning should change cities into livable and vibrate towns.

Keywords

Urban Regeneration, Sustainable Mobility, River Corridors

1. Objectives

1.1. Bandung's River Corridor: A Catalyst for Urban Transformation

Bandung, located in the highlands of West Java approximately 150 kilometers southeast of the capital, Jakarta, maintains a population of around 2.5 million people, rendering it the third most populous city in Indonesia, following Jakarta and Surabaya. Compared to other big towns in Indonesia, Bandung has relatively colder climate which makes it a favorable place for a short vacation. Bandung is known for having a mix of old colonial architectures and creative city, attractively built with historical charm and urban energy. Bandung hosts various cultures and high-quality educational institutions. The city has the name of "Paris van Java (the Paris of Java)", an epicentrum of popular fashion districts, rich culinary precincts, and a creative-city labs to students, artists, and tourists from all over the country.

Bandung, as a tourist city, is growing rapidly. It possess many problems, such as high traffic congestions during the weekends, uncontrollable growth of urban slums, and degrading environment. These problems exacerbates the city conditions causes by unplanned urban development. It decreases the quality of life over time for both residents and visitors.

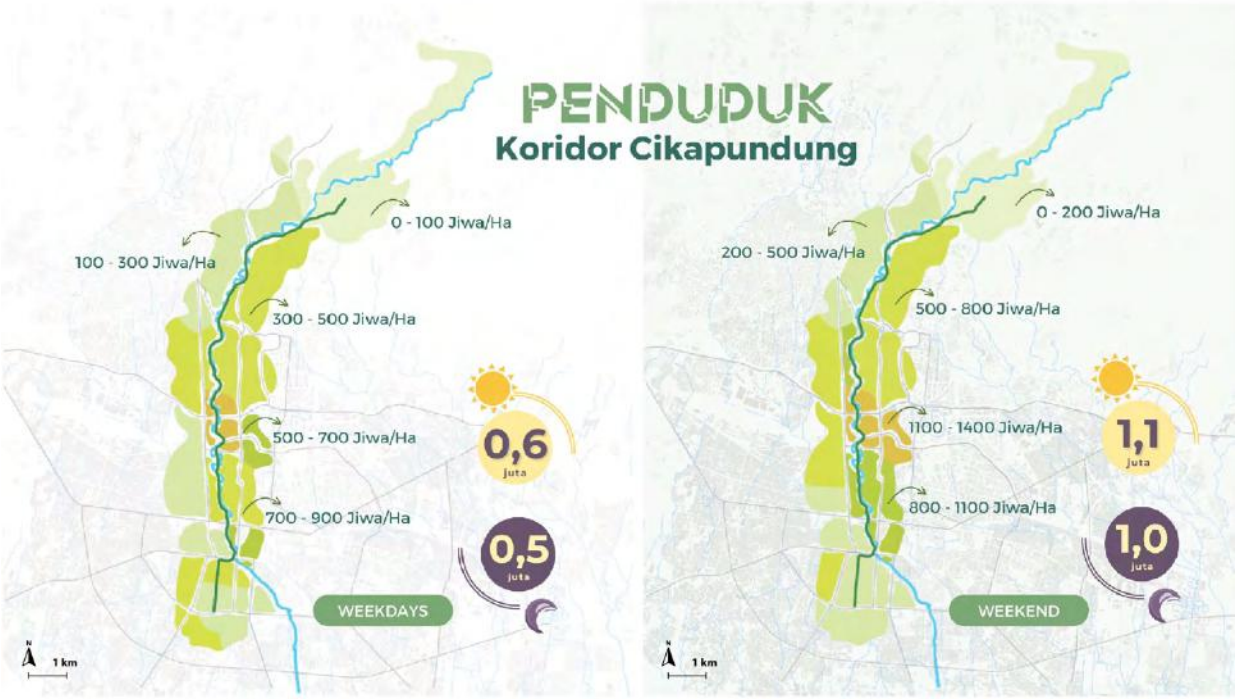


Figure 1. Cikapundung river corridors during weekdays & weekend. Source: Author

Amidst these challenges, the Cikapundung River corridor, once the important backbone of the city, has been neglected. The river corridors are often considered the most 'invisible' spaces and hold great potential for urban regeneration and sustainable development. They may become an invaluable ecological asset and generate recreational opportunities and better city connectivity.

This case study sees and explores the possibilities of reviving the Cikapundung River corridor in Bandung, a river corridor in Indonesia, to place in corrective spatial or urban policies for sustainable development. The study sheds light on some of the challenges surrounding the river corridor, formulates a revitalization plan with detailed attention to several improvements in mobility, the environment, social equity, and offers suggestions for policymakers to achieve enhancements in line with those interests. Ultimately, this will refine the process of making a city sustainable, equitable, and resilient by addressing issues such as unplanned infrastructures, environmental degradation, and social inequity.

This case study aligns with the overall theme of ISOCARP 2024: Innovation, creativity, legacy: Cities of/for Tomorrow. By proposing innovative solutions for the revitalization of the Cikapundung River corridor, this study engages in the larger urban transformation and sustainable development dialogue. The proposed intervention seeks to create a fairer, more inclusive, more resilient city within the framework of diverse mobility and urban development issues.

2. Theoretical Study

2.1. Regenerative Urban Development and Cikapundung River Corridor Revitalization

With a concept of regenerative urban development: where ecological restoration, social equity, and economic resilience are the main priorities to establish a livable and sustainable city. The integration of public transportation and green infrastructure, as demonstrated in successful case studies such as Seoul's Cheonggyecheon Stream and Medellfn's river park, is a key component of the proposed study. The project's emphasis on community participation, innovative planning approaches, and long-term sustainability further reflects the principles of regenerative urban development. The Cheonggyeche on Stream project in Seoul was one such example where the restoration of a buried stream and linear park led to improved water quality, biodiversity, and quality of public spaces. The project has turned a polluted river corridor into a vibrant public space of parks, trails, and cultural facilities. In the meantime, it is participating in the revitalization of its surrounding neighborhoods while bettering the lives of its residents.

2.2. The Benefits of Integrating Public Transportation and Green Infrastructure

The Cikapundung River corridor project presents benefits of integrating public transportation and green infrastructure in urban regeneration. It can be achieved by developing a mobile pod system along the river corridor and creating new green spaces. The project also aims to improve mobility to connect the Bandung City, reduce pollution, improve public health, and stimulate economic activity. This integrated approach is consistent with the findings of many studies that have highlighted the positive impacts of combining transportation system with green infrastructure.

2.3. The Role of Innovative Planning Approaches

The Cikapundung River corridor project demonstrates the need to use new approaches of planning to make the city more sustainable. Using the participatory planning method helps the project to ensure that the needs and desires of the local people are listened to and incorporated into the final design as appropriate. The project also incorporates green infrastructure and sustainable design principles and demonstrates how visionary planning can create more resilient and sustainable cities.

3. Challenges & Opportunities

3.1. Existing Condition of Cikapundung River

The uncontrolled growth of urban slums and informal settlements along the Cikapundung River has become problematic and worsening as the urbanization, poverty and lack of affordable housing are hardly addressed. These problems has brought contamination/pollutions, soil erosion, and flash flooding and deforestation along the river corridor. The inadequate infrastructural services and waste disposal, set these communities wildly open for disease outbreaks and other health issues.

3.2. Analysis of Existing Public Transportation Systems and Green Spaces

The public transport system in Bandung is insufficient with increasing demand, especially at weekends and in rush hours. This leads to an increased dependence on private vehicles, which leads to congested traffic and deteriorating air quality. The city has a good amount of green space, but for some residents from marginalized areas, access proves difficult. Many green spaces are owned privately. Such spaces limit access and opportunities of benefiting from health and ecological advantages.

However, the Cikapundung River corridor could prove a mighty opportunity to urban renewal amidst these challenges. Addressing the uncontrolled growth of slum settlements, improvement of public transport systems and upgrading green areas is a way to develop a more sustainable, just, and resilient city.

4. Case Study: CARE Approach

4.1. Proposed Framework for Development (CARE)

After careful analysis and study, Bandung Cikapundung River corridors revitalization presents both substantial challenges and unique opportunities. This case study explores the approach framework through CARE BANDUNG as a strategic vision that aligns with these opportunities and actionable objectives.

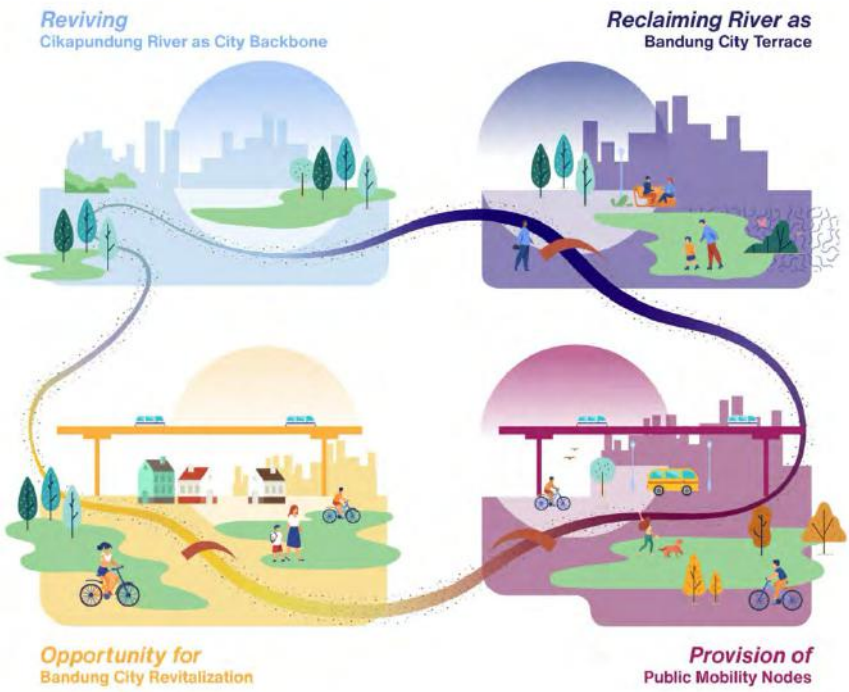


Figure 2. CARE BANDUNG framework principles. Source: Author

Through CARE BANDUNG, we aim to reimagine Bandung's riverfront spaces as active, accessible, and ecologically vibrant areas that serve the community, enhancing quality of life while respecting the city's heritage and aspirations for the future. Meanwhile, it also capitalizing the space for the provision of public transportation to increase urban mobility. CARE BANDUNG is a transformative approach to urban revitalization, guided by four key principles: *re-Connect, re-Activate, Revive,* and *re-Establish.* Each principle reflects a strategic commitment to restoring and enhancing Bandung's river corridors as vital community assets

Re-Connect the city through a network of sustainable mobility options that connected 14 nodes along the Cikapundung River corridor. The study aims to creating seamless mobility through improved public transportation, pedestrian pathways, bicycle-friendly infrastructure and also reduce dependence on private vehicles. This will contribute to a more connected and livable urban environment.

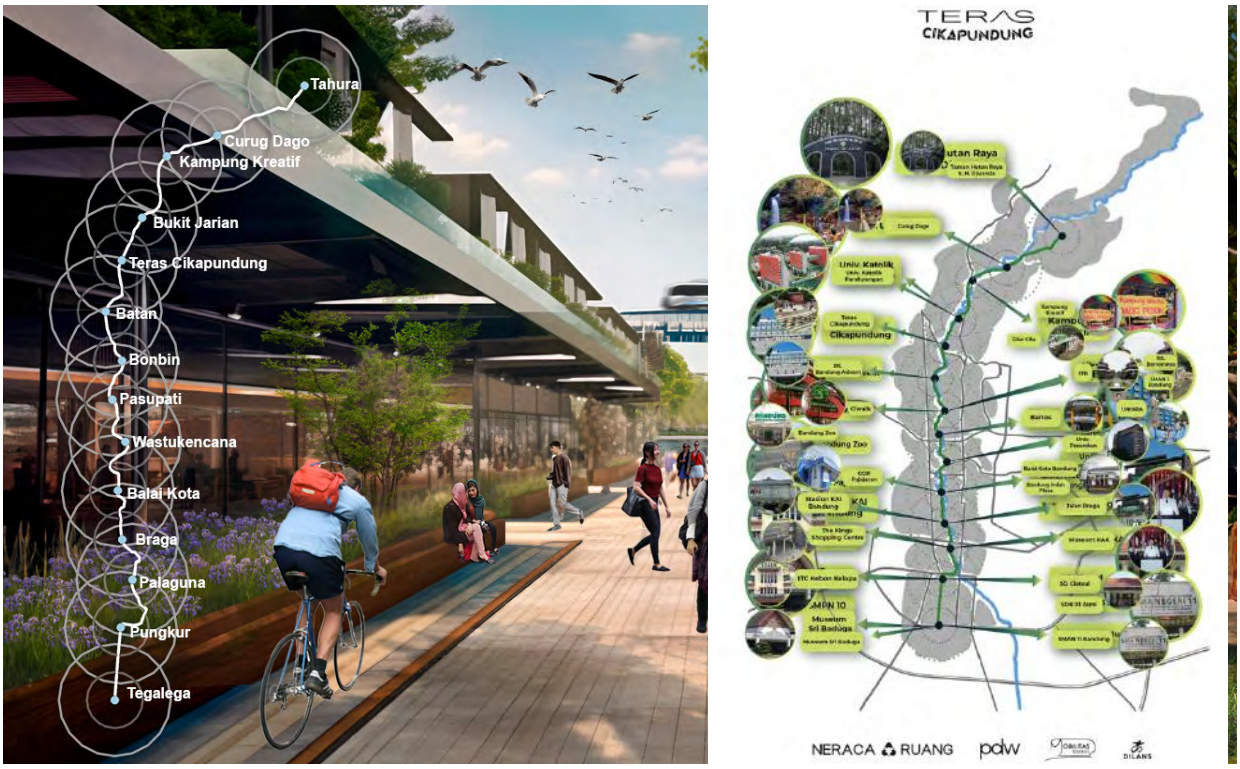


Figure 3. Proposed concept for Cikapundung river corridor. Source: Author

We proposed the Metro Capsule modules as an innovative mode of transportation that is particularly well-suited to the hilly terrain and compact urban fabric of Bandung, in accordance with the re-Connect principle. This compact metro system is engineered with a small turning radius and the capacity for climbing steeper inclines, rendering it more adaptable to the layout of Bandung than traditional MRT or LRT systems. Although the Metro Capsule is compact in size, it has the capacity to function as a mass transit solution, connecting critical areas while minimizing the space and infrastructure requirements of densely populated communities. This method ensures enhanced mobility throughout Bandung by connecting communities through a transit system that is customized to the city's unique topography.

Figure 4. Metro Capsule Bandung modules. Source: Author

The re-Activate principle focuses on revitalizing the riverbanks with public amenities and green spaces, creating vibrant and inviting public spaces for residents and visitors of all ages. This will not only improve the quality of life but also stimulate local economic activity. It seeks to reintegrate the community with its riverfront through social and recreational activities.

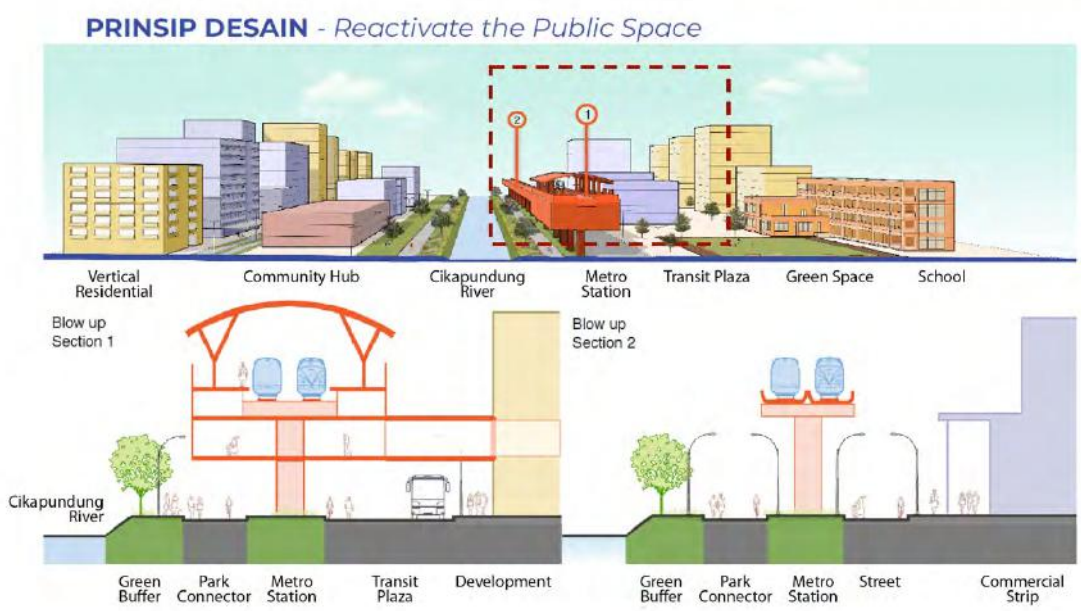


Figure 5. Section concept to reactivate the Cikapundung River corridors. Source: Author

Revive focuses on the river's ecological health, the study proposes measures to improve waterfront ecological quality, restore biodiversity, and create a more resilient ecosystem. This approach not only improves environmental health but also enhances Bandung's resilience to urban challenges like flooding, contributing to a balanced and beautiful river ecosystem. This will contribute to the overall sustainability of the city while providing accessible green open space.

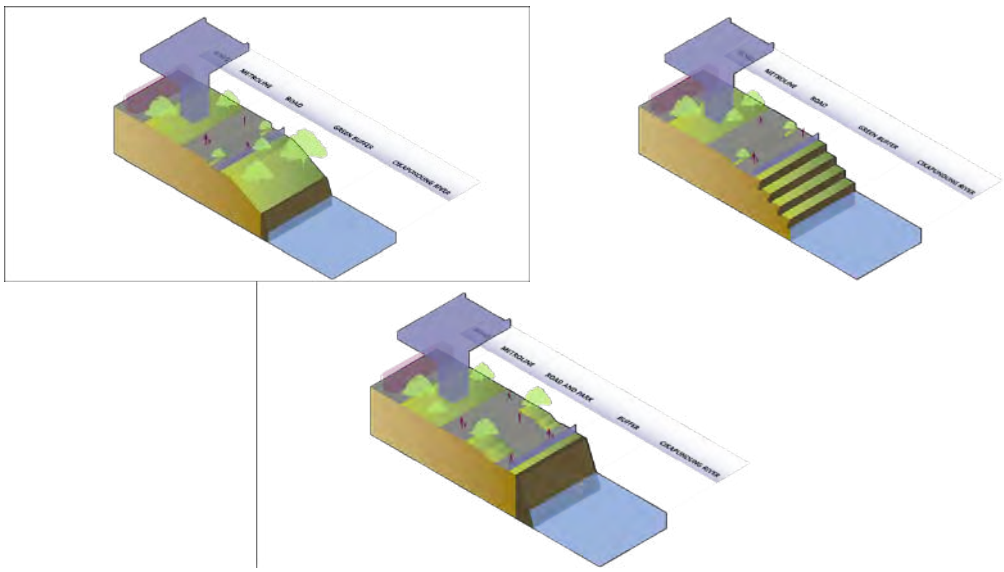


Figure 6. Section concept to riverfront design for the Cikapundung River edges (natural, terraced landscape, gabion wall). Source: Author

Finally, the re-Establish principle aims to address the issue of slum settlements along the river corridor. By implementing participatory planning, rolling development strategies and providing affordable housing options, the study aims to improve living conditions for residents and reduce the negative impacts of informal settlements.

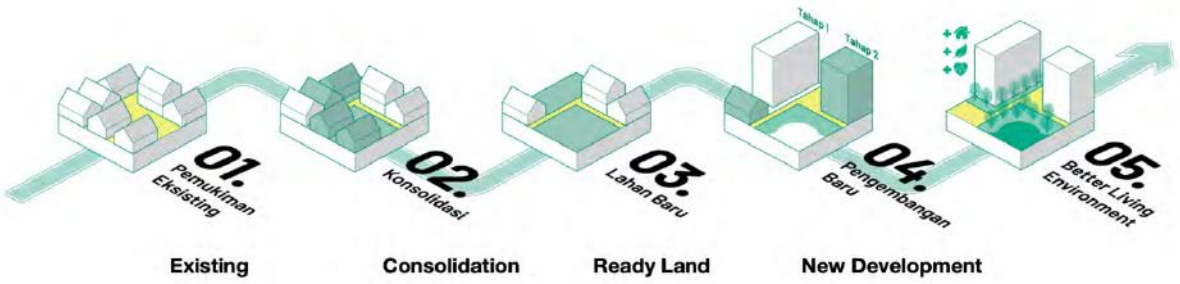


Figure 7. Rolling development and land consolidation. Source: Author

Collectively, these principles establish a comprehensive vision for the transformation of Bandung's river corridors into ecologically sustainable, accessible, and vibrant spaces. CARE BANDUNG is dedicated to a sustainable urban future that prioritizes connectivity, environment, and community.

5. Pilot Project Area (Project Implementation Proposal)

5.1. Case Study: Bandung Zoo District

In order to realize the CARE BANDUNG vision, we have designated a pilot project area where the re-Connect, re-Activate, Revive, and re-Establish principles will be implemented. Bandung Zoo district area, which is distinguished by its dense, organic settlements along the riverbank, serves as an optimal testing ground for revitalization. By emphasizing this pilot area, we can demonstrate the potential design components to enhance ecological health, promote neighborhood quality, energize community spaces, and improve connectivity. This will establish a scalable model for the broader implementation of the project throughout Bandung.

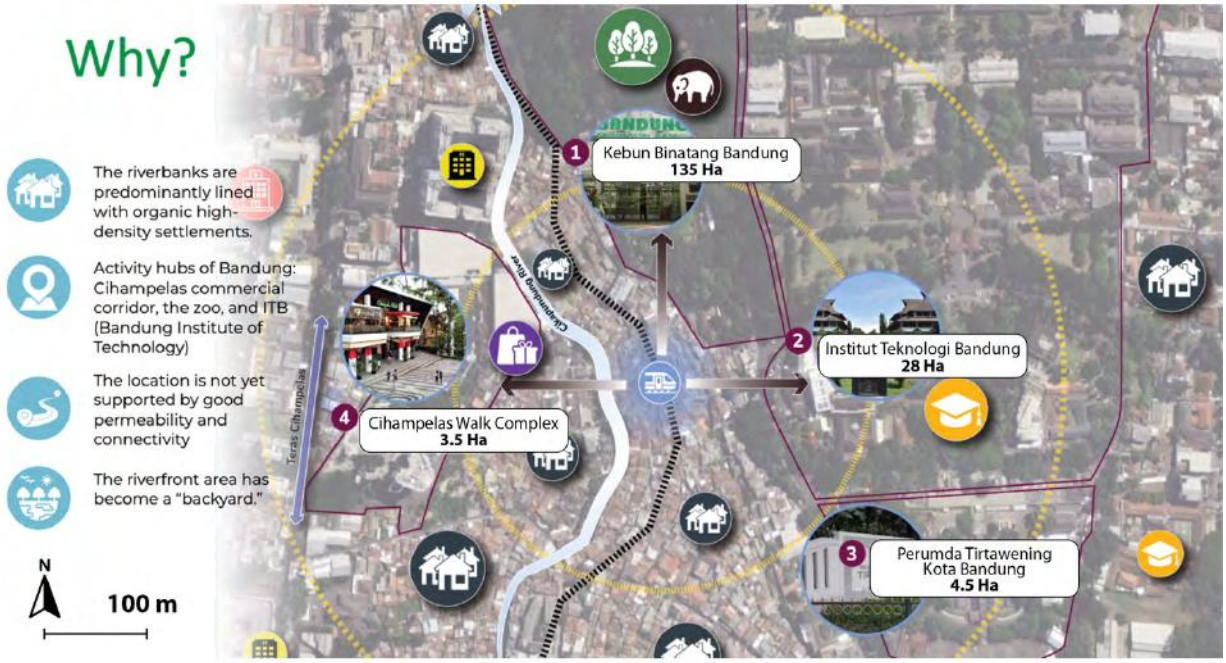


Figure 8. Bandung Zoo District context analysis. Source: Author

The design for the Bandung Zoo district area is based on the vision of CARE BANDUNG and utilizes the four fundamental principles—re-Connect, re-Activate, Revive, and re-Establish—to establish a community-oriented, sustainable, and cohesive urban space. We intend to transform the zoo and its adjacent district into a vibrant, accessible hub that is in harmony with the natural and cultural landscape of Bandung by incorporating these principles into the master plan. Each principle is carefully incorporated to address particular needs, including the enhancement of connectivity, the cultivation of ecological resilience, and the enhancement of neighbourhood vitality. The subsequent strategies define the implementation of each principle in the Bandung Zoo area, follow with the concept master plan and visualization of the area.

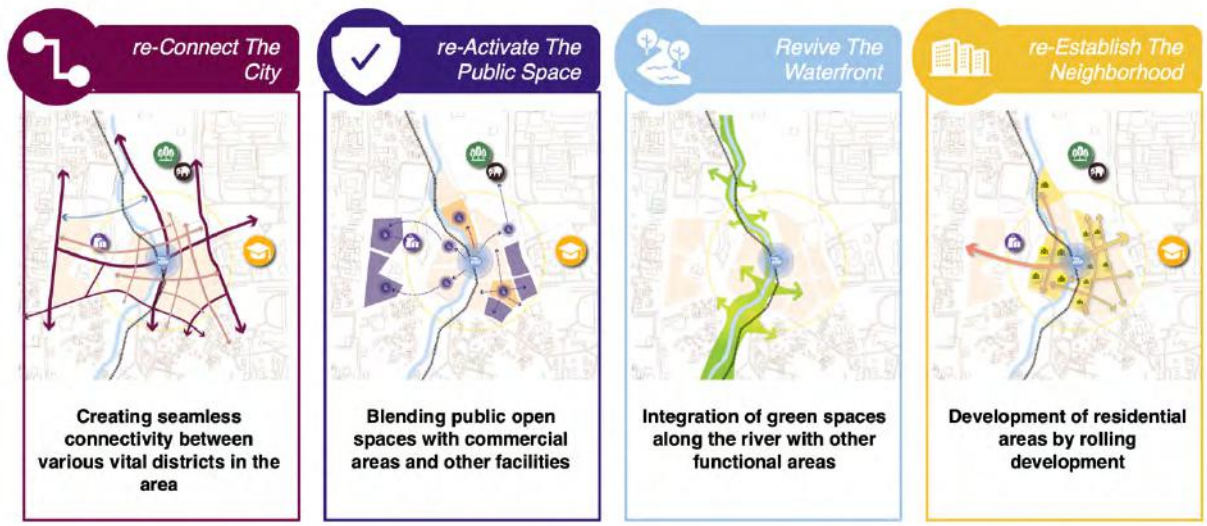


Figure 9. CARE BANDUNG principles for Bandung Zoo District. Source: Author

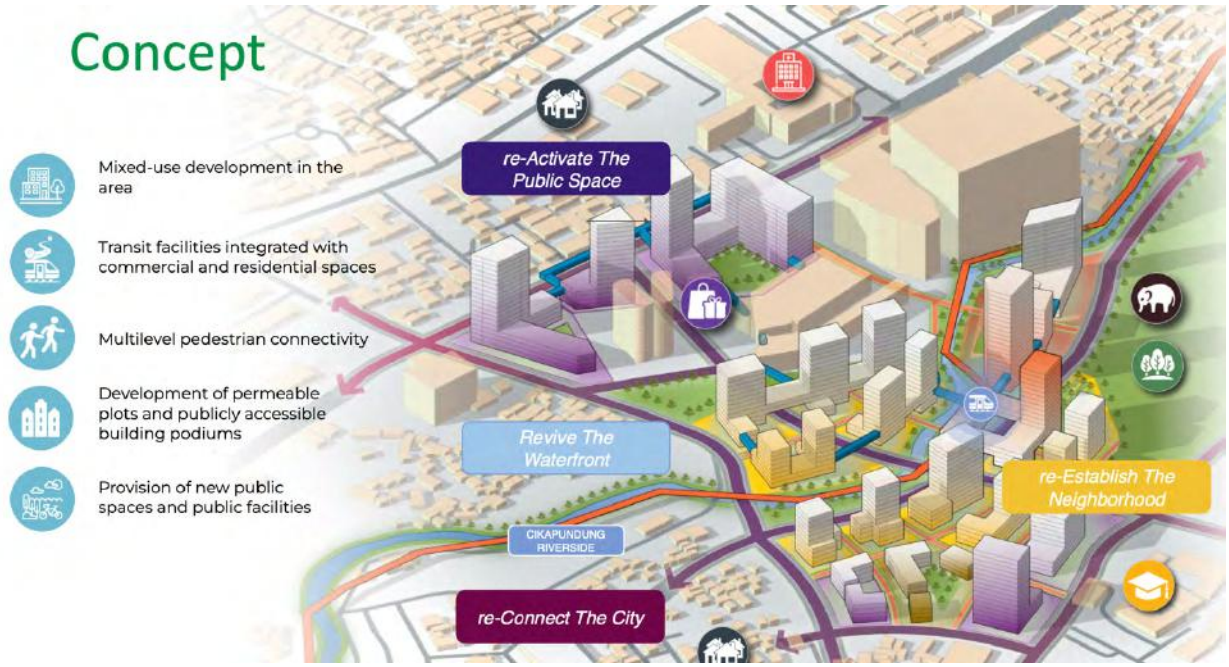


Figure 10. CARE BANDUNG implementation concept for Bandung Zoo District. Source: Author

Figure 11. Visualization of Zoo entrance plaza. Source: Author

Figure 12. Visualization of constructed bicycle lane along riverfront area. Source: Author

Figure 13. Visualization of public amenities along the river as part of urban renewal. Source: Author

Figure 14. Visualization of Water Sensitive Urban Design approach for Cikapundung River corridors. Source: Author

6. Project Outcomes and Impacts

6.1. Social Outcomes

The revitalization of the Cikapundung River corridor is expected to have significant social benefits such as encouraging social and cultural cohesion while enhancing social relations (Anderson et al., 2019). By redeveloping slum areas and providing improved housing and infrastructure, the project will improve living conditions for residents. The creation of new public spaces, such as parks, trails, and cultural facilities, will enhance social cohesion and community engagement. These spaces can serve as gathering places for residents, promoting social interaction and fostering a sense of belonging.

6.2. Economic Outcomes

The project is proposed to boost local economies through the creation of new jobs related to infrastructures, maintenance, and other industries. Other benefits of the redeveloped river corridor are greater investment to businesses and developers, creating new businesses such as commercial and property sectors. Moreover, the improved urban development can stimulate tourism by attracting more tourists to the city's attractions. Additionally, the services developed from the revitalized river ecosystems positively impact not only economic profits but also the well-being of humans through an output of the ecosystem (Schmidt et al., 2016).

6.3. Environmental Outcomes

The river corridor revitalization will have major environmental benefits. The project will improve air and water quality through the enhancement of water quality, restoration of biodiversity, and pollution abatement. Development of green infrastructure, including parks and green roofs, will help mitigate flood risks and enhance climate resilience. This project aims to protect and restore natural systems to enhance biodiversity and develop a sustainable urban ecosystem.

6.4. Mobility & Connectivity

The reactivation of the river corridors will create new connections of the city's network. New integrations between transport modes can enhance connections between places, shorten travel time, and reduce the urgency of using the private vehicles. The improved mobility system will encourage more people to rely using public transportation. This new mobility & connectivity system will significantly reduce the pollution, traffic congestions and supports healthy living.

7. Future Challenges & Mitigation Strategies

7.1. Potential Risks

The revitalization of the Cikapundung River corridor are prone to challenges. Financial risks may arise due to the high costs of environmental restoration, infrastructure development, and social programs. Technical challenges may include difficulties in managing water quality, preventing erosion, and ensuring the safety of public spaces. Additionally, social challenges may arise due to potential conflicts over land use, displacement of residents, and concerns about gentrification. Community resistance and potential displacement risks are significant concerns. Residents may be apprehensive about changes to their neighborhoods and may fear losing their homes or businesses. Displacement and relocation can lead to social disruption and inequality of living condition.

7.2. Mitigation Measures

To address these challenges, tactical mitigation strategies implementation is crucial in the process. Financial challenges can be mitigated through strategic partnerships with public and private sector organizations, as well as by exploring innovative financing mechanisms. Technical challenges can be addressed through careful planning, and the use of sustainable materials and technologies. To prevent gentrification and ensure equitable development, policies and programs should be implemented to protect affordable housing and support local businesses. Strategies such as community engagement and local participation should be prioritized to ensure that the needs and concerns of residents are considered.

7.3. Long-Term Sustainability

The long-term sustainability of the Cikapundung River corridor project relies on effective maintenance and management. A long-term comprehensive maintenance plan should be developed to ensure that infrastructure is properly maintained and repaired. The participation of local community can play a vital role in ensuring the project's long-term success. This can be done by empowering local communities to participate in the management process and maintenance of public spaces, resulting in a sense of ownership and responsibility. Additionally, the public-private partnerships can also contribute to the project's sustainability. By leveraging the resources and expertise of both public and private sector organizations, it is possible to develop innovative solutions and ensure the project's long-term viability.

8. Policy Recommendations and Plausible Actions

8.1. Integrating Sustainable Mobility with Urban Regeneration

To effectively integrate sustainable mobility with urban regeneration, policymakers should prioritize sustainable transportation options, invest in infrastructure, implement traffic management measures,

and promote mixed-use development. By fostering a more sustainable transportation system, cities can reduce congestion, improve air quality, and create more livable urban environments.

8.2. Regulating Riverbank Boundaries

The condition of the riverbank is crucial for the success of urban regeneration projects. Policymakers should review and revise existing riverbank regulations to ensure they align with the goals of ecological restoration and public access. This study shows plausible efforts of reviving the river as backbone by expanding public access to the riverbank and implementing ecological restoration measures, cities can create vibrant public spaces and improve the health of their waterways.

8.3. Promoting Equitable Development and Inclusive Planning

To ensure that urban regeneration benefits all residents, policymakers should adopt frameworks for equitable development and inclusive planning. This includes involving local communities in the planning process, implementing affordable housing policies, supporting inclusive economic development, and promoting social justice initiatives. By prioritizing equity and inclusion, cities can create more just and sustainable urban environments.

8.4. Scalability and Replicability

The Bandung case study can serve as a valuable model for other cities facing similar challenges. However, it is important to recognize that the specific implementation of the CARE principles and strategies may vary depending on local conditions. To ensure the scalability and replicability of the Bandung case study, cities should conduct thorough assessments, tailor strategies to their specific needs, build partnerships, and monitor and evaluate progress. By following these guidelines, cities can effectively apply the lessons learned from Bandung to their own urban regeneration efforts.

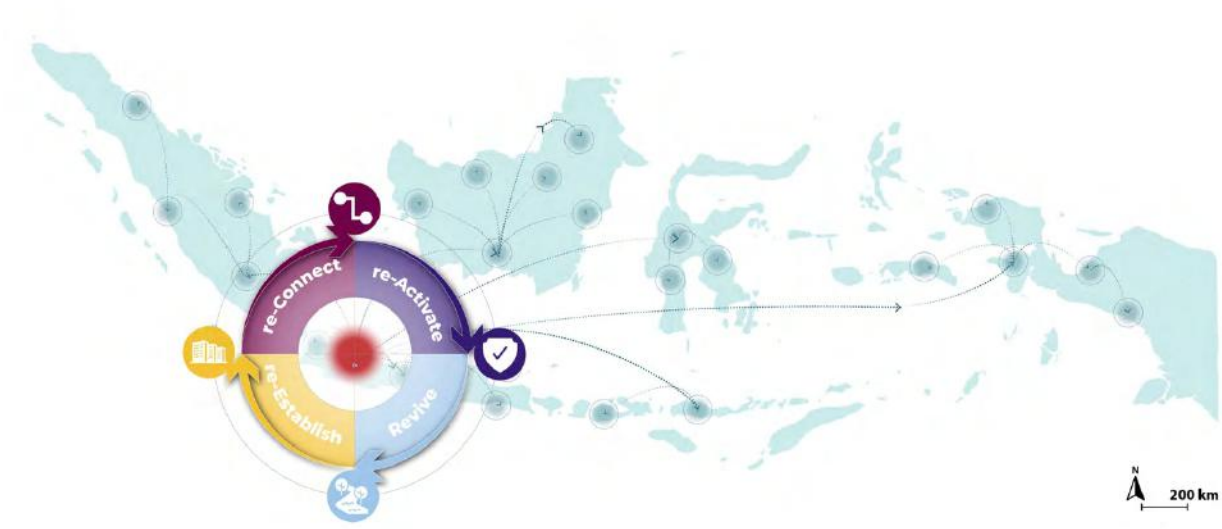


Figure 15. Scalability & replicability concept to similar cities in Indonesia. Source: Author

9. Conclusions

This case study has demonstrated the potential of revitalizing the Cikapundung River corridor as a means of promoting sustainable urban development in Bandung, Indonesia. By focusing on the CARE BANDUNG principles—Connect, Activate, Revive, and Establish—the study has identified a comprehensive approach to address the city's pressing urban challenges. The river corridor, once a vital backbone of the city, has become neglected and marginalized over time. This project aims to restore the river's ecological ecosystem, reactivate its riverbanks with accessible public spaces, and reconnect the city through improved mobility.

Key findings of this study include the importance of river corridors as catalysts for urban regeneration, the potential benefits of integrating sustainable mobility and green infrastructure, the need for inclusive planning and community engagement, and the importance of addressing social, economic, and environmental challenges in a holistic manner. The revitalization of the Cikapundung River corridor has the potential to transform Bandung into a more sustainable, equitable, and resilient city. By creating vibrant public spaces, improving mobility, and enhancing environmental quality, the project can significantly improve the quality of life for residents and visitors.

The lessons learned from this case study can be applied to other cities facing similar challenges. By adopting innovative, inclusive, and sustainable urban planning approaches, cities can create more livable, equitable, and resilient urban environments. The future of cities depends on our ability to balance economic growth with social justice and environmental sustainability.

10. References

Deffner, Jutta & Haase, Peter. (2018). The societal relevance of river restoration. Ecology and Society, 23(4), 14. doi: 10.5751/ES-10530-230435

Anderson, E. P., Jackson, S., Tharme, R. E., Douglas, M., Flotemersch, J. E., Zwarteveen, M., & Arthington, A. H. (2019). Understanding rivers and their social relations: A critical step to advance environmental water management. WIREs Water, 6(1), e1381. https://doi.org/10.1002/wat2.1381

Schmidt, K., Sachse, R., & Walz, A. (2016). Current role of social benefits in ecosystem service assessments. Landscape and Urban Planning, 149, 49-64. https://doi.org/10.1016/j.landurbplan.2016.01.005

OpenAI (2025) ChatGPT: Language Model for Generating Textual Responses. Version 4. Available at: https://openai.com (Accessed: March 2024).

GM Appdev Limited (2025) JustdoneAI: GPT-4 AI Writing Assistant. Version 1.3.11. Available at: https://justdone.ai/ai-detector (Accessed: January 2025).

Midjourney. Inc (2022) Midjourney: GPT-4 AI Image Generator. Version 6. Available at: https://www.midjourney.com/home (Accessed: March 2024).

Learno. Inc (2018) QuillBot: Natural Language Processing AI-powered writing tool. Version 2.0.12. Available at: https://quillbot.com (Accessed: October 2024 & January 2025).

Case Study Report

Walking Towards Sustainability: Optimizing Public Transit though the “Walkable Cities” by Time-Oriented Model

Süleyman Nurullah Adahi ŞAHİN, Sakarya University of Applied Sciences, Turkey

Yavuz HALİMERGÜN, Sakarya University of Applied Sciences, Türkiye

Abdulkadir ÖZDEN, Sakarya University of Applied Sciences, Türkiye

Abstract

Urban planning has changed in both real and intangible ways to address the pressing problems of sustainability, climate resilience, and efficient urban mobility. In order to make cities more livable, accessible, and connected, sustainable transportation ideas are heavily emphasized in contemporary urban planning techniques. One of the most crucial urban regulations that cities must adhere to in recent years is the idea of sustainable mobility. One of the most popular approaches for designing sustainable urban transportation is the "10-minute cities" model. Combating the detrimental effects of climate change on cities is another major function of this paradigm. This study examines the current public transportation stops' walking distances and their distances to one another from a methodological standpoint. The efficiency of the stops, their significance in multi-modal public transportation, which public transportation lines (particularly bus lines) they serve as they currently exist, and the number of passengers they serve are all determined by calculating the 5-8-10 minute walking circular areas to the stops. In addition to making public transportation more appealing by doing a walkability analysis of the stations, more effective stop locations can also be created by optimizing the stops that are inefficient or lack sufficient demand. With an average walking speed of 5 km/h, it is estimated that a person can cover 416 meters in 5 minutes, 666 meters in 8 minutes, and 832 meters in 10 minutes. Therefore, when an analysis is conducted based on these walking figures, the effects of the pauses on residential, industrial, and commercial districts may also be tracked. In addition to encouraging a more efficient and inclusive urban walkability system, this approach supports the development of flexible and sustainable urban landscapes. Therefore, the study's outputs can be very useful to urban planners who want to incorporate innovative and sustainable mobility solutions in their communities.

Keywords

Walkability, Geographic Information System, Time-Oriented Model, Public Transit, Sustainability

1. Introduction

To preserve and improve the standard of living in cities, sustainable urban mobility is essential. There are now more options and demands for public transit and transportation networks as the population of cities grows. Urban transportation planning has therefore emerged as a crucial issue for cities (Vuchic, 2017). According to the European Commission, sustainable mobility plans concentrate on creating urban transportation networks by fulfilling important objectives, such as providing transportation options for all

citizens, ensuring safety, combatting pollution, being cost-effective, and enhancing the standard of living in urban areas (Chou, 2017). To satisfy the needs of passengers and citizens, administrators create a variety of transportation projects and solutions. These initiatives and solutions are carried out in accordance with specific aims and objectives. When waiting or switching between different forms of transportation, passengers use stops. (Rietveld, 2004; García-Palomares, Gutiérrez and Cardozo, 2013; Johar, Jain and Garg, 2017; Jie, Zhiwei and Meng, 2019) Crucial metrics include the stops' location, passenger density, area served, and the number of transportation lines and modes they can transfer from the stop serve.

For cities to achieve sustainable mobility goals, public transportation is essential, and the network's quality must be acceptable (Mohammed and Senadheera, 2022). Social contact (Kaufmann, Audikana, and Drevon, 2021), energy efficiency (Moriarty and Honnery, 2012), and a sustainable environment (Tezangi, 2014) are all impacted by public transportation, both directly and indirectly. By implementing comprehensive public transit, cities may provide all passengers safer, more effective, and low-emission travel options (Kandt et al., 2015; Friman, Lättman, and Olsson, 2020).

Additionally, by offering accessible routes to transit terminals, public transportation systems can promote active transportation and encourage walking and bicycling as essential parts of daily commutes (Wigan, 1995) + Corazza & Favaretto, 2019; Lachapelle et al., 2011). Research shows that cities that make investments in multimodal transportation systems—where walking and bicycling infrastructure is seamlessly integrated with public transportation—have lower levels of vehicle dependency and higher rates of public transportation use (Rifai & Arifin, 2020). In addition to increasing the transport network's efficiency, this integration promotes an active mobility culture, which results in healthier lifestyles and less traffic in cities (Oleśków-Szłapka et al., 2020). Public transportation can lessen the cost burden of car ownership by decreasing the need for private vehicles, hence increasing mobility for low-income groups (Tiwari et al., 2021).

In this study, Geographic Information Systems (GIS) were used to analyze the walkability of the planned tram stops in Sakarya province, Turkey. Sakarya, which has a population of 1.098.115 and a surface area of 4817 km2, is situated in northwest Turkey (T.C. Sakarya Valiligi İl Brifingi, 2024) (Figure 1). Sakarya Metropolitan Municipality revealed the planned tram project, which is divided into three sections (Figure 2). After assessing the city's main transportation hubs at the beginning of the project, the authors decided that Phase 1 and the eastern portion of Phase 3 should be developed jointly, as seen in Figure 2. Based on this integrated route, a walkability analysis was carried out. The tramway project, which nearly matched the path taken in the authors' study, was approved after discussions between the municipality and the Ministry of Transport. The study's recommended route and the official plan's overlap have been approved as the designated infrastructure project (Figure 3).

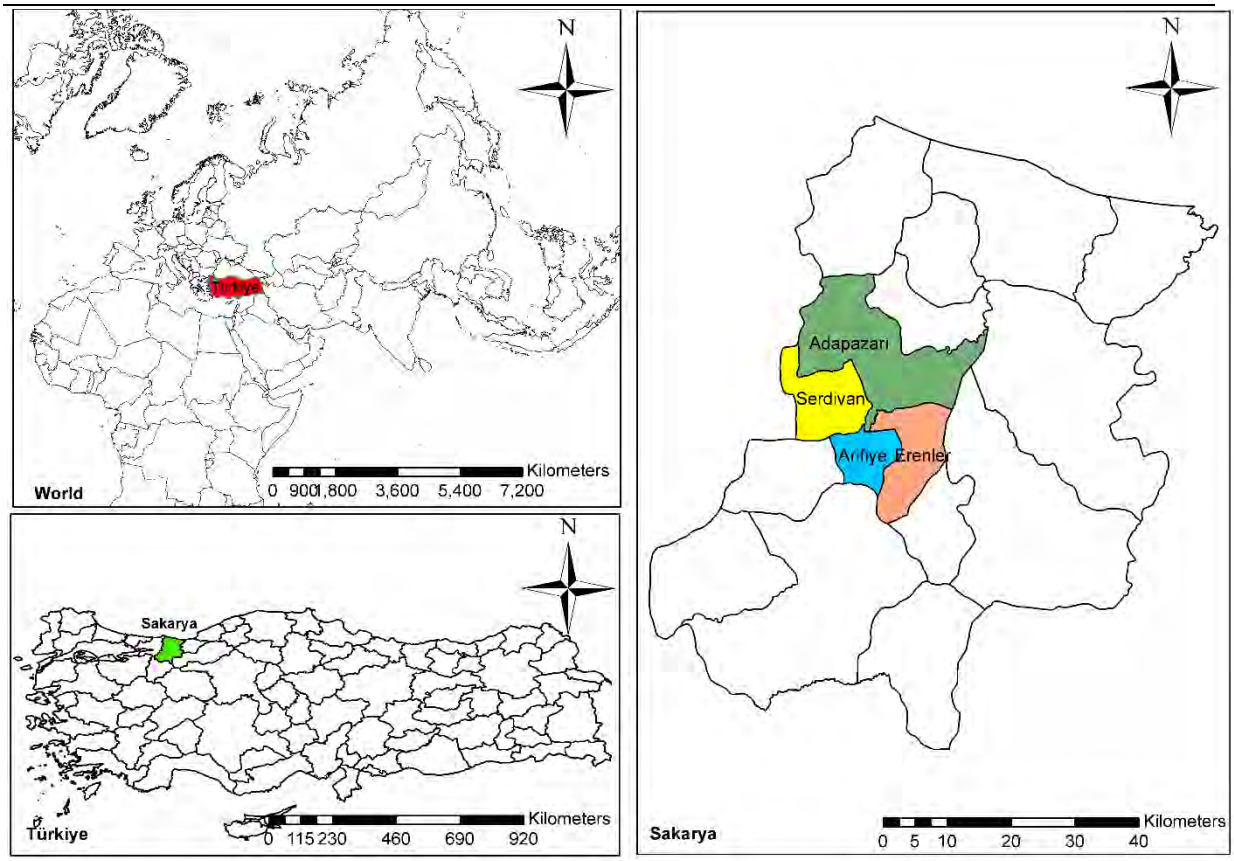


Figure 1. Location of Sakarya from various scales

Figure 2. The Planned Tram Project (*Raylı sistemde güzergahlar belirlendi*, 2023)

Figure 3. Analyzed tram lines and stops

2. Methodology and Analysis

The proposed tram line project will provide a new form of transportation to Sakarya, a city whose residents have long walked, cycled, and used train systems, all of which have influenced their travel habits. The new tram system is anticipated to significantly improve walkability and support current transit patterns, and residents are likely to swiftly adjust to it. In order to assess the accessibility of planned tram stops and their closeness to existing bus stops, walkable zones have been meticulously mapped. After the tram is finished, this analysis offers suggestions for improving bus routes, resulting in a more accessible and integrated transportation system that fits well with the city's established travel habits.

To build the structure of this paper and to assist the structure of sentences both editing and proofreading, ChatGPT-4o is used. In general, for analysis, ESRI's ArcGISTM is used in this study to identify and assess walkable areas. Walkable routes (polyline layer) are incorporated into the algorithm to identify these walkable locations. OpenStreetMap, an open access mapping tool, is the source of this data. Then, using ESRI's ArcGISTM Network Analysis Tool, this polyline data is examined, and walkable regions are established by enclosing them with a predetermined range of durations and distances. The walking pace employed in this study is 5 km/h, which is typically regarded in the literature to be between 4.90 and 5.80 km/h (Arango Diaz, 2008). Then, walkable zones are determined by calculating walking distances of five, eight, and ten minutes. A 5-minute walk is 416 meters, an 8-minute walk is 666 meters, and a 10-minute walk is 832 m.

The following map (Figure 4) displays the projected tram line and tram stations. Red stops indicate potential

tram stops in the near future, whereas blue stops indicate planned tram stops. The tram route is 12 kilometers long, with stops spaced 0.35 to 1.8 kilometers apart (Table 1). Additionally, three virtual tram stops were built in consideration of the attraction centers in the areas where a large number of students congregate, as these may be a potential future extension of the tram stops. For those who can use these three virtual stations for transportation, they are also appealing locations.

Table 1. Length of The Planned Tram Line

From	To	Length of Tram Line (km)
SAÜ CAMPUS	KYK DORMS	1.4
KYK DORMS	FARAZA	1.8
FARAZA	MEDAR	1.1
MEDAR HOSPITAL	SERDIVAN MUNICIPALITY	1.3
SERDIVAN MUNICIPALITY	ASEM	0.8
ASEM	AGORA	0.8
AGORA	MILLET BAHCESI	0.7
MILLET BAHCESI	OFIS SANAT	0.6
OFIS SANAT	DEMOKRASI SQUARE	0.6
DEMOKRASI SQUARE	YENICAMI	0.35
YENICAMI	REHABILITATION	0.55
REHABILITATION	SCHOOLS	0.9
SCHOOLS	STADIUM	1.1
TOTAL:		**12**

Figure 4. Tram lines, tram stops and virtual tram stops

Figure 5 depicts the walking spaces, often known as time-oriented regions. The regions that are green, orange, and red represent the 0–5, 5-8, and 8–10-minute walking times, respectively. When using this kind of transportation, passengers may be more inclined to walk to the tram stops (Aksoy, 2022). The walkability map in relation to the tramway line was displayed using buffer analysis. Walkability to the stops was demonstrated using network analysis, and tram line attractiveness was demonstrated using buffer analysis. In network analysis, walkability was examined using pedestrians or appropriate paths (Figure 6). Figure 7 clearly illustrates the distinction between buffer area analysis and network (service) area analysis. To put it briefly, network analysis requires a layer to be used for analysis, whereas buffer analysis can be done without a layer (Aslan and Kocaman, 2018). In network analysis, a specific network layer must be created, and the attributes in that network must be appropriately provided for an accurate analysis, whereas in buffer analysis, determining the distance from a line or point is sufficient.

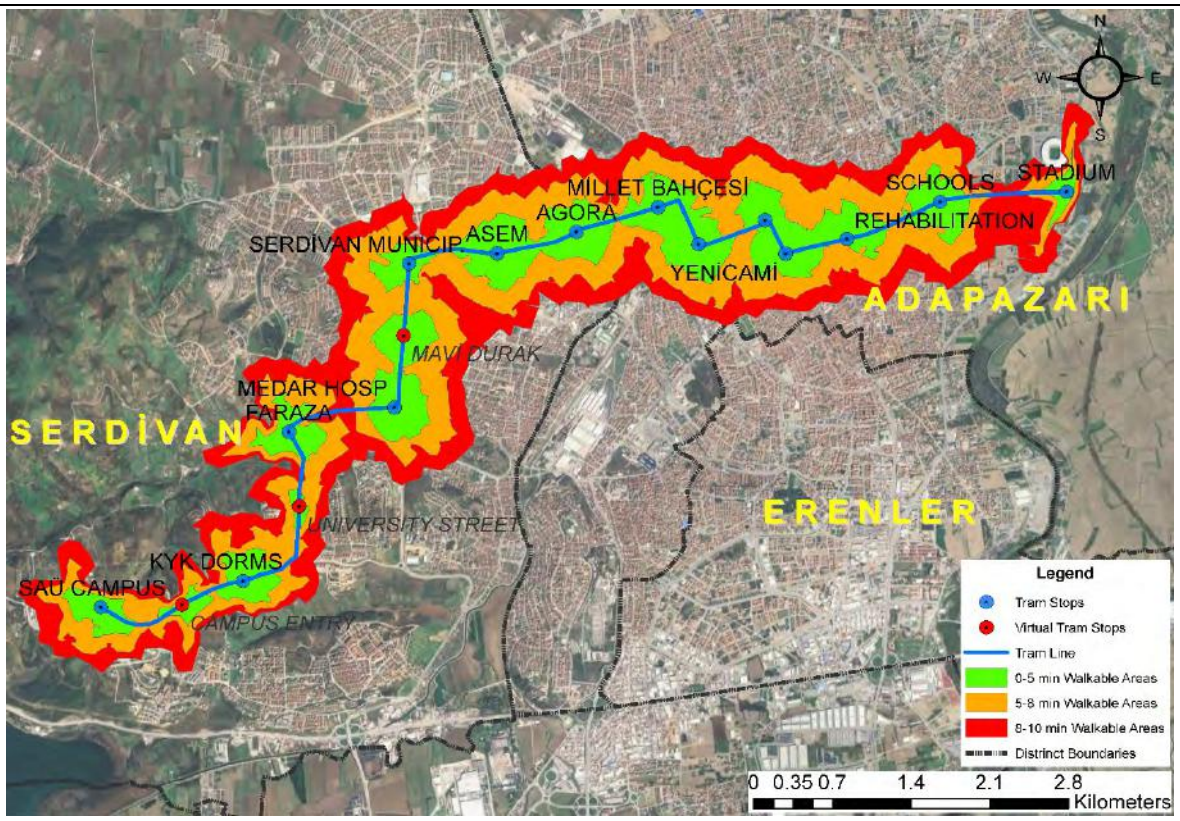


Figure 5. Time-Oriented Areas in 5-8-10 min to walk

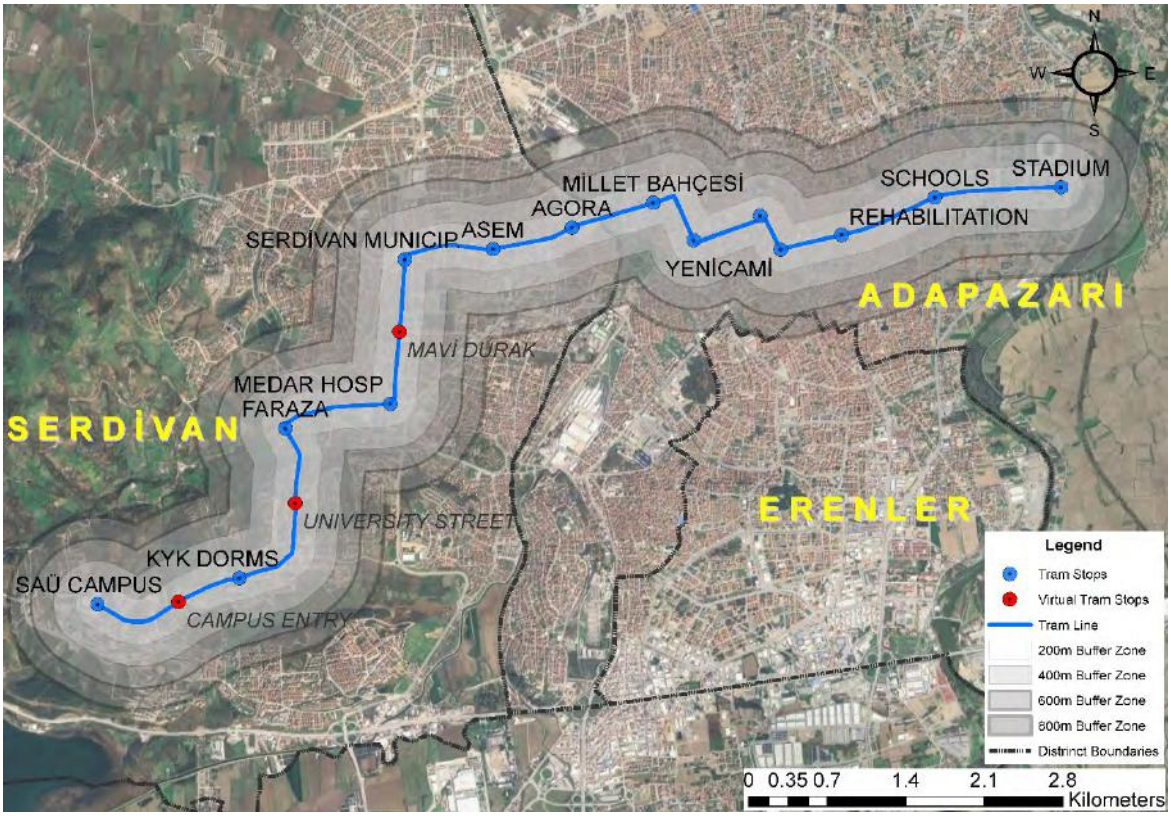


Figure 6. Buffer Area Analysis in 5,8,10 min

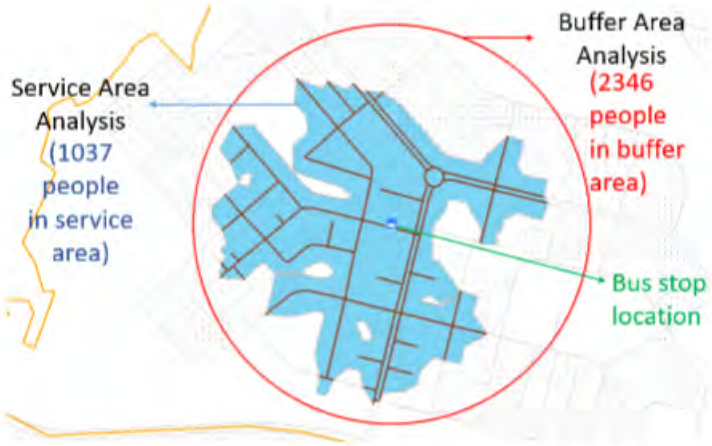


Figure 7. The difference between Service Area (Network) Analysis and Buffer Analysis in GIS (Aslan and Kocaman, 2018)

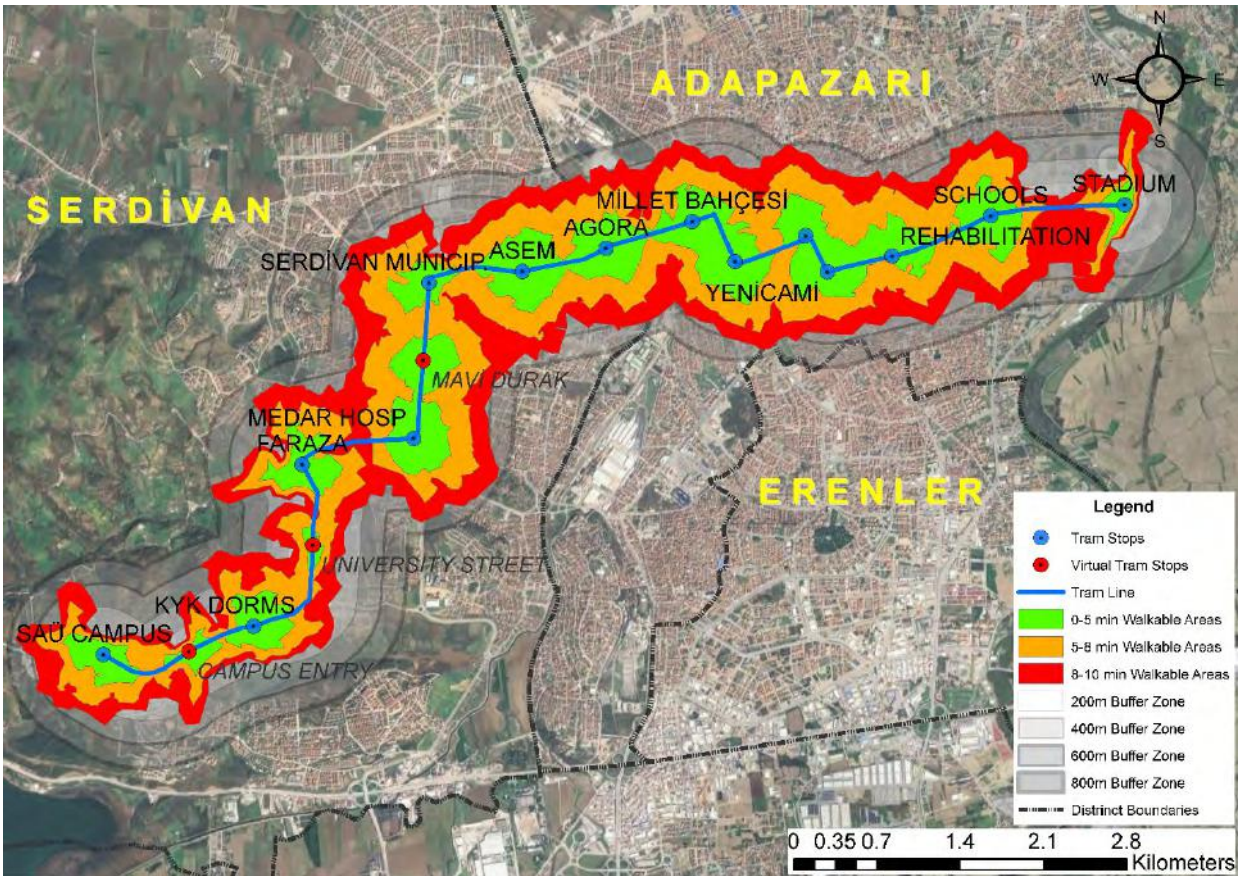


Figure 8. Time-Oriented Walking Areas and Buffer Zones on the same Map

According to Table 2, the 5-minute walkable catchment has a total surface area of 3.333 km2, the 8-minute walkable catchment has 8.213 km2, and the 10-minute walkable catchment has 12.832 km2. The buffer zones at 200, 400, 600, and 800 meters have surface areas of 4.894, 9.935, 15.125, and 20.481 kilometers, respectively. According to the 5 km/h walking speed, the walking distances for 5 minutes, 8 minutes, and 10 minutes are 416 meters, 666 meters, and 833 meters, respectively. The buffer analysis was conducted

based on the bird's eye distance, whereas the network analysis was conducted based on the walking speed. Figure 8 makes it easy to see the distinction between network analysis and buffer analysis. As previously mentioned, the buffer zone's surface areas are significantly larger than those of time-oriented zones. People cannot walk all roads and zones in urban areas because of the boundaries of personal areas or other uses, non-walkable areas like only traffic zones and some limitations for walking. Due to them, the network analysis method is more sensitive and accurate for walkability analysis.

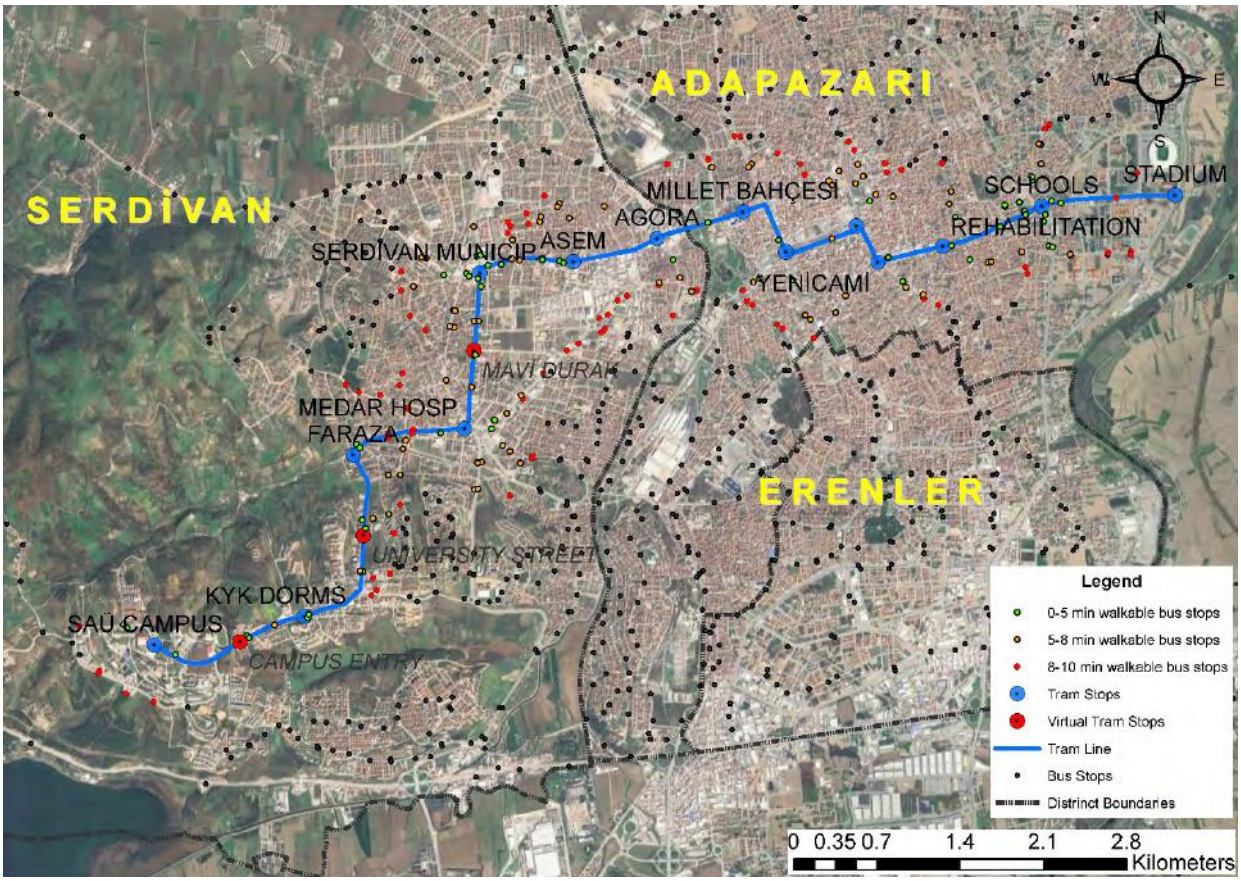


Figure 9. Bus Stops on the Map

The spatial arrangement of bus stops in respect to the suggested tram stops is depicted in Figure 9. The green markers indicate bus stations, including planned virtual tram stops, that are reachable by foot from the tram stops within five minutes. Whereas the red markers indicate bus stops within 8 to 10 minutes' walking distance from the tram stations, the orange markers suggest bus stops within 5 to 8 minutes' walking distance. After the tram line project is finished, these bus stations will be further optimized. Enhancing multimodal connection, guaranteeing smooth transitions between tram and bus services, and raising overall network efficiency are the goals of the optimization process.

Table 2. Number of stops and walking areas

	Number of Stops	Cumulative Number of Stops	Walking Areas (km^2)	Cumulative Walking Areas (km^2)
0 – 5 min	51	51	3.333	3.333
5 – 8 min	73	124	4.880	8.213

8 – 10 min	78	202	4.619	12.832

3. Discussions and Conclusions

One of the most accessible and environmentally friendly forms of transportation is walking, which provides door-to-door connection for everyday travel requirements. By offering crucial multimodal links, it enhances public transportation systems, particularly when those networks are intended to be integrated and easily accessible. A key element of urban planning is walkability, and assessing walkability can assist track and enhance the efficiency of city public transportation systems. Cities may boost public transit use, lessen dependency on private vehicles, and promote environmental sustainability by making walking a desirable alternative.

Tram stops in strategic locations, in particular, can improve public transportation's effectiveness and appeal. Tram stops should ideally be situated in places that are convenient for pedestrians to get to on foot; a distance of less than 1 km is ideal. More people use public transportation when it's close by, especially when it's safe and enjoyable to stroll. Walking distances of 416, 666, and 832 meters—or 5, 8, and 10 minutes of walking time, respectively—were examined in this study. In order to determine how far individuals are willing to walk to get tram services and how this affects the utilization of the public transportation system, these lengths were selected.

The proposed tram line in Sakarya has been developed along a visually appealing axis that crosses a range of land uses, such as workplaces, residential neighborhoods, industrial zones, educational institutions, and sports facilities. Instead of only operating during rush hour, this mixed-use development guarantees that the tram system will serve people all day long, meeting a variety of demands at various times. In addition to improving the tram's capacity use, this diversity in land use guarantees that the service will continue to be useful to a broad spectrum of consumers.

Additionally, high-interest locations like shopping malls and parks have been included in the thoughtful arrangement of the tram stops along this line. Additionally, a number of bus lines pass through or close to the tram stops, demonstrating how well-integrated these stops are with the city's current bus system. For commuters who use a variety of transportation options, this integration of modes guarantees that the stops are both handy and accessible.

A promising and convenient addition to Sakarya's transportation network, the proposed tram line combines multimodal connections, walking access paths, and thoughtfully designed tram stops. Given the high-density zones, walking areas, and effective bus line connections, it is probable that many locals will choose this new tram system as their primary means of transportation.

4. References

Aksoy, S. (2022) *Surroundings of metro stations as public spaces: user perceptions in the cases in İzmir*. Master’s Thesis. Izmir Institute of Technology (Turkey). Available at: https://search.proquest.com/openview/96e559a9333f6633bcf68c8846c376d6/1?pq-origsite=gscholar&cbl=2026366&diss=y (Accessed: 20 October 2024).

Arango Diaz, J.A. (2008) ‘Analysis of pedestrian walking speed for traffic engineering design and operations’. Available at: https://mspace.lib.umanitoba.ca/bitstream/1993/29709/1/Arango_Diaz_Analysis_of.pdf (Accessed: 20 October 2024).

Aslan, H. and Kocaman, H. (2018) ‘GIS Based Bus Stop Optimisation For Sakarya Public Transportation System’, *Sakarya University Journal of Science*, 22(5), pp. 1298–1308. Available at: https://doi.org/10.16984/saufenbilder.394911.

Chou, J.-R. (2017) ‘A Fuzzy-based Sustainability Assessment Approach for Promoting Sustainable Urban Mobility’, in *Proceedings of the 2017 International Conference on Organizational Innovation (ICOI 2017). 2017 International Conference on Organizational Innovation (ICOI 2017)*, Weihai, China: Atlantis Press. Available at: https://doi.org/10.2991/icoi-17.2017.53.

Corazza, M. and Favaretto, N. (2019). A methodology to evaluate accessibility to bus stops as a contribution to improve sustainability in urban mobility. Sustainability, 11(3), 803. https://doi.org/10.3390/su11030803

Friman, M., Lättman, K. and Olsson, L.E. (2020) ‘Public Transport Quality, Safety, and Perceived Accessibility’, *Sustainability*, 12(9), p. 3563. Available at: https://doi.org/10.3390/su12093563.

García-Palomares, J.C., Gutiérrez, J. and Cardozo, O.D. (2013) ‘Walking Accessibility to Public Transport: An Analysis Based on Microdata and GIS’, *Environment and Planning B: Planning and Design*, 40(6), pp. 1087–1102. Available at: https://doi.org/10.1068/b39008.

Jie, Z., Zhiwei, W. and Meng, M. (2019) ‘Optimization of bus stop locations for on-demand public bus service’, *Transportation Letters* [Preprint]. Available at: http://gala.gre.ac.uk/id/eprint/24951/ (Accessed: 20 October 2024).

Johar, A., Jain, S.S. and Garg, P.K. (2017) ‘A Conceptual Approach for Optimising Bus Stop Spacing’, *Journal of The Institution of Engineers (India): Series A*, 98(1–2), pp. 15–23. Available at: https://doi.org/10.1007/s40030-017-0199-x.

Kandt, J. *et al.* (2015) ‘Gauging interventions for sustainable travel: A comparative study of travel attitudes in Berlin and London’, *Transportation Research Part A: Policy and Practice*, 80, pp. 35–48.

Kaufmann, V., Audikana, A. and Drevon, G. (2021) *Europe Beyond Mobility: Mobilities, Social Cohesion and Political Integration*. Routledge. Available at: https://www.taylorfrancis.com/books/mono/10.4324/9780429325014/europe-beyond-mobility-vincent-kaufmann-ander-audikana-guillaume-drevon (Accessed: 20 October 2024).

Lachapelle, U., Frank, L., Saelens, B., Sallis, J., & Conway, T. (2011). Commuting by public transit and physical activity: where you live, where you work, and how you get there. Journal of Physical Activity and Health, 8(s1), S72-S82. https://doi.org/10.1123/jpah.8.s1.s72

Mohammed, M. and Senadheera, S. (2022) ‘Public Transport Affordability Evaluation for Addis Ababa City’, *Sustainability*, 14(11), p. 6883. Available at: https://doi.org/10.3390/su14116883.

Moriarty, P. and Honnery, D. (2012) ‘Energy efficiency: Lessons from transport’, *Energy policy*, 46, pp. 1–3.

Oleśków-Szłapka, J., Pawłyszyn, I., & Przybylska, J. (2020). Sustainable urban mobility in poznan and oslo-actual state and development perspectives. Sustainability, 12(16), 6510.

https://doi.org/10.3390/su12166510

Raylı sistemde güzergahlar belirlendi (2023) *Medyabar*. Available at: https://medyabar.com/haber/14920873/sehrin-en-cok-merak-edilen-projesinde-son-durum-rayli-sistemde-guzergahlar-belirlendi (Accessed: 20 October 2024).

Rietveld, P. (2004) ‘Optimal distances between metro stations in centre dominated metropolitan areas’. Available at: https://www.econstor.eu/handle/10419/116967 (Accessed: 20 October 2024).

Rifai, A. and Arifin, F. (2020). Analysis of the level of passenger satisfaction with services and transport facilities-based integration in jakarta. Journal of World Conference (Jwc), 2(2), 66-73. *https://doi.org/10.29138/prd.v2i2.211*

T.C. Sakarya Valiligi İl Brifingi (2024) *T.C. Sakarya Valiligi*. Available at: http://www.sakarya.gov.tr/kurumlar/sakarya.gov.tr/y_site/sakarya/brifing/Brifing_150224.pdf (Accessed: 20 October 2024).

Tezangi, N.R. (2014) ‘Sustainable urbanism: Analysis of sustainable environment principles in practical urban form’, *Journal of Engineering and Architecture*, 2(2), pp. 197–205.

Tiwari, R., Singh, J., & Kumar, N. (2021). Impact of urban transit system on housing rents evidences from india.. https://doi.org/10.47472/ctlthym8

Open AI. (2024). *ChatGPT-4o*. https://chatgpt.com

Vuchic, V.E. (2017) *Urban Transit: Operations, Planning, and Economics*. 1st edn. Wiley and Sons.

Wigan, M. (1995) ‘Treatment of walking as a mode of transportation’, *Transportation Research Record*, 1487, p. 60.

Research Paper

Walkability Index as a Strategic Planning Instrument for the Historic Center of Rio de Janeiro

Gustavo RIBEIRO, Royal Danish Academy, Denmark

Victor ANDRADE, Technical University of Denmark (DTU), Denmark

Abstract

This paper describes the design and application of a walkability index developed by the Institute for Transportation and Development Policy – Brazil – and the City of Rio de Janeiro, with two of the authors acting as external consultants in the period 2015 - 2017. The walkability index presented here was designed in the context of strategic planning and strategic interventions in the historic centre of Rio de Janeiro, which aimed at the improvement of conditions of liveability in that area. The authors present a discussion of the methodology and approach adopted in the development of this walkability index with reference to the work of authors who have investigated the benefits of active mobility and to other walkability indexes and methodologies for measuring the effects of active mobility. This walkability index embodies an attempt to balance the design of a method for the systematic measurement of variables concerning urban form (such as width of sidewalks and block size), use of urban spaces (through count of pedestrian circulation) and environmental conditions (such as noise levels) on the one hand, and the development of a strategic instrument in the urban transformation of the historic center of Rio de Janeiro on the other hand. The development of this walkability index coincided with the investment by the Municipality of Rio de Janeiro on new transport infrastructure in the form of a light-rail system linking the historic centre with surrounding areas such as the newly redeveloped port and Santos Dumont Airport. At the same period, the programme *Centro para Todos* (Centre for All) was implemented by the Rio de Janeiro World Heritage Institute (IRPH) – with a focus on the improvement of conditions of the centre from the point of view of physical infrastructure (involving for instance the upgrading of sidewalks) and public safety and in view of boosting the residential use of the Rio de Janeiro's historic city centre. In this context, this walkability index was developed to highlight spatial conditions of Rio de Janeiro's historic centre that were estimated to have a relevant impact on pedestrian use. The authors present a reflection on the application of this walkability index in the formation of current urban policies such the 'Reviver Centro' programme.

Keywords

Walkability Index, Urban Policy, Strategic Planning

1. Introduction

1.1. Shift in Urban Policies in Rio de Janeiro

The Rio de Janeiro walkability index discussed in this paper was developed within the context of a major shift in urban policy towards revitalizing the historic center of Rio de Janeiro with a primary aim to recuperate many derelict buildings worth preservation and increase residential uses.

This shift was notably marked by the implementation of the programme "Centre for All" (Centro para Todos) (Prefeitura do Rio de Janeiro, 2015), which comprised a detailed mapping of land use and the condition of preservation of individual buildings in the historic center. The "Centre for All" programme was implemented in parallel with other important initiatives, notably:

(1) *Porto Maravilha Urban Regeneration Project*: a land value capture initiative involving the sale of development rights to renew the former industrial harbor, implementing mixed-used development and new cultural buildings.

(2) Light Rail: linking the center with surrounding areas such as the newly redeveloped port and Santos Dumont Airport

We argue in this paper that the development of the Rio de Janeiro Walkability Index should be considered a strategic element of urban planning and transformation in the context of the above-mentioned urban policies and initiatives as part of an overall shift in the political focus in urban planning. In that way, the walkability index contributed by developing a new methodology to measure and analyze urban spaces from the point of view of pedestrian use and to provide recommendations for further development of the historic center based on such analysis.

1.2. The Historic Centre of Rio de Janeiro

The historic centre covers an area 572,31 hectares, and it has a unique architectural value which has experienced a gradual loss of residential uses and a shift to predominantly commercial and business uses throughout the twentieth century. Many historic buildings were left empty and underused and fell in disrepair.

The historic center of Rio de Janeiro had undergone a long and continuous process of decay that can be traced back to the beginning of the twentieth century when the wealthier segment of the population began to move in greater numbers to the neighborhoods in the south of the city, such as Botafogo, Flamengo, and Copacabana. In 2022, the population was 32,758, down from 41,142 in 2010.

In parallel with such demographic dynamics, the centre underwent an accelerated pace of modernization with the 1930 Revolution and the institution of Getulio Vargas' *Estado Novo*, which brought about the replacement of the existing urban fabric by modern high-rise buildings, such as the Ministry of Education and Health (1936 – 1943) designed by Le Corbusier in collaboration with Oscar Niemeyer and Lucio Costa amongst other leading Brazilian architects at the time.

Whilst recognizing the architectural and cultural importance of the modern movement's legacy for the city of Rio de Janeiro and internationally and the necessity of urban interventions of modernization of obsolete urban infrastructure, it is nonetheless important to point out that a valuable heritage of historic buildings dating from the nineteenth century and from previous centuries was destroyed or abandoned as part of that process. In connection with this trajectory of urban development, the historic center experienced a gradual loss of residential use throughout the twentieth century, which has further contributed to the decay of historic buildings and the historic urban fabric.

In the new millennium the City of Rio the Janeiro devised urban policies and legislation aimed at boosting residential use and at promoting the rehabilitation of the historic buildings and urban fabric. (Saelens & Handy, 2008, p. 550)

The guidelines by the City of Rio de Janeiro (Secretary of Housing) issued in 2003 for the development of housing programmes stressed the need for a holistic approach towards the historic heritage of Rio de Janeiro's centre that should include not only the architectural heritage, but also the unique local cultures of each neighbourhood. (Prefeitura da Cidade do Rio de Janeiro, Secretaria Municipal de Urbanismo, 2003, p. 1)

The focus on rehabilitating Rio de Janeiro's historic centre and increasing residential use gained further momentum with urban plans, such as the Plan for Sustainable Urban Development – *Plano Diretor de Desenvolvimento Urbano Sustentável do Município do Rio de Janeiro* (Prefeitura do Rio de Janeiro, 2011c), urban legislation (Prefeitura do Rio de Janeiro, 2011b) (Prefeitura do Rio de Janeiro, 2012a) (Prefeitura do Rio de Janeiro, 2012b) and strategic projects and initiatives by the Rio de Janeiro World Heritage Institute (IRPH) (Instituto Rio Patrimônio da Humanidade, 2013).

The residential population of the central area of Rio de Janeiro in 2010 was twenty-eight thousand inhabitants and the IRPH set at target to increase the population to one hundred thousand inhabitants by 2020. (Instituto Rio Patrimônio da Humanidade, 2013, p. 8)

1.3. Programme Centre for All

The programme Centre for All was an initiative for urban regeneration of the historic centre of Rio de Janeiro implemented by the IRPH comprising two main fronts of action: one institutional and another operational. At the institutional level, the goal was to promote a culture of coordination between the services of different agencies of the Municipality of Rio de Janeiro (Cet-Rio, Comlurb, Guarda Municipal, RioLuz, Seconserva, Ordem Pública (Seop), Secretaria de Desenvolvimento Social (SMDS), and IRPH). (O Dia, 2015). Representatives from each agency met periodically to devise and implement plans of action. At an operational level, the programme Centre for All focused on the improvement of the safety of the inhabitants and the improvement of conditions for pedestrians through maintenance of sidewalks, street cleaning and lighting of public spaces, amongst other initiatives. (Prefeitura do Rio de Janeiro, 2015)

IRPH divided the historic centre into eight areas (shown in Figure 1). The first area designated for implementing the programme was the neighbourhood around Tiradentes Square. In view of coordinating the work of the Walkability Index with that of the Programme Centre for All, the first area of application for the Walkability Index was the neighbourhood around Tiradentes Square.

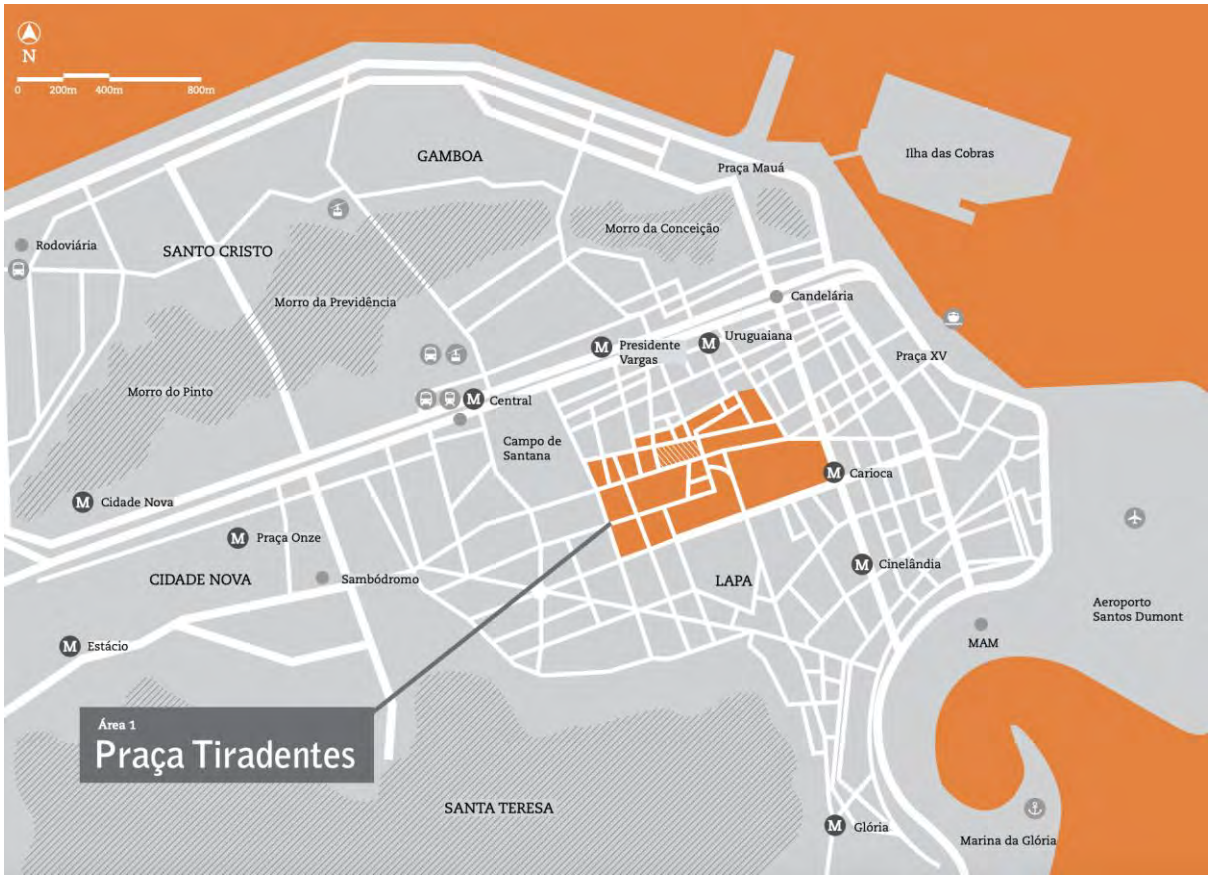


Figure 1 Designated area to start the "Center for All" program and develop the Walkability Index application. Source: ITDP, 2018.

2. Walkability

The primary purpose of this Walkability Index has been to provide a tool for the Municipality of Rio de Janeiro (and other municipal governments in Brazil) to be used to assess the built environment from the point of view of walkability. The formulation of specific indicators dealing with aspects such as land use mix and physical quality of sidewalks has been based on a close dialogue with the key departments in the Municipality of Rio de Janeiro and on a review of academic literature (Vale, Saraiva and Pereira, 2015) (Saelens and Handy, 2008) (L. Frank & Engelke, P. 2001) (Saelens, Sallis and Frank, 2003) (Cervero and Duncan, 2003) (Forsyth *et al.*, 2008) (Brownson *et al.*, 2009) that has documented the relevance of these aspects as important components of walkability.

Authors, such as Cevero & Duncan in their study of active mobility in the San Francisco Bay Area have looked critically at indicators usually included in studies of active mobility and have concluded that "Although well-connected streets, small city blocks, mixed land uses, and close proximity to retail activities were shown to induce nonmotorized transport, various exogenous factors, such as topography, darkness, and rainfall, had far stronger influences." (Cervero and Duncan, 2003, p. 1482). In their comprehensive review of evidence on the built environment correlates with walking (including 13 reviews and 29 original studies), Saelens & Handy highlight in particular consistent associations between walking for transportation purposes and density, land use mix, and proximity of nonresidential destinations (Saelens and Handy, 2008, p. 563), whilst findings for route/network connectivity, parks and open space, and personal safety were, according to the authors, more equivocal (Saelens and Handy, 2008, p. 550). Furthermore, Saelens & Handy point to "evidence less consistently found a relation between transportation walking and pedestrian infrastructure, such as sidewalk presence and

condition, although pedestrian infrastructure was more consistently related to recreation walking" (Saelens and Handy, 2008, p. 550).

The elaboration of this Walkability Index was based on a selection of environmental factors that would be included as indicators, based both on a critical examination of walkability studies methodologies and academic reviews of walkability indexes and on the specific characteristics of the urban and institutional context of the city of Rio de Janeiro.

With those considerations in mind, this Walkability Index has sought to include a wide range of indicators dealing not only morphological urban features such as "dimension of urban blocks", but also "environmental" considerations such as "shade and shelter" that are particularly relevant in the case of the hot and wet summers of Rio de Janeiro, and "public security" such as "street lighting," amongst other categories.

3. The Rio de Janeiro Walkability Index

3.1 Background

According to the Brazilian Association for Public Transport (ANTP), in Brazilian cities with over sixty thousand inhabitants, 41% of all transport journeys are realized on foot, whilst 25% are realized by individual motorized vehicles and 28% on collective transport (ANTP, 2018). There is an urgent need to assess and qualify the built environment in Brazilian cities from the point of view of pedestrians and to produce knowledge that can inform the elaboration of urban policies, strategies, and planning. The elaboration of the Rio de Janeiro Walkability Index was motivated by that need.

The centre is the urban district in the City of Rio de Janeiro, where the highest percentage (26%) of jobs are located (Prefeitura do Rio de Janeiro, 2011a, p. 8). It is an urban district that pedestrians intensively use on a daily basis.

The first version of the Rio de Janeiro Walkability Index was launched in 2016 by the Institute for Transportation and Development Policy in partnership with IRPH. The Walkability Index was developed in 2015 through a close dialogue between the ITDP and IRPH. The proposed indicators were discussed and adjusted in parallel with a pilot application of the Index in the neighbourhood of Tiradentes Square. This pilot application of the Index preceded the implementation of the first phase of the programme Centre for All in Tiradentes Square (Prefeitura do Rio de Janeiro, 2015) and by identifying specific challenges (such as maintenance of sidewalks down to particular location of holes in pavement) it delivered relevant input for the implementation of the programme.

As the main partner at the Municipality of Rio de Janeiro in elaborating the Walkability Index, the Rio de Janeiro World Heritage Institute (IRPH) coordinated the involvement of other municipal secretaries and departments. The involved public agencies participated actively in elaborating indicators relevant to their area of responsibility. That process contributed towards anchoring the Walkability Index in the different levels of the local administration.

In the period from 2016 to 2017 the Walkability Index was discussed in different forums with professionals from the Municipality of Rio de Janeiro, academics, and civil society. And as a result of that process, the Index was revised to simplify the data collection, reconfigure some indicators and making it more easily applicable in other Brazilian cities.

3.2. Indicators

The Walkability Index was developed in 2015 through a close dialogue between the ITDP and IRPH. The proposed indicators were discussed and adjusted in parallel with a pilot application.

The indicators of the Walkability Index are grouped according to six different categories (Figure 2). Aiming at anchoring the Walkability Index at different institutional levels of public administration, the categories were

defined by the areas of responsibility of departments of the Municipality of Rio de Janeiro and given the integration of the application of indicators in the work planning, public administration, and infrastructure maintenance performed by these departments. By defining these six categories and the fifteen indicators in close dialogue with the relevant departments of the Municipality of Rio de Janeiro, the authors also aimed at anchoring the Walkability Index at different institutional levels of public administration.

Sidewalk focuses on the physical attributes of the sidewalk, namely the width and level of pavement maintenance.

Mobility measures access to public transportation through two indicators:

1. Dimension of urban blocks
2. Distance to station of transport of medium or high capacity[1]

Attraction comprises indicators for the assessment of visually accessible activity behind the facades, public activity in the streets during daytime and nighttime and land use:

3. Facades visually transparent
4. Facades visually active
5. Public activity during daytime and nighttime.
6. Mixed use

Traffic Safety includes indicators measuring the conditions of safety for pedestrians concerning motorized traffic in streets and street crossings and the standard of universal design:

7. Street Typology
8. Crossings

Public Security is one of the central challenges in boosting residential use. Two indicators are included that concern both the perception of security by pedestrians as well as lighting and pedestrian use viewed as factors that can have a preventive effect on criminal behavior in public spaces:

9. Street lighting
10. Pedestrian flow measured at the daytime and at nighttime

Environment comprises indicators that measure environmental comfort factors that can have an impact on walkability:

11. Shade and shelter
12. Noise pollution
13. Garbage collection

[1] ITDP. Tod standard. 3rd Ed., 2017. Available at: <https://www.itdp.org/wp-content/uploads/2014/03/TOD-2017-v3.pdf>.

Figure 2 The six categories of the Walkability Index. Source: ITDP, 2018.

4. Methodology

4.1. Measurement

The Walkability Index was based on a methodology developed by ITDP and published in reports such as "Footpath design: A guide to creating footpaths that are safe, comfortable, and easy to use" (ITDP, 2013) and TOD Standard, 3rd edition (ITDP, 2017). Some indicators developed in connection with those guides are integrated in an adapted form in this Walkability Index. In addition, recent publications by WHO concerning traffic safety contributed towards the revision and refinement of some of the indicators (World Health Organization, 2017) (Global Road Safety Partnership *et al.*, 2008)

Furthermore, the structure of the Walkability Index, including the choice of indicators and definition of categories, was based on an assessment of its potential to be integrated into the daily activities of different departments and agencies of the City of Rio de Janeiro. Through a close dialogue with the different departments of the City of Rio de Janeiro, the following aspects were considered for the composition of the Walkability Index:

- Potential of inclusion of indicators already used by the Municipality of Rio de Janeiro
- Methodologies and protocols used by relevant departments and agencies of the Municipality of Rio de Janeiro in urban interventions and maintenance work.

The basic spatial unit of measurement used in the indicators of the Walkability Index is the *sidewalk segment* – defined as part of a sidewalk (sidelining a street) located between adjacent intersections of the pedestrian network - including non-motorized crossings – and considering only one side of the sidewalk (see figure 3).

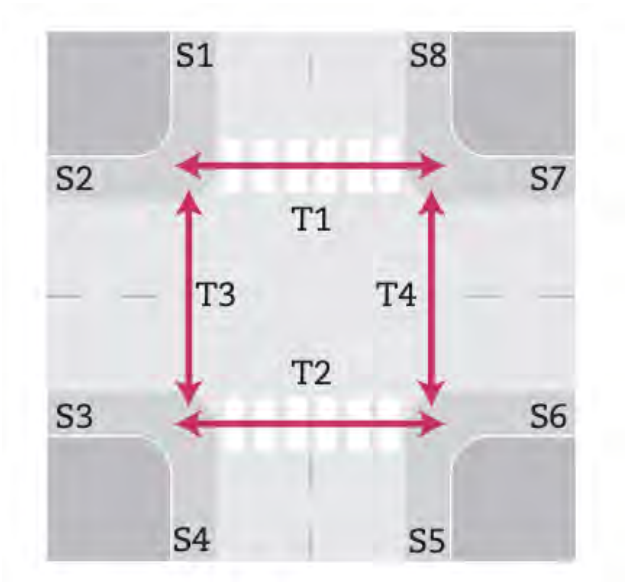


Figure 2 Sidewalk segments (S) and Crossing segments (T). Source: ITDP, 2018.

With particular indicators, such as *(5) Facades Visually Transparent (6) Facades Visually Active*, a spatial unit of measurement compatible with those indicators was chosen – in this case, the façade of an entire block corresponding to a sidewalk segment. In the case of the indicator (9) *Street Typology*, the measurement was applied for the segment of the street and used in scoring the opposite segments of the sidewalk alongside the street.

The application of the Walkability Index was based on three types of data:

- Primary data collected in field research (such as the width of the sidewalks).
- Secondary data collected from pre-existing documentation, aerial / satellite photographs, and georeferencing programmes (such as Google Earth).
- Secondary data collected from public agencies (such as road hierarchy).

5. Discussion

5.1. Walkability Index as a Planning Instrument

The application of this index is based on evaluating the aspects of the urban environment that favour or discourage walking, and the basic unit of analysis is the sidewalk segment. The idea behind the adoption of that scale of analysis is to promote an understanding pedestrian networks in the scale of the neighbourhood. Following that approach, this Walkability Index is recommended for areas of up to one square kilometre.

Studies of walkability on the city scale provide a different (and complementary) perspective and make comparative studies between different cities possible. The publication “Pedestrians First: Tools for a Walkable City” developed by ITDP includes indicators at territorial scales different from this Walkability Index (ITDP, 2018).

The distribution of indicators under different categories is not without some ambiguity. The same indicator could have been assigned to different categories, as is the case of the Dimension of the Blocks indicator: even though it figures under the category Mobility, it could also be placed under the Traffic Safety category (to the extent that large blocks can encourage people to drive at speeds inappropriate to pedestrian safety), or it could be placed under the category Public Safety (large blocks may inhibit the circulation of more vulnerable groups due to the risk of crimes such as rape, sexual harassment or robbery), or it could even belong to the category Attraction (because it is an element related to the built environment).

This limitation stems mainly from the effort to carry out a holistic assessment of the aspects that affect walkability, through several indicators grouped into six categories. The fifteen indicators in this Walkability Index have different attributes, making alignment and compliance with the content of each category more difficult. In some cases, the indicator measures data that are directly related to a phenomenon evaluated in the category and, in others, it registers attributes by proxy, as is the case of the indicators related to the Public Safety category: the Indicator Flow of Pedestrians and Illumination are proxies of the Public Safety phenomenon.

Finally, the categorization of indicators of walkability into categories follows the intention of providing a readable and easy-to-apply tool and minimizing conceptual and technical inconsistencies. Consequently, we chose the list of indicators that through pilot applications were considered to be essential for each category, regardless of the variations in the number of indicators under each category. The Road, Mobility, Road Safety and Public Safety categories have two indicators each, differing from the Environment category - with three indicators, and the Attraction category - with four indicators. The calculation methodology of the categories or the proposed final index considers the arithmetic mean of the indicators that compose them and, therefore, an indicator of the category Attraction or Environment will have weights smaller than the indicators of the other categories.

Redundancy between indicators arises as creating a prioritized comprehensive tool has resulted in partial overlaps between indicators. This is the case, for example, of the indicators Mixed Uses and Public Day and Night Use, which refer to the question of the uses of buildings. However, the Mixed Uses indicator aims to focus on the diversity aspects of use in buildings, while Daytime and Nighttime Public Use is restricted to buildings that have public daytime and/or nighttime use.

5.2. Application

The data collection method was determined to allow the application of the Walkability Index in cities where there is a lack of public data (relating mainly to local land use, traffic management and public service management), as well as contexts where the evaluation of an indicator is not accessible (as is the case of an alternative survey for the Illumination indicator, in cases of impossibility of measuring by light metre).

Some indicators are based on quantitative data from field research, (Street typology and Crossings), while other indicators are based on qualitative data that depend on on-site observation and registration, as in the category Pavement (Pavement and Width). It was sought to attenuate the researcher's bias through the criteria defined for data collection, however, the variation of the methods used inevitably confers to the Walkability Index a certain degree of subjectivity.

Auditing could have been used to calibrate some of the indicators further, for instance, in the case of indicators measuring the perception of security by pedestrians. Auditing could have been used to assess how the presence of lampposts in different segments of sidewalks affects pedestrians' perception of security. Auditing could have been used to further specify the threshold of perception of public safety based on the number of people in a street.

6. Conclusion

A central argument of this paper is that a key contribution of the Rio de Janeiro Walkability Index to urban planning is its role in documenting, mapping and describing urban spaces in the historic centre through the development of a novel methodology with a focus on pedestrian use. Through a systematic and detailed approach to the development of indicators focussing on urban form (such as width of sidewalks and block size), use of urban spaces (through count of pedestrian circulation) and environmental conditions (such as noise levels) the Rio de Janeiro Walkability Index can be considered as strategic instrument of urban transformation. The development of the Walkability Index has concurred with other urban policies to promote a shift at a discursive

level and at the level of concrete interventions. In that sense, this Walkability Index can be seen as playing a key strategic role in the urban transformation of the Rio de Janeiro Historic Centre.

Strategic urban leadership has played a central role in developing policies promoting the rehabilitation of the historic centre through the administration of mayor Eduardo Paes. The work with Rio de Janeiro Walkability Index was initiated as a partnership between ITDP and the Municipality of Rio de Janeiro under Eduardo Paes leadership in parallel with other key policies and interventions, such as the programme Center for All, the implementation of a light-rail system and the Porto Maravilha programme. In the subsequent administration without Eduardo Paes at the helm, there was very limited further development of those policies. And with Eduardo Paes return as the mayor of Rio de Janeiro, the 'Reviver Centro' plan has been implemented with a focus on urban, cultural, social and economic revitalization of the historic centre. The 'Reviver Centro' plan and adopts a land value capture model with transfer of development rights to stimulate the increase in residential land use is a central component of the plan and rehabilitation of public spaces is one of the main aims of the plan.

The municipality has passed new legislation focusing on walkability, notably with a focus on tax incentives to promote the reoccupation of derelict buildings. In addition, the current Strategic Plan defines the city centre as a priority for redevelopment. The implementation of such urban policy and legislation elements highlights the importance of long-term strategic urban leadership, and in the context of this paper, it highlights the importance of conceiving the development of a walkability index of one initiative amongst several others for the promotion of shift towards pedestrian-centered urban planning.

At an institutional level, it is important to highlight the close partnership between the Institute for Transportation and Development Policy (ITDP Brazil) and the Municipality of Rio de Janeiro. Such partnership promoted a close dialogue and collaboration in developing the Walkability Index, designing each indicator, and implementing it in selected areas of the Rio de Janeiro historic centre. A key argument in this paper is that beyond a consideration of the extent to which methodical components of the Walkability Index have been adopted in urban planning practice at the Rio Municipality, the Walkability Index should be considered as a strategic element in the context of other plans and initiatives (such as Centre for All, Porto Maravilha, and Reviver Centro) towards a paradigm shift in policy making

7. References

ANTP (2018) 'Sistema de Informações da Mobilidade Urbana da Associação Nacional de Transportes Público - Simob/ANTP Relatório geral 2016'. Available at: http://www.antp.org.br/sistema-de-informacoes-da-mobilidade/apresentacao.html.

Brownson, R.C. *et al.* (2009) 'Measuring the built environment for physical activity: state of the science', *American Journal of Preventive Medicine*, 36(4 Suppl), pp. S99-123.e12. Available at: https://doi.org/10.1016/j.amepre.2009.01.005.

Cervero, R. and Duncan, M. (2003) 'Walking, Bicycling, and Urban Landscapes: Evidence From the San Francisco Bay Area', *American Journal of Public Health*, 93(9), pp. 1478–1483.

Forsyth, A. *et al.* (2008) 'Design and destinations: Factors influencing walking and total physical activity', *Urban Studies*, 45(9), pp. 1973–1996. Available at: https://doi.org/10.1177/0042098008093386.

Frank, L. and Engelke, P. (2001) 'The Built Environment and Human Activity Patterns: Exploring the Impacts of Urban Form on Public Health', *Journal of Planning Literature*, 16, pp. 202–218. Available at: https://doi.org/10.1177/08854120122093339.

Global Road Safety Partnership *et al.* (2008) *Speed management: a road safety manual for decision-makers and practitiioners.* Geneva: Global Road Safety Partnership. Available at: http://www.grsproadsafety.org/themes/default/pdfs/Speed%20management%20manual.pdf (Accessed: 15 June 2019).

Instituto Rio Patrimônio da Humanidade (2013) *Projeto Vazios Urbanos*. Prefeitura da Cidade do Rio de Janeiro, Gabinete do Prefeito. Available at: http://www.rio.rj.gov.br/dlstatic/10112/5333332/4139324/24VaziosUrbanosIRPH082014.pdf (Accessed: 6 December 2019).

ITDP (2013) *Footpath Design: A guide to creating footpaths*. Available at: https://www.itdp.org/2014/03/26/footpath-design-a-guide-to-creating-footpaths/ (Accessed: 15 June 2019).

ITDP (2017) *TOD Standard*. Available at: https://www.itdp.org/2017/06/23/tod-standard/ (Accessed: 15 June 2019).

ITDP (2018) *Pedestrians First: Tools for a Walkable City*. Available at: https://www.itdp.org/publication/walkability-tool/ (Accessed: 16 June 2019).

O Dia (2015) 'Centro é dividido em oito regiões para revitalização', *O Dia*, 15 August. Available at: https://odia.ig.com.br/_conteudo/noticia/rio-de-janeiro/2015-08-16/centro-e-dividido-em-oito-regioes-para-revitalizacao.html.

Prefeitura da Cidade do Rio de Janeiro, Secretaria Municipal de Urbanismo (2003) *A retomada do Centro da Cidade - Macrofunção Habitar o Centro/Prefeitura da Cidade do Rio de Janeiro*. 20030601. Rio de Janeiro: Prefeitura da Cidade do Rio de Janeiro, Secretaria Municipal de Urbanismo, Instituto Municipal de Urbanismo Pereira Passos. Available at: http://portalgeo.rio.rj.gov.br/estudoscariocas/download/2347_A%20retomada%20do%20Centro%20da%20cidade%20-%20Macrofunção%20Habitar%20o%20Centro.pdf.

Prefeitura do Rio de Janeiro (2011a) *Distribuição dos empregos formais na cidade do Rio de Janeiro em 2008: uma análise espacial*. Rio de Janeiro. Available at: http://portalgeo.rio.rj.gov.br/estudoscariocas/download/2938_Distribuição%20dos%20empregos%20na%20cidade%20do%20Rio%20de%20Janeiro%20em%202008.pdf (Accessed: 13 June 2019).

Prefeitura do Rio de Janeiro (2011b) *Lei complementar nº 111 de 1º de fevereiro de 2011. Dispõe sobre a Política Urbana e Ambiental do Município, institui o Plano Diretor de Desenvolvimento Urbano Sustentável do Município do Rio de Janeiro e dá outras providências.* Rio de Janeiro.

Prefeitura do Rio de Janeiro (2011c) *Plano Diretor de Desenvolvimento Urbano Sustentável do Município do Rio de Janeiro*. Rio de Janeiro.

Prefeitura do Rio de Janeiro (2012a) *Decreto no 35.646 de 16 de maio de 2012. Estabelece as diretrizes para outorga de uso a terceiros de próprios municipais sem destinação pública específica e em mau estado de conservação.* Rio de Janeiro.

Prefeitura do Rio de Janeiro (2012b) *Decreto no 35.648 de 16 de maio de 2012. Dispõe sobre o procedimento de arrecadação dos imóveis urbanos abandonados.* Rio de Janeiro.

Prefeitura do Rio de Janeiro (2015) 'Programa Centro para Todos entra na segunda etapa', 17 August. Available at: http://www.rio.rj.gov.br/web/irph/exibeconteudo?id=5529919.

Saelens, B.E. and Handy, S.L. (2008) 'Built environment correlates of walking: a review', *Medicine and Science in Sports and Exercise*, 40(7 Suppl), pp. S550-566. Available at: https://doi.org/10.1249/MSS.0b013e31817c67a4.

Saelens, B.E., Sallis, J.F. and Frank, L.D. (2003) 'Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures', *Annals of Behavioral Medicine*, 25(2), pp. 80–91. Available at: https://doi.org/10.1207/S15324796ABM2502_03.

Vale, D., Saraiva, M. and Pereira, M. (2015) 'Active accessibility: A review of operational measures of walking and cycling accessibility', *Journal of Transport and Land Use*, 9, pp. 1–27.

World Health Organization (2017) *Managing speed*. Geneva. Available at: http://www.who.int/violence_injury_prevention/publications/road_traffic/managing-speed/en/ (Accessed: 15 June 2019).

Case Study Report

The Sustainable Energy and Climate Action Plan (SECAP) design and development: the case study of the Municipality of Grosseto (Italy)

Michela MARCHI, Ecodynamics Group, University of Siena, Italy
Enrico NOCENTINI, Ecodynamics Group, University of Siena, Italy
Fabiola TROPEA, Ecodynamics Group, University of Siena, Italy
Asia TONIELLI, Department of Economics and Statistics, University of Siena, Italy
Nadia MARCHETTINI, Ecodynamics Group, University of Siena, Italy
Federico Maria PULSELLI, Ecodynamics Group, University of Siena, Italy

Abstract

In 2013, the Municipality of Grosseto in Italy became a member of the Covenant of Mayors, fulfilling its Sustainable Energy Action Plan (SEAP) by the year 2020. By 2022, the Municipality reaffirmed its commitment to the Covenant of Mayors by launching the Sustainable Energy and Climate Action Plan (SECAP), which aims for new goals: a 40% reduction in greenhouse gas (GHG) emissions by 2030 compared to 2008 levels, and achieving carbon neutrality, meaning negative net emissions, by 2050. This case study outlines Grosseto's pathway to decarbonization. The SECAP begins with the elaboration of a Baseline Emission Inventory (BEI), which in this case derives from the combination of two accounting methods: 1) the Intergovernmental Panel on Climate Change (IPCC) guidelines; and 2) the Global Covenant of Mayors methodology. Combining these two methods gives policymakers a deeper understanding of the sources of emissions and the perspective of final users. The second step of SECAP is the preparation of the mitigation plan, which will identify measures for optimizing policies to prevent and compensate for GHG emissions. The third step involves systematic monitoring to validate these policies and gradually engages a wide range of stakeholders in an Alliance for carbon neutrality. The experiment aims to promote environmental awareness through enhanced knowledge.

Keywords

Renewable energies, Environmental strategies, Baseline emission inventory, Systematic monitoring, Public Organization

1. Introduction

In 2007, leaders of the European Union set forth the main objectives for the 2020 Climate-Energy Package, which aimed for a 20% reduction in greenhouse gas (GHG) emissions, a 20% boost in energy efficiency, and a 20% increase in energy production from renewable sources. The following year, during the second Sustainable Energy Week (EU, 2008), the EU launched the Covenant of Mayors, a voluntary initiative aimed at bringing local entities together to achieve the goals of the 2020 Climate-Energy Package. This effort was carried out through the implementation of a Sustainable Energy Action Plan (SEAP). The European Commission launched in 2014 the Mayors Adapt project to encourage cities to respond to climate change adaptation. Their two initiatives were consolidated into one the same following year (2015) leading to the Covenant of Mayors for Climate and Energy which meant equal attention both to mitigation and strategies for climate change adaptation (EU,2015). In 2016, the Covenant of Mayors for Climate and Energy was

joined by the Compact of Mayors, established a few years prior in the United States (UN 2014). Following this partnership, the Global Covenant of Mayors for Climate & Energy (GCoM) was created (2019). The initiative's focus is on three key areas established at the regional level: 1) mitigation of climate change; 2) adaptation to the adverse impacts of climate change; and 3) ensuring universal access to secure, clean, and affordable energy. The local authorities that wish to become a part of GCoM should then develop a Sustainable Energy and Climate Action Plan (SECAP).

1.1. Case study background

In 2013, the Municipality of Grosseto in Tuscany (central Italy) became a member of the Covenant of Mayors and began working on its Sustainable Energy Action Plan (SEAP). By 2022, the municipality decided to build on the technical and administrative framework set by the Covenant of Mayors by reviewing the actions taken and creating a new management tool called the Sustainable Energy and Climate Action Plan (SECAP). The SECAP has enabled the Municipality to pledge a reduction in GHG emissions of 40% by 2030 in comparison to 2008 (reference year) levels, allowing for the current environmental condition to be identified and future interventions to be planned (Grosseto, 2024). The long-term objective of the local Administration is to achieve Carbon Neutrality (i.e., negative net emissions) by 2050. To achieve this goal, the Municipality plans to implement a series of strategic policies designed to mitigate emissions, adapt to climate change, and compensate for any residual emissions.

The drafting of the SECAP and the related monitoring inventories was entrusted by this public organization to the Ecodynamics Group of the University of Siena. The partnership began during the 2019–2021 triennium to produce tools to support the elaboration of territorial GHG emission reduction policies in key economic sectors, namely electricity generation and use, transport, heating, waste, and forestry (Marchi et al., 2023).

This case study aims to demonstrate the progress made by a public administration in reducing greenhouse gas emissions and addressing climate change.

2. Material and Methods

Each SECAP includes a Baseline Emission Inventory (BEI) of the reference year, as well as climate risk and vulnerability assessments, which are key to informing strategic decisions (Neves et al., 2016).
The BEI serves as the foundation of the SECAP, identifying priority areas for action. This case study BEI is based on the combination of the two accounting methodologies:

1) the Municipality-Scale GHG Inventory, which has been compiled following the Intergovernmental Panel on Climate Change (IPCC) guidelines, represents a standardized approach that is valid at the international level and is one of the most widely used (IPCC, 2006, 2019). It provides a perspective on emission sources (Sporchia et al., 2023);

2) the Global Covenant of Mayors for Climate and Energy methodology, which is focused on the final user's perspective (GCoM, 2019).

These two accounting methods combined enable informed decisions on climate action to be made at the local level.

Furthermore, the SECAP includes the programming of a mitigation plan, which means the measures and actions that the municipality will implement to mitigate its climate impact and to compensate for what emissions remain, thus participating in global climate change efforts.

The effectiveness of the implemented mitigation strategies is monitored and assessed through the regular compilation of monitoring emission inventories. This constant tracking allows results to be continuously updated, and progress to mitigate against GHG emissions-cutting targets to be measured, creating a dynamic and responsive approach to tackling climate change.

The incorporation of all the human activities typically excluded from the survey (e.g. Industrial Processes and Product Use (IPPU) and Agriculture, Forestry, and Other Land Use (AFOLU)) enhances the potential for GHG emission reduction and facilitates stakeholder involvement (Sporchia et al., 2023).

3. Results and Discussion

3.1. BEI and GHG monitoring of the Municipality of Grosseto

In 2008 (baseline or reference year) the Municipality of Grosseto recorded gross GHG emissions amounting to 462,103 t of carbon dioxide equivalent (CO_2eq). The removals, amounting to 69,329 t CO_2eq, were found to be lower than the gross emissions, resulting in a net accumulation of 392,773 t CO_2eq in the atmosphere. This scenario indicates a balance with an emission removal of approximately 15%.

Table 1 shows the historical series (2008, 2017-2022) of GHG emissions and highlights key sectors responsible for emissions reduction. Particularly, the analysis of these temporal changes points out the sectors where the greatest emissions reductions have been achieved and where actions need to be strengthened (Sporchia et al., 2024).

Table 1. Historical series of GHG monitoring by the Municipality of Grosseto: 2008 (Baseline), 2017-2022.

Human activity	2008 (BASELINE)	2017	2018	2019	2020	2021	2022	Variation (2008-2022)
	t CO_2eq							
ENERGY	***403,754***	***331,493***	***340,468***	***349,751***	***284,940***	***350,524***	***349,021***	***-13.6%***
Transport	198,860	188,184	194,227	216,628	189,298	208,748	206,796	4.0%
Heating	62,496	59,388	61,418	58,805	55,444	56,549	52,459	-16.1%
Combustion for industrial activities	14,667	7,608	11,244	8,476	7,672	6,886	6,140	-58.1%
Waste-to-energy plant	10,108	8,629	10,688	10,608	3,757	8,301	2,670	-73.6%
Electricity imported from the grid	112,030	57,648	52,557	45,015	20,014	61,716	72,835	-35.0%
Anaerobic digestion	145	3,142	3,138	3,106	2,519	2,488	2,432	1,582.5%
Fugitive emissions	5,447	6,894	7,196	7,113	6,237	5,836	5,689	4.4%
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)	***0***	***0***	***0***	***0***	***0***	***0***	***0***	***—***
WASTE	***22,175***	***18,344***	***19,548***	***18,870***	***15,591***	***16,202***	***17,524***	***-21.0%***
Landfill	19,638	15,790	17,015	16,194	13,114	13,781	14,615	-25.6%
Composting plants	401	428	420	543	517	590	959	139.2%
Selection plants	1,083	1,278	1,296	1,185	999	859	741	-31.5%
Wastewater treatment	1,054	847	817	948	961	972	1,209	14.8%
AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)	***36,173***	***45,722***	***41,748***	***38,119***	***33,803***	***31,436***	***29,948***	***-17.2%***
Carbon loss (harvesting, fires)	7,323	10,621	7,323	4,561	4,585	4,957	5,752	-21.5%
Urea use	416	356	279	168	180	174	55	-86.9%
Enteric fermentation	19,049	24,016	22,740	23,044	18,583	18,126	17,149	-10.0%
Manure management	2,674	3,500	3,875	3,700	2,954	2,462	2,442	-8.7%
Nitrogen addiction to the soils	5,078	4,925	5,779	4,979	4,679	3,590	2,495	-50.9%
Wetlands	424	522	522	522	411	411	411	-3.0%
Rice cultivation	1,129	1,694	1,144	1,057	895	201	209	-81.5%

Aquaculture	80	87	87	87	80	80	0	-100.0%
Land use change	0	0	401,764	0	1,436	1,436	1,436	
GROSS EMISSIONS	**462,103**	**395,559**	**401,764**	**406,740**	**334,334**	***398,162***	**396,493**	**-14.2%**
UPTAKE	**-69,329**	**-67,600**	**-67,550**	**-67,551**	**-71,326**	***-70,888***	**-70,888**	**2.2%**
NET EMISSIONS	**392,774**	**327,959**	**334,214**	**339,189**	**263,008**	***327,274***	**325,605**	**-17.1%**
PERCENTAGE ABATEMENT	**15.0%**	**17.1%**	**16.8%**	**16.6%**	**21.3%**	***17.8%***	**17.9%**	

In particular, the Municipality recorded an overall reduction in gross emissions of 14.2%, which can be attributed to a few factors:

- the decrease in heating consumption due to building energy efficiency and renewable resources exploitation (-16.1%);
- the adoption of more efficient technologies, the modernization of production processes, and the use of less polluting energy sources in industrial activities (-58.1%);
- the increase in local electricity production from renewable/alternative resources and the reduction of local consumption of the energy imported from the national grid (-35%);
- an increase in waste recycling and material reuse practices (-21%);
- an emission reduction in the AFOLU sector due to an improvement in manure management and the nitrogen distribution to agricultural soils from the application of fertilizers and crop residues (-17.2%).

Conversely, the reduction of transport emissions necessitates the implementation of sustainable urban mobility policies, which should encourage a reduction in the overall number of vehicles on the road, while simultaneously improving engine efficiency and reducing dependence on fossil fuels.

3.2. Pathway for the GHG emissions mitigation plan development

The procedure for identifying the environmental policies to be included in the SECAP Mitigation Plan of the Municipality of Grosseto has commenced with an exhaustive analysis of all emission sources and their intensity. The hotspots have been identified, covering more than 95% of cumulative emissions.

Once the major emission sources have been identified, the focus has shifted to the identification of potential stakeholders to whom policies should be addressed. The identification of stakeholders is of paramount importance to target tax and regulatory benefits at specific final user classes.

The Italian municipalities that have joined the Covenant of Mayors and that have published an Action Plan for achieving their GHG emission reduction targets were identified. From the Action Plans identified in the literature, a list of the main actions implemented has been extracted, with the policies divided into sectors or areas of intervention. Furthermore, experiences from other territories at the international level have been analyzed to gain a broader understanding of successful mitigation strategies (EU, 2024).

The environmental action proposals were selected by a methodical step-by-step process in collaboration with the technical staff of the municipal Administration. Each proposed action was subjected to a rigorous examination to ascertain its practical feasibility and compatibility with local resources (e.g., data availability, implementation capacity, political consistency, and economic feasibility).

The main criteria that have informed the selection of policies to be incorporated into the SECAP are as follows:

- the coherence of the policies planned in the SECAP with the missions reported in the Single Programming Document. This guarantees that the actions are integrated into a long-term strategic vision, coordinated with other planned interventions, avoiding duplication and wasted resources;

- the possibility of giving a comprehensive economic report of the activities undertaken. Transparency and traceability of actions allow for continuous and accurate evaluation of the effectiveness of policies. Detailed reporting is essential for internal monitoring, but it is also needed to communicate the results achieved to citizens and funders.

3.3. The mitigation actions

The mitigation actions, outlined in Table 2, have been selected for the SECAP and have been developed to reduce GHG emissions by 40% compared to 2008 levels. The action plan foresees a reduction of at least 97,000 t CO_2eq by 2030, compared to the average values for the period 2017-2019. This ambitious plan includes 21 different strategic actions involving various sectors and activities:

1) Energy Renovation of Public and Private Buildings

The policies E1-E6 are designed to enhance efficiency and curtail consumption in public and private buildings. One of the principal planned interventions is the thermal retrofitting of constructions, which includes the installation of insulating windows. Another key is replacing old heating systems with modern ones (condensing boilers, heat pumps, central heating). Also, low-energy electronic equipment and lighting (such as LEDs) are urged. These not only use less energy but are also longer lasting and therefore operate with a lower running and maintenance cost.

2) Energy Efficiency and Renovation of Public Lighting

Policy L1 replaces the old lighting infrastructure with LED lighting, to improve energy efficiency and reduce environmental impact. It will be used to make public lighting more up-to-date and will also have a significant impact on energy use and longevity of the devices.

3) Production of Electricity from Renewable Resources

Policies R1 and R2 are concerned with producing electricity from renewable resources. They have twofold objectives: the installation of photovoltaic systems on public buildings and the promotion of photovoltaic technology among private citizens and businesses. The objective of these policies is to encourage the adoption of renewable energy sources, promoting energy self-sufficiency.

4) Sustainable Mobility

Policies T1-T8 focus on ensuring infrastructure for sustainable mobility and on actions to minimize the use of personal cars. Among the many aspects of these policies is encouraging people to use bicycles for transportation to work, school, and recreational destinations. Moreover, charging stations for electric vehicles help the change to a greener fleet with support from adequate infrastructure and buying incentives. Besides this, the introduction of electric public transport, with improved services to make urban buses more accessible and attractive to people is also planned. The "30 km/ha Zones", as well as Limited Traffic Zones (LTZ) and pedestrian areas, are introduced to curb the traffic in the cities and consequently reduce road accidents and improve air quality. The policies also encourage work from home, which can substantially reduce traffic congestion as you don't have to commute daily anymore.

5) Waste Management

Policies W1-W3 focus on sustainable waste management. That encompasses a series of programs and initiatives aimed at reducing, reusing, and recycling materials, to minimize landfill disposal.

6) Conservative/Organic Farming Techniques

Policies A1-A3 encourage local production ("km 0") and promote agronomic practices focused on conservation and organic farming. This is done to support the local economy, reduce environmental impact, and improve the quality of food products.

7) Tree planting

The F1 policy entails the planting of native trees within the municipal area, to remove carbon dioxide (CO_2) from the atmosphere and adapt to climate change (extreme heat and the reduction of heat islands in urban environments).

8) Communication

The S1 policy emphasizes the dissemination of knowledge and the involvement of communities in climate mitigation actions. Through awareness campaigns targeted at citizens, service sector operators, and businesses, the policy seeks to encourage the adoption of sustainable behaviors and the implementation of efficient technologies.

Table 2. Summary of mitigation actions (The values of saving/increase and CO_2eq reduction are calculated concerning the average of the period 2017-2019 or the last years with data availability).

#[a]	Environmental policy	Savings/Increase	Local electricity production	Avoided emissions
			$MWh_{E.}$	t CO_2eq
E1	Reduction of electricity consumption for residential buildings	-8,262 $MWh_{E.}$ avoided	\	**-2,759**
E2	Reduction of electricity consumption in the tertiary sector	-3,496 $MWh_{E.}$ avoided	\	**-1,168**
E3	Reduction of electricity consumption in the industry	-1,271 $MWh_{E.}$ avoided	\	**-424**
E4	Replacement of window frames in public buildings (pentagonal hall, locker room in the sports hall)	-13 $MWh_{T.}$ avoided	\	**-3**
E5	Energy efficiency of the building stock - Energy Performance Certificate (EPC)	-29,759 $MWh_{T.}$ avoided	\	**-5,960**
	EPC – Residential buildings	*-27,703* $MWh_{T.}$ avoided	\	*-5,549*
	EPC – Commercial buildings	*-2,055* $MWh_{T.}$ avoided	\	*-412*
E6	Boilers and heat pumps	-2,676 $MWh_{T.}$ avoided	\	**-510**
	More efficient boilers	*-1,884* $MWh_{T.}$ avoided	\	*-483*
	Heat pumps	*-792* $MWh_{T.}$ avoided	\	*-26*
L1	LED street lighting	-3,819 $MWh_{E.}$ avoided	\	**-1,276**
R1	Photovoltaic panels currently installed	\	**94,320**	**-31,501**
R2	Installation of new photovoltaic panels to cover residual consumption	\	**41,521**	**-13,867**
T1	Cycle paths	-101 km avoided/car	\	**-801**
	Using cycle paths to get to work	*-8 km avoided/car*	\	*-65*
	Using cycle paths to go to school	*-0,44 km avoided/car*	\	*-4*
	Using cycle paths to go to the sea	*-92 km avoided/car*	\	*-732*
T2	30 km/ha Zone	-347 km avoided/car	\	**-3,893**
T3	Limited Traffic Zones (LTZ)	-61 km avoided/car	\	**-687**
T4	Smart working	-546,260 km avoided	\	**-80**
T5	Increase in pedestrian areas	-876,47 km avoided/car	\	**-8**
T6	Electric city buses	-210,55 t diesel avoided	**594**	**-682**
T7	Replacement of vehicle fleet owned by	-101,230 km avoided	\	**-17**

	the Municipal Administration				
T8	Renewal of private vehicle fleet with electric vehicles	\		**38,868**	**-27,887**
	Gasoline	*-2,054*	*t gasoline avoided*	*8,931*	*-6,572*
	Diesel	*-6,148*	*t diesel avoided*	*27,446*	*-19,901*
	Liquefied Petroleum Gas (LPG)	*-274*	*t LPG avoided*	*1,384*	*-842*
	Natural gas	*-200*	*t natural gas avoided*	*1,107*	*-572*
W	Waste management	*-17,760*	*t waste avoided*	\	**-4,762**
W1	*Increase in separate collection of organic waste*	*475,89*	*t waste added*	\	*43*
W2	*Reduction of undifferentiated waste in the selection plant*	*-7,427*	*t waste avoided*	\	*-677*
W3	*Reduction of landfill disposal*	*-10,808*	*t waste avoided*	\	*-4,128*
A	Conservative/organic farming techniques	956	ha added	\	**-1,048**
A1	*CO_2 sequestration (Reduced tillage in croplands with temporary forage)*	*474*	ha added	\	*-427*
A2	*CO_2 sequestration (Crop residues in the fields, cultivated with cereals)*	*370*	ha added	\	*-420*
A3	*CO_2 sequestration (Grassing in croplands with tree crops)*	*112*	ha added	\	*-201*
F1	Planting 2 ha of oak forest	2	ha added	\	**-36**
S1	Awareness, involvement, and dissemination	Unquantifiable		\	Unquantifiable
TOTALE				**214,170**	**-97,367**

[a] E = Energy efficiency; R = Renewable energies; L = Public lighting; T = Transport; W = Waste; A = Agriculture; F = Forests; S = Other.

Figure 1 shows the contribution of specific actions to achieving the 2030 target. In particular, the contributions due to the implementation of renewable energies (R1 and R2; 46.6%), mobility actions (T1-T8; 35%), and energy efficiency of buildings (E1-E6; 11.1%) are relevant. The implementation of actions aimed at sustainable waste management (W) contributes to the achievement of the 4.9% reduction target. Sustainable agricultural practices (A) and the upgrading of public lighting (L1) each provide a marginal contribution of approximately 1%.

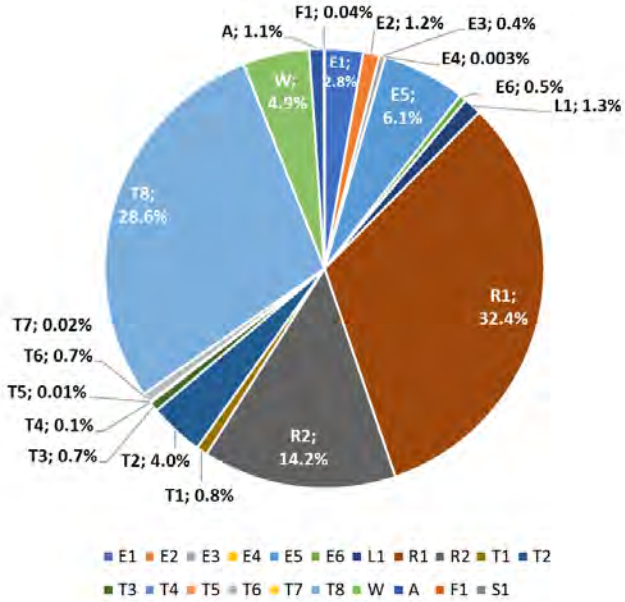


Figure 1. Percentage contribution of actions to 2030 target.

The target set for 2020 with the SEAP has been met, yet it is imperative to implement a comprehensive plan of policies to achieve the ambitious goal set for 2030 with the SECAP (Figure 2).

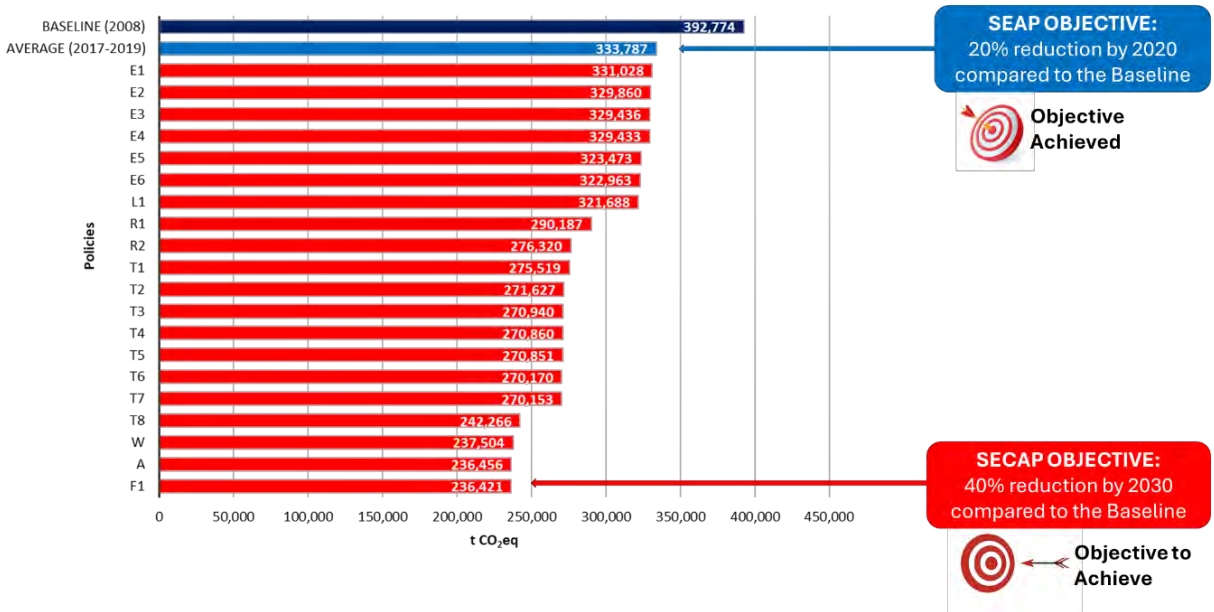


Figure 2. Simulation of GHG emission reductions through the mitigation plan

4. Conclusion

The proposed decarbonization plan is founded upon robust scientific knowledge, and it is anticipated that it will serve as a model for replication in different territorial contexts. The plan provides for the involvement of different components and actors in urban planning:

1) A science-based contribution to the adaptation/improvement of the GHG inventory methodology and its practical application at the local level, through external support from the University of Siena;

2) An organizational contribution of the city's technical managers to the implementation of the plan and a progressive involvement of all possible stakeholders;

3) An active role of the Grosseto City political institutions in the design and development of the strategies within the framework of the program (from the formal signing of the Covenant of Mayors to the approval of environmental measures and policies to be implemented).

The proposed experiment demonstrates a method to spread environmental awareness and responsibility through improved knowledge and research outcomes. Such insights can be translated into tangible strategies and measures that directly or indirectly benefit urban infrastructure, activities in the productive sector, citizens, and ultimately the entire territory. This establishes a framework for the formation of an Alliance for carbon neutrality between diverse actors.

5. Acknowledgments

I would like to acknowledge the use of OpenAI's ChatGPT-4o for assistance in refining the grammar and improving the academic quality of the English language in this document. This support was accessed on 16 September 2024 at 10:30 AM, and its contributions were limited to language editing, without influencing the content of the work.

6. References

ChatGPT-40 (2024). ChatGPT-40 for translation and correcting grammar. OpenAI. Available at: https://www.openai.com/chatgpt (Accessed: 16 September 2024).

EU (2008). Sustainable Energy Cities Take the Lead on Climate Change: The European Commission Launches the Covenant of Mayors, IP/08/103. European Commission: Brussels, Belgium.

EU (2015). Cities Unite for Energy and Climate Action: New Integrated Covenant of Mayors Launch. European Commission: Brussels, Belgium.

EU (2024). Covenant of Mayors – Europe. Available at: https://mayors.ec.europa.eu/en/home (Accessed: 30 September 2024).

GCoM (2019). Global Covenant of Mayors Explanatory Note Accompanying the Global Covenant of Mayors Common Reporting Framework. Available at: https://www.globalcovenantofmayors.org/wp-content/uploads/2019/04/Data-TWG_Reporting-Framework_GUIDANCE-NOTE.pdf (Accessed: 18 September 2024).

Grosseto (2024). Covenant of Mayors. Available at: https://new.comune.grosseto.it/web/sezioni/patto-dei-sindaci/ (Accessed: 16 September 2024).

IPCC (2006). *IPCC 2006 Guidelines for National Greenhouse Gas Inventories*. In Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (eds.); IGES: Kanagawa, Japan; ISBN 4-88788-032-4.

IPCC (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. IPCC: Geneva, Switzerland.

Marchi, M., Capezzuoli, F., Fantozzi, P.L., Maccanti M., Pulselli, R.M., Pulselli, F.M., Marchettini, N. (2023). GHG action zone identification at the local level: Emissions inventory and spatial distribution as methodologies for policies and plans. *Journal of Cleaner Production* 386, 135783.

Neves, A., Blondel, L., Brand, K., Hendel Blackford, S., Rivas Calvete, S., Iancu, A., Melica, G., Koffi Lefeivre, B., Zancanella, P., Kona, A. (2016). *The Covenant of Mayors for Climate and Energy Reporting Guidelines*. Climate-ADAPT: Luxembourg.

Sporchia, F., Marchi, M., Nocentini, E., Marchettini, N., Pulselli, F.M. (2023). Sub-national scale initiatives for climate change mitigation: refining the approach to increase the effectiveness of the Covenant

of Mayors. *Sustainability* 15, 125.

Sporchia, F., Marchi, M., Petraglia, A., Marchettini, N., Pulselli, F.M. (2024). The pandemic effect on GHG emission variation at the sub-national level and translation into policy opportunities. *Journal of Environmental Management* 349, 119539.

UN (2014). Mayors at UN Climate Summit Announce Pledges towards Major Carbon Cuts in Cities. UN: New York, NY, USA.

Research Paper

Co-creating eco-cities

Increasing residents' willingness to take action to enhance biodiversity in their neighbourhood

Janneska SPOELMAN, Rotterdam University of Applied Sciences, The Netherlands

Anja OVERDIEK, Rotterdam University of Applied Sciences, The Netherlands

Abstract

This study investigates strategies to enhance resident engagement in increasing neighbourhood biodiversity in Rotterdam, aligning with municipal biodiversity agendas. Despite competing priorities, residents' proactive involvement is crucial. Insights from expert interviews and behavioural models inform recommendations for effectively motivating residents and addressing urban biodiversity challenges.

Keywords

Participatory city making, Citizen engagement, Urban Living Lab, Nature-inclusive cities, Behaviour change, Urban Biodiversity

1. Introduction

Biodiversity and the quality of nature worldwide is rapidly declining (IPBES, 2022). This is also the case in the Netherlands. Not only in the countryside but also in cities. Meanwhile, many municipalities have adopted biodiversity implementation agendas. However, the agenda of the city of Rotterdam published in 2023 indicates that achieving systemic change also requires the engagement of the city's residents (Gemeente Rotterdam, 2020). Residents' understanding and willingness to take action and engage with nature can contribute to increasing biodiversity in both (semi-)private areas and public spaces.

This paper examines how the COM-B behavioural model and related Behaviour Change Wheel (BCW) framework (Michie et al., 2011) can be valuable within the context of participatory design research. On the base of expert interviews, this study aims to nuance the BCW framework and formulate recommendations for engaging and motivating residents to take action in order to increase the amount of green space and biodiversity in their neighbourhood. The contribution of this study lies not only in identifying what topics might be relevant in this context, but also in offering practical guidelines on how to translate these to working practices.

The findings describe opportunities and challenges for involving and engaging residents and nature in enhancing neighbourhood-level biodiversity. Thus, the research also provides valuable insights into translating biodiversity policy into practical implementation.

2. Context

In January 2024, the four-year research project "Neighbourhood as Biotope" (Dutch WAB) was launched, investigating how networks of people, nature, and technology can collaborate to enhance biodiversity at the neighbourhood level (Hogeschool Rotterdam, 2022). In partnership with a quadruple helix consortium of multidisciplinary partners, Rotterdam University of Applied Sciences will conduct practice-oriented participative design research in two districts in the province of South Holland. This research will use the Urban Living Lab methodology, where solutions to increase biodiversity at the neighbourhood level will be co-created with local residents (De Lille and Overdiek, 2021; Slingerland, G., & Overdiek, A., 2023).

Oud-Mathenesse is one of the neighbourhoods involved, where many residents face socio-economic and other challenges which are quite possibly experienced as more pressing than increasing biodiversity or greening their environment (Gemeente Rotterdam, 2024a). This neighbourhood is characterised by a relatively young population, low incomes and a predominantly pre-war housing stock with significant maintenance backlogs. Additionally, the neighbourhood has a highly diverse population of which 75% has a migrant background and a relatively low number of residents feels a sense of connection to the neighbourhood (Gemeente Rotterdam, 2024a, 2024b). The neighbourhood profile of Oud-Mathenesse and Witte Dorp shows that the objective figures regarding safety (above average relative to all districts of Rotterdam) and physical aspects (equal to the average) perform well compared to the average score for Rotterdam. However, the objective figures of the social index present a less positive picture. What is particularly striking is that the subjective figures, reflecting residents' perceptions, reveal a very negative outlook (Gemeente Rotterdam, 2024b). Consequently, a key question that emerged in the context of the WAB research is how to increase residents' willingness to take action to enhance biodiversity in this neighbourhood?

At present, the willingness of residents in the Oud-Mathenesse district to engage in greening the neighbourhood and enhancing biodiversity is low (Slingerland, G. and Overdiek, A., 2023). In general, biodiversity is perceived as an abstract concept by many individuals (Christmas et al., 2013). To encourage residents to take action, it is essential to explore how pro-environmental behaviour can be influenced.

3. Literature

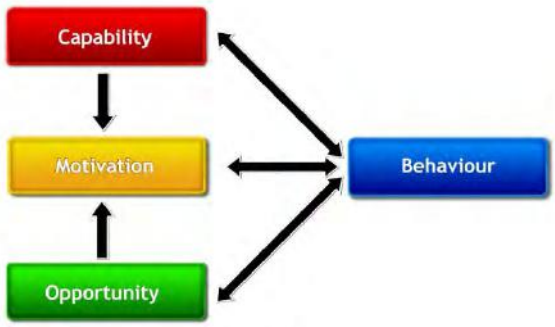
The Municipality of Rotterdam has commissioned research on this topic (Christiaanse et al., 2022) and it is also widely studied in previous academic literature (Michie et al., 2011). Scientific literature identifies citizen science as a method to engage citizens in biodiversity efforts. In citizen science, citizens assist scientists with their research (Newman et al., 2012). However, it is often observed that only a small group of citizens with an interest in science and climate participate in such initiatives. Furthermore, while citizen science raises awareness, it does not necessarily change attitudes or behaviours (Peter et al., 2021). Therefore, alternative interventions are required to motivate residents to act.

Knowledge transfer is another approach to activate people, but it is a limited intervention when considering the full range of possible interventions (Cipriani et al., 2024). A review of the literature on "co-creation", "urban biodiversity," "urban living lab," and "biodiversity" provides general, practical guidelines for shaping such co-creation interventions (Mohr-Stockinger et al., 2023; Wilk et al., 2020) but does not offer specific direction for activities focused on promoting biodiversity action. In most cases, the emphasis in the literature on similar frameworks is placed on the role of government, specifically in the design of governance structures (Hölscher et al., 2024). Moreover, existing knowledge regarding the engagement of hard-to-reach actors remains limited (Hölscher et al., 2024). Nielsen et al. argue that the lack of

scientifically grounded policies and interventions for behavioural change may be a key reason for the failure to effectively address the biodiversity crisis (K. Nielsen et al., 2021; K. S. Nielsen et al., 2021).

4. The Behavioural change wheel and the COM-B model

cvccvcvThe Behavioural change wheel (BCW) is an evidence based framework underpinned by nineteen previous behavioural change frameworks. At the core of this framework lies the COM-B behaviour model. “In this ‘behaviour system,’ capability, opportunity, and motivation interact to produce behaviour, which in turn influences these components" (Michie et al., 2011) as illustrated in Figure 1. Although primarily a behavioural model, COM-B also serves as a foundation for designing interventions aimed at behaviour change. By incorporating intervention functions and policy categories, the Behaviour Change Wheel (BCW) is formed, enabling the COM-B model to be linked to potential behaviour-influencing interventions. Any intervention may modify one or more elements within the behaviour system. The causal relationships within the system can either mitigate or amplify the effects of interventions by triggering changes in other areas. In the BCW framework, the three components that generate behaviour are further subdivided based on key distinctions noted in the research literature. See Figure 2 for the BCW. This serves as the foundation for a systematic analysis to guide the selection of interventions and policies.



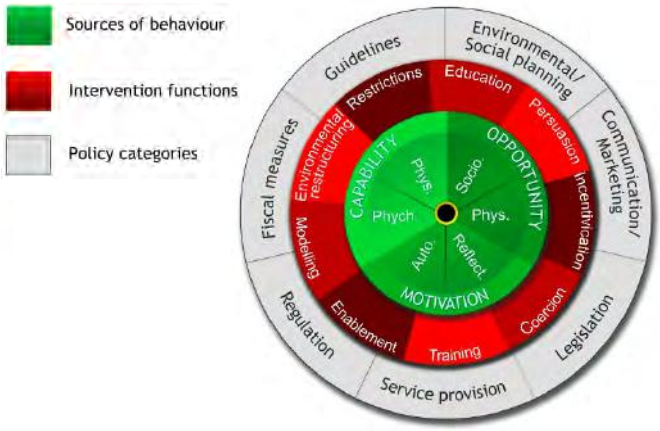


Figure 1. The COM-B system - a framework for understanding behaviour (Michie, van Stralen and West, 2011).

Figure 2. The Behaviour Change Wheel (Michie, van Stralen and West, 2011), adaptation of text size and addition of abbreviations of sub-determinants by J. Spoelman, 2025. For full description of sub-determinants see figure 3.

Marselle and Golding (Marselle, Melissa R. and Golding, Sarah E., 2023) describe how the BCW and the associated COM-B model can provide a scientific basis for designing and selecting the type and desired function of an intervention aimed at mitigating the biodiversity crisis. Their work explores the BCW by plotting possible biodiversity enhancing interventions on the intervention functions of the framework (figure 2). They highlight one of the key strengths of the BCW framework: its applicability across various contexts. However, the work of Marselle and Golding does not detail how possible interventions should be specifically designed, nor how they contribute to the three behaviour-influencing components of the COM-B model, thus providing an incomplete response to the preciously stated key question in the WAB research. Therefore the research question for this paper became:

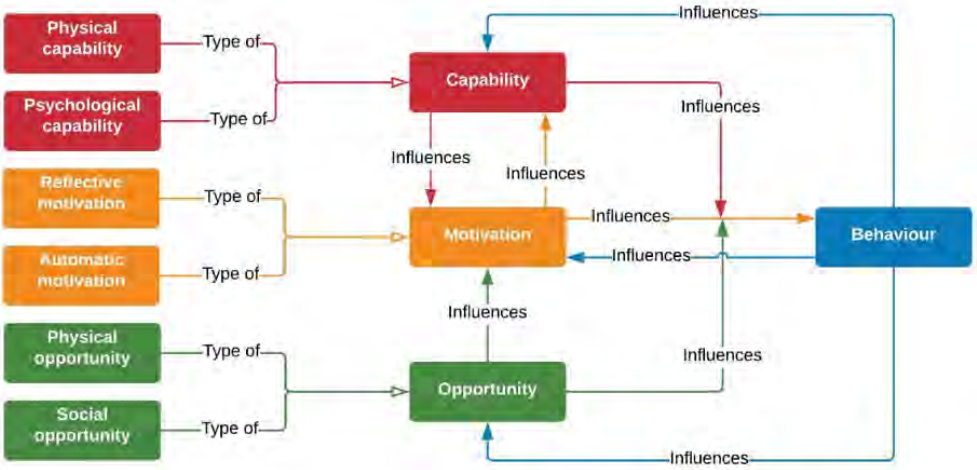
How can the core determinants of the COM-B model (capability, motivation and opportunity) be nuanced by contextual knowledge?

In the following sections, the methods used will first be explained and substantiated in the Methods chapter. The "Results and Findings" chapter will then present the findings in the form of identified topics and practices, which are discussed according to each determinant of the COM-B model. These findings will be elaborated with brief descriptions and illustrated using one or more quotes. Finally, the Discussion chapter will explore the relevance of these findings for both practice and theory, including an analysis of how some results relate to the practical challenges in Oud-Mathenesse. The paper will conclude with a summary and recommendations for further research.

5. Methods

The aim of this research is to identify topics and practices that can serve as input for an Urban Living Lab to be organised in the Oud-Mathenesse neighbourhood in Rotterdam, as part of the participatory design research project Wijk als Biotoop (WAB). As outlined in the literature review, no single theory fully addresses this question. Therefore, this paper explores the application of behaviour change theory to substantiate the choice of specific interventions in participatory design research.

During this study, semi-structured and in-depth interviews were conducted with experts working within the Dutch context to gather practical knowledge. The transcribed interviews were thematically coded, with motivation emerging as the most prominent concept. This led to the decision to compare the findings with the evidence-based behaviour model, COM-B, developed by Michie, van Stralen and West (2011), which places motivation at the centre of influencing and changing behaviour. For this investigation, the most recent version of the COM-B model was used, including the subdivision of the primary determinants of behaviour. See Figure 3.



Capability is an attribute of a person that together with opportunity makes a behaviour possible or facilitates it.

Opportunity is an attribute of an environmental system that together with capability makes a behaviour possible or facilitates it.

Motivation is an aggregate of mental processes that energise and direct behaviour

Behaviour is individual human activity that involves co-ordinated contraction of striated muscles controlled by the brain.

Physical capability is capability that involves a person's physique, and musculoskeletal functioning (e.g. balance and dexterity).

Psychological capability is capability that involves a person's mental functioning (e.g. understanding and memory).

Reflective motivation is motivation that involves conscious thought processes (e.g. plans and evaluations).

Automatic motivation is motivation that involves habitual, instinctive, drive-related, and affective processes (e.g. desires and habits).

Physical opportunity is opportunity that involves inanimate parts of the environmental system and time (e.g. financial and mterial resources).

Social opportunity is opportunity that involves other people and organisations (e.g. culture and social norms).

Figure 3. The COM-B model behaviour change with sub-division of the main determinants for behaviour (West and Michie, 2020).

The Oud-Mathenesse neighbourhood, the research area for the first Urban Living Lab in the WAB project, was then used as a case study to assess the applicability of the results and to help formulate practical recommendations.

In total, fourteen experts were interviewed using an open, thematic interview style. Whenever possible, the interviews were conducted face-to-face and voice recorded. Eleven of the experts were from the WAB research consortium, with three additional external experts recruited through snowball sampling. All participants provided consent for their data to be used in this paper. The experts represented a range of expertise areas, working either at a national level or within the regional context of the WAB project. Collectively, their knowledge and experience provided a broad range of insights into the relevant aspects of increasing residents' willingness to act on biodiversity at the neighbourhood level. For an overview of the interviewees' expertise and roles within the WAB project, see Table 1.

ID	Internal /external (of consortium)	Organisation	Expertise	Role in research consortium
R1	Internal	Regional government	ecology, biodiversity	LL2
R2	Internal	Knowledge institution	citizen participation	LL1 en 2
R3	Internal	Civil organisation	local context, citizen participation	LL2
R4	Internal	NGO	biodiversity monitoring	LL1
R5	Internal	Regional government	ecology, biodiversity	LL1
R6	Internal	Knowledge institution	citizen participation	LL1 en 2
R7	Internal	Civil organisation	local context	LL1
R8	External, local expertise	NGO	biodiversity, citizen participation	external
R9	Internal (joined after interview)	NGO	biodiversity, citizen participation, citizen science	advisory board
R10	Internal	Company	developer built environment en biodiversity	advisory board
R11	External, local expertise	Company	greening the city, urban ecology	external
R12	Internal	Knowledge institution	biology, biodiversity	advisory board
R13	Internal	Regional government	innovative collaboration	LL1
R14	External, citizen sciences expertise	Company	citizen science, biodiversity monitoring	external
O1	Internal	Knowledge institution	urban and regional development	researcher
O2	Internal	Knowledge institution	citizen participation, Urban Living Lab	researcher, main responsible

Table 1. This table shows an anonymised overview of all respondents, detailing whether they are part of the research consortium (internal) or not (external), the type of organisation they represent and their expertise relevant to the research (by J. Spoelman, 2024).

Based on the main research questions and the knowledge and experience of the second author (interviewed in her role of lead researcher with expertise in urban and regional development, as O1) the interview was structured around five key themes:

1. Introduction: to gain a general understanding of the respondent. While not all information gathered in this section was directly relevant to the main research question, it contributed to the broader context of the RAAK-pro research proposal.
2. Experience with biodiversity: what experience does the respondent have in working on biodiversity with citizens?
3. Engaging citizens: what knowledge or experience does the respondent have regarding involving citizens in projects aimed at enhancing biodiversity?
4. Role of government: how does the respondent perceive the role of government in such initiatives?
5. Conclusion: questions regarding collaboration with other parties and technologies, and suggestions for additional respondents

For each theme, related questions were developed, but depending on the respondent's expertise and answers, deviations were made; questions were either skipped or explored in greater depth. On average, the interviews lasted 60 minutes, with some extending up to 150 minutes. After 14 interviews, data saturation was observed.

The interviews were transcribed using the online transcription program Sonix and then thematically coded in Atlas.ti. Documents with numbers five and six are from respondent five and documents with number fifteen and sixteen are from respondent fourteen as they both were interviewed on two different days. Open coding was employed without any predetermined theoretical framework. Based on recurring themes, thematic groups were created in Atlas.ti, and the frequency of codes in each group was analysed. The codes were mapped onto the COM-B model in Atlas.ti by assigning them to one of the three behavioural determinants: capability, motivation, and opportunity. Additionally, all codes were examined to determine whether they answered the two sub questions:

RQ1a: What can be done to enhance each main determinant of the COM-B model in order to increase residents' willingness to act?

RQ1b: How can these three determinants be increased in order to increase residents' willingness to act?

In this research, the “what” refers to a description of an action or intervention (in this paper later referred to as topics), while the “how” refers to the manner in which such actions or interventions can or should be implemented (later referred to as practices). The codes for each determinant were then categorised into two groups, distinguishing between those that describe the 'what' and those that describe the 'how'. To ensure the reliability of the research, inter-coder calibration was conducted. The created codes were reviewed by the second author who is an expert in co-creation within Living Labs. Since all interviews were conducted in Dutch, the codes and quotes were translated into English by the two authors with the help of Chat GPT-4. Chat GPT-4 was also used for translation of original (Dutch) text passages throughout this paper. All translated text passages generated by Chat GPT-4 were reviewed by the authors before inclusion in this paper.

In a series of three collaborative sessions, both authors analysed the codes, identifying the key topics and practices that emerged. Through thorough discussion and mutual deliberation, they jointly formulated topics for the 'what' category and practices for the 'how' category. A detailed overview of these can be found in the section "Results and Findings".

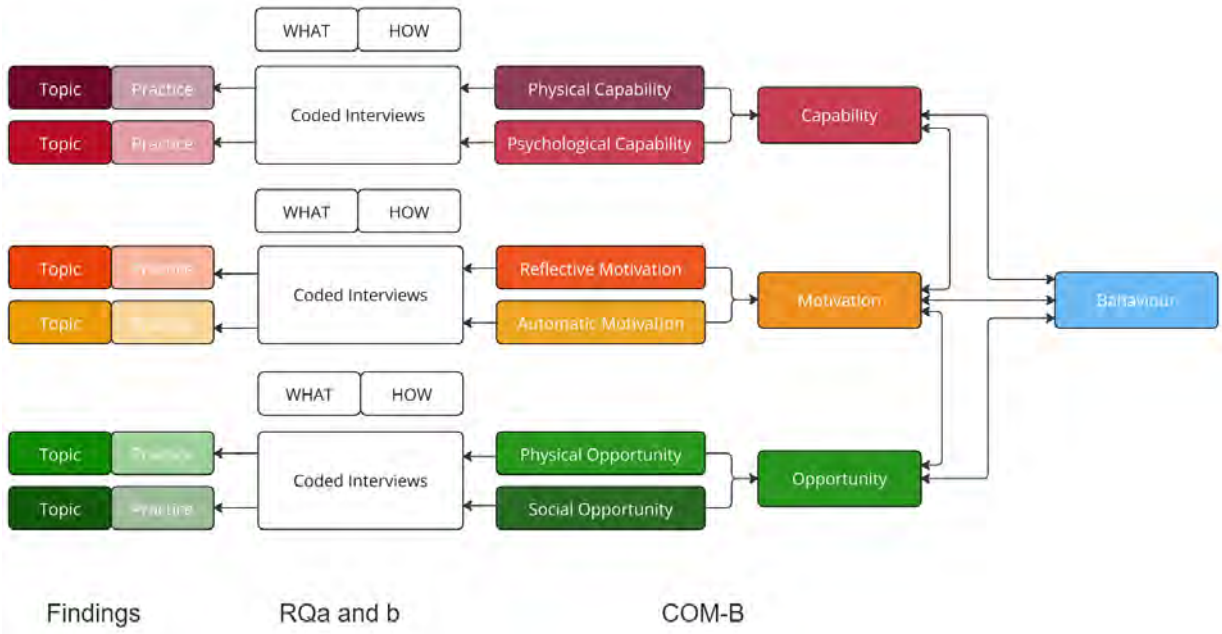


Figure 4. Visualization of relation between theory, methods, research questions and findings (by J. Spoelman, 2024).

Zotero was used as a citation manager to add in-text citations and to generate the accompanying reference list.
In the Discussion paragraph we describe how the Oud-Mathenesse neighbourhood was used as a testcase for the applicability of the results.

6. Results and findings

The results and findings included below will together contribute to answering the research question: How can the core determinants of the COM-B model (capability, motivation and opportunity) be nuanced by contextual knowledge?

The results describe opportunities and challenges for involving and engaging residents and nature in enhancing neighbourhood-level biodiversity. The table below provides an overview of the formulated topics and practices for each determinant.

Element COM-B	Topics	Practices
Capability	C-T1 Knowledge acquisition (through cs)	C-P1 Collective learning (about biodiversity)
	C-T2 Nature conscious	C-P2 Sharing/ communicating knowledge
	C-T3 Care for nature	C-P3 Mode of communication
	C-T4 Diversity (in capabilities)	
Motivation	M-T1 Positive urgency	M-P1 Communicate with visuals and stories
	M-T2 Eco-system services	M-P2 Trigger curiosity and playfulness
	M-T3 Empathy with nature	M-P3 Trigger reflection on different ideals of nature
	M-T4 Social values of green	M-P4 Connect with values and needs of residents
		M-P5 Provide feedback on impact of interventions
Opportunity	O-T1 Economic aspects	O-P1 Aligning different interests
	O-T2 Social cohesion (in the neighbourhood)	O-P2 Connect networks and initiatives
	O-T3 Rol of the municipality	O-P3 Multifunctional use in public space
	O-T4- Synergy	O-P4 Regenerative approach

Table 2. Overview of found topics and practices per determinant (by J. Spoelman, 2024).

These new, original topics and practices have been derived from the interview data. A more detailed overview of all these topics and practices can be found in table 5, 6 and 7 in the Appendix. In these three tables the topics and practices have been structured per main determinant (see table 5 for capability, table 6 for motivation and table 7 for opportunity). Each topic and practice is accompanied by an interpretation and illustrated with one or more quotes from the interviews.

7. Discussion

The previous paragraph outlined how the core determinants of the COM-B model (capability, motivation, and opportunity) could be nuanced by contextual knowledge. The topics and practices formulated based on the data can be applied in participatory design research projects aimed at enhancing biodiversity. This paragraph discusses the relevance of the research for both theory and practice.

7.1. Relevance for theory

During the process of mapping the data onto the COM-B model, several observations were made.

Nuancing the Core Determinants of the COM-B Model. Mapping the data onto the COM-B model has yielded not only topics relevant to co-creation processes for enhancing biodiversity but also practices that outline specific methods for strengthening each determinant. Through this process, the research has contributed to a more nuanced understanding of the COM-B model. In addition to mapping the data onto the COM-B model, the topics and practices were assigned to the sub-determinants (Figure 3).

This assignment was successful for three-quarters of the topics and practices. The remaining six could be aligned with a primary determinant but not with a specific sub-determinant (see Table 3). These six related topics and practices could be described as general (or cross-over) sub-determinants and provide new knowledge for the intentional design of interventions.

Element COM-B	General determinant or Sub-determinant	Topics	Practices
Capability	Physical capability	C-T3 Care for nature	
	Psychological capability	C-T1 Knowledge acquisition (through cs)	C-P2 Sharing/ communicating knowledge
		C-T2 Nature conscious	
	General (both physical and psychological)	C-T4 Diversity (in capabilities)	C-P1 Collective learning (about biodiversity)
			C-P3 Mode of communication
Motivation	Reflective motivation	M-T2 Eco-system services	M-P3 Trigger reflection on different ideals of nature
		M-T4 Social values of green	M-P5 Provide feedback on impact of interventions
	Automatic motivation	M-T3 Empathy with nature	M-P1 Communicate with visuals and stories
			M-P2 Trigger curiosity and playfulness
	General (both reflective and automatic)	M-T1 Positive urgency	M-P4 Connect with values and needs of residents
Opportunity	Physical opportunity	O-T1 Economic aspects	O-P3 Multifunctional use in public space
	Social opportunity	O-T2 Social cohesion (in the neighbourhood)	O-P1 Aligning different interests
		O-T3 Rol of the municipality	O-P4 Regenerative approach
		O-T4- Synergy	
	General (both physical and social)		O-P2 Connect networks and initiatives

Table 3. Overview of alignment topics and practices with sub-determinants of COM-B model, with new sub-determinants in white rows (by J. Spoelman, 2024).

The topics and practices that could only be assigned to a primary determinant are as follows:

- **C-T4 Diversity (in capabilities):**
  Diversity in capabilities may relate to knowledge or skills, both of which are relevant within a community group. For instance, while some individuals have extensive knowledge of certain plants, others may be particularly skilled in applying for grants.

- **C-P3 Mode of communication:**
  The mode of communication is relevant to all topics and practices, particularly for sharing both knowledge and skills.

- **C-P1 Collective learning (about biodiversity):**
  Collective learning encompasses both skills and knowledge.

- **M-T1 Positive urgency:**
  Creating a sense of positive urgency can impact both conscious and unconscious motivation.
- **M-P4 Connect with values and needs of residents:**
  People may consciously or unconsciously embody certain values and pursue specific needs.
- **O-P2 Connect networks and initiatives:**
  Connecting networks and initiatives can influence both organisational and social aspects, as well as mobilising material resources.

Not Only *What* but Also *How.* The model is applicable not only to interventions that describe *what* can be done, but it also provides guidance in strategically determining *how* a particular intervention can best be designed. The *how* is equally important in shaping co-creation interventions. This addition provides a valuable nuance to the COM-B model

Not all data can be easily mapped onto one of the three primary determinants of the COM-B model. Respondents placed significant emphasis on methods of collaboration and communication. While this is partially reflected within capability and opportunity, it is also broadly applicable to the overall co-creation process. Consequently, it cannot be mapped onto the model, as it pertains to all determinants.

Distinction between Physical and Mental Capability: Noticeable absence of data on individuals with physical (or mental) limitations. It is notable that none of the respondents mentioned physical factors—such as individuals' physical characteristics that influence their capability to participate in a co-creation project. This could include auditory, visual, or other physical impairments that might limit participants in performing specific actions. Respondents did, however, describe how sharing knowledge and experience can help increase both the mental (knowledge, memory, understanding) and physical capacity (dexterity, skills) of participants. It was also emphasised that involving participants in co-creation should be done in an inclusive manner. The primary emphasis in capability-building, however, remains on learning and knowledge-sharing. Further research into the topic should be formulated more inclusively.

7.2. Relevance for practice

Applicable to other transition issues vs Biodiversity specific. Several identified themes are not necessarily unique to behaviour change related to willingness to act for biodiversity. They are also applicable to engaging residents in other major transition issues that require transformative change, such as the energy and climate transitions.

However, the research design did yield five biodiversity-specific topics: “Nature Consciousness” and “Care for Nature” for enhancing capability, and “Ecosystem Services,” “Empathy with Nature,” and “Social Values of Green” for strengthening motivation. Additionally, a practice specific to motivation was identified: “Trigger Reflection on Different Ideals of Nature” (see Table 4).

COM-B determinant	Broader applicable themes	Biodiversity specific themes
Capability	C-T1 Knowledge acquisition (through citizen science)	C-T2 Nature conscious
	C-T4 Diversity (in capabilities)	C-T3 Care for nature
	C-P1 Collective learning (about biodiversity)	
	C-P2 Sharing/ communicating knowledge	
	C-P3 Mode of communication	
Motivation	M-T1 Positive urgency	M-T2 Eco-system services
	M-P1 Communicate with visuals and stories	M-T3 Empathy with nature
	M-P2 Trigger curiosity and playfulness	M-T4 Social values of green
	M-P4 Connect with values and needs of residents	M-P3 Trigger reflection on different ideals of nature
	M-P5 Provide feedback on impact of interventions	
Opportunity	O-T1 Economic aspects	
	O-T2 Social cohesion (in the neighbourhood)	
	O-T3 Rol of the municipality	
	O-T4 Synergy	
	O-P1 Aligning different interests	
	O-P2 Connect networks and initiatives	
	O-P3 Multifunctional use in public space	
	O-P4 Regenerative approach	

Table 4. Overview of topics and practices that are more broadly applicable versus those that are biodiversity specific (by J. Spoelman, 2024).

Participatory Design Research Meets Behavioural Change Research. This study integrates and focused specifically on identifying tools for an Urban Living Lab project. Our analysis shows how the COM-B model can aid in designing more targeted interventions for co-creation in ULL settings. However, focusing solely on one component of the COM-B model does not always lead to behavioural change in practice. For example, simply providing information on a municipal website (C) is often insufficient; this approach only benefits those who are already motivated (M) and capable of creating their own opportunities, such as by applying for a grant from the municipality (O).

Finally, the limitations of this research need to be clarified.

- Specifically relevant to participatory design research within the Urban Living Lab (ULL) setting.
- Outcomes gathered within a Dutch context; for example, engagement with residents has been a long-established practice in the Netherlands, and participation is now incorporated into the Environmental Planning Act.
- Practices and topics: the distinction between practices and topics is not always clearly defined. A topic can often also be translated into a practice.

By identifying the specific needs of a target group or neighbourhood, interventions can be more strategically and substantively tailored using the COM-B framework. The formulated topics and practices provide additional guidance for the development of effective interventions. The below test case illustrates how a practice can be applied during the research process.

Test Case: Oud-Mathenesse

To assess the applicability of our findings, one of the practices was translated into the context of the WAB Urban Living Lab (ULL1) in Oud-Mathenesse.

The motivation-enhancing practice, M-P3 "Trigger Reflection on Different Ideals of Nature," was implemented during the first workshop of the project in Oud-Mathenesse on 22 and 24 October, 2024.

During the workshop, participants were invited to share a cherished childhood memory of nature and were subsequently asked to create a collage representing their ideal vision of nature (Figure 4 and 5). Extensive reflection on these memories and perceptions of nature took place during and after the activity. The childhood memory exercise facilitated rich and meaningful conversations, where participants, many of whom were previously unacquainted, shared recollections of the places where they grew up. This was further explored during a communal meal, fostering deeper discussions.

Participants indicated that memories which had not surfaced in their daily lives were revived. This led to profound and insightful contributions for the collage depicting their ideal vision of nature. Through these two exercises, participants were able to transcend the challenges of the present moment and engage in profound discussions about nature and biodiversity.

Figure 5. Memory of nature card (Photograph by C. Duijsens, 2024).

Figure 6. Making a collage of ones ideal vision of nature (Photograph by C. Duijsens, 2024).

This case shows how differences in perceptions of nature can be significantly influenced by factors such as age, cultural background, and the place where an individual grew up. Memories from childhood can profoundly impact our functioning later in life.

8. Conclusion and recommendations

This study has demonstrated the value of applying the COM-B model in participatory design research. The model could be nuanced by primary determinants into topics and practices that can be implemented in practice. The majority of these are broadly applicable and can assist in shaping interventions, also for other transition contexts. Four topics and one practice are specifically aimed at engaging residents in enhancing biodiversity.

The research adds value to existing studies, which are predominantly written from the perspective of governmental roles. The findings of this study emerged from the experiences of practitioners who indicated

how to activate residents and what residents need. Our results provides tools focused on involving residents in participatory design research to enhance biodiversity at the neighbourhood level. These tools are intended not only for municipalities but also for other stakeholders involved in participation projects.

The formulated topics and practices will be further tested in practice during Urban Living Lab workshops, organized in four iterative rounds from October 2024 to December 2025 in more urban districts . In these workshops, residents will collaborate with partners, including the different municipalities, to increase biodiversity at neighbourhood level. Ultimately, the findings will contribute to the development of a scalable model for neighbourhood-focused action to enhance biodiversity. The findings will also contribute to theory development by making the COM-B model applicable to required transitions regarding biodiversity loss in cities.

Recommendations for future research:

- Inventory the extent to which the found topics and practices (table 2) are reflected in municipal biodiversity policies.
- Investigate how the topics and practices can be linked to intervention functions as described by Michie et al. (2011) and connected to successful existing interventions.
- Pay attention to inclusiveness (people with mental or physical disabilities).
- Explore further how modes of collaboration and communication relate to the COM-B model.

9. References

Christiaanse, B., Epskamp, M., Schäfer, A., Van Veelen, N. and Vogels, M. (2022). 'Hoe stimuleren we Rotterdammers tot groene gedragingen? Factoren die bijdragen aan klimaatadaptatie en biodiversiteit op privaat terrein.' Gemeente Rotterdam.

Christmas, S., Wright, L., Morris, L., Watson, A. and Miskelly, C. (2013) 'Engaging people in biodiversity issues' 121.

Cipriani, L., Foglieni, F., Leoni, F. and Maffei, S. (2024) 'Empowering urban wellbeing and biodiversity through design-driven citymaking.' https://doi.org/10.21606/drs.2024.814

De Lille, C. and Overdiek, A. (2021) 'From System to Local to System: Design principles to scale for a system in transition.' Presented at the Proceedings of Relating Systems Thinking and Design (RSD10) 2021 Symposium, OCAD University Library, Delft, pp. 185–194.

Gemeente Rotterdam (2024a) Buurt Oud-Mathenesse (gemeente Rotterdam) in cijfers en grafieken (bijgewerkt 2024!).

Gemeente Rotterdam (2024b) Wijkprofiel 2014-2024.

Gemeente Rotterdam (2020) Samen werken aan rijke Rotterdamse stadsnatuur. Uitvoeringsagenda biodiversiteit.

Hogeschool Rotterdam (2022) Projectvoorstel_WAB_RAAK-PRO indieningsronde oktober 2022.

Hölscher, K., Frantzeskaki, N., Kindlon, D., Collier, M.J., Dick, G., Dziubała, A., Lodder, M., Osipiuk, A., Quartier, M., Schepers, S., De Sijpe, K.V. and der Have, C. van (2024) 'Embedding co-production of nature-based solutions in urban governance': Emerging co-production capacities in three European cities. *Environmental Science & Policy* 152, 103652. https://doi.org/10.1016/j.envsci.2023.103652

IPBES (2022) 'Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://doi.org/10.5281/zenodo.6417333

Marselle, M. and Golding, S. (2023) 'Applying the Behaviour Change Wheel to mitigate the biodiversity crisis', in: Gatersleben, Birgitta; Murtahg, Niamh, M. (Ed.), Handbook on Pro-Environmental Behaviour Change. Edward Elgar publishing, Cheltenham, pp. 353–371. https://doi.org/10.4337/9781800882133

Michie, S., van Stralen, M.M. and West, R. (2011) 'The behaviour change wheel: A new method for characterising and designing behaviour change interventions.' *Implementation Science* 6, 42. https://doi.org/10.1186/1748-5908-6-42

Mohr-Stockinger, S., Sanft, S.J., Büttner, F., Butenschön, S., Rennert, R. and Säumel, I. (2023) Awakening the sleeping giant of urban green in times of crisis—coverage, co-creation and practical guidelines for optimizing biodiversity-friendly and health-promoting residential greenery.' *Frontiers in Public Health* 11, 1175605. https://doi.org/10.3389/fpubh.2023.1175605

Newman, G., Wiggins, A., Crall, A., Graham, E., Newman and S., Crowston, K. (2012) 'The future of citizen science: emerging technologies and shifting paradigms.' *Frontiers in Ecology and the Environment* 10, 298–304. https://doi.org/10.1890/110294

Nielsen, K., Bauer, J., Bradbury, R., Broad, S., Burgess, G., Burgman, M., Byerly, H., Clayton, S., Espelosin, D., Ferraro, P., Fisher, B., Garnett, E., Jones, J., Otieno, M., Polasky, S., Ricketts, T., Trevelyan, R., van der Linden, S. and Balmford, A. (2021) 'Biodiversity conservation as a promising frontier for behavioural science.' *Nature Human Behaviour* 5. https://doi.org/10.1038/s41562-021-01109-5

Nielsen, K.S., Cologna, V., Lange, F., Brick, C. and Stern, P.C. (2021) 'The case for impact-focused environmental psychology.' *Journal of Environmental Psychology* 74, 101559. https://doi.org/10.1016/j.jenvp.2021.101559

OpenAI ChatGPT-4 (2024) ChatGPT-4, response to Janneska Spoelman, September - October 2024.

Peter, M., Diekötter, T., Höffler, T. and Kremer, K. (2021) 'Biodiversity citizen science: Outcomes for the participating citizens.' *People and Nature* 3, 294–311. https://doi.org/10.1002/pan3.10193

Slingerland, G. and Overdiek, A. (2023) 'Beyond human sensors: More-than-human Citizen Sensing in biodiversity Urban Living Labs' in: May 2023. pp. 27–38.

West, R. and Michie, S. (2020) 'A brief introduction to the COM-B Model of behaviour and the PRIME Theory of motivation.' *Qeios.* https://doi.org/10.32388/WW04E6

Wilk, B., Hanania, S., Latinos, V., Anton, B. and Olbertz, M. (2020) 'Guidelines for co-designing and co-implementing green infrastructure in urban regeneration processes.' Project proGIreg.

9. Appendix

Table 5. Topics and practices about increasing capability illustrated by quotes from respondents (by J. Spoelman, 2024).

Capability			
Topic	**Description**	**Quote(s)**	**Rx**
C-T1 Knowledge acquisition (through citizen science)	Biodiversity is an abstract concept for many individuals, and knowledge about biodiversity and ecosystems is complex. It concerns systems in which various elements interact and influence one another. Respondents indicate that this knowledge is often lacking among many residents. Additionally, maintaining greenery within a community requires knowledge (and perseverance). Citizen science offers a means for residents to actively acquire knowledge on biodiversity and the impact of specific actions over time through measurement and monitoring.	1 "There's very little knowledge about nature and plants, and about what is or isn't possible. Let alone what is or isn't allowed. So, knowledge is really important." 2 "And then there are also people who may be true experts, for example, in a specific group of birds. But that doesn't necessarily mean they have a full understanding of the broader concept of biodiversity, or how a bird relates to that." 3 "So, you can actually consider what you could try to investigate. What would a green element, that's more or less the same, do in an urban environment? What kind of services does it provide—such as cooling or supporting biodiversity, those kinds of things. Of course, there are always physical differences, like different soil types where such a forest is located. Or whether it's more on the outskirts of a city, in a green park, or even on a parking lot, and so on." 4"...that is citizen science from the perspective of wanting to increase the number of data observations. But you also have citizen science aimed at contributing to engagement and awareness around a topic, like, for example, the air quality lab around Tata Steel. By actively getting involved themselves, people became much more aware of the issue. I think it would be wonderful if something like that could also be meaningful for biodiversity. If you encourage people, for instance, to map urban nature—because, as the saying goes, you can't care for what you don't know."	R4 R5 R14 R5
C-T2 Nature awareness	It is noted that people are often no longer fully aware of the natural environment around them; they do not truly see it. While common species may be visible and perhaps even recognizable, there are numerous other organisms of which we are largely unaware. These organisms, however, are crucial to us—we are part of their ecosystem and even dependent on them. Respondents indicate that this awareness is often lacking.	1 "If I hear a woodpecker a kilometre and a half away, I think, "Ah, a Great Spotted Woodpecker." That's something you can pick out from all the other sounds. It gives you an awareness of nature and a connection to it, and that's something we need to teach people. Because what is it, really? What are you seeing? What are you hearing? There's a whole story behind it that makes you feel like a part of nature. And it also gives you a sense of responsibility—that, the city is also for these creatures. And they are so fortunate. Literally. Because if the weather is bad, they can just fly somewhere else, where the sun is shining."	R12
C-T3 Care for nature	In addition to knowledge of nature and biodiversity, it is equally important to understand how to care for the natural environment. This requires not only knowing what actions can be taken but also understanding how to effectively carry	1 "It is very easy to create a green design, and the implementation is relatively straightforward. Designing is also quite simple; however, ensuring that the greenery is maintained over time is considerably more complex."	R11

	them out. Such efforts require specific skills. By actively engaging with and maintaining nature, individuals become more familiar with it and are likely to develop a greater sense of care and responsibility toward it.		
C-T4 Diversity (in capabilities)	Respondents describe a significant disparity in capability, both among individuals and across different neighbourhoods. While some individuals navigate funding opportunities with ease, others struggle to do so. Similarly, gaining knowledge and skills requires access to experts or a digital platform where such information is available. Respondents emphasise the importance of experiencing success occasionally, as this fosters a sense of competence and accomplishment. Therefore, it can be beneficial to keep projects manageable in scope and grounded in local settings.	1 "Some people know how to navigate the council exceptionally well, while others do not at all. Each neighbourhood is also quite different. For instance, if we had conducted this project in neighbourhood X instead of neighbourhood Y, there would likely have been a waiting list for that community garden. It can be quite challenging to explain that I have to attend meetings there to encourage people to get involved in the garden, especially when I had to lobby internally for that budget myself."	R5
Practice	**Description**	**Quote(s)**	**Rx**
C-P1 Collective learning (about biodiversity)	Residents possess substantial experience and knowledge about their neighbourhood. They understand local dynamics, what is effective, and what is not. Often, there is also a rich diversity of knowledge present; for instance, one resident may have extensive understanding of biodiversity and plants, while another may be experienced in securing grants. By sharing knowledge and experiences, community members can support one another. Such exchanges and collaborative learning can also reveal gaps in knowledge and identify ways to collectively address them. A greening initiative or a citizen science project focused on biodiversity monitoring can further enhance this shared learning process.	1 "For example, I adopted a few tree pits with my fellow residents. And, in conversations with the neighbours, you notice things like, "No, you shouldn't prune the ivy just yet, because it's blooming now, and in early spring or late winter, it produces berries, which are good for this and that." You can see that, even on that level, it's already making a difference."	R12
C-P2 Sharing/ communicating knowledge	Knowledge is not always easily accessible, and determining which sources are reliable can be challenging. Clear sharing and communication of information are therefore essential. Consolidating and presenting various types of knowledge on a (digital) platform—through stories, practical examples of plants, or useful tips and tricks—can help individuals more readily locate the information they need.	1 "How can you best reach people...? Well, I think ultimately by simply involving them. That's what they do at 'Duurzaam Den Haag' by just telling the story: why is it important? 2 "You can explain that every bit of nature supports every other bit of nature. And by doing so, you maintain that larger complex of what nature is—which you can call an ecosystem, or whatever—keeping it intact. This ensures that ecosystems remain healthy and continue to provide the services you need to survive, both now and in the future."	R1 R12

	Additionally, a "green coach" within the community or distributing maintenance tips via flyers are highlighted as effective methods to facilitate learning about green spaces and biodiversity.		
C-P3 Mode of communication	Biodiversity is a complex concept, yet it is important to clearly explain why it matters. The same applies to ecosystems. Simplifying explanations and making these concepts visible can help engage people more effectively. Additionally, introducing the concept gradually can be beneficial: starting with "green" initiatives, then moving on to biodiversity. For example, beginning with a community greening project in the neighbourhood can provide a foundation upon which the importance of biodiversity can later be introduced and explained.	1 ".by giving examples. That could be something digital, like a website where you see a sort of virtual garden and how it works. But it can also be done, for instance, by simply showing people—like when I was on that rooftop in Rotterdam, where they showed those small plots and explained which plants were grouped together and how that works. Just giving a real-life example of how it looks and functions. And what is native and what isn't? I think that's a good way to convey the message." 2 "And I think it's much better to actually approach it through green spaces. Then, gradually, through the activities you do together, you arrive at questions like, "What do we do with the soil? How do we manage the water? Which plants go well together? Which plants support each other?"	R6 R2

Table 6. Topics and practices about increasing motivation illustrated by quotes from respondents (by J. Spoelman, 2024).

Motivation			
Topic	**Description**	**Quote(s)**	**Rx**
T1 Positive urgency	Respondents emphasise the importance of framing the issue of greening and enhancing biodiversity as urgent, given that residents often prioritise other concerns. It is essential to create a sense of urgency, but in a positive and constructive manner.	1 *"...people here are focused on survival. Or... or they only see green spaces as, well, just somewhere to walk the dog, so to speak, or it has to be functional, or it just needs to look neat."* 2 *"...you do come across people who are constantly telling everyone that you must consider every single species. Well, that's not going to work. It doesn't resonate with anyone."*	R1 R9
T2 Eco-system services	A greener environment provides several ecosystem services, such as food production, water retention, cooling, and air purification. Explicitly highlighting and emphasising these services can help residents recognise the broader benefits of greening initiatives.	*1 ...But that you want an environment where you can also see a tree and have the sense that there is fresh air.* 2 *There are people who think, "Yes, the hedgehog is nice and all, but my health is what matters to me." For that reason, they are motivated to support the preservation of certain ecosystems.*	R2 R13
T3 Empathy with nature	People do not always feel connected to nature. Out of sight, out of mind. By making nature once again tangible and visible, we can cultivate empathy for the natural world. A positive relationship with nature also contributes to an improved sense of well-being.	1 *" ..a filmmaker has created some truly fantastic documentaries. He approaches the subject very locally and even watches a roof across the street with someone at home, observing oystercatchers. That can really resonate with a person, can't it? I find it very appealing that he seeks to make it very close and personal."*	R12

T4 Social values of green	A green environment can encourage social gatherings, recreation in public spaces like sports, walking, or simply sitting. Moreover, greening initiatives can help foster community engagement by bringing residents together through collective action within the neighbourhood. This can serve as a motivation for residents to participate in greening initiatives.	*1 "Social factors can also serve as motivation. For instance, engaging in biodiversity initiatives, such as collaboratively creating a facade garden with the appropriate plants, can be beneficial. This could involve working together to establish a garden or maintaining a specific garden in the neighbourhood."* *2 "Whether you are practically or theoretically educated, or wherever you come from and whatever your background may be, nature holds a certain importance across all cultures, and that is something that connects us all, so to speak. Yes, engaging with the environment. Literally."*	R6 R5
Practice	**Description**	**Quote(s)**	**Rx**
P1 Communicate with visuals and stories	Utilising visualisation techniques can make it easier to inform and engage residents. Spatially representing data can, for instance, provide insights into the current situation or demonstrate the impact of activities they have been involved in. Visualisation can also help to sharpen the focus of discussions during co-creation processes. Storytelling enhances engagement by making it easier for people to empathise with others—whether human or animal. Additionally, it aids in perceiving the broader system and the interconnections within it, rather than focusing solely on individual elements.	*1 We had a table with a map of the neighbourhood, and we highlighted opportunity areas by enlarging them and marking them with a pin connected by a string. The residents could then look at these opportunity areas. "Why is this an opportunity spot?" On the back of the photo of each opportunity area, they could read the reasons why it was considered one.* *2 You may enjoy watching that little bird, but you forget that there's an entire system behind it. However, when you share the story behind the bird, that's when it becomes clear.*	R2 R4
P2 Trigger curiosity and playfulness	You can enhance people's engagement by stimulating their curiosity. Additionally, incorporating elements of play can be effective in involving individuals with a topic in a more light-hearted manner.	1 *"I believe it should always be enjoyable, in the sense that it should spark their curiosity. For example, with (that research project in which we used) that pop-up tea stall. That was really successful because we were able to engage with a wide variety of residents."* 2 *"Go and see what you can discover in the summer with a magnifying glass or something like that. It's about introducing knowledge in a more playful way, rather than discussing it in abstract terms... because that makes it too difficult to grasp. Yes, too complex concepts."*	R2 R3
P3 Trigger reflection on different ideals of nature	We are not always aware that we do not all share the same perception or ideal image of nature. Differences in this perception can be influenced by factors such as age, culture, or the place where one was raised. By reflecting on each individual's view of nature, these potential differences can be made explicit, while also creating opportunities for open discussion.	*1 "Rewilding is such a beautiful concept—it's about letting nature take its course, like in Chernobyl, which has beautifully regained balance. That's one vision. But you can also take a more active role, ensuring people find it enjoyable, and not just leaving everything to nature's power, which indeed often starts with pioneer species. So, these are different perspectives."* *2 "Someone else's idea of nature might be that cow in the meadow. And that's not necessarily wrong, but it is different. So if your image of nature is a manicured lawn with neatly raked parks, you'll never see the value of the jungle on Earth, because that's frightening, dangerous, and somewhere you shouldn't go."*	R4 R1
P4 Connect with values and	When working with residents to green their environment and enhance biodiversity, it is essential to listen to their concerns and	1 *"I will listen to their needs or the issues in the neighbourhood, and then explore how nature and biodiversity can be part of the solution."*	R10

needs of residents	align projects with these local issues. Seek solutions that both address their needs and values, while also contributing to the greening of the area and the promotion of biodiversity.	2 *"… connecting with people's experiences, focusing on what they find interesting and important, and in that way also teaching them about biodiversity."*	R5
P5 Provide feedback on impact of interventions	Biodiversity, like climate change, is a crisis that can seem abstract to individuals; they may question the value of their contribution. By providing feedback on the impact of actions they have participated in, their personal contribution to the desired change is made more tangible.	*1 I think it really comes down to the idea of, "OK, if I do something now, does it actually make a difference?" That's very important if you want to encourage people to take action. So, you need some kind of feedback or examples of others taking action. That really plays a significant role.*	R6

Table 7. Topics and practices about increasing opportunity illustrated by quotes from respondents (by J. Spoelman, 2024).

Opportunity			
Topic	**Description**	**Quote(s)**	**Rx**
O-T1 Economic aspects	Financial aspects have a significant impact on the extent to which residents can take action to enhance biodiversity at the neighbourhood level. Budgets from local councils for increasing biodiversity are often tight, requiring creative solutions to source funds, such as those allocated for climate adaptation. However, residents need to be able to locate these funding sources, which not everyone manages to do. When they do succeed, residents may find the financial administration of greening initiatives a heavy responsibility to bear. Many people are already busy with work and making ends meet, so increasing biodiversity may not be their top priority. Financial incentives for biodiversity-enhancing activities could provide additional motivation for residents to contribute.	1 "How can we, linked to their regular tasks, embed this theme there? What about the sewage system? Are renovation works going to take place, or will the street need to be opened up? Seize that opportunity. And then it turns out that, without specifically allocating a budget for biodiversity, if someone were to simply create an overview of everything that's going to happen in that neighbourhood over the next two or three years… Well, I think you'd end up with a really great layering of activities." 2 "You can also pay people if they contribute to biodiversity, water management, education, and so on." 3 "It's also difficult, of course, even for us, to apply for projects or get subsidies or funding. Yes, because you can't precisely say what the impact will be." 4 "Because a lot of people who live in those concrete urban neighbourhoods don't want the responsibility of spending, say, €1,000, or even €20,000 for bulbs. They simply don't want that responsibility." 5 "But subsidies aren't really that accessible to everyone. They often require you, firstly, to be able to find the subsidy. Secondly, to understand the rules of the subsidy. And thirdly, to be able to fill out the form properly. Those are quite specific skills that not every resident in Rotterdam has."	R10 R11 R14 R14 R6
O-T2 Social cohesion (in the neighbourhood)	Working to increase biodiversity can help strengthen social cohesion within a neighbourhood. Green spaces are generally viewed positively by many, making it a unifying topic. Working together in the local area can help bring people into contact who might not	1 "At the same time, there are plenty of people who, for example, go green simply because they see it as a social thing. If you can then say, for instance, well, there's a community initiative and we provide the plants, it doesn't really matter that they don't know the plants are organic and good for butterflies and bees, as long as you tap into that effectively. You see, you may not really raise their awareness, but you do get them to take action."	R5

	otherwise meet or engage in conversation with one another.	2 "Everyone is welcome, and maintaining contact with one another is, of course, highly useful for connecting with like-minded individuals."	R11
O-T3 Role of the municipality	The local council plays an essential role in increasing biodiversity at the neighbourhood level. It sets policies, provides grants, and carries out (green) maintenance in public spaces. Additionally, the council is key in sharing knowledge and facilitating resident-led initiatives. A collaborative, supportive council is seen as crucial in working effectively with residents. At the same time, "the council" is not a single entity. Within the council, there are various departments, roles, areas of expertise, and people, who may not always speak the same language. For residents, it's not always clear how decisions are made or who has the mandate to make decisions on matters such as carrying out a greening initiative or adjusting mowing policies.	1 "And we approach this in a much more facilitative way. So, we have various subsidies, "Opzoomer mee" budgets, community initiatives. And since this year, people can receive a contribution for greening their private spaces." 2 "That leads to a lot of good cross-pollination, and that's how we learn to speak each other's language. Sometimes you do have to take a step back, and then I see, for example, that an ecologist looks at trees in a functional way, thinking about which insects will be attracted to them. A landscape architect, on the other hand, looks at a tree and wonders if it fits the aesthetic and if it's functional in the sense that people can relax under it. Then a maintenance manager thinks, "Is it functional? How often will I need to prune it?" So, we're all talking about the function of that tree, but we're talking about completely different things. And the urban planner is thinking, "There's going to be a building development here, and I need a sightline," so to them, the tree isn't functional. All about the same tree!" 3 "You can also start from the idea of temporariness, recognising that you're actually a guest in a context where people have been around much longer than you. And how do you then behave as a good guest? Often, we as the council take on more of a host role, even though we're only temporarily active in a neighbourhood."	R5 R4 R13
O-T4 Synergy	At the neighbourhood level, many individuals and organisations are active. This may involve greening efforts but also, for example, work in the fields of well-being and care. By linking the activities and interests of different parties, greater effectiveness can be achieved, and knowledge-sharing is encouraged. In this way, the combined impact can be greater than the sum of each part individually.	1 "Usually, there's already some kind of action group or something like that within the neighbourhood—people who feel something needs to be done or who are already working on greening a school playground or something similar. You try to build on and strengthen that. Because we, as an external organisation, especially X with its international reputation, can seem a bit like an outsider at the local level. So, you want to activate and support such local groups. And that works best because they have a strong connection with the residents." 2 "That really is a responsibility of the government—working with green initiatives in neighbourhoods because that's where the actual work is being done. And, of course, the policy is made at the council level. So, if you can build that fruitful bridge, I'd say, both parties can really benefit from it. ... On the one hand, you're taking action, but at the same time, the question is: what do you need from the officials or those involved? And what can you do? Could we, for instance, speak at a council meeting? Would that create momentum? So, how can we complement each other in a way that works for both sides, so to speak."	R14 R3

Practice	Description	Quote(s)	Rx
O-P1 Aligning different interests	Parties involved in co-creation processes often have different interests. For an initiative to succeed, it is essential to continually seek the common interest. This can be between the council and residents, but also among various resident initiatives or between residents themselves. It can be helpful to articulate these differing interests, making them open for discussion.	1 "When I listen to their needs or the problems in the neighbourhood, I then look at how nature and biodiversity can be part of the solution. So, you're not saying, "I want to sell this," but rather, "I'll listen to their issues and see how what I'm offering can be part of the solution."	R10
O-P2 Connect diverse networks and initiatives with one another	By connecting active parties, networks, and existing initiatives, benefits can be generated for all involved. Linking different interests and initiatives creates greater support and effectiveness, and can sometimes attract additional external opportunities, such as funding.	1 "Additionally, it's important to involve as many people and organisations in the neighbourhood as possible, especially those who will still be there after the project ends. That's why we're working with the two foundations that are based in the neighbourhood and will remain there." 2 "I would really look at what is already there and tap into that. Yes, I think that's quite important. And the initiatives that exist—some are very open to getting involved, while others feel like they're already so busy. So, don't be put off by that."	R2 R11
O-P3 Strive for multiple functional uses in spatial initiatives	By designing spatial projects for multiple functions, they can serve various interests and target groups. In this way, an initiative becomes appealing to multiple parties, as it addresses several goals simultaneously.	1 "With the garden, what else can you do? I think it's important that we focus more on its functional use and improve that. Perhaps we could also link it to food?" 2 "I've noticed that they are more easily motivated when we link biodiversity to various functions, such as recreation and relaxation. So, it's important to connect functions to greenery—such as spaces for staying, recreational areas, and places for sports."	R10 R5
O-P4 Regenerative approach	Ensure that a co-creation initiative genuinely originates from the neighbourhood. Only when residents feel truly involved in the project and endorse its importance will it yield sustainable results. Therefore, focus on the ambitions of residents rather than what must be done in co-creation projects. As an organisation supporting the co-creation process, come in as a guest. Adopt that mindset. You are only there for a short time. Instead of telling residents what to do, inspire them and encourage them to come up with their own ideas.	1 "And that does mean you have to be willing to relinquish some control. For a council, this is particularly challenging because they are used to having total control over their projects. However, we're seeing in our projects that when you let go, something beautiful can happen. You also can't control participation; I can't just tell someone, "Now you have to participate." I need to persuade them to take part." 2 "Additionally, it's important to involve as many people and organisations in the neighbourhood as possible, especially those who will still be there after the project ends."	R14 R2

Research Paper

Envisioning the Rural Metropolis:
"Ethanol Urbanism" for Ecological and Social Sustainability in the Near-Collapse Scenario for the Year 2074

Yiqun Wang, University of Innsbruck, Austria &Harvard Graduate School of Design, United States

Corresponding author: Yiqun Wang

Charles Song, Harvard Graduate School of Design, United States

Em Sawyer, Harvard Graduate School of Design, United States

Regina Yang, Harvard Graduate School of Design, United States

Abstract

According to the Near Collapse scenario, which is part of a Harvard Graduate School of Design academic study, Cova da Beira, Portugal, will have robust urban design strategies by 2074. The research, which emphasizes ecological self-sufficiency, social integration, and dynamic equilibrium with ecosystems, is impacted by "sci-fi urbanism." 2312 by Kim Stanley Robinson and Pedro Gadanho's ideas on sustainable urbanism both work in a similar way. Under extreme environmental stress, it uses scenario thinking to explain responses to food, energy, and societal crises. Important strategies include creating closed-loop energy and food systems, integrating agriculture into urban areas, advocating for social justice, and designing infrastructure to coexist with natural ecosystems. The report provides a framework for future crises that urban planners and policymakers may utilize to advance sustainable urban expansion and environmental justice.

Keywords

resilient urban design, ecological self-sufficiency, sci-fi urbanism, environmental justice, social integration, adaptive infrastructure

1. From Sci-fi urbanism to contemporary ecological challenges

1.1. Sci-Fi Urbanism And Ecological Insights

For a long time, authors of science fiction have envisioned how people may react to the ecological constraints of Earth. Kim Stanley Robinson imagines a future in which environmental concerns drive human colonization of the solar system in his book *2312*. His inventive "sci-fi urbanism" includes amazing adaptations such as creating cities that run around Mercury's equator to avoid its blazing sun and protecting Earth's threatened biomes inside hollowed-out asteroids (Robinson, 2012). Though intriguing, these images highlight an important point: we must handle urgent issues on Earth before we can dream

about colonizing other planets.Our knowledge of resource constraints underwent a sea change in the wake of the 1973 oil crisis. William Catton and other environmental experts started drawing attention to the fact that throughout the past four centuries, humankind's remarkable expansion has depended on using resources that the planet can't naturally produce. "Borrowing" from other countries, seas, fossil resources, and even future generations was necessary for this expansion (Catton, 1982). With humankind's combined resource usage now equaling that of two Earths, glaring global disparities and pressing environmental justice issues are brought to light. Robinson's futuristic vision, in which humans colonize distant planets and space stations, is both a cautionary tale and an inspiration. His innovative solutions force us to reconsider how we handle Earth's current environmental problems, even though space colonization is still only a speculative idea (Gadanho, 2024). The creativity displayed in conceiving off-world solutions may be more useful to us in resolving domestic issues.

1.2. Applying Scenario Planning for Regional Climate Adaptation

Scenario planning is the cornerstone of sci-fi urbanism's approach to imagining future cities (Gadanho, 2024). This strategic tool has a fascinating history, having been developed for military forecasting in the 1950s by Herman Kahn of the RAND Corporation. It later found wider applications in business strategy and public policy (Schwartz, 1991). Kahn developed the approach of creating detailed "future narratives" or scenarios, which gained popularity through institutions such as the Hudson Institute and the Stanford Research Institute (Kahn, 1965). By the 1970s, major corporations such as Shell and DHL had implemented scenario planning to cope with uncertain futures (Chermack, Lynham, and Ruona, 2001). The current climate catastrophe has made scenario planning even more important. One part of the challenge is predicting the effects of climate change; another is communicating complex adaptation alternatives to a variety of audiences, such as lawmakers, designers, and local residents (Harvard Graduate School of Design, 2024). Kira, a climate design researcher, offers an innovative method called place-based scenario planning. This approach situates false climate projections into the familiar context of local infrastructure, cultural institutions, and landscapes. By focusing on specific communities while recognizing shared regional features, such as urban centers, water bodies, rural highlands, and critical infrastructure, planners may develop more inclusive and relevant adaptation strategies.As we look to 2074, a significant year that will mark both the 100th anniversary of Portugal's democratic revolution and the anticipated 10 billion-person global population peak, our effort is divided into two stages. We start by creating thorough scenarios of potential futures. Next, we develop adaption strategies based on regional requirements. The goal of this systematic approach is to develop a framework that is adaptable to the specific climate issues faced by communities around the world (Town Green 2025, n.d.).

2. Rural Metropolis and its ecological prospect

2.1. The Model of Rural Metropolis

In many places, the surge in urbanization around the world results in population reduction, ecological harm, and economic degradation (Pallagst et al., 2009). For example, as more individuals from rural areas have moved to cities, the "emptying" of rural towns has gotten worse (Lei, 2009). This scenario involves "the whole migration of abandoned houses, hollow villages, abandoned settlements, the trend of pre-empty waste of remote settlements caused by urbanization, empty waste and empty waste development of public construction land, empty waste of agricultural production facilities, the phenomenon of agricultural homes and abandoned development of traditional dwellings" (Lei, 2002). These phenomena affect people's

quality of life and threaten the balance of the local ecology in addition to wasting land resources and building antiquated infrastructure (Koolhaas and AMO, 2020).

By guiding 17 communities and towns in Portugal's eastern core to apply for the 2027 European Capital of Culture, Pedro Gadanho, a professor at Harvard University, proposed the "rural metropolis" model as a solution to these issues and as a prime location for future climate migration. This approach seeks to achieve rural self-sufficiency through socioeconomic measures, energy structural reform, and ecological restoration (Gadanho, 2024).

Numerous European nations have established systems to address comparable rural issues. For instance, France encourages organic farming and agrotourism while bolstering ecological and environmental protection in an effort to boost the rural economy. Germany encourages rural residents to participate in community planning and management through the "village revitalization plan," which aims to improve the area's attractiveness and quality of life; Italy encourages sustainable rural development through the restoration of traditional agriculture, the preservation of cultural heritage, and the growth of rural tourism (Koolhaas and AMO, 2020). Gadanho's "rural metropolis" concept is particularly good because it encompasses not only agricultural development but also decarbonization, energy mobility, food security, water management, resource extraction, biodiversity conservation, and cross-species mobility. These national programs have produced impressive results in their respective contexts. Utilizing a range of renewable energy sources is preferred in order to accomplish energy recycling and self-sufficiency, lessen regional reliance on outside energy sources, and improve the resilience of rural communities (Harvard Graduate School of Design, 2024). This study looks at Portugal's "rural metropolis" ecological approach and its implications for rural regeneration around the world.

2.2. Portugal's Rural Metropolis Concept and its Ecological Prospects

Only 3 million people live in the interior of Portugal, whereas 7 million live in a 30-kilometer-wide coastal area. The rural eastern hinterlands have been severely depopulated as a result of this coastal focus, and by 2100, they are predicted to be almost completely deserted. Nevertheless, despite this population reduction, eastern Portugal has a wealth of natural resources, such as farms, rivers, and woods, which make it the perfect place for a "rural metropolis" approach. As Portugal's digital transformation and EU infrastructure improvements create opportunities for low-density urbanization in rural regions, the COVID-19 pandemic and climate change may reverse population emigration. In order to revitalize the eastern countryside, Gadanho suggested using eco-migration and rural regeneration to draw in skilled workers, migrants, returning locals, newcomers, and digital nomads. This would stimulate social,economic, and ecological redevelopment.

Low-density development near nature that makes use of abundant natural and cultural resources is part of the concept of a "rural metropolis." These rural metropolises could be centers of ecologically beneficial societal change as Europe moves toward decarbonization under the Green New Deal. Because locals attend activities in other municipalities, small villages in the area are already culturally integrated. Better intercity public transportation, including electric bikes and ecological microbuses, might strengthen these ties in places like Cova da Beira and promote sustainable movement between urban nodes.

"Business as usual," "managed degrowth," and "near-collapse" were the three future scenarios that interdisciplinary teams investigated for Cova da Beira in 2074 as part of a research experiment that Gadanho started at Harvard GSD in 2024 to further this plan. For sustainable development, luring climate

migrants, and ecological self-sufficiency, each team created creative plans. According to the "business as usual" scenario, economic development will continue while decarbonization targets are postponed. The "managed degrowth" scenario envisions the EU establishing a test area for sustainable urban development and the circular economy. The "near-collapse" scenario concludes by discussing the preparations for food, energy, and societal issues. By demonstrating how rural metropolises could adapt to severe ecological and social challenges, these scenarios help Portugal's interior regions become more resilient and experience sustainable growth.

3. Regional Planning Strategies for a "Rural Metropolis"

3.1. Timeline and Regional Analysis

The "Near Collapse" initiative envisions potential reactions from the Cova da Beira regional administration in the form of time nodes and outcome triggers throughout the 2024–2074 time frame in awareness of the growing dangers of food, energy, and social collapse. For instance, the region needs to guarantee food security beforehand because the drought in Europe is expected to result in famine in 2042. Alternative energy sources need to be identified beforehand in case of a gas crisis in 2060. By foreseeing and creating plans to make the area environmentally balanced and nearly self-sufficient while embracing and integrating 120,000 locals and climate migrants, the initiative seeks to attain ecological stability and dynamic balance. Economic systems and land usage that support food, energy, and social self-sufficiency are taken into account in the design in the wake of environmental disasters and deglobalization.

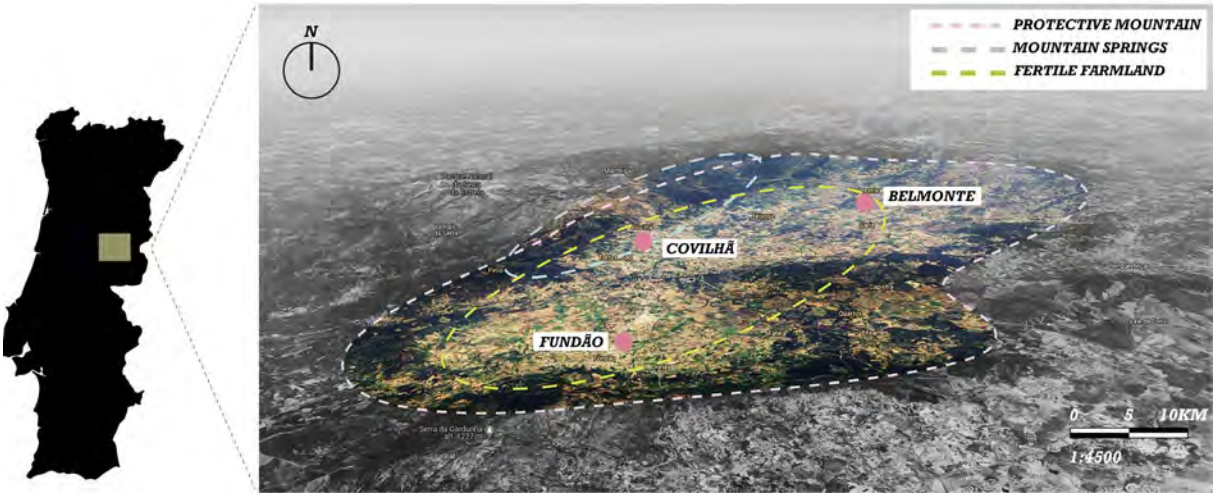


Figure 1. Aerial view of the Cova da Beira area. Source: Authors.

In the middle of the Iberian Peninsula, between Lisbon and Madrid, sits the Cova da Beira region. It is primarily an agricultural valley with a total area of roughly 1,000 square kilometers (Figure 1). The area is home to several minor towns and villages in addition to the three major cities of Covilha, Fundao, and Belmonte. A river flows across the valley from north to south, and there are other mountain streams that

supply drinking water. The area maintains a strong connection to nature in spite of the environmental and climate crises: it has been largely spared from industrialization, has no major sources of pollution, has fertile land and intriguing natural landscapes, and is far from scenarios of desertification and water scarcity (Harvard Graduate School of Design, 2024). The project team believes that achieving self-sufficiency in energy, food, and ecosystems is the key to success in the "near collapse" scenario.

3.2. Energy Independence and Circular Economy

The "Near Collapse" project has implemented a novel ethanol energy system in order to achieve energy independence (Figure 2). Due to its low startup costs, easy access to resources, and limitless availability, ethanol is the ideal option because many fossil fuel substitutes depend on internationally traded resources and have substantial entry barriers (Boyle and Open University, 2012). Ethanol is renewable yet less efficient than gas and oil. To guarantee energy recycling and self-sufficiency, the system operates in a closed-loop mode (Lin and Tanaka, 2006). In contrast to traditional ethanol production, which blends cattle and corn, the system selects chicken and cacti due to their high yield efficiency and minimal water requirements. Cacti are drought-tolerant, low water requirements, easy to cultivate, and highly efficient at producing ethanol (Alencar et al., 2022). In addition to producing more manure that can be utilized to make ethanol, poultry use less water (Getahun et al., 2013). The ethanol generated can be used to power generators, public transit, and local vineyards, boosting revenue.

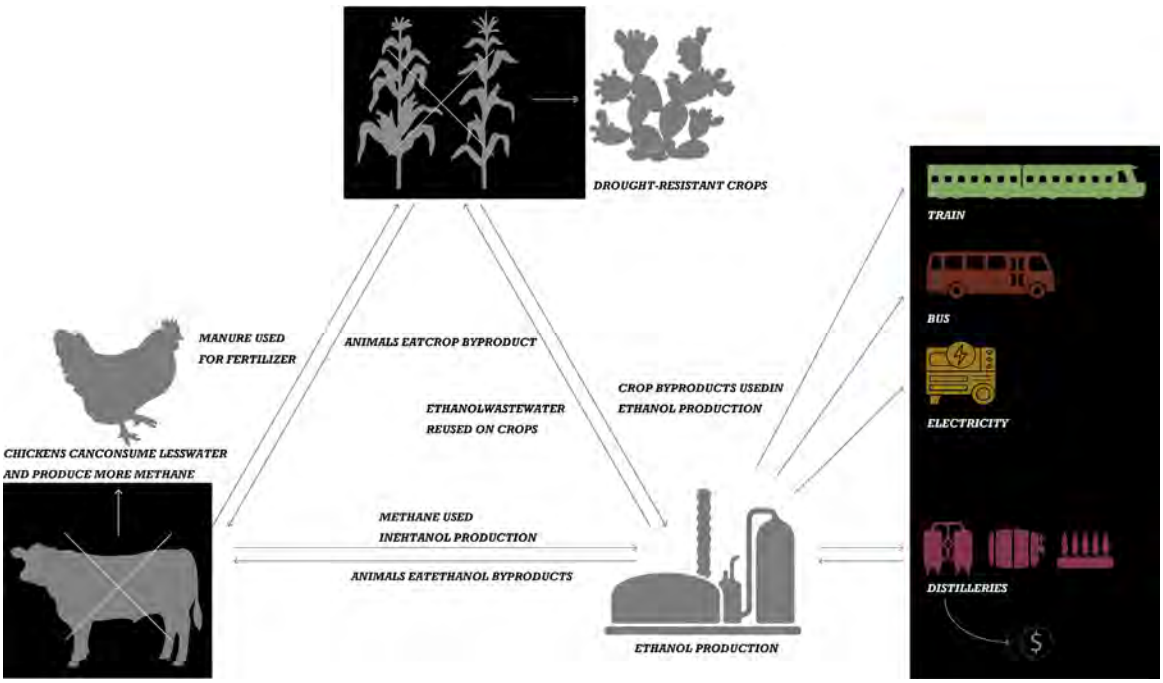


Figure 2. Diagram of ethanol circulation system based on cactus and poultry. Source: Authors.

Utilizing Portugal's wealth of natural resources, the project also incorporates a number of additional renewable energy sources, including geothermal and hydropower, to guarantee a sustainable energy

supply (Figure 3). Stable power can be generated from nearby mountain streams, rivers, and micro-dams using hydropower, which is simple to maintain (Kurtagić et al., 2022). The new strategy intends to continue using hydropower for the manufacturing of ethanol, in addition to the region's long-standing legacy of using it for the textile sector. Similarly, hydropower and ethanol can be effectively supplemented by geothermal energy, which comes from deep under the mountains and uses subterranean heat to produce heating and cooling. A green energy transition can be achieved by encouraging the use of renewable energy sources and decreasing reliance on fossil fuels. In addition to increasing rural communities' energy self-sufficiency, this strategy lowers carbon emissions, which benefits sustainable development and environmental preservation.

Figure 3. Renewable energy systems composed of ethanol, hydropower and geothermal. Source: Authors.

3.3. Ecological Interventions, Water Management, and Social Sustainability

Achieving self-sufficiency and safeguarding the entire area are the goals of the ecological intervention. In addition to the ecological corridor created by reforestation to link the region's existing dispersed patch forests, the "Near Collapse" project planted an agave defense belt and a fire forest belt at the regional border. At the same time, reforestation was planted around the city to create a buffer zone and stop the spread of the fire forest (Figure 4). During energy crises and severe weather, these actions safeguard communities from alien populations and forest fires while promoting the production of ethanol. Furthermore, by promoting carbon sinks and lowering carbon emissions, these ecological interventions aid in the achievement of rural decarbonization objectives.

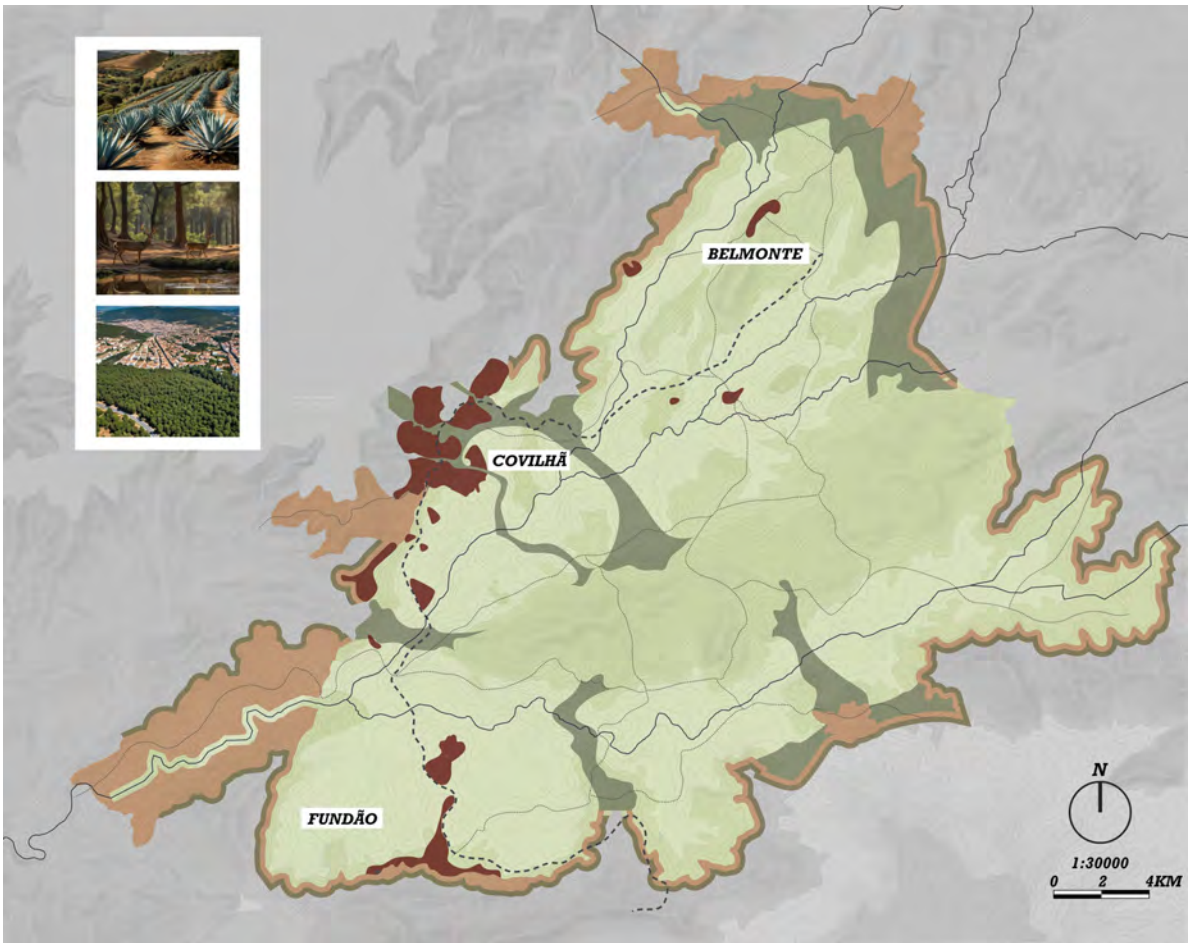


Figure 4. Agave borders, reforestation ecological corridors and urban peri-buffer zones. Source: Authors.

The majority of the land in the area will be used for agricultural in order to raise the population by 50%. In order to prevent cattle from using a significant amount of space for food production, the project suggests switching to a nearly vegetarian diet consisting of a variety of plants, home-raised livestock, and occasionally hunting in the forest. Agroforestry zones serve as a transition between forests and agricultural areas (Figure 5), facilitating wildlife mobility and connecting natural corridors. Ecological buffer zones preserve the environment and produce a wealth of agricultural goods by growing a variety of crops and trees. The people of the dispersed villages in the eastern portion of the area were incorporated into the western metropolis to aid in population control, and the old villages were converted into work camps and maintenance stations for forestry and agriculture. Numerous abandoned Urban farms, greenhouses, and vertical agriculture are examples of spaces that can be transformed into food producing areas in urban environments. The study concentrated on passive thermal techniques to lower heating usage. In the winter, the ground floor is heated by the thermal energy of the donkeys and hens that use it as a source of food and transportation.

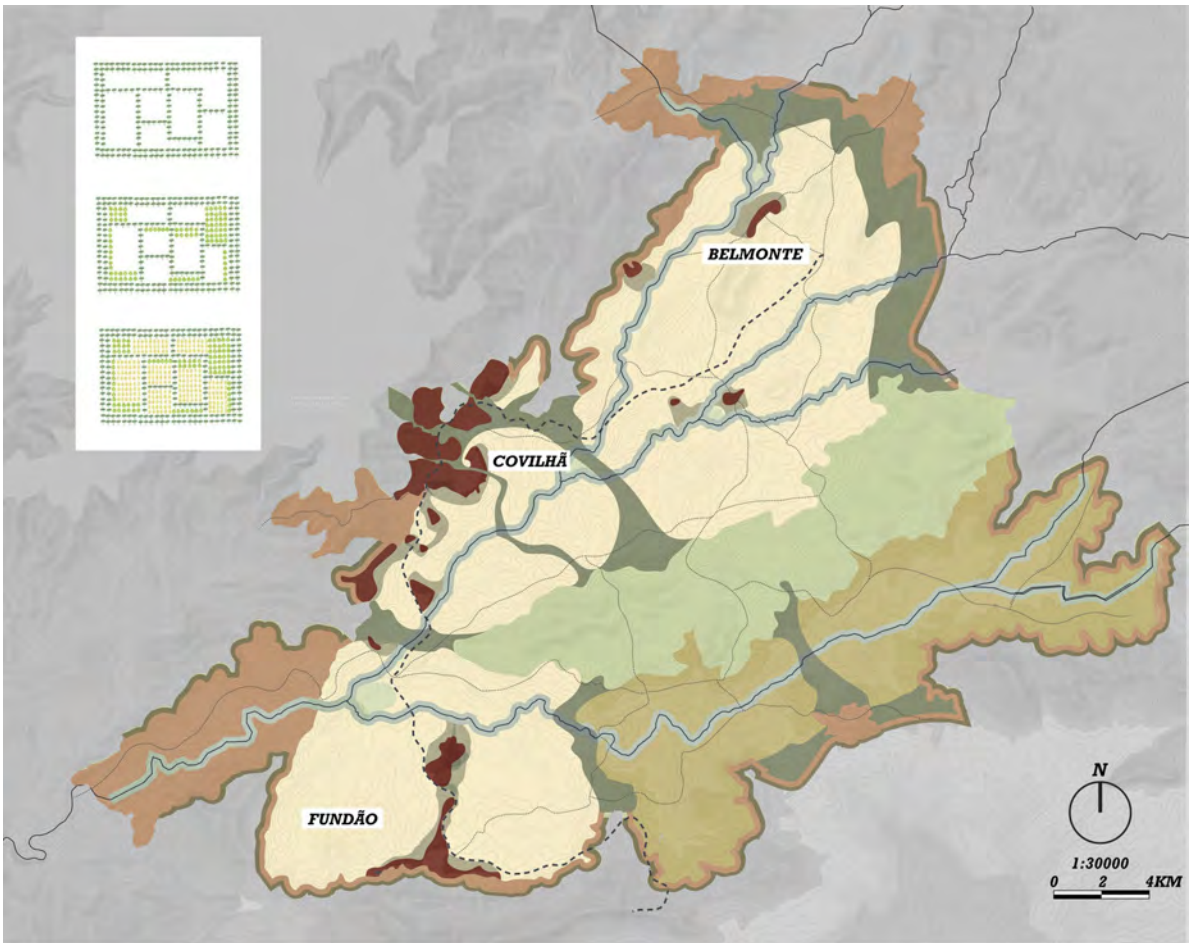


Figure 5. Distribution map of agricultural and agroforestry area. Source: Authors.

Micro-dams and reservoirs are constructed at river confluence in conjunction with topographic advantages to extend river water bodies in order to guarantee a year-round supply of water in hot and arid regions (Unami et al., 2013) (Figure 6). Micro-dams maintain agricultural output by controlling water flow, preventing flooding, and storing water during dry seasons. In order to supply irrigation water and integrate into the environment, the reservoir combines ecological and landscape purposes. To maximize water use, develop drip irrigation systems, encourage the adoption of drought-tolerant cereals and vegetables, and practice excellent agricultural management. Along the enlarged main river channel, ecological buffer zones were created to provide recreational opportunities while shielding it from agricultural activity.

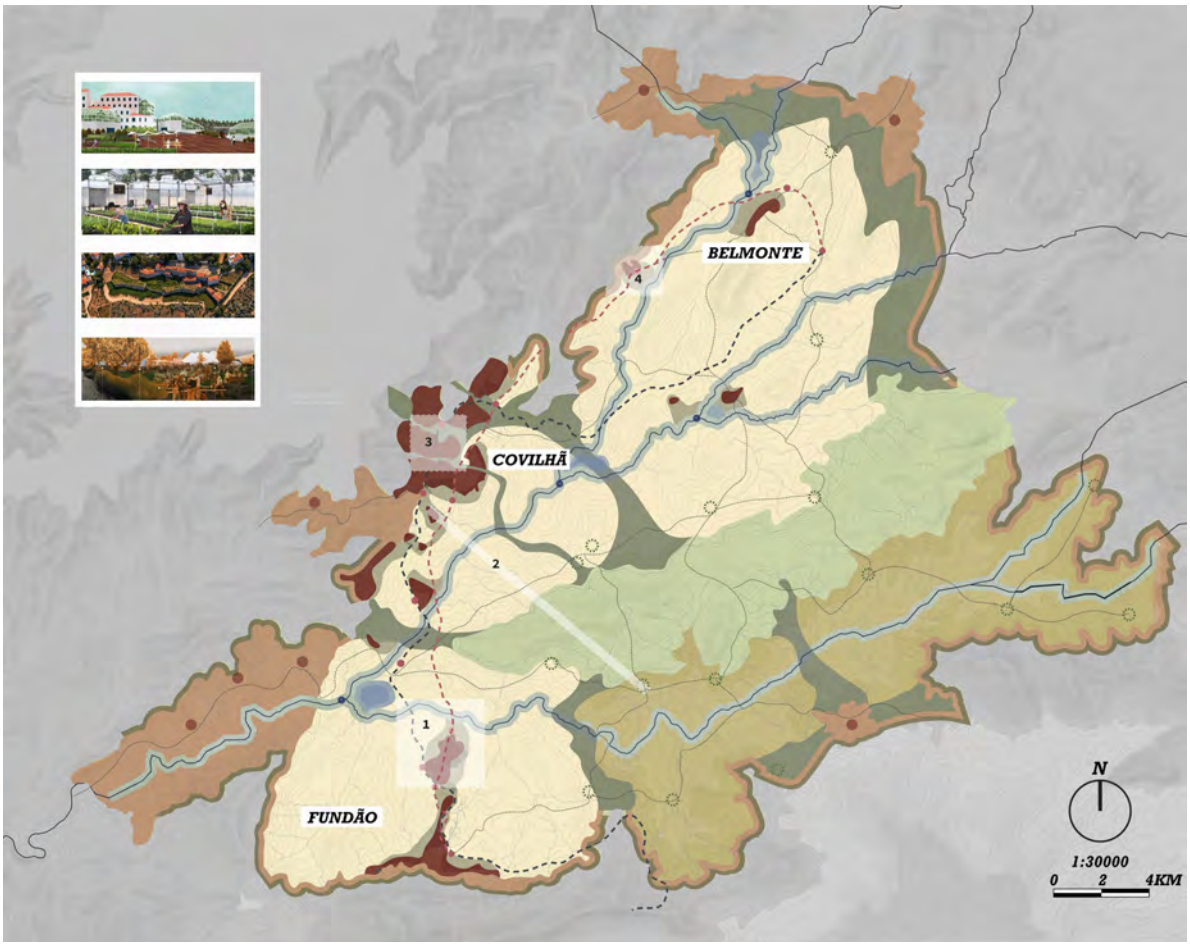


Figure 6. Ecoregional water resources management planning map. Source: Authors.

Data indicates that the EU has incentives to fund regional initiatives that aim to achieve food security, shelter, and energy independence (European Commission, 2024). The goal of the "Near Collapse" project was to create a Community Land Trust (CLT) that would unite all of the small towns and villages in the area, manage food production, develop agricultural plans, provide housing subsidies for new immigrants, and support businesses such as restaurants, wineries, and agriculture (Davis, 2010). A self-sufficiency cycle is created when farms supply food for restaurants, wineries supply alcohol, and restaurants supply compost for agriculture.

The public and private sectors of food production and distribution are connected by community land trusts, which also guarantee the land's sustainable use and long-term protection while encouraging community members to work together and share benefits. The land trust will oversee the production and distribution of 70% of the food, grow food for 120,000 people in public spaces, and harvest food from private family gardens for their personal consumption. Everyone works equally hard and receives the same quantity of food. Currently, 80% of the population gets their food from farmland; the remaining 20% comes from urban and vertical farming, which lowers the carbon impact of conventional agriculture.

3.4. Broader Project Impact and Future Development

The applicability of Portugal's "rural metropolis" ecological transformation model could be tested in different types of villages wordwide, especially in China. It needs to be comprehensively considered in combination with geographical, climatic and economic conditions. The rural terrain of eastern Portugal is diverse, which is similar to the mountainous areas of Yunnan and Guizhou in China and the North China Plain. Its Mediterranean Sea and Marine climate are similar to the southern and eastern coastal areas of China. The economy is relatively backward, relying on agriculture and handicrafts, which is highly consistent with the characteristics of many rural areas in China. This model has provided many useful experiences for China's rural revitalization, especially in coping with climate change, enhancing ecological resilience and promoting economic revitalization. In the future, through the joint efforts of policy support, technological innovation and community cooperation, China's rural areas are expected to achieve a dynamic balance between ecological protection and economic prosperity, showing higher sustainable development potential.

Acknowledgments

The authors wish to acknowledge the use of artificial intelligence (AI) applications, including Grammarly and ChatGPT, during the writing process of this paper. Grammarly was employed for stylistic and grammatical corrections, ensuring clarity and accuracy, while ChatGPT provided iterative suggestions that enhanced the coherence and structural framework of the content.

The authors would also like to express gratitude to Professor Pedro Gadanho, (former) Design Critic at Harvard University Graduate School of Design (GSD), for providing invaluable guidance on this project through the Option Studio "Envisioning the Rural Metropolis," Spring 2024.

4. References

Alencar, B., Medeiros, N., Lira, C., Torres Sales, A., Damilano, E., Sampaio, E.V.D.S., Menezes, R. & Júnior, M. (2022) 'Bioethanol production from cactus cladode biomass: considerations of harvesting time, dry matter concentrations, and enzymatic hydrolysis', *Biomass Conversion and Biorefinery*, 12. doi: 10.1007/s13399-020-00960-2.

Boyle, G. and Open University (2012) *Renewable Energy: Power for a Sustainable Future*. 3rd edn. Oxford: Oxford University Press in association with the Open University.

Catton, W.R. (1982) *Overshoot: The Ecological Basis of Revolutionary Change*. Urbana/Chicago: University of Chicago Press.

Chermack, T.J., Lynham, S.A. and Ruona, W.E.A. (2001) 'A Review of Scenario Planning Literature', *Futures Research Quarterly*, 7(2), pp. 7-32.

Davis, J.E. (2010) *Community Land Trust Reader*. Cambridge, MA: Lincoln Institute of Land Policy.

European Commission (2024) 'Portugal's Recovery and Resilience Plan' [online]. Available at: https://commission.europa.eu/strategy-and-policy/recovery-and-resilience-plan-portugal_en (Accessed: 23 October 2024).

Eurostat (2023) *Demography of Europe – 2023 edition* [online]. Available at: https://ec.europa.eu/eurostat/web/interactive-publications/demography-2023#expandable-example-content (Accessed: 23 October 2024).

Forman, R.T.T. (2008) *Urban Regions: Ecology and Planning Beyond City*. Cambridge, Massachusetts: Cambridge University Press.

Gadanho, P. (2024) 'Ecological Stress Test: On the Awes and Wonders of Sci-Fi Urbanism' [online]. Available at: https://weirdeconomies.com/contributions/ecological-stress-test (Accessed: 23 October 2024).

Getahun, T., Adila, M., Gabbiye, N. and Abera, S. (2013) 'Bio-ethanol Production from Poultry Manure at Bonga Poultry Farm in Ethiopia', *Research Journal of Chemical Sciences*, 3(12), pp. 11-17. Available at: https://www.researchgate.net/publication/262312722_Bio-ethanol_production_from_poultry_manure_at_Bonga_Poultry_Farm_in_Ethiopia.

Grammarly (2025) *Grammarly [AI software]*. Available at: https://www.grammarly.com (Accessed: 18 January 2025).

Harvard Graduate School of Design (2025) 'Place-Based Scenario Planning for the Climate Emergency: Spring 2025' [online]. Available at: https://www.gsd.harvard.edu/course/place-based-scenario-planning-for-the-climate-emergency-spring-2025/ (Accessed: 23 October 2024).

Harvard Graduate School of Design (2024) *Envisioning the Rural Metropolis: Syllabus* [online]. Available at: https://www.gsd.harvard.edu/course/envisioning-the-rural-metropolis-spring-2024/ (Accessed: 23 October 2024).

Kahn, H. (1965) *Thinking About the Unthinkable*. New York: Horizon Press.

Koolhaas, R. and AMO (2020) *Countryside: A Report*. Cologne: Taschen.

Kurtagić, S., Trožić-Borovac, S., Bijelić, B., and Hadziahmetovic, H. (2022) 'Sustainability Assessment of Small Hydropower Plants', *DAAAM International Scientific Book*, pp. 0123-0132. doi: 10.2507/33rd.daaam.proceedings.018.

Lei, Z.D. (2002) 'Concept of Rural Settlement Vacancy and its Quantitative Analysis Model', *Journal of Northwest University Natural Science Edition*, 32(4), pp. 421.

Lei, Z.D. (2009) *Integration and Reconstruction: A Study on the Transformation of Guanzhong Village Settlements*. Nanjing: Southeast University Press.

Lin, Y. and Tanaka, S. (2006) 'Ethanol Fermentation from Biomass Resources: Current State and Prospects', *Applied Microbiology and Biotechnology*, 69(6), pp. 627-642. doi: 10.1007/s00253-005-0229-x.

OpenAI (2025) *ChatGPT (Jan 2025 version) [AI software]*. Available at: https://www.openai.com (Accessed: 18 January 2025).

Pallagst, K., Aber, J., Audirac, I., Cunningham-Sabot, E., Fol, S., Martinez-Fernandez, C., Moraes, S., Mulligan, H., Vargas-Hernandez, J., Wiechmann, T., Wu, T. and Rich, J. (eds.) (2009) *The Future of Shrinking Cities: Problems, Patterns and Strategies of Urban Transformation in a Global Context* [online]. eScholarship. Available at: https://escholarship.org/uc/item/7zz6s7bm (Accessed: 23 October 2024).

Robinson, K.S. (2012) *2312*. London/New York: Orbit.

Schwartz, P. (1991) *The Art of the Long View: Planning for the Future in an Uncertain World*. New York: Currency Doubleday.

Town Green 2025 (n.d.) 'HU CACC Research Proposal' [online]. Available at: https://towngreen2025.org/perch/resources/hucaccresearchproposal.pdf (Accessed: 23 October 2024).

Unami, K., Yangyuoru, M., Alam, A.H.M.B. and Kranjac-Berisavljevic, G. (2013) 'Stochastic Control of a Micro-Dam Irrigation Scheme for Dry Season Farming', *Stochastic Environmental Research and Risk Assessment*, 27(1), pp. 77-89. doi: 10.1007/s00477-012-0555-3.

Research Paper

Spatial justice education in non-democratic planning spaces: A case study of Jordan

Nermeen Dalgamoni, Jordan University of Science and Technology, Jordan

Yasmein Okour, Jordan University of Science and Technology, Jordan

Abstract

Spatial justice education provides urban planners with the necessary tools to employ just and equitable planning practices. However, current spatial justice education does not effectively explore spatial justice applications in non-democratic spaces. For example, when joining the workforce, urban planning graduates in non-democratic spaces are forced to navigate power dynamics, varying interests, and corruption in their everyday professional practices. Generally, sources of unethical planning practices and decision-making create barriers to applying spatial justice tools and theories. This research explores the limitations of spatial justice education in Jordan, where curricula are based on Western concepts and disconnected from the realities of local governance and decision-making.

This study answers two research questions: (1) What are the limitations of current spatial justice education in Jordan? and (2) What coping mechanisms do planners use to navigate non-democratic practices in the planning discipline in Jordan? Semi-structured interviews with educators and practitioners were employed in this study. The findings suggest that current education in Jordan does not adequately prepare urban planning students for the complexities of local power dynamics, nor does it integrate community knowledge necessary for just outcomes. Planners often rely on inefficient coping mechanisms, such as networking, to address power dynamics, while job insecurity and grassroots advocacy remain significant challenges. The study concludes by calling for adaptive spatial justice education that considers diverse sociopolitical contexts, emphasizing the need for local knowledge and broader support systems in urban planning practice.

Keywords

Power dynamics, non-democratic spaces, adaptive spatial justice tools.

1. Introduction

According to the literature, spatial justice education provides urban planners with the necessary tools to employ just and equitable planning practices. However, current spatial justice education does not effectively explore spatial justice applications in non-democratic spaces. For example, when joining the workforce, urban planning graduates in non-democratic spaces are forced to navigate power dynamics, varying interests, and corruption in their everyday professional practices. Generally, sources of various interests within the planning practices and decision-making processes create barriers to applying spatial justice tools and theories.

Taking a better understanding of this challenge, we explore spatial justice education and planning practice in local governments in Jordan. We argue that current spatial justice education in Jordan operates in a metaphorical space that draws from Western conceptions of spatial justice and planning practice without consideration of actual spaces of decision-making. Specifically, the research questions are (1) What are the

limitations of current spatial justice education in Jordan? And (2) What are the coping mechanisms and tools that urban planners seeking spatial justice employ in non-democratic spaces?

1.1. Planning in Jordan

Jordan has witnessed rapid urbanization combined with socio-economic challenges in addition to the political unrest in the surrounding countries. All these factors increased the pressure on the Jordanian limited resources and contributed to the recent planning practices and decisions (Alnsour, 2016; Ababsa, 2018). Urban development and planning initiatives in Jordan are typically carried out using a master planning approach (Okour et al., 2024). However, these master plans have faced criticism for lengthy preparation and approval times, as well as limited engagement with local communities (Abu-Dayyeh, 2004; Beauregard & Marpillero-Colomina, 2011; Meaton & Alnsour, 2012).

Several actions have been taken to reform current urban planning practices in Jordan including a shift toward strategic planning, supporting planning capacities at the municipal levels, and enhancing public participation (Beauregard & Marpillero-Colomina, 2011). Planning reform in Jordan requires a more robust alignment between the scientific research in the planning discipline and the governmental policies and strategies to contextualize sustainable development objectives to address the ongoing challenges facing the Jordanian cities. Thus, decision-makers need to prioritize a research agenda that align and responds efficiently to the urban challenges that face each city across Jordan (Okour et al., 2024).

1.2. Planning Education in Jordan

Several universities in Jordan offer undergraduate and graduate programs in urban planning and related fields, such as architecture. However, these curricula remain largely theoretical, with a predominant emphasis on planning history, urban theories, and technical aspects, often lacking integration of context-specific urban challenges. Additionally, as most of these programs are housed within architecture faculties, they prioritize the physical dimensions of the built environment, with limited focus on the social and economic dynamics that shape communities and lack the interdisciplinary approach needed (Tawil & Beaumer, 2018).

Urban planning education in Jordan is witnessing a notable development in the scope and applications to address national issues such as rapid urbanization, socio-economic challenges, and environmental concerns. However, there is still a gap between the acquired skills in academic programs and those required in the field due to a weak focus on practical, project-based learning and insufficient engagement with local planning authorities and private sector stakeholders (Zeadat & Haddad, 2024).

While many faculty members in Jordan advocate for integrating more critical issues, such as spatial justice, smart cities, and sustainable urban development, in planning education, they face challenges that limit abilities such as limited financial and educational resources, access to training, weak support to the role of researchers in the national decision-making process, and limited opportunities for international collaboration (Tawil & Beaumer, 2018).

Planning curricula in Jordanian universities require serious efforts to develop the learning outcomes to bridge the gap between the academic and the job market requirements, and thus, equip planning program graduates with the necessary knowledge, skills, and competencies needed to participate in the national sustainable development effectively. To achieve this, place-based learning practices and the involvement of local planning authorities and stakeholders in the learning process, especially when designing program learning outcomes, are urgent. Moreover, curricula reform will strengthen the role of academic institutions in shaping national policies and regulations through inter/transdisciplinary approaches that offer new

opportunities for professional development and capacity building to bridge the gap between academia and professional practice (Al-Kodmany & Ali, 2013; Tawil & Beaumer, 2018).

1.3. Study Objectives

The research seeks to bridge the gap between planning education and practice in spatial justice, fostering a more equitable and just spatial planning environment in Jordan. This study aims at:

1. Provide a comprehensive understanding of the role of spatial justice education in non-democratic planning spaces
2. Offer practical solutions to improve spatial justice in Jordan
3. Bridge the gap between education and practice in spatial justice.
4. Advancing spatial justice in non-democratic spaces and ultimately contributing to more inclusive and sustainable urban development in Jordan.

2. Methods

This study investigates the integration of spatial justice education and planning practices within local governments in Jordan. We contend that the current framework of spatial justice education in Jordan operates within a metaphorical space heavily influenced by Western conceptions, often neglecting the contextual realities of local decision-making processes. The research employs semi-structured in-depth interviews as the primary data collection method, engaging two distinct participant groups.

The first group consists of planning educators (N=10) from both public and private universities, who teach within planning or architecture programs. The interview questions aim to assess the existing tools and platforms for spatial justice education, evaluate the extent to which planning curricula incorporate spatial justice concepts, investigate the effectiveness of course content in addressing spatial justice issues, and identify the strategies educators employ to teach these concepts, alongside the challenges they encounter in integrating spatial justice into their pedagogical objectives.

The second group includes practicing professionals (N=11) who hold degrees in urban planning, allowing for an exploration of how they define and interpret spatial justice in their professional practice. This group's interviews focus on the challenges faced when implementing planning interventions for marginalized communities, the practical solutions adopted to overcome these challenges, and the role of community engagement in addressing spatial justice issues.

3. Findings and Discussion

Spatial Justice is perceived through 3 main lenses: physical built environment, social context, and urban governance and management. While each lens discusses spatial justice from a different angle, they all address the impact of urban practices and policies on shaping people's spatial experiences.

3.1. Physical spatial justice

The spatial justice concept refers to the equitable distribution of resources, services, and opportunities among different spatial and social landscapes particularly to disadvantaged populations (Soja, 2010). Literature on public open spaces pointed at the unequal distribution of public open spaces across different social contexts which indicates a sign of inequality (Jian et. al, 2020).

Physical spatial justice discussed by the participants focused on how urban planning practices ensure fair distribution of housing, transportation networks, health facilities, educational institutions, employment, and public spaces concerning the physical structure, layout, and systems of the built environment. Both participant groups argued that the inequitable distribution of these resources would create social segregation and increase social tension. Educators mentioned that class discussions always highlighted the importance of addressing accessibility considerations of different population groups with different abilities regardless of their economic status. Just cities must be walkable and provide easy access to all residents to city public services and amenities. They stated that class discussions included a debate on how to define a "disadvantaged population" regarding physical spatial justice. According to them, physical spatial justice can be perceived from the perspective of physical disabilities, age, and gender. Literature on social justice indicates that vulnerable groups feel unwelcome due to accessibility constraints Low & Iveson, 2016; Wendel, Zarger, & Mihelcic, 2012). Thus, avoid visiting these locations and look for other alternatives (Rigolon, Browning, & Jennings, 2018; Xiao, Lu, Guo, & Yuan, 2017).

On the other hand, while some practitioners and decision-makers have relatively similar perceptions of accessibility, others noted that planning practices in Jordan focus more on the actual accessibility definition regardless of the social dimension. They noted that planning laws, zoning, and land use regulations, transportation services, and housing policies mainly consider the national growth planning strategies and the governmental financial allocation for these types of developments. Governmental efforts, due to limited financial capacities and rabid urbanization, prioritize improving access to essential services such as healthcare, education, and public infrastructure such as water supply, sanitation, electricity, and transportation. The Bus Rapid Transit (BRT) project in Amman, for instance, is a regional transit project that presents a shift in the transportation practices in Jordan. The project aligns with the national strategic plan, Vision 2025, that focuses on promoting environmentally friendly transportation modes, supporting economic growth through transit-oriented districts along the bus corridor, and improving access to services and opportunities through affordable mobility.

3.2. Social spatial justice

According to Morani, 2020, social justice issues come to the surface when a specific power structure requires justification (Morani, 2020). This lens investigates how social factors influence the distribution of resources and how spaces are used and experienced by different social groups. According to the participants, this lens is the most complicated and least defined one. Social variables are intangible and, in many cases, hard to measure. Under this lens, several key issues were highlighted by the participants including power and control over urban space, spatial segregation and marginalization, resource inequity, limited public participation, gentrification, and security and surveillance.

Both participant groups pointed at the top-down political structure in Jordan and the centralized governance system as the main reasons to limit public participation and transparency and favor the need for higher income and more powerful population groups. Accordingly, service distribution and the quality of service significantly varies among neighborhoods. The unequal distribution of these services leads to spatial segregation. Planning decisions, zoning laws, and housing policies contribute to this spatial segregation (Talen,2012; Denton, 2000). While many decision-makers avoided admitting that current planning policies created notable segregation between urban and rural communities, between one city to another, and even between communities within the same city, other participants highlighted this segregation and related it to the political economy of urban development. They noted that powerful actors such as real estate developers, investors, and political elite can orient spatial policies to posterize economic development over spatial and social justice.

Several participants pointed to the AL-Abdali Boulevard project as an example of how current planning regulations in Amman created a semi-private district that limits access to population groups, even in a non-direct way. While the goal of this project was to create a high-end development in the heart of the city to modernize planning practices in Jordan (Sharaf, et. al, 2023), the project took over a significant part of the old downtown and replaced it with high-value luxury apartments, hotels, and retail stores. According to one educator who took Al-Abdali as a study area in one of her planning classes, this project favored attracting foreign investments over keeping the city's identity or providing more affordable public spaces. Many residents had to leave the neighborhood since they felt unwelcome and/or unable to keep up with the new lifestyle. She noted that while many students discussed this project as an enhancement of the physical built environment, other students highlighted how physical design decisions can contribute to social segregation and foster spatial injustice. Moreover, the Al-Abdali Boulevard project is also an example of how powerful economic players orient planning priorities to favor economic development objectives over spatial justice and inclusive design and urban expansion over disparities across communities.

3.3. Urban governance and management of social spaces

Urban governance structure in spatial planning draws the role of institutions, policies, and decision-making processes in ensuring equitable distribution of resources, services, and opportunities among various communities. This structure includes public and private institutions, civil society, and the laws and regulations that participate in managing urban spaces and resources. Both participant groups discussed the multi-level governing system that requires collaboration between local and national governments to formulate just urban policies that address the complexities of spatial issues and to ensure the success of implementing these policies.

Participants also discussed that to achieve spatial justice, a participatory planning approach should be enacted to ensure that marginalized groups have a voice in shaping their spatial experiences. Educators discussed some of their experiences working with the local communities of the study areas covered in their classes. They argued that involving local representatives in designing the development vision helped the students to propose design guidelines and solutions that were more welcomed by the local community. Moreover, local representatives noted that they were more willing to share their experiences and expectations with the students than with governmental representatives.

Practitioners and decision-makers highlighted some of the challenges that might hinder the efforts of implementing spatial justice in a non-democratic planning context. Adopting a participatory governance and management approach may face power imbalances, limited resources, weak institutional capacities, a lack of political will, and limited trust between citizens and the government. They noted that even in democratic or non-democratic contexts, power dynamics and political economies play a critical role in shaping the way that governments implement spatial justice. They added that identifying "marginalized" groups and development "objectives" when discussing spatial policies and actions are linked, in most cases, to the national economic growth priorities, international development agendas, and funding international organization scope of work. Accordingly, suggests developing a new governance approach that can be adopted at multiple levels including individuals, communities, institutions, as well as new groups of actors and practices (Jansson et. al, 2020).

Achieving spatial justice in a non-democratic planning context requires urban planners to adopt a holistic approach to adequately navigate the multi-dimensional aspects of the concept, political and economic power dynamics, and complicated political interests. The adaptive approach must emphasize participatory urban policy development, promote equity-focused planning laws, and target balanced growth and social inclusivity (Alnsour, 2016).

3.4. Integrating spatial justice in planning education and practice

The findings suggest that current spatial justice education in Jordan does not incorporate diverse levels of learning beyond academia and the importance of cumulative local community knowledge to achieve spatial justice. The findings also highlight that students are not equipped with the necessary tools and skills to address power dynamics in urban planning decision-making. Moreover, coping mechanisms employed by urban planners are not efficient in addressing the multi-dimensionality and political conflicts in planning practices. Specifically, job insecurity associated with challenging power dynamics and advocating for and empowering grassroots movements are key barriers. The main coping mechanism identified is networking within and outside the spaces of planning practice and maintaining broader support systems.

Integrating spatial justice into planning education and practice requires addressing the interconnected relationships between equity, access, and social inclusion into the planning curricula and the professional settings. Several actions can take place including curricula reform to create an interactive learning environments, facilitate designing with the community workshops to localize planning solutions, implement public engagement platforms to enhance participatory approach, and building institutional partnerships to foster interdisciplinary collaboration.

Advancing spatial justice in Jordan requires enhancing urban planning education through a comprehensive place-based framework that addresses the unique socio-economic and political dynamics of the Jordanian context, promotes collaboration among different disciplines, and empowers future planners and building their capacities to equip them with required knowledge, skills, and competencies to navigate power dynamics. This can be achieved through integrating local community knowledge and sociopolitical realities into planning curricula, reforming the urban governing system, and supporting innovation in planning practices. Some challenges may hinder efforts to promote special justice including institutional barriers, social and cultural factors, economic constraints, and political dynamics.

4. Conclusion

In general, this study highlights the limitations of current spatial justice education in nondemocratic planning spaces and calls for adopting adaptive spatial justice teaching and learning practices that consolidate broader sociopolitical contexts. The findings of this paper underscore the urgent need for an integrated practical approach to spatial justice integration in Jordan. Curricula reform, incorporating community knowledge, equipping future planners with the necessary knowledge, skills, and competencies to address and navigate power dynamics, and providing robust support systems for urban planners, we can move toward more ethical and just planning practices. Empowering both planners and communities to advocate for equitable spatial arrangements is essential for achieving long-term sustainability and justice in urban development.

Future research should investigate different adaptive pedagogical approaches to evaluate the effectiveness of teaching methodologies tailored to spatial justice education in nondemocratic planning contexts. Analyzing the learning outcomes of these methods will provide educators with toolkits and insights into best practices for spatial justice education. Future research should also investigate the multidimensional relations between governmental policies, educational institutions, community knowledge, and urban development agenda to examine the broader sociopolitical factors that influence the integration of spatial justice principles into urban planning education. Future research will also aim at developing a framework for curriculum reform that aligns spatial justice and addresses the limitations and challenges within nondemocratic planning environments to propose strategies to overcome resistance.

5. References

Ababsa, M., Ababsa, M., Dupret, B. and Denis, E., 2012. Public Policies Toward Informal Settlements in Jordan (1965–2010). Popular Housing and Urban Land Tenure in the Middle East: Case Studies from Egypt, Syria, Jordan, Lebanon, and Turkey, pp.259-82.

ABU-DAYYEH*, N.I., 2004. Persisting vision: plans for a modern Arab capital, Amman, 1955–2002. Planning Perspectives, 19(1), pp.79-110.

Al-Kodmany, K. and Ali, M.M., 2013. The future of the city: Tall buildings and urban design. WIT press.

Alnsour, J.A., 2016. Managing urban growth in the city of Amman, Jordan. Cities, 50, pp.93-99.

Beauregard, R.A. and Marpillero-Colomina, A., 2011. More than a master plan: Amman 2025. Cities, 28(1), pp.62-69.

Denton, N.A., 2000. The role of residential segregation in promoting and maintaining inequality in wealth and property. Ind. L. Rev., 34, p.1199.

Jansson, M., Vogel, N., Fors, H., Dempsey, N., Buijs, A. and Randrup, T.B., 2020. Defining urban open space governance and management. In Urban open space governance and management (pp. 11-29). Routledge.

Jian, I.Y., Luo, J. and Chan, E.H., 2020. Spatial justice in public open space planning: Accessibility and inclusivity. Habitat International, 97, p.102122.

Low, S. and Iveson, K., 2019. Propositions for more just urban public spaces. In The Routledge Handbook of People and Place in the 21st-Century City (pp. 135-154). Routledge.

Meaton, J. and Alnsour, J., 2012. Spatial and environmental planning challenges in Amman, Jordan. Planning Practice and Research, 27(3), pp.367-386.

Moroni, S., 2020. The just city. Three background issues: Institutional justice and spatial justice, social justice and distributive justice, concept of justice and conceptions of justice. Planning Theory, 19(3), pp.251-267.

Okour, Y., Dalgamoni, N. and Al-Rqaibat, S.A., 2024. Researching the Jordanian city: toward an urban planning research agenda in Jordan. Archnet-IJAR: International Journal of Architectural Research.

Rigolon, A., Browning, M. and Jennings, V., 2018. Inequities in the quality of urban park systems: An environmental justice investigation of cities in the United States. Landscape and urban planning, 178, pp.156-169.

Sharaf, F.M., Çinar, H.S. and Irmeili, G.A., 2023. Quality Evaluation of Public Pedestrian Spaces: The Case of Abdali Development in Amman City, Jordan. Civil Engineering and Architecture, 11(5), pp.2321-2335.

Soja, E., 2010. Spatializing the urban, Part I. City, 14(6), pp.629-635.

Talen, E., 2012. Zoning and diversity in historical perspective. Journal of Planning History, 11(4), pp.330-347.

Tawil, M. and Baeumer, K., 2018. New perspectives for planning education in the Middle East: added value through intercultural dialogue. International Development Planning Review, 40(2), pp.121-141.

Wendel, H.E.W., Zarger, R.K. and Mihelcic, J.R., 2012. Accessibility and usability: Green space preferences, perceptions, and barriers in a rapidly urbanizing city in Latin America. Landscape and urban planning, 107(3), pp.272-282.

Xiao, Y., Lu, Y., Guo, Y. and Yuan, Y., 2017. Estimating the willingness to pay for green space services in Shanghai: Implications for social equity in urban China. Urban Forestry & Urban Greening, 26, pp.95-103.

Zeadat, Z.F. and Haddad, N.A., 2024. Insights on the obstacles, challenges, and complexities of engaging youth in urban planning in Jordan: assessment and recommendations. Archnet-IJAR: International Journal of Architectural Research.

Research Paper

Characterizing the spatial and temporal correlation between urban shrinkage and social-ecological system resilience

A case study of Liaoning Province, China

Hong LENG, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Tianyu ZHANG, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Qing YUAN, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

The number of shrinking cities in China is increasing and they are generally facing an incompatibility between urban social and ecological development. This phenomenon may contribute to the declining social-ecological system resilience of shrinking cities, and thus the government will needs new planning and governance strategies to enhance the level of social-ecological system resilience in cities, while responding to the future transformation and sustainable development needs of shrinking cities. This study attempts to establish a research perspective related to the coupling of urban shrinkage and social-ecological system resilience. Taking cities in Liaoning Province, China, as an example, it identifies the spatial and temporal trajectories of urban shrinkage and social-ecological system resilience over the past 20 years, and reveals the correlation level and characteristics of the two trajectories. The results of the study show that: (1) The degree of population shrinkage in Liaoning Province slowed down over the two periods studied here, while the shrinkage of population structure showed an aggravating trend. (2) The social-ecological system resilience of most of cities increased first and then fell back, while the difference is obvious between the center and edges. (3) There may be a time lag characteristic in the impact of population shrinkage on social-ecological system resilience.

Keywords

urban shrinkage, urban resilience, spatial-temporal evolution, coupled coordination

1. Introduction

While facing challenges such as global climate change and industrial shifts, shrinking cities are generally lacking in the ability of response and recovery(Zhang 2017, p. 2). As a result, they are more likely to experience economic degradation and environmental collapse, which represents shrinking cities in a more sensitive socio-ecological system state.

Currently, “social-ecological system resilience” has become a new research hotspot, which emphasizes the interaction and dependency between social systems and ecosystems, and focuses on the system's ability

to adapt, transform, as well as learn and innovate(Folke 2006, p. 253; Mayar 2022, p. 8327). "Social-ecological system", also known as 'human-natural coupling system', refers to the coupling system characterized by complexity, non-linearity, uncertainty and multi-layer nesting that is formed by the interaction between human society and the ecological environment(Liu 2023, p. 6930; Zhang 2022, p. 199). "Resilience" refers to the ability of a system to maintain stability and recover gradually in the face of external disturbances(Holling 2001, p. 390).

Socio-ecological system resilience emphasizes the coordination of multiple dimensions of the urban system and represents the ability of cities to respond, adjust and transform in response to external shocks and pressures(Wang 2023, p. 9564). Maintaining a sufficient level of socio-ecological system resilience can effectively resist and minimize the risks and negative impacts of urban contraction, and at the same time support the recovery of the shrinking cities(Allen 2016, p. 844). As an integrated and dynamic sustainability research paradigm, the social-ecological system resilience research method can also provide theoretical support and new methodological perspectives for the sustainability research of shrinking cities. This will help to promote a more scientific and rational process of adapting to urban shrinkage(Feldhoff 2013, p. 99), which is of great significance to the sustainable development and construction of shrinking cities.

However, the relationship between urban shrinkage and social-ecological system resilience remains unclear in existing studies. Therefore, this study attempts to establish a research perspective on the correlation between urban shrinkage and social-ecological system resilience. Taking Liaoning Province cities in Northeast China as an example, we identify the spatio-temporal evolutionary trajectories of urban shrinkage and socio-ecological system resilience over the past 20 years, and compare the degree of correlation and characteristics of the two trajectories. These perspectives can provide a scientific basis for future investigations of governance strategies that harmonize the goals of shrinking cities' transformation with the goals of social-ecological system resilience enhancement.

2. Methods and Data

2.1. research area

In Northeast China, the resource-driven and heavy-industry-dependent development model prevalent during the planned economy era brought huge economic benefits to the city, and the cities expanded rapidly. However, under the influence of the global economic crisis and the shift in the center of industrial gravity, the city's traditional advantages have gradually disappeared, resulting in a significant economic downturn, growing unemployment, a sharp decline in population, and a large number of vacant properties(Lu 2022, p. 12). At the same time, contradictions between human activities and the ecological environment, caused by the early model of rough development, are gradually coming to the forefront. For these reasons, the Northeast has become a typical region with the most serious population loss in China(Guo 2021, p. 119).

The research area of this paper is Liaoning Province in China, which has certain special characteristics in the northeast region. First, Liaoning Province is located in the southern part of the Northeast region, and is the gateway to the Northeast region's opening up to the outside world, and has an important position in the implementation of the "One Belt, One Road" construction and the promotion of the comprehensive revitalization of the Northeast. Secondly, unlike Heilongjiang and Jilin provinces, where population contraction is relatively stable and GDP grows slowly and then stabilizes(Yang 2019, p. 63), Liaoning's GDP showed a "precipitous decline" after 2012, and there is a large volatility in both population and economic changes(Du 2022, p. 515). In addition, there is a serious paradox between population decline and spatial expansion in Liaoning Province, and the issues of "empty cities" and "ghost cities" are prominent, resulting

in a series of problems such as ecological damage, dilution of the social network, and waste of public facilities(Yang 2015, p. 20), and the social-ecological system is facing greater vulnerability. Therefore, the transformation and development of shrinking cities in Liaoning Province and the enhancement of system resilience have become representative key issues.

2.2. Research Methods

(1) Measurement of population shrinkage

The degree of population shrinkage is calculated in two periods, 2000-2010 and 2010-2020.

The shrinkage in population size is characterized with the rate of change in the resident population of the city, by the formula(Luo 2024, p. 1060):

$$PQR_i = (\sqrt[n]{\frac{PQ_{i2}}{PQ_{i1}}} - 1) \times 100\%$$

Liaoning Province is currently facing an increasingly severe aging. Population shrinkage occurs not only in terms of quantity, but also in terms of structure. Population aging is the most intuitive indicator to reflect the shrinkage of population structure, this paper uses the rate of population aging change to characterize population structure shrinkage, the formula is(Luo 2024, p. 1060):

$$PAR_i = (\sqrt[n]{\frac{PA_{i2}}{PA_{i1}}} - 1) \times 100\%$$

In this paper, the population aging indicator is used to amend the academic population shrinkage measure with the population size as a single dimension, therefore, the formula for calculating the population shrinkage is as follows(Luo 2024, p. 1060):

$$PCR_i = mPQR_i + kPAR_i$$

(2) Measurements of social-ecological system resilience evolution

The evaluation of social-ecological system resilience is accomplished using an evaluation system consisting of four dimensions: ecological environment, infrastructure, economic level, and socio-cultural, and the weights of the indicators are determined by the entropy method(Liang 2023, p. 49).

In order to eliminate the effect of the difference in the scale on the results, it is necessary to standardize the values of each indicator, and this study uses the polar value method for standardization(Gan 2022, p.58).

For positive indicators (larger is better), Eq:

$$x'_{tij} = \frac{x_{tij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}$$

For negative indicators (smaller is better), Eq:

$$x'_{tij} = \frac{\max(x_{ij}) - x_{tij}}{\max(x_{ij}) - \min(x_{ij})}$$

Calculate the social-ecological system resilience index for the years 2000, 2010 and 2020 with the formula(Li 2024, p. 6):

$$p_{tij} = \frac{x'_{tij}}{\sum_{t=1}^{k}\sum_{i=1}^{n} x'_{tij}}$$

$$e_j = -\frac{1}{\ln(nk)}\sum_{t=1}^{k}\sum_{i=1}^{n} p_{tij}\, ln\, p_{tij}$$

$$d_j = 1 - e_j$$

$$w_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$$

$$u_i^l = \sum_{j=1}^{m^l} w_j p_{tij}$$

$$R_i = \sum_{l=1}^{4} u_i^l$$

Table 1. Indicator system of socio-ecological system resilience for Liaoning province. Source: table created by the author.

Objective level	Normative level	Evaluation elements	Indicators	Attributes	Weights
Ecology	Absorption	Ecological stress	X_1 Total annual value of PM2.5 (t) X_2 Per capita impervious area (km2)	- -	0.055 0.058
	Adaptation	Vegetation Cover	X_3 Green coverage rate of built-up area (%) X_4 Green space per capita (㎡)	+ +	0.055 0.052
	Transformation	Pollution control	X_5 Centralized sewage treatment (%) X_6 Harmless treatment of domestic garbage (%)	+ +	0.055 0.02
Infrastructure	Absorption	Capacity of supply and discharge	X_7 Length of drainage pipes (km) X_8 Road area per capita (km2)	+ +	0.027 0.052
	Adaptation	Capacity of Disaster Relief	X_9 Number of beds in hospitals and health centers (beds) X_{10} Municipal utilities fixed asset investment (10000 yuan)	+ +	0.042 0.004
	Transformation	Informatization level	X_{11} Number of cell phone subscribers at the end of the year (10,000 households)	+ +	0.034 0.018

			X_{12} Number of Internet broadband access subscribers (10,000 households)		
Economic level	Absorption	Economic Performance	X_{13} GDP growth rate (%) X_{14} Total Retail Sales of Consumer Goods (billion yuan) X_{15} Fixed Asset Investment (10000 yuan)	+ + +	0.058 0.029 0.033
	Adaptation	Economic Stability	X_{16} Local general financial revenue (10000 yuan) X_{17} Per capita household savings deposit balance (10000 yuan)	+ +	0.044 0.019
	Transformation	Economic structure	X_{18} Concentration index of tertiary structure X_{19} Foreign Investment Dependence (%)	+ -	0.051 0.059
Socio-cultural	Absorption	Social Governance	X_{20} Employment rate (%) X_{21} Number of employees in public administration and social organizations (persons)	+ +	0.056 0.032
	Adaptation	Culture and Education	X_{22} Number of books in public libraries (volumes) X_{23} Number of students in primary and secondary schools (persons) X_{24} Number of full-time teachers in general primary and secondary schools (persons) X_{25} Number of full-time teachers in ordinary schools of higher education (persons)	+ + + +	0.021 0.046 0.044 0.017
	Transformation	Science and Technology Innovation	X_{26} Science and Technology Expenditures (RMB) X_{27} Number of Patent Applications (cases)	+ +	0.007 0.012

Note: '+' indicates that the indicator is positive, '-' that it is negative.

Calculate the degree of change in the resilience index RE_i of each city for the two time periods 2000-2010 and 2010-2020, Eq:

$$RE_i = (\sqrt[n]{\frac{R_{i2}}{R_{i1}}} - 1) \times 100\%$$

(3) Pearson correlation test

The SPSS software was used to test whether the data showed a normal distribution, and when the kurtosis was over 10 and the skewness was less than 3, it was determined that the data basically conformed to a normal distribution, then the Pearson correlation method could be applied.

The relationship between urban population shrinkage and changes in social-ecological system resilience was quantified using Pearson correlation analysis with the formula(Yi 2023, p. 15):

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

(4) Bivariate spatial autocorrelation analysis

The global spatial autocorrelation formula is(Zhu 2024, p. 325):

$$Moran's\ I = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}W_{ij}(x_i - \bar{x})(y_j - \bar{y})}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}W_{ij}}$$

2.3. Data sources

The administrative division data comes from the National Center for Basic Geographic Information (NCBGI), the update time of the data is January 2024, the review map number is GS (2024) 0650, and the base map has no modification. The LandScan population raster data comes from the Oak Ridge National Laboratory (https://landscan.ornl.gov/), and by summing up the raster values of the cities, we get the population size of each city in Liaoning Province. Population structure data and various socio-economic statistics were obtained from China Statistical Yearbook and China Urban Statistical Yearbook, 2000-2021.

3. Analysis of results

3.1. Characteristics of urban population shrinkage in Liaoning Province

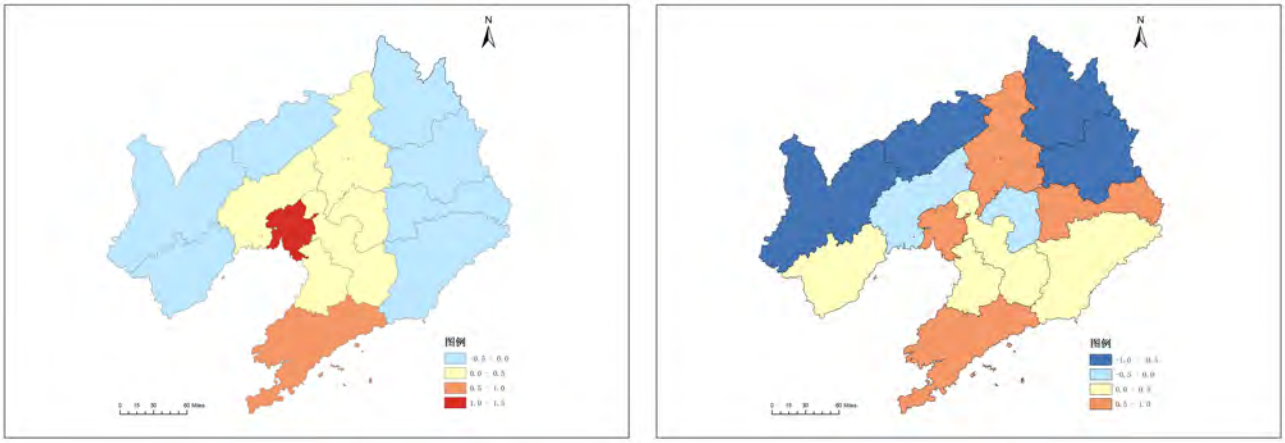
The results show that the shrinkage of population size in Liaoning Province is more severe in the first period and relatively less severe in the second period. Among them, the number of cities with population shrinkage decreased, while the shrinkage of cities with severe shrinkage increased. The shrinkage of population structure in Liaoning Province is more serious, as the province entered the state of aging society in the early stage of the study, and the shrinkage of population structure continues to aggravate with the passing of time.

(1) Characteristics of shrinkage in population size

In terms of quantity, the number of cities with shrinking populations in Liaoning Province decreased from seven to six during the 2000-2010 and 2010-2020 phases, all of which were dominated by resource-based cities. However, four of these cities experienced enhanced shrinkage in population size, namely Chaoyang, Fushun, Fuxin and Tieling. Benxi and Dandong, on the other hand, reversed their population shrinkage and realized population growth.

The spatial distribution of population shrinkage within the two phases are heterogeneous. Among them, the population shrinkage in the first phase presents obvious spatial clustering characteristics, that is, the

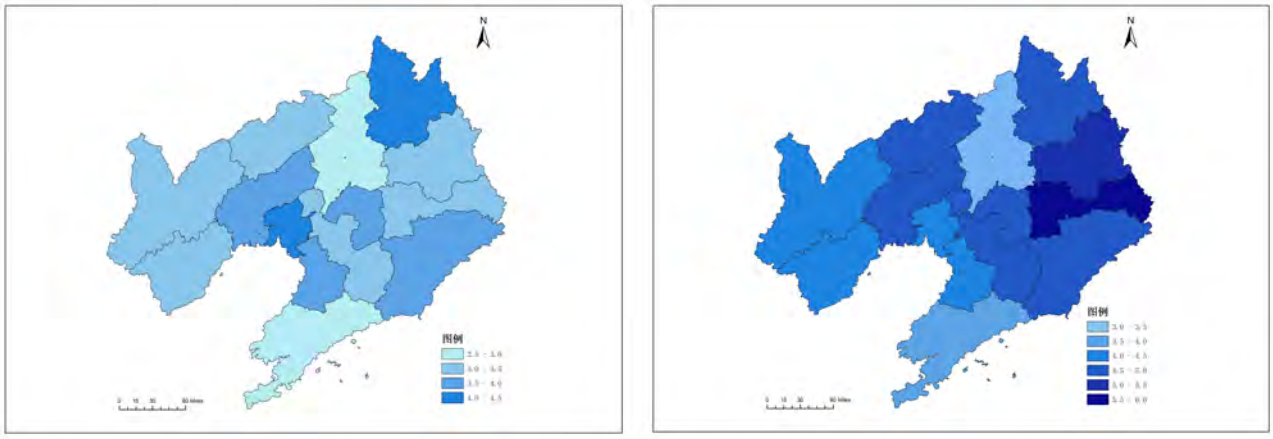
non-shrinking cities are concentrated in the center of the Shenyang-Dalian regional development axis, while the population shrinking cities are concentrated in the fringes of the two flanks. The distribution of the shrinkage in population size in the second stage shows a tendency towards enhanced shrinkage on both flanks and a tendency to spread from the two flanks to the center of the district. In particular, except for Benxi and Liaoyang, the degree of population shrinkage has increased in cities in both flanks, while the two new mildly shrinking cities in the second stage, namely Jinzhou and Liaoyang, are located in the central region.



(a) (b)

Figure 1. Distribution of population size shrinkage. (a) 2000-2010. (b) 2010-2020. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)

(2) Characteristics of shrinkage in population structure



(a) (b)

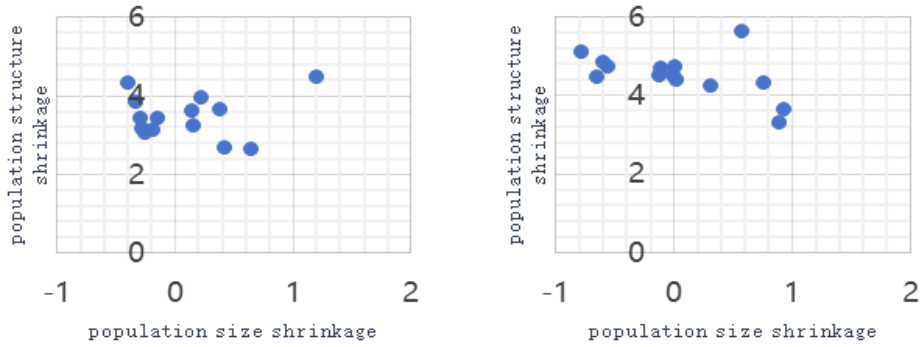
Figure 2. Distribution of population structure shrinkage. (a) 2000-2010. (b) 2010-2020. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)

The results show that the aging rate of all 14 cities in Liaoning Province exceeded 10% in 2000, entering the state of aging society. The rate of population structure change in all the cities in the two phases are

positive, and the values are gradually increasing, which means that the population structure shrinkage in Liaoning Province shows an increasingly serious trend of the labor force population is in a long-term net outflow state.

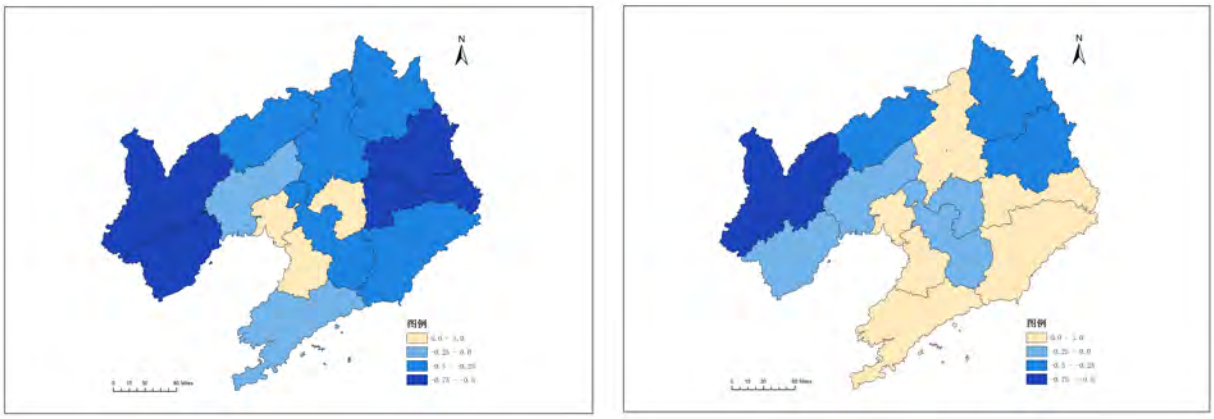
From 2000 to 2010, only the provincial capital city namely Shenyang and the sub-provincial city Dalian showed relatively small rates of population structure shrinkage, while all other cities showed serious population structure shrinkage. From 2010 to 2020, the degree of population structure shrinkage in a large number of cities has further intensified, and a population structure shrinkage belt around Shenyang has appeared. This phenomenon reflects the siphoning effect of central cities on the labor force of surrounding cities.

(3) Characteristics of shrinkage in population dimensions



(a) (b)

Figure 3. Scatterplot of shrinkage in population size versus shrinkage in population structure. (a) 2000-2010. (b) 2010-2020. Source: Drawn by the author.

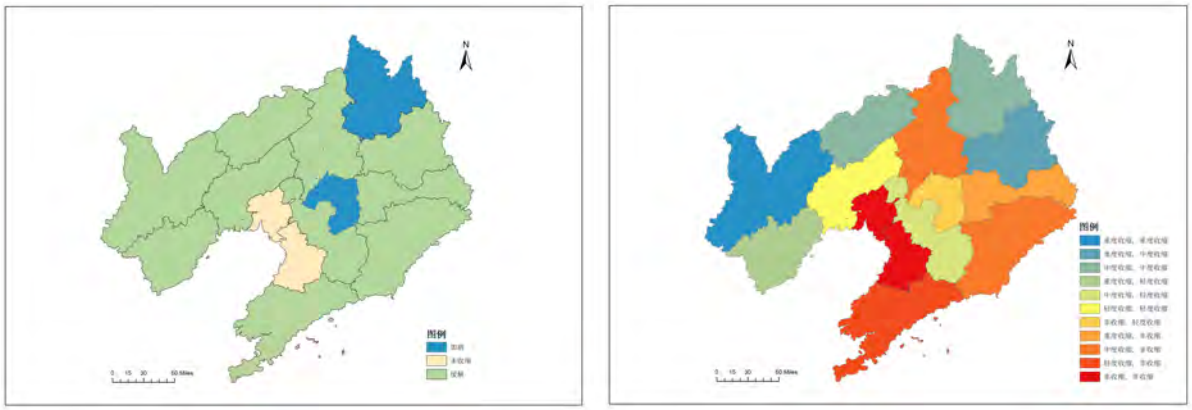


(a) (b)

Figure 4. Combined population shrinkage distribution. (a) 2000-2010. (b) 2010-2020. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)

Within the two phases of the study, the combined population shrinking degree in Liaoning Province showed a trend towards alleviation. Considering the number of shrinking cities, it decreased from 11 to 8. Among them, the number of cities with severe shrinkage decreased from 4 to 1, the number of cities with moderate shrinkage decreased from 5 to 3, and the number of cities with mild shrinkage increased from 2

to 4. Considering the evolution of the shrinking degree, which of all 10 cities has alleviated, and only Tieling and Liaoyang have had their shrinkage aggravated. IConsidering the evolution of the shrinking type, severe and moderate shrinkage are concentrated in the western and northern of Liaoning, while mildly shrinking cities and non-shrinking cities predominate in the region including Shenyang and southeastern of Liaoning. For example, Chaoyang was in the state of severe shrinkage at both phases, Fushun shifted from severe to moderate shrinkage, Huludao shifted from severe to mild shrinkage, and Benxi realized a reversal from a severely shrinking city to a non-shrinking city.



(a) (b)

Figure 5. (a) Evolution of the combined degree of population shrinkage. (b) Evolution of the combined type of population shrinkage. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)

3.2. Characteristics of the evolution of social-ecological system resilience in Liaoning province cities

(1) Overall characteristics of social-ecological system resilience

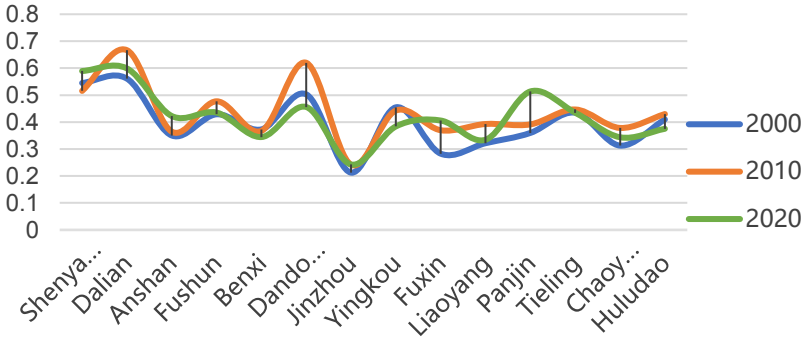
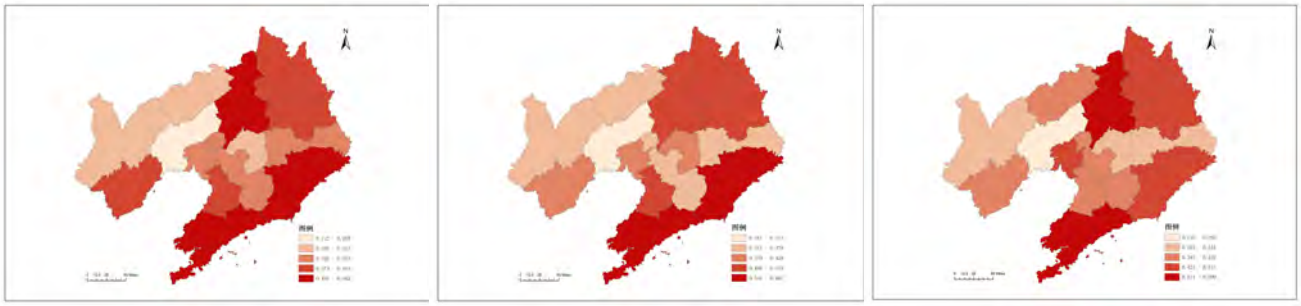


Figure 6. Evolution of social-ecological system resilience indices for cities in Liaoning province. Source: Drawn by the author.

From the results, it can be seen that the cities with the highest social-ecological system resilience in Liaoning Province are Dalian and Shenyang, and the lowest is Jinzhou. In terms of spatial distribution, the social-ecological system resilience of eastern Liaoning is higher than that of western Liaoning, and there is a significant difference between the edges of the centers with Shenyang and Dalian as the central areas. In terms of temporal evolution, the social-ecological system resilience of most cities increases in the first

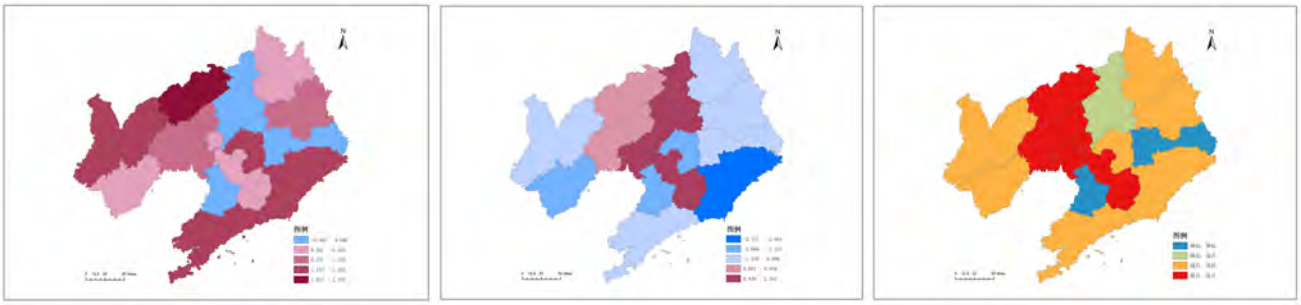
stage, and then falls back in the second stage, with little overall change in resilience. Among them, the cities with reduced social-ecological system resilience from 2000 to 2020 include Benxi, Dandong, Yingkou and Huludao.



(a) (b) (c)

Figure 7. Spatial distribution of socio-ecological system resilience. (a) 2000 (b) 2010 (c) 2020. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)

(2) Characterizing the extent and type of change in socio-ecological system resilience



(a) (b) (c)

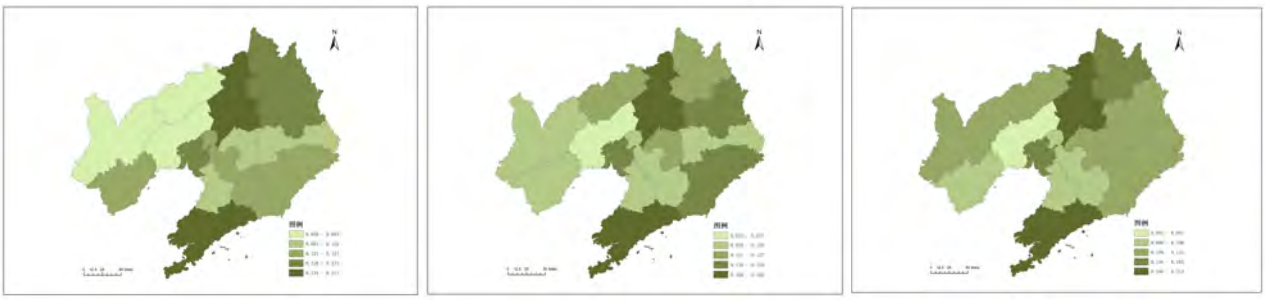
Figure 8. Spatial distribution of the rate of change in socio-ecological resilience. (a) 2000-2010. (b) 2010-2020. (c) Spatial distribution of the type of evolution of socio-ecological resilience. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)

From the perspective of the comprehensive evolution of social-ecological system resilience, the number of cities with reduced resilience in the first stage was only three, while the number increased to nine in the second stage, with a clear downward trend in social-ecological system resilience for the region as a whole. In terms of spatial distribution, the cities with decreasing social-ecological system resilience in the first stage are Shenyang, Yingkou and Benxi, which are mainly located in the central and eastern parts of Liaoning Province, while the situation is reversed in the second stage, with the social-ecological system resilience of the cities in the western and eastern parts of Liaoning declining significantly, while the resilience of the cities in the central part of the region is rebounded, which shows a clear difference between the center and the edges of the region. In terms of the evolving type, the cities with continuously

increasing social-ecological system resilience include Anshan, Jinzhou, Fuxin, and Panjin; the cities with continuously decreasing social-ecological system resilience include Yingkou and Benxi; Shenyang shows a decreasing and then an increasing trend; and the remaining seven cities show an increasing and then a decreasing trend.

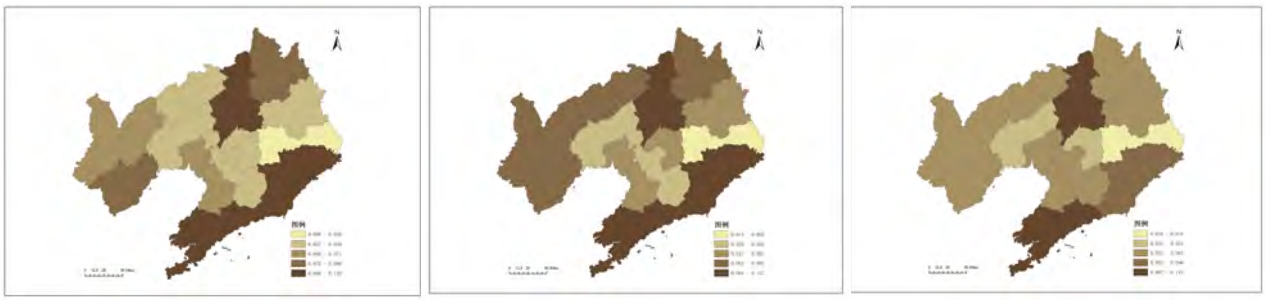
(3) Characteristics of social-ecological system resilience in different dimensions

The ecological environment subsystem resilience index is highest in Shenyang and Dalian, and lowest in Jinzhou. In terms of spatial distribution, at the beginning of the study period, the overall ecological resilience of eastern Liaodong was higher than that of western Liaoning; while in the following 20 years, the ecological resilience of western Liaoning improved, and by the end of the study period, the overall development of ecological resilience was relatively balanced. In terms of temporal evolution, the ecological environmental resilience of Fuxin, Panjin, Tieling and Chaoyang was greatly improved during the study period, Liaoyang, Dandong and Fushun showed an increase and then a decrease, Shenyang and Jinzhou showed a decrease and then an increase, while the fluctuation of the ecological environmental resilience values of the other cities was small.



(a) (b) (c)

Figure 9. Spatial distribution of ecological resilience. (a) 2000 (b) 2010 (c) 2020. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)

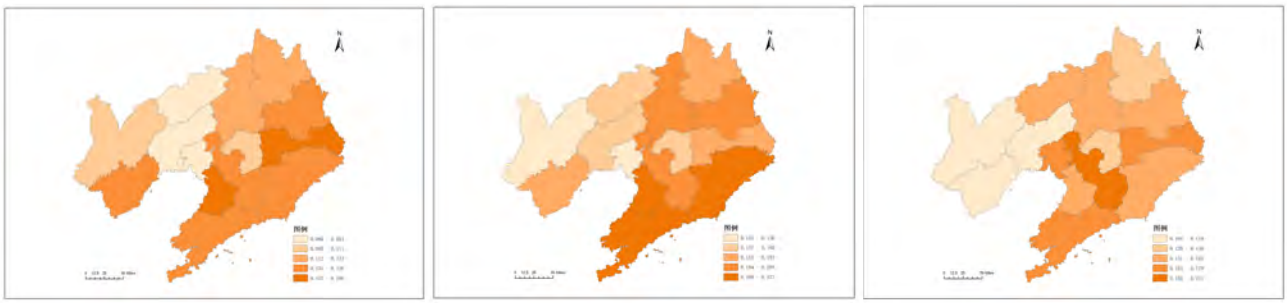


(a) (b) (c)

Figure 10. Spatial distribution of Infrastructure resilience. (a) 2000 (b) 2010 (c) 2020. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)

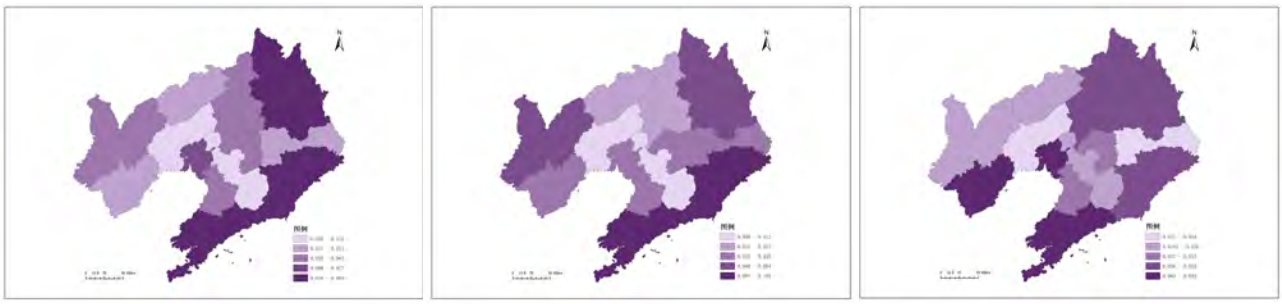
Infrastructure subsystem resilience is highest in Dalian, Shenyang and Dandong, and lowest in Benxi. In terms of temporal evolution, the infrastructure resilience of Dandong declined significantly, while Shenyang, Anshan and Panjin showed a first decline and then a rebound, and the other cities experienced minor fluctuations. Within the first stage, Benxi has the largest increase in the level of infrastructure subsystem resilience and Anshan has the largest decrease; within the second stage, Anshan has the largest increase in the level of infrastructure subsystem resilience and Liaoyang has the largest decrease.

In terms of spatial distribution, the development of the economic subsystem resilience level of cities in Liaoning Province is relatively well-balanced, and the economic subsystem resilience of eastern Liaoning is slightly higher than that of western Liaoning. In terms of temporal evolution, the economic resilience of each city during the study period has a large range of changes, and the economic resilience index of most cities shows a trend of growth followed by a decline, with Benxi showing a sustained decrease, and only Anshan, Panjin and Fuxin showing a sustained growth trend. Among them, the level of economic resilience of Panjin shows the greatest growth within both stages, while Huludao and Dandong show the sharpest decrease in the second stage.



(a) (b) (c)

Figure 11. Spatial distribution of economic resilience. (a) 2000 (b) 2010 (c) 2020. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)



(a) (b) (c)

Figure 12. Spatial distribution of Socio-cultural resilience. (a) 2000 (b) 2010 (c) 2020. Source: Drawn by the author. Source of base map: the open source map data service provided by the National Platform for Common GeoSpatial Information Services (https://www.tianditu.gov.cn/)

In terms of spatial distribution, the trend of increasing resilience level along the coastal belt gradually emerges over time, while the feature of Shenyang and Dalian as the aggregation center of high values is

not obvious. From the perspective of temporal evolution, the social and cultural resilience of each city changed by a large margin during the study period, with nine cities, including Shenyang, Anshan, Yingkou, Fuxin, Panjin, and Huludao, showing a trend of decreasing and then rebounding. Dalian, Benxi, and Dandong, on the other hand, show a rising and then falling trend, with Benxi showing the sharpest decline.

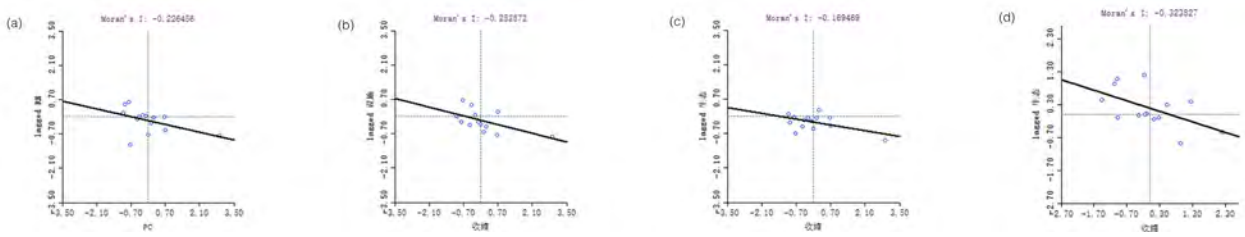
3.3. Relationship between urban shrinkage and social-ecological system resilience in Liaoning Province

(1) Spatial correlations between population shrinkage and social-ecological system resilience

Based on the Geoda software platform, a spatial weight matrix was created to plot the Moran scatter plot of the change rate of population shrinkage and social-ecological system resilience. From the results, it can be seen that the Moran index from 2000 to 2010 is -0.226 and the p-value is 0.047, which passes the significance test, indicating that the rate of population shrinkage and the change rate of social-ecological system resilience show a spatial negative correlation. That is, the more serious the population shrinkage is, the greater the increase or less the decrease in social-ecological system resilience; while the more the population grows, the less the increase or greater the decrease in social-ecological system resilience.The Moran index for the period of 2010-2020 does not pass the test of significance, which indicates that there is no spatial correlation between the rate of population shrinkage and the change rate of social-ecological system resilience in the second stage.

(2) Spatial correlation between population shrinkage and different dimensions of social-ecological system resilience

Moran scatterplot of population shrinkage versus change rate of social-ecological system resilience in different dimensions. In particular, the Moran indices of population shrinkage versus the change rate of infrastructure resilience from 2000 to 2010, population shrinkage versus the change rate of ecosystem resilience from 2000 to 2010, and population shrinkage versus the change rate of ecosystem resilience from 2010 to 2020 are -0.253, -0.169, and -0.324, respectively, and pass the significance test. This indicates that in the first stage, the population shrinkage rate is spatially negatively correlated with the change rate of infrastructure resilience and the change rate of ecological environment resilience; in the second stage, the population shrinkage rate is spatially negatively correlated with the change rate of ecological environment resilience. In addition, the negative correlation between the population shrinkage rate and the change rate of ecological resilience enhanced within the two stages. The population shrinkage rate and the change rate of social-ecological system resilience in other dimensions did not pass the significance test.



(a) (b) (c) (d)

Figure 13. Moran scatterplot of population shrinkage versus rate of change in social-ecological system resilience. Source: Drawn by the author.

4. Discussion

(1) Limitations

This paper analyzes the population shrinkage and social-ecological system resilience changes in 14 cities in Liaoning Province from 2000 to 2020, which provides a certain research basis for exploring the relationship between population shrinkage and social-ecological system resilience changes. However, this paper still has the following limitations. Firstly, this paper utilizes statistical data to construct the index system for measuring the resilience of social-ecological systems, so the research scale still remains at the macro level. Second, this paper utilizes Pearson correlation and spatial correlation to test the relationship between population shrinkage and changes in socio-ecological system resilience, ignoring the effects of latent variables and model endogeneity. Third, the data obtained in this paper may be slightly different from the actual situation due to differences in the quality of statistical data and data availability issues.

(2) Future Research Directions

With the rapid development of big data and remote sensing technology, the future study of the relationship between urban shrinkage and social-ecological system resilience from the geographical scope of the city and the micro-scale will be a valuable potential topic. Second, the interaction effects of population shrinkage and social-ecological system resilience should be explored in the future through more effective quantitative analysis methods. Finally, exploring the relationship between population shrinkage and social-ecological system resilience in different regions will be an important direction for future research.

5. References

Du, P. Liu, L. Wang, G.L. (2022) 'Identification of regional contraction in the context of transformation: A case study of 100 counties in Liaoning province', *Journal of Liaoning Normal University (Natural Science Edition)*, 45 (4), p515–23.

Gan, L. (2022) *Quantitative Evaluation of sDGs sustainable Development Framework of Chengdu-Chongqing Economic Circle*. Chong Qing: Chongqing Normal University.

Li, J.L. Lei, Q.H. Hu, D.W. (2024) 'Characterization of spatial and temporal correlation between human activity intensity and ecosystem service value in the Yangtze River Economic Zone', *Resources and Environment in the Yangtze Basin*, p1–17.

Liang, D. Yao, S. (2023) 'Study on Urban Resilience Evaluation of Liaoning Province Based on Entropy Method and GIS', *Science Technology and Industry*, 23(12), p49–55.

Lu, X. Xu, Z.C. (2022) 'Shrinkage Characteristics and Influencing Factors of County-level Cities in Liaoning Province', *DEVELOPMENT OF SMALL CITIES & TOWNS*, 40(1), p12–19.

Luo, X.L. Jin, X.B. Liu, X.J. (2024) 'Identification and optimization of territorial spatial types based on population shrinking characteristics:A case study of Sichuan Province', *Resources Science*, 46(6), p1060-1073.

Wang, Y.T. Chen, L.D. Li, C. (2023) 'Progress in social-ecological systems research towards the Sustainable Development Goals - based on bibliometric analysis', *ACTA ECOLOGICA SINICA*, 43(22), p9564–75.

Yang, D.F. Long, Y. Yang, W.S. (2015) 'Losing Population with Expanding Space:Paradox of Urban Shrinkage in China', *Modern Urban Research*, (9), p20–25.

Yang, Z.S. Yang, D. (2019) 'Exploring shrinking areas in China availing of city development index', *Human Geography*, 34(4), p63–72.

Yi, L. (2023) 'Exploring the Vitality Enhancement of Waterfront Open Space Based on Pearson's Correlation--Taking the Grand Canal and Xujiang River as an Example', *Annual Conference on Urban Planning in China, 2022/2023*, p15

Zhang, J.X. Feng, C.F. Chen, H (2017) 'International Research and China's Exploration of Urban Shrinking', *Urban Planning International*, 32(5), p1–9.

Zhang, P. Lin, X. Zhang, Y.X. (2022) 'Research on sustainable management framework of urban multi-scale social-ecological system in China', *Journal of China Agricultural University*, 27(7), p199–209.

Zhu, L. Zhao, M. Li, Y.F. (2023) 'The Space-time Relationship between the Ecosystem Service Value and the Human Activity Intensity in Xi' an Metropolitan Area', *Journal of Ecology and Rural Environment*, 40(3), p325-334.

Allen, C.R. Hannah, E.B. (2016) 'Avoiding Decline: Fostering Resilience and Sustainability in Midsize Cities', *Sustainability,* 8(9), p844.

Feldhoff, T. (2013) 'Shrinking Communities in Japan: Community Ownership of Assets as a Development Potential for Rural Japan?', *URBAN DESIGN International,* 18 (1), p99–109.

Folke, C. (2006) 'Resilience: The emergence of a perspective for social–ecological systems analyses', *GLOBAL ENVIRONMENTAL CHANGE-HUMAN AND POLICY DIMENSIONS*, 16 (3), p253–67.

Guo, F. Xiaoqian Q, Yuanyuan M. (2021) 'Spatiotemporal Pattern Evolution and Influencing Factors of Shrinking Cities: Evidence from China', *Cities*, 119, p103391.

Holling, C.S. (2001) 'Understanding the Complexity of Economic, Ecological, and Social Systems', *Ecosystems*, 4(5), p390–405.

Liu, F. Erfu D. Jun Y. (2023) 'A Review of Social–Ecological System Research and Geographical Applications', *Sustainability*, 15(8), p6930.

Mayar, K. David G. Carmichael. (2022) 'Resilience and Systems—A Review', *Sustainability*, 14(14), p8327.

Case Study Report

Trend of New Quality Productivity forces of International Biomedical Parks and the Shanghai Spatial Action Plan

Hao CHEN, Shanghai Tongji Urban Planning & Design Institute, China

Xuanyuan GU, Shanghai Tongji Urban Planning & Design Institute, China

Abstract

International biomedical industry clusters are mainly categorized into four types: research, venture capital, headquarters and manufacturing. The theory of new quality productivity forces provides a new perspective for observing the international cases, in which the emergence of new quality development and new quality spatial demand deserves focused attention. Based on the "four-in-one" new cluster ecosystem, the study optimizes the spatial pattern of Shanghai's existing biomedical industry, and explores the spatial network of new clusters in a hierarchical manner, as well as the guidelines for the allocation of parks around new production and services.

Keywords

New Quality Productivity force, Biomedical Park, Shanghai, Spatial Layout

1. Backgrounds

In September 2023, General Secretary Xi Jinping first put forward the concept of "new quality productivity" at a symposium on comprehensive revitalization of the northeast. New quality productivity has the characteristics of high technology, high performance and high quality, which is generated by the revolutionary breakthrough of technology, innovative allocation of production factors, deep transformation and upgrading of industries, with the progress of workers, labor materials and labor objects and their optimal combinations as the basic connotation, and with the significant increase in the total factor productivity as the core symbol. It is characterized by innovation, the key is quality, and the essence is advanced productivity (Ye, 2024).

New quality productivity is closely related to strategic emerging industries and future industries, and the biomedical industry is a capital-technology dual-intensive industry that meets the development requirements of new quality productivity. Globally renowned biomedical industry clusters and regions are highly specialized regions to demonstrate national strength and create world wealth (Wang, 2019). After the outbreak of the new crown epidemic, governments have increased biomedical industry policy, accelerate the seizure of the commanding heights of biomedical technology and industrialization, and further highlight its major strategic significance for the world's public health protection. China's biopharmaceutical industry started late, and is still in the low-value segment of technology catch-up and the non-core position of the global innovation network (Zhang, 2013). Under the background of domestic

and international double cycle, it is of great strategic significance and practical urgency to comply with the development trend of new quality, optimize the industrial space pattern, match the space needs of new quality, and guide the high-quality transformation and development of the park.

2. Types of international biopharmaceutical clusters and new qualitative development dynamic

2.1. New research-based clusters: moving from "industry-academia-research" to "industry-academia-research-government-medicine" model

Focusing on scientific and technological innovation drive to enhance the new quality of productivity development momentum is a typical feature of most research-based clusters. Compared with other industries, the biomedical industry is characterized by the diversity of innovation subjects, from university research to enterprise mass production between the existence of medical institutions, large research institutions, medical R&D outsourcing service providers and other innovation subjects, all with independent innovation capabilities, especially hospitals rely on their clinical advantages to become a key element of the development of the new quality. In the face of continuous refinement of the industrial innovation track, the traditional "industry-academia-research" model has been difficult to sustain, research-based clusters are gradually shifting to the "industry-academia-research-government-medicine" model.

2.2. New VC-type clusters: from "simple incubation" to "pyramid-style" multi-level support

The high-risk and high-investment characteristics of the biopharmaceutical industry determine that venture capital is crucial for biopharmaceutical venture-based clusters. Compared with large pharmaceutical companies, innovative companies have advantages in creativity, agility, and growth, and it is crucial to capture the needs of startups and realize precise facility support. The diversity, accessibility, and affordability of innovation incubation facilities are the focus of startups. Taking Kobe Medical Industry Metropolis in Japan as an example, it attaches great importance to the provision of rental innovation facilities in the early planning and later operation, giving full play to the role of the government and the market, with professional R&D organizations and business support organizations providing full-cycle solutions ranging from sharing experimental instruments, renting workstations, surgical laboratories and meeting rooms to renting out whole floors and whole buildings with more than 1,000 square meters of workspace.

2.3. New headquarters-type clusters: from "headquarters office" to "new culture and new consumption+"

Integrated biomedical headquarters clusters are characterized by the clustering of large multinational companies' headquarters space, and the clusters are usually located in the heart of the city in order to gather the top management talent and financial capital. Along with new cultural and consumer trends, as well as the iterative evolution of functions in traditional downtown areas, healthcare headquarters have become more than just business offices. Especially for low-rise building space with high commercial value, in Tokyo, Japan, for example, more and more headquarters buildings are opening medical and aesthetic complexes along the street, and also attracting a large number of drugstores, realizing a composite space

that integrates headquarters office, cultural exhibition, drugstore sales, medical and aesthetic plastic surgery, and health care.

2.4. New modeling clusters: from “local clusters” to “regional synergies”

Manufacturing clusters usually rely on the government to take the lead in establishing them, and carry out industrial chain integration and cost control to gain competitive advantages through policy preferential subsidies and infrastructure provision, etc. Path dependence is one of the important reasons for the formation of local industrial clusters. Most of the parks are located in low-rent areas on the outskirts of cities, and the surrounding raw materials and supply chain services are complete, which is the main type of biomedical parks in China and India. In terms of management system, China's “government-led, enterprise-led” model has realized the local cluster pattern of enterprises transferring to the parks for a certain period of time by virtue of policy preferences, but with the reduction of local financial subsidies and the further reduction of regional transportation and logistics costs in recent years, cross-regional manufacturing collaboration has gradually become a new trend.

3. Industrial Spatial Reconfiguration and Factor Allocation Driven by New Quality Productivity: The Case of Shanghai

3.1. Development Path: Constructing a “Four-in-One” New Quality Cluster Ecosystem

Whether it is traditional productivity or new quality productivity, the combination and matching of labor means, laborers and labor objects are carried out in space, so the spatial optimization of production factors is the basic way to realize new quality productivity. Facing the optimization of industrial spatial layout at the city level, the study concludes that the development direction of new quality productivity in biomedicine should not be limited to high-tech breakthroughs at the technological level, innovation cooperation and efficiency enhancement at the level of innovation bodies, or policy support and enhancement of individual parks, but should be re-examined from the level of the global city and think about the path to optimize the spatial pattern of Shanghai's biomedicine industry to strengthen the matching of elements of new technology, new talents and new space, and draw a new pattern of high-quality development. Instead, we should re-examine and rethink the path to optimize the spatial pattern of Shanghai's biomedical industry from the global city level, strengthen the matching of new technologies, new talents and new spaces, and draw a new pattern of high-quality development.

The new quality cluster ecosystem is the key to transcend enterprise clusters and industrial clusters and move towards regional collaborative innovation. Unlike other globally renowned biomedical cities that can only accommodate a single or a few types of clusters, Shanghai has the opportunity to realize a relatively complete and diversified innovation ecosystem by virtue of the global city's oversized hinterland, population base, and policy support. In order to further promote the brand of “Zhangjiang R&D+Made in Shanghai” and lead the biomedical industry in the Yangtze River Delta to the center of the world stage, the study takes the experience of the top biomedical clusters in the world and their development trend of new quality as an important consideration, and explores the construction of a new headquarter, a new VC, a new scientific research, and a new manufacturing “ four-in-one” new innovation ecosystem. explore the construction of a new cluster ecosystem with new headquarters, new venture capital, new scientific research and new manufacturing.

3.2. Spatial Reconstruction: From Unipolar to Circularized Spatial Network of Neoplasmic Clusters

In line with the international biomedical new quality development trend, and with the goal of building a "four-in-one" new quality cluster ecosystem, the study identifies different types of clusters at the industrial space level by combining the development orientation of Shanghai's industrial map and the assessment reports of biomedical parks in various districts, and through the superposition of the four elements of demography, economy, industry, and innovation with the cluster analysis, and explores the transformation of the industrial space pattern from unipolarization to circlization, and guides the stock and new parks under different circles. The study aims to identify different types of clusters by overlaying GIS clustering analysis of population, economy, industry and innovation factors, to identify the clustering areas of different types of clusters, to explore the transformation of industrial spatial pattern from unipolar to circling, and to guide the transformation of functions and allocation of elements of new parks under different circles.

①New Headquarters Circle: The spatial scope is concentrated in the business core within the inner ring road of the central city such as Huangpu, Jing'an and Pudong Lujiazui. Shanghai as a global city, international financial center and international consumption center is the core function. The study suggests drawing on the experience of New York of the United States and Tokyo of Japan, strengthening internationalization, forming a two-way radiation sector, playing the role of global resource deployment of the headquarters economy, expanding the local-global multi-scale cooperation network, further highlighting and strengthening the biomedical metropolitan area on the basis of the existing urban CBD space, enriching the spatial configuration of functions of the headquarters circle, and in particular increasing the number of cultural display and medical and aesthetic complexes, drugstores and health promotion centers oriented to new consumption.

② New Venture Capital Circle: the spatial scope is concentrated along the Central Ring Road, combining key parks such as Fenglin Life Science Park and Shanghai Juco Bio-Park, and the renewal of the "Golden Central Ring" point-like industrial plots, to further strengthen the support of venture capital and incubation facilities, and strive to realize the advantages of highly coupling the R&D outsourcing of CROs/CMOs of large enterprises and the flexible production of small and medium-sized enterprises. The study recommends to learn from the experience of Silicon Valley in the United States. The study suggests drawing on the experience of Silicon Valley in the United States, making full use of the economic advantages of leased buildings to promote the cooperation and exchange of venture capital, innovation teams and innovation intermediaries, and to support the construction of R&D outsourcing and service centers in the Asia-Pacific region in Shanghai. At the same time, we should strengthen the supply of pyramid-type "accessible and affordable" leased innovation facilities, including shared experimental instruments, leased workstations, surgical laboratories, meeting rooms, and so on. Market capital and social organizations will be introduced to participate in the construction and operation of these facilities, so as to achieve refined management that is closer to market demand.

③ New Research Circle: The spatial scope is focused on the zone between the outer ring in Pudong and the outer suburban ring in Puxi, such as around the university towns of Jiading, Minhang and Songjiang, and externally, along the G60 Hukun and Shanghai-Nanjing-Hejia Science and Innovation Corridor to connect with the Yangtze River Delta's research resources. The study proposes to learn from the trend of multi-body innovation in the U.S. Longwood Medical District, and further expand the original "industry-academia-research" to "government-industry-academia-research-medicine" innovation body mode on the basis of the original "industry-academia-research" to include clinical hospitals, community health grid

centers, etc., in the exchange network of full-caliber innovation bodies. The model of "government, industry, academia, research and medicine" has been further expanded to "government, industry, academia, research and medicine". In addition, in terms of government-led investment and construction of large facilities, drawing on the experience of the Kobe Medical City in Japan, with supercomputing centers and other large scientific devices and five new cities of national laboratories in colleges and universities as a breakthrough, to promote the formation of a large scientific device zone, a scientific service zone, the results of the transformation of the zone, and other functional spaces.

④ New Manufacturing Circle: The spatial scope is concentrated along the suburban ring of Shanghai. The world-class manufacturing cluster in the Yangtze River Delta gives Shanghai a unique industrial chain advantage and cost advantage. Under the international background of "manufacturing reflux", Shanghai should firmly grasp the regional manufacturing base, avoid industrial "deconcentration", further exert the two-way support role of manufacturing and innovation, and strengthen the high-end medium-sized and small-sized manufacturing industries. Two-way support role, strengthen the high-end pilot and manufacturing functions. Combined with sufficient land indicators, relatively low rent and labor in Zhejiang, Jiangsu, Anhui and other parks, independent industrial bases located along Shanghai's suburban ring will be connected outward through the corridor along the river and the corridor along the bay to form a world-class collaborative manufacturing system in the Yangtze River Delta.

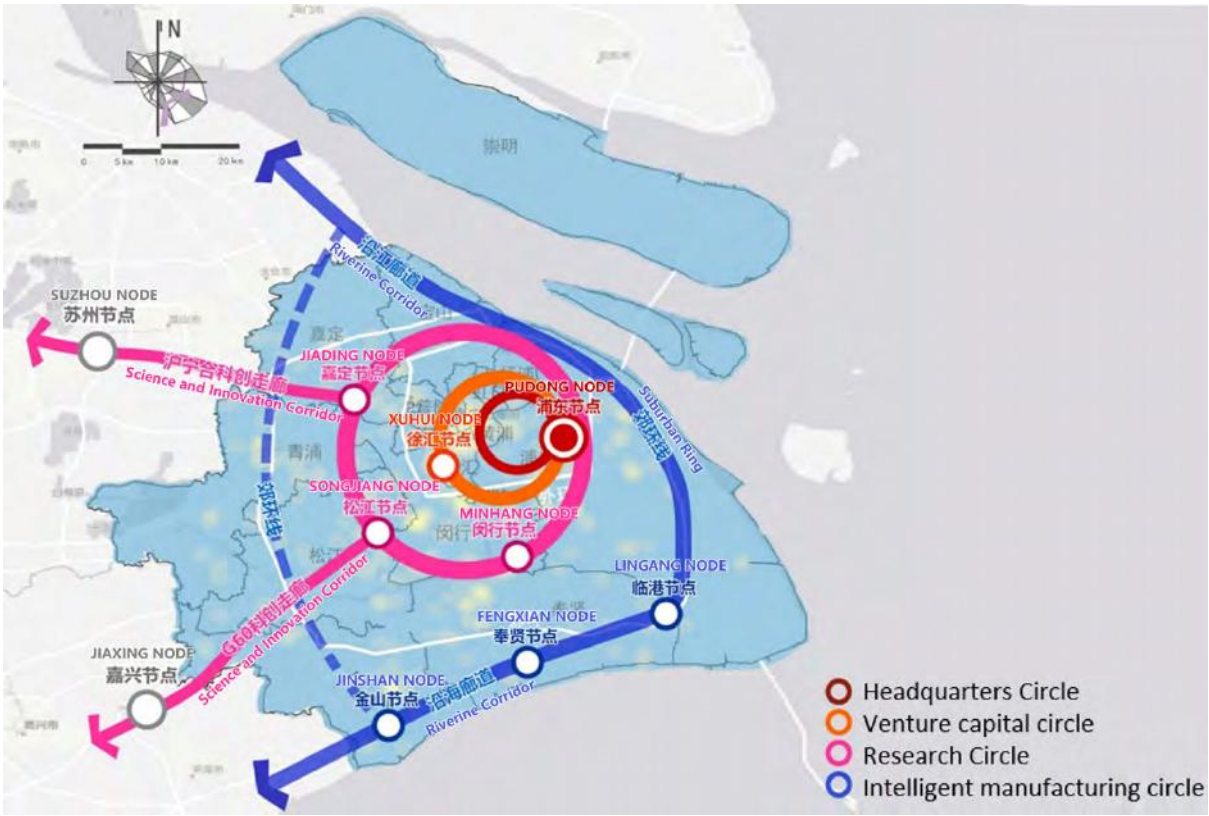


Figure 1. Circle based new quality cluster spatial network. Source: author.

3.3. Factor Configuration: Configuration Guidelines around New Quality Production and Services

The configuration of park elements in the era of new quality productivity includes two parts: new quality production and new quality service. New quality production elements refer to facilities directly affecting innovation, R&D and production and operation, and new quality service facilities refer to facilities indirectly affecting them.

The configuration of new quality production facilities is guided by: ① New Headquarters Circle: emphasizing the extension and expansion of new quality functions, i.e., new culture and new consumption facilities, such as medical and aesthetic complexes of more than 10,000 square meters, small and medium-sized enterprise culture exhibition halls, health promotion centers, and drugstores. ② new venture capital circle: on the basis of the existing shared meeting rooms and studios, guide the addition of small-scale innovation cultivation facilities, such as CRO innovation intermediary outlets, surgical laboratories, leasing workstations, shared experimental equipment, etc.; ③ new scientific research circle: the core of the facilities of the large scientific devices, expanding the surrounding services around the supercomputing center to form the supercomputing facilities cluster, while upgrading the five new cities with five new national laboratory; ④ New Manufacturing Circle: In line with the trend of intelligent manufacturing and digital transformation, the configuration of new quality pilot center and new quality data center is taken as a hand to realize efficient specialized, flexible and customized production.

The configuration of new quality service facilities is mainly a universal facility package focusing on the new quality needs of innovators, adopting universal configuration requirements, and the scope of application includes the allotment in the biomedical park as well as packages in the periphery of the park, including Netflix Café, industrial foundations, academic and alumni organizations, fitness centers, and international childcare facilities.

4. Conclusion and prospects

New quality productivity is the inevitable product of the progress of the times and the development of productivity to an advanced stage. In the face of the global scientific and technological blockade triggered by the rise of local protectionism, the new quality of productivity is the key to realize the independent control of our country, break through the traditional constraints of productivity, and make a key transition from quantity to quality.2022 In May, China released the “14th Five-Year Plan” for the development of bio-economy, proposing that the bio-economy will become a strong driving force for high-quality development, and the comprehensive strength of biotechnology and the development of industrial integration should achieve a new leap forward. In May 2022, China released the “14th Five-Year Plan” for the development of bioeconomy, proposing that the bioeconomy will become a powerful driving force for high-quality development, and that the comprehensive strength of biotechnology and the integrated development of the industry should realize a new leap. It is believed that the “four-in-one” integrated development of new quality cluster ecosystem is a higher-order form beyond enterprise clusters and industrial clusters. The reconfiguration of the industrial space pattern in line with the trend of new quality and the allocation of service facilities for new quality parks will be conducive to the overall high-quality development of Shanghai's biopharmaceutical industry.

5. References

Ye, G. (2024) 'Development Logic and Spatial Optimization Strategy of Characteristic Industrial Parks under the Perspective of New Quality Productivity', Urban Observation, (01), pp. 60-71, 160-161.

Wang, J. (2019) The Space of Innovation: Industrial Clusters and Regional Development (Revised Edition). Beijing: Science Press.

Zhang, X. (2013) Research on the Development of Zhangjiang Biomedical Industry Based on Global Innovation Network. PhD thesis. East China Normal University.

Research Paper

Walking Towards Tomorrow:

Humanizing Urban Spaces in NIZWA Souq, Oman.

Ar. Nasreen Kauser Dummi Shabbir, Lecturer of College of Engineering and Architecture, University of Nizwa, Sultanate of Oman.

Dr. Mohammadjavad Mahdavinejad, Professor of College of Engineering and Architecture, University of Nizwa, Sultanate of Oman.

Ar.Afshin Ghorbani, Guest Researcher at HAReC (Highperformance Architecture Research Cluster), University of Nizwa, Sultanate of Oman.

Abstract

This study explores the humanization of public spaces in Nizwa Souq, Oman, by analysing and exploring different Streets within and around souq, which are connecting the multifaceted spaces of shopping, cultural, religious and residential spaces. This research is to understand how Spatial configurations of Nizwa Souq influences walkability with parameters like connectivity accessibility, universal inclusivity, active social spaces with its aesthetic quality and amenities, and how these factors contribute to the humanization of public spaces in alignment with Oman's Vision 2040. Spatial data is gathered including footprints, open spaces and street networks, and possible movement paths are identified by spatial connectivity, spatial integration and its correlation is analysed by Depthmapx with Space Syntax analytical tools. Qualitative methods are used to extract the user preferences and choices with series of surveys and questionnaires with focus group within the delineated study area. The effects of these street patterns are evaluated to understand the spatial dynamics of the Souq on the people's wellbeing, as these spaces at present are more car oriented and less pedestrian friendly with inaccessible to the marginalized groups. The findings provide insights into spatial connectivity and its impact on pedestrians and human life. Findings are compared with similar studies conducted in other GCC countries to highlight best practices and areas for improvement. It informs urban planners and designers in making evidence-based decisions to improve pedestrian flow, enhance safety and form an accessible active public space with overall vitality. By aligning the design strategies with Sustainable development goals, Nizwa souq can evolve into a model of sustainable urban development that preserves its rich heritage while catering to the needs of its contemporary users. Paper also argues the philosophy that prioritizes human life, this research takes a people centred approach to urban revitalization by promoting walkable, liveable, sustainable and resilient public spaces to human life.

Keywords

Humanization, Space Syntax, Walkability, Accessibility, Connectivity Public spaces. Sustainability

1. Introduction

1.1. Structure and limitation of this paper

This Research paper addresses the significance of Nizwa Souq in its first part and the paper aims to investigate the current issues in terms of walkability, accessibility, liveable human activities and the hindrances faced by them due to growing car traffic in its second part and remaining of the paper is structured by the methodological sequence explaining the systematic analysis of the empirical data and the analytical data extracted by the program DepthmapX space syntax (Dezfuli et al., 2024) with plans for future strategies that enhances the vitality of this Souq by providing best practices and aligning the

strategies with sustainable development goals, The limitation of this study include the small sample size in the surveys at micro level, economic impacts are not studied in this research.

1.2. Background (Nizwa Souq)

Nizwa Souq, nestled in the Hajar Mountains, is a vibrant hub showcasing the interplay of culture and urban form in traditional Arabian marketplaces.

Social Hub: It is a social hub fostering community, connection, and belonging.

Cultural Heritage: The souq exemplifies Omani culture, preserving crafts like pottery, weaving, and silverwork while reflecting the nation's heritage.

Economic Importance: Nizwa Souq is a key economic hub where locals sell produce, livestock, spices, dates, and crafts, supporting many families and boosting the economy.

Tourism Attraction: The Souq catches tourists from around the world, providing glimpses of Omani life with 17th-century Nizwa Fort, The Grand Masjid, Traditional residential buildings called haraths (Al Aqar) and the Date palm farms with Falaj system in close proximity to the Souq. at present the Souq area bustled with life, it acts as Nizwa's cultural centre by boosting local economy and enhancing cultural exchange. The Souq has been continuously enhanced

Figure 1.0 Location map. Source: Google map, rendered by authors Scale: 1:15000.

Figure 1.1. The picture on the left shows the Alhabta event of auction and sale of livestock, with a huge crowd in the souq and car parking in the wadi area. The picture on the right is in front of the Nizwa souq. Book Source: Suleman bin Mohammed bin Suleiman bin Suleimani. *Alhara Aqr Nizwa*. [Book], p. 35.

and upgraded with harmonious blend of heritage conservation and progressive change. Nizwa souq is the most important market in the ancient and in the modern times, souq comprises various markets within itself like the eastern Al-Sansra, Silver and craft market, pottery, Gold market, Arms market, Omani dates and sweets market, vegetable, fish and meat market, a large part of which the livestock like sheep and cows are sold in collective auction on Friday mornings starting from 5.00 am to 11.00 am, and Major festival days, this famous business activity in Oman is locally known as Al Habbat, these live stocks are transported from various governorates within Oman, one can see remarkable crowding and variety of goods which spills over the large wadi areas for parking and movement.

1.3. Problem statement

As Oman is witnessing modernization, Nizwa Souq becomes an important case study in understanding the different aspects of urban development, especially in the case of maintaining cultural heritage. The Souq's importance in Nizwa's urban fabric one can witness the resilience, adaptation, and continuity but its importance for urban studies in the field of sustainability, resilient, walkable, human friendly, child safety, elderly accessibility and safety in urban development is hardly seen. Despite its historical significance (Damir et al., 2024) and allure as a tourist destination, Nizwa Souq confronts challenges in walkability and universal accessibility. With the emergence of modern shopping malls and hypermarkets with good accessibility and infrastructure for all user group's shopping comfort has let down the interest of certain groups for shopping in the souq. The population in the souq are not inclusive of all age groups and genders, with added disadvantage from the hot arid climate in summers (Vatani et al., 2024) and the flooding wadis during rains creates a chaos in traffic and movement. This paper aims to show the Souqs usages showing peak activity mainly to weekends and festivals. The sporadic yet intense rainfalls lead to flooding with 2 m higher level of water flow into the Wadi-Al-Musanna where car parking and vendors occupy during non-rainy days, causing closures that disrupt the market's operations however the rains just last 4 to 6 days in a year which is at a very minimum ratio. The insufficient parking spaces is leading to congestion and accessibility issues. These problems, along with the transformation of surrounding harath into commercial hub, have witnessed a demographic shift to newer residential areas for more privacy and spacious localities.

1.4. Aim of the study

The study aims to address the challenges by applying space syntax as an analytical tool to evaluate the spatial configuration of Nizwa Souq. Space syntax provides a quantitative approach to understanding the relationship between spatial layout and social behavior, which is crucial for enhancing the souq's functionality and user experience. To provide a comprehensive context for this research, literature review to explore previous studies on urban design in traditional marketplaces, with a particular focus on the Gulf Cooperation Council (GCC) countries is focused. With this study we can draw concepts from sustainable urban development, aligning with Oman's Vision 2040, which also encourages creating healthy, sustainable urban environments, enhancing walkability and pedestrianization in places like Nizwa Souq is very important for providing a resilient and engaging active urban environment for its people.

1.5. Literature review

The review of scientific papers from GCC using space syntax to analyse the spatial configurations of traditional souqs, can significantly enhance social sustainability and spatial identity by improving accessibility, connectivity, and fostering social interactions (Alalouch, 2024). has provided a guiding framework to assess how spatial layout influences accessibility, social interactions, and overall walkability in Nizwa Souq. the spatial configurations of Sanaa's architecture, analysed through space syntax, reveal how permeability and visibility influence social practices and spatial complexity Araguz, M., & Psarra, S. (2017). These projections can be applied to Nizwa Souq to know how spatial design, road networks can enhance human interactions and create functional flexible and accessible spaces. The study of spatial design in the Souq Matrah in its traditional settings plays a significant role in enhancing urban social interactions and addressing safety concerns. This insight helps in analysis of Nizwa Souq, focusing on how spatial configurations can attract more users and support their needs (Al-Maimani, Salama, & Fadli, 2014). The spatial and functional analysis of Souq Mutrah and Souq Waqif reveals how urban morphology (Javanroodi et al., 2018) and land use influence the socio-economic sustainability of traditional markets. This input guides in the analysis of Nizwa Souq on how spatial configurations can enhance both urban social

interactions and economic viability (Major & Tannous, 2020). The space syntax theory gives a framework for analysing spatial configurations, emphasizing the relationship between space and society through measures like integration and connectivity. Hiller's work demonstrates how spatial layout can predict human spatial behavior, offering valuable insights for designing urban spaces that enhance accessibility and social interactions (Hillier, 1996), Gehl (2013) and Jacobs (1961) both emphasize the humanization of streets and public spaces by designing them to foster vibrant street life and social interactions, which can be applied to enhance the social sustainability and community engagement in Nizwa Souq.

1.6. Humanizing Urban spaces in Nizwa Souq

Many articles and news channels are addressing the rich heritage- culture, architecture splendor, tourists' attractions etc. about the Nizwa souq but the need for prioritizing human needs is minimally addressed, this paper touches the need of the hour to bring in sustainable mobility, healthy, lively, active spaces by replacing major part of public spaces from cars to humans. Pedestrianization converts streets for pedestrian use, eliminate vehicle access, it makes urban areas more resilient, livable and healthy by reducing traffic, lowering of emissions, fostering community and supporting local businesses (2023 ESG Real estate lab, future mobility network). Some studies and news highlight the well-organized shops and products in the souq but what about the well-organized amenities for the safety of the pedestrians. Most of the areas in and around Nizwa souq lack pedestrian infrastructure and forcing people to walk on the road along with cars, bikes and trucks well maintained footpaths are available but they are not connected or they are inaccessible for the required destinations and not inclusive for the diverse needs of humans, hence proper pedestrian amenities is required to enhance accessibility and safety, footpaths can also serve as human space hence shaping human realm in the human space is vital in humanizing active urban human spaces, this can be called as human focused process, An inclusiveness addresses the diverse users, including people with disabilities, elderly, children, male, female and provides detailed information on accessibility features like ramps, public seats , shade, trees, clear pathways to improve human mobility , improvement in human environments aim to increase the humanization. Human mobility, walkability and wheelability pattern should be comfort, safe and accessible. Walking and cycling should encourage all ages and abilities this is the main concept the author is trying to achieve in this paper. Understanding human activities in and around souq area such as pedestrian movement and urban traffic which are shaped by the surrounding structure is important, hence space syntax is one of the unique guiding tool for these assessments.

2. Methodology

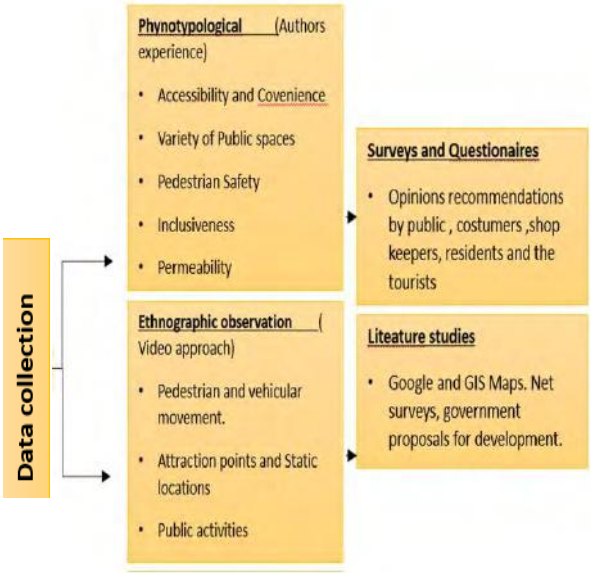
In order to Humanize the spaces in and around Nizwa Souq, it is essential for creating urban areas that supports urban social connections, physical activities, and enhances community well-being along with preserving cultural heritage and promoting economic revitalization. In this research the authors have conducted surveys and questionnaires using selective sampling strategies with stakeholders in Nizwa Souq, such as buggy drivers, local vendors, tourists, and visitors. Utilizing Karimi's (2012) evidence-based design methods, detailed evidence was gathered through questions about their experiences (Omrani et al., 2024), preferences, and suggestions for improving walkability in the souq. Additionally, Bill Hillier's Space Syntax methods were applied to analyse spatial configurations and walkability, aiming to revitalize the Nizwa Souq area. With the support of comprehensive literature review on analytical methods and urban philosophies and to identify key challenges and opportunities, for enhancing pedestrian flow with universal accessibility. this research assimilates a mixed-methods approach of combining qualitative and quantitative techniques, this includes producing cad maps, axial maps, collecting data and observations, performing behavioural studies. The proposed design strategies and suggestions aim to promote universal accessibility, pedestrianization, walkability, bicycling, safety, comfort, and resilient spaces in alignment with the

Sustainable Development Goals (SDGs), thereby enhancing the social, cultural, and economic vitality of the souq. This research used AI tool named Copilot to analyze historical data from Nizwa Souq, which allowed us to uncover intricate patterns (Goodarzi et al., 2023) and trends that would have been challenging to detect manually.

SNo	Methodological sequence of study, analyses and proposal
1	Literature study and overview on the proposals given by the development authorities
2	Empirical Data collection by Phenotypological observation, Human behavioural mapping by Ethnographic study, identifying public spaces within delineated area, tracing Pedestrian and vehicular movement.
3	Analysing the data collected and observational analysis in the form of mapping, charts, tables and bubble diagrams.
4	Identifying the problems and SWOT analysis of the delineated study area
5	Analytical tools Space syntax by using DepthmapX, generating spatial connectivity and integration with its corelation.
6	Combining the Empirical data and analysis with the space syntax analysis.
7	Evidence based design solutions and recommendations in the form of sections, illustrations and development strategies.
8	Design output

Table 2. showing methodology followed in this research. Source: Authors.

2.1. Data collection



For the phenomenological data collection, we conducted a hands-on exploration of the Nizwa Souq with our children and elderly mother, traveling by foot and using skates. This method allowed us to personally experience and identify universal accessibility issues, movement challenges and safety concerns faced by different age groups inside and outside surrounding to Nizwa souq.

Table 2.1 Data collection. shows the methods used. Source: Authors.

2.2. Ethnographic study

Data collection with respect to pedestrian and vehicular movement, attraction points, static locations, and urban public activities were done by marking on maps and taking samples at different times of the day, morning peak hours, afternoon, evening, weekends, and working days to analyse the temporal dimensions and traffic patterns. Key observation points at the souq's entries and exiting spaces were focused with its connections to the fort, Masjid and the parking area which is affected by flooding during rains. The observations of pedestrians crossing in this area during rains were monitored along with the traffic congestions during non-rainy days were recorded. At many points inside the souq, Drone footages were available which were published by the news channels we noted that arcaded corridors lack proper accessibility for all users and is not very much activated for the end users. Vendors sitting outside these corridors disrupt the safe movement of pedestrians and force them to walk on the road alongside vehicles, this way highlighting significant accessibility and safety challenges were systematically reviewed.

Figure 2. shows the green vegetation of Date palm farms intervened with the surrounding built forms of the Al Harath, most visited destination and attractions, and Figure 2.1. Showing the footprint. Source: Authors. Scale: 1:15000

2.3. Empirical Data collection by Phenotypological observation within Souq Nizwa

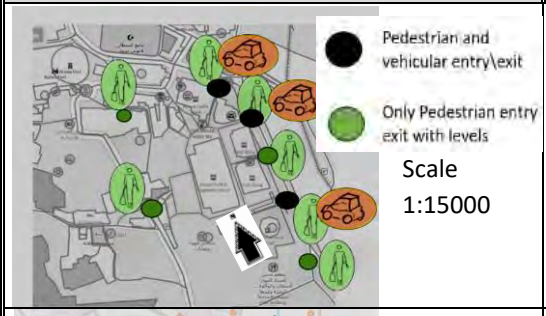
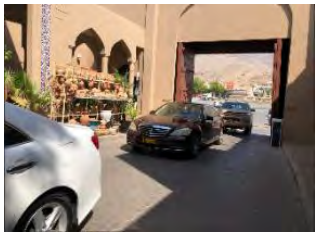
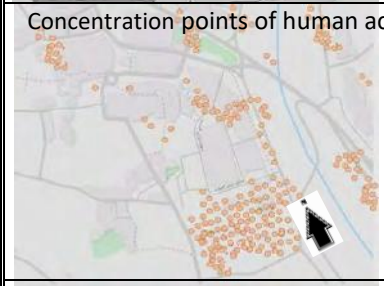
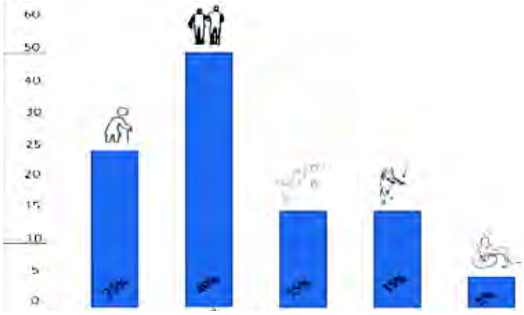
Parameters	Observation	Readings	Scenarios
Accessible and convenience	Vehicular and Pedestrian Entry-Exit points		
Active Public spaces	Quality of the space, shaded not shaded, distance	Concentration points of human activities. Scale 1:15000 	
Pedestrian Safety	Risk of Pedestrian vs vehicular Conflict points	Scale NTS	
Inclusiveness	Age group gender and special needs		
Permeability	Access to public spaces outside the souq	Linkage of public spaces outside the market surrounding, access to the Al-Aqra Village, Grand Masjid and the Nizwa fort. The steps and different levels without ramps, this makes some inconvenience	

Table 2.3. shows Empirical Data collection by Phenotypological method at Souq Nizwa. Source: Authors

2.4. SWOT Analysis from the empirical observation and data analysis

Strength	Weakness	Opportunity	Threat
The Souq's prime location, surrounded by natural and historical landmarks, attracts both domestic and foreign tourists, and enhancing it with pedestrian-friendly areas and cycling paths will boost foot traffic and transform it into a vibrant, healthy destination.	The Souq faces challenges such as insufficient parking, vehicular-pedestrian conflicts, poorly connected public spaces, obstructed pedestrian routes, limited accessibility, lack of diverse activities, inadequate amenities, no bike lanes, and limited public transportation options.	Creating an appealing pedestrian boulevard with active public spaces, connecting areas to promote walking and cycling, introducing universally accessible attraction points, supporting women's enterprises, and implementing climate-responsive designs can draw marginalized communities and address SDGs 11, 11.2, and 11.7.	Rain-related flooding, summer heat waves, insufficient parking, lack of universal design in streets and pathways, and shared use of roads by pedestrians and vehicles create inefficiencies and marginalize certain groups due to inadequate amenities.

Table 2.4. SWOT analysis. (Source: Authors)

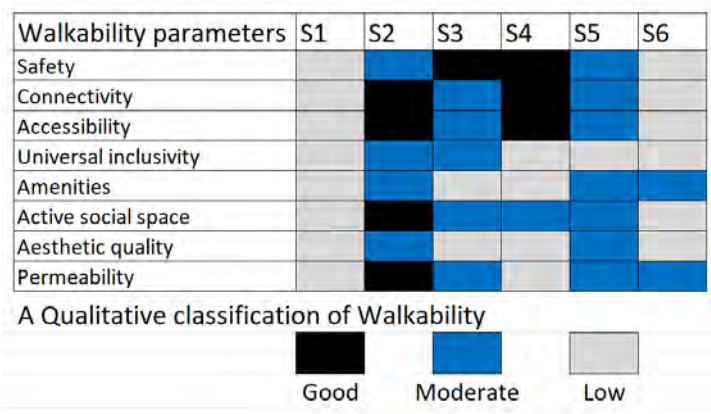


Table 2.5. depicting the existing scenarios of Nizwa Souq precinct (Source: Authors)

Figure 2.2 depicting the existing scenarios of Nizwa Souq precinct (Source: Authors)

3. Results

3.1 Introduction to space syntax

From a methodological perspective, Space Syntax provides tools for analyzing urban areas and evaluating design solutions to create vibrant cities and neighborhoods, following the concepts of Jane Jacobs and Jan Gehl. The importance of pedestrians in making the cities lively is very well addressed by Jane Jacob's (The death and life of great American cities, 1960), Gehl (1971, explains about social life and activities which depends on physical quality of the built environment, is very well said in (Life between buildings), In line with Jacob and Gehl, Space Syntax provides a tool set to analyze the social spaces and testing the design solutions to create a lively cities and spaces. Space and Social are closely related to each other, the human behavior shapes the surrounding space, hence It's important to understand the relation between the space and the society with evidence-based analysis and solutions instead of vague presumptions and precise

solutions, for this reason the authors in this research have adopted space syntax as their tool to focus on the spaces between the physical objects and its connectivity and accessibility to all other spaces in the built environment within and around the Nizwa souq area. By understanding human activities in and around souq area such as pedestrian movement and urban traffic which are shaped by the surrounding structure, space syntax plays a vital role as a tool for these predictions. The Ethnographic and phenomenological data is then co related with the spatial analysis data generated by space syntax tool which provides us with the understanding of how space and society affected each other, the measure of spatial connectivity and spatial integration with its correlation is analyzed.

3.2. Application of space syntax to Nizwa Souq: Geometry to Syntax

We developed spatial connectivity and spatial integration maps using DepthmapX for the souq and its surrounding study area to understand the formation and identity of Nizwa Souq based on Islamic geometry (Ranjazmay Azari et al., 2023). This analysis highlighted the spatial connectivity and integration, revealing sight lines that interconnect open spaces and facilitate visual and physical access to urban areas. We then explored the correlation between spatial connectivity and spatial integration to gain insights into the urban structure and its impact on human behavior

3.3. Spatial connectivity analysis

Figure 3 DepthmapX-based spatial connectivity analysis rendered by authors, Scale 1:9000.

The areas with higher connectivity as shown in warm colors (red and orange) in figure 3, has opportunity for better walkability and accessibility, enhancing these spaces may give overall urban experience. But, areas with lower connectivity, as depicted in cooler colors (green and blue) in figure 3, highlights the need for improved pedestrian pathways and amenities. This spatial connectivity map analysis helps to identify key areas for interventions, allowing us to propose solutions such as creating more pedestrian-friendly zones and enhancing public spaces to foster a vibrant, accessible, and walkable environment.

3.4. Spatial integration analysis

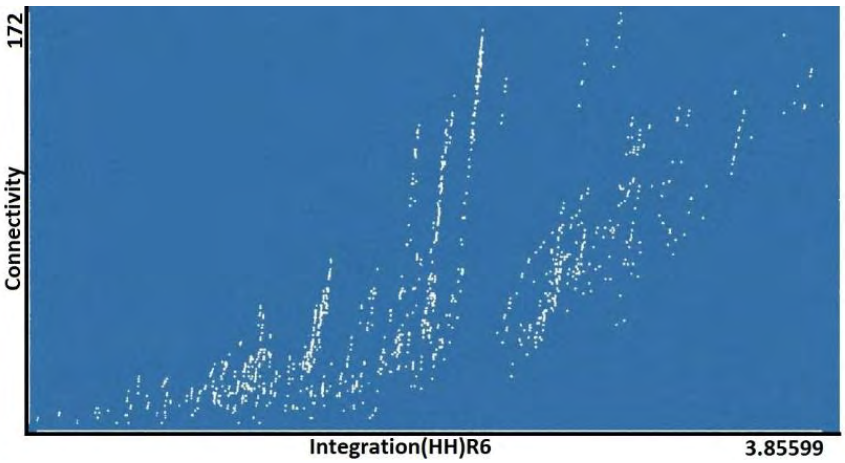
Figure 3.1 DepthmapX-based spatial Integration analysis (Source: Authors), Scale 1:9000.

The Integration Index, extracted from DepthmapX software (Figure 3.1), is another key metric for the study area. Warmer colors (red and orange) on the map indicate higher degrees of integration within the studied urban fabric. Conversely, cooler colors (green and blue) represent lower integration, suggesting weaker connections.

3.5 Correlation Analysis

By correlating spatial connectivity and spatial integration, a deeper insight about how the physical layout of the Souq influences movement patterns and human behavior is analyzed. This analysis suggests to create spaces that are both well-connected and well-integrated to enhance usability and attractiveness. This encourages walking and cycling by ensuring that key destinations can be easily accessed and this in turn could Support Community activity spaces that support a variety of activities, making the Souq a vibrant and dynamic place.

Figure 3.2 Correlation of Spatial Connectivity Index and Integration Index in and around Nizwa Souq (Source: Authors)



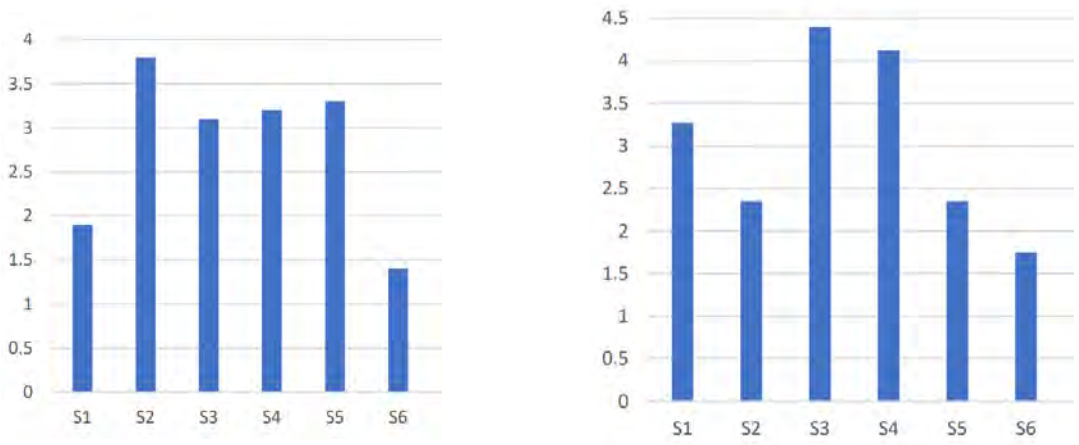


Figure 3.3 Graph showing Connectivity level and Integration level in six different selected streets in and around Nizwa souq (Source: Authors)

The connectivity levels in six different streets range from a minimum value of 2 to a maximum value of 4.4. The integration levels in these streets range from a minimum value of 3.1 to a maximum value of 4.8.

4. Conclusion:

Considering the spatial connectivity, integration, and correlation between the six streets analyzed using space syntax, the authors, propose to align their strategies with SDG 11,11.2,11.7. This proposal fosters sustainable resilience through universally accessible and inclusive spaces, along with robust pedestrian and bicycling infrastructure and promoting green vehicles and enhanced public transportation to have a dynamic urban environment that encourage diverse social interactions and vibrant community life near the souq area.

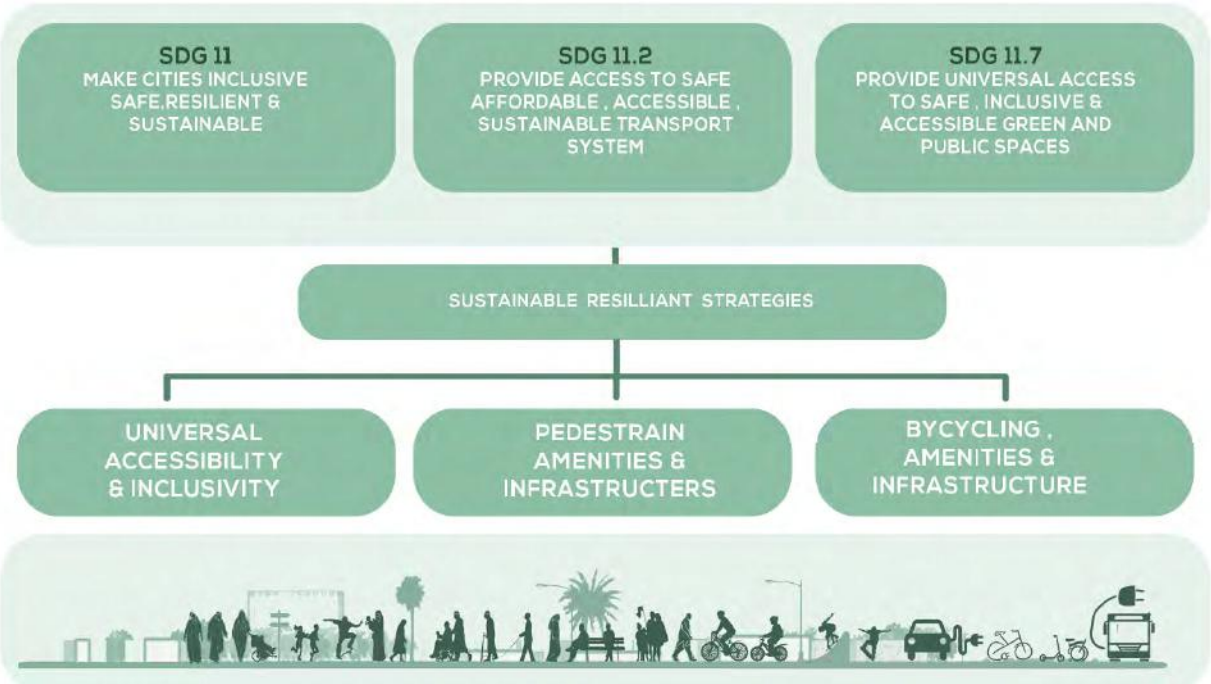


Figure 4. Pictures depicting the existing scenarios of Nizwa Souq precinct (Source: Authors)

This paper has analyzed the walkability and accessibility of Nizwa Souq using space syntax tool, it is highlighting the importance of humanizing urban spaces and aligning with SDGs 11.1, 11.2, and 11.7. The study proposes the creation of vibrant public spaces, such as pedestrian plazas and boulevards, to enhance social interaction and universal accessibility. In order to foster human interaction, it is necessary to transform these streets in and around the Souq into welcoming, user-friendly areas where people can stroll, shop, eat, and converse by walking, cycling, skating or wheeling without being interrupted by passing cars. The stronger the relationship between people and the city, the better the public spaces. The authors suggest the future research that could explore the use of advanced technologies and innovative software to further enhance walkability and public space utilization. Additionally, expanding the scope to include the entire historic area of Nizwa will provide a more comprehensive understanding of urban connectivity and human behavior. Continued investigation into spatial design and human behavior will help develop more inclusive and vibrant urban environments.

4. References

1) (n.d.) Urban planning, design and management approaches to building resilience: An evidence review.

2) Ranjazmay Azari, M., Bemanian, M., Mahdavinejad, M., Körner, A., and Knippers, J. (2023). Application-based principles of Islamic geometric patterns; state-of-the-art, and future trends in computer science/technologies: a review. *Heritage Science*, 11(1), 22. https://doi.org/10.1186/s40494-022-00852-w

3) Akkelies, V.N. and Coudia, Y. (2021) *Introduction to space syntax to urban studies*. Springer Open Access. ISBN: 978-3-030-59140-3.

4) Al Qeisi, S. and Al-Alwan, H. (2020) 'Generative urban design concepts and methods: A research review', *IOP Conference Series: Materials Science and Engineering*, 1090, 012085. Available at: https://doi.org/10.1088/1757-899X/1090/1/012085 (Accessed: 20 September 2024)

5) Al Qeisi, S. and Al-Alwan, H. (2023) 'From local qualities to global morphology: The typology of road nodes and its effect on the morphology of the traditional urban fabric', *AIP Conference Proceedings*, 2651, 020065. Available at: https://doi.org/10.1063/5.0106783 (Accessed: 20 September 2024).

6) Alalauch, C. (n.d.) 'The space of the maybe: Traditional souqs as potential catalysts for social sustainability and spatial identity', Proceedings of the 14th International Space Syntax.

7) Aragüez, M. and Psarra, S. (2017) 'Spatial and social patterns of an urban interior – The architecture of SANAA', *The Journal of Space Syntax*, 7(2), pp. 193-218. ISSN: 2044-7507. Available at: http://www.journalofspacesyntax.org (Accessed: 20 September 2024).

8) City of Vancouver (n.d.) *Downtown public space strategy: Places for people*. Gehl Studio. Available at: http://gehlpeople.com (Accessed: 20 September 2024).

9) Damir, M., Oevermann, H., Meyer, M., Mahdavinejad, M., and Elmouelhi, H. (2024). Sites of Modern Industrial Heritage in Egypt and Iran: Local, National, and International Relevance for Conservation and Reuse. Docomomo Journal, (71), 4-12.

10) David Lock Associates, Jeneal, D.G. and Chris, B.M. (2023) *Active design: Creating active environments through planning and design*. Sport England, May.

11) Dezfuli, R. R., Mehrakizadeh, M., Najar, B. S. A., Bazazzadeh, H., and Mahdavinejad, M. (2024). Geometric investigation of entrance proportions of houses from the Qajar to the beginning of the early Pahlavi in Dezful City (1789–1979). *Frontiers of Architectural Research*, 13(1), 57-78. https://doi.org/10.1016/j.foar.2023.09.007

12) ESG Real Estate Lab (2023) *The vital role of the bicycle in creating cleaner, more liveable smart cities*. [online].

13) Gehl, J. (2019) Soft city: Building density for everyday life.

14) Gehl, J. (2021) Shanghai riverfront evaluation.

15) Goodarzi, P., Ansari, M., Rahimian, F. P., Mahdavinejad, M., and Park, C. (2023). Incorporating sparse model machine learning in designing cultural heritage landscapes. Automation in Construction, 155, 105058. https://doi.org/10.1016/j.autcon.2023.105058

16) Healthy Public Policy Directorate. (2014) *Healthy Streets: Evidence Review*. E-book library [online]. Available at: http://www.toronto.ca/health (Accessed: 15 May 2024). Robert Mantha's (not known). URBAN DESIGN TOOLS & RESOURCES FOR THE PLANNING PRACTITIONER. A ROUTLEDGE FREEBOOK. (Accessed: 20 June 2024)

17) Hillier, B. (2014) 'Strange cities – or the axis as symbol and as instrument'. Lecture given as part of the module 'Spatial Cultures' within the MSc Spatial Design: Architecture & Cities, University College London.

18) Javanroodi, K., Mahdavinejad, M., and Nik, V. M. (2018). Impacts of urban morphology on reducing cooling load and increasing ventilation potential in hot-arid climate. Applied energy, 231, 714-746.

19) Legible Leeds – City Wayfinding (n.d.) Available at: https://www.citywayfinding.com/legible-leeds/ (Accessed: 20 September 2024).

20) Mantha, R. (n.d.) *Urban design tools & resources for the planning practitioner*. A Routledge freebook [online]. (Accessed: 20 June 2024).

21) Microsoft Copilot http: //copilot.microsoft.com

22) Ministry of Housing and Urban Affairs (n.d.) Streets for people, pathways of change from India's smart cities. Available at: https://smartcities.gov.in/ (Accessed: 20 September 2024).

23) National Disability Authority (n.d.) *What is universal design*. Available at: https://universaldesign.ie/what-is-universal-design/ (Accessed: 20 September 2024).

24) Omrani Azizabad, S., Mahdavinejad, M., and Hadighi, M. (2024). Three-dimensional embodied visibility graph analysis: Investigating and analyzing values along an outdoor path. *Environment and Planning B: Urban Analytics and City Science*, 23998083241303199. https://doi.org/10.1177/23998083241303199

25) Sara, H. (2021) Sense of place and mental wellbeing: Autoethnographic explorations through the streets of Stockholm. Available at: http://www.kth.se (Accessed: 20 September 2024).

26) Schweninger, E., Edmunds, M. and Atherton, E. (2021) *Transportation: A community driver of health*. American Public Health Association [online] March 2023The Vital Role of The Bicycle in Creating Cleaner, More Liveable Smart Cities, ESG real estate lab.

27) Smith, J. and Doe, A. (2020). Urban resilience in modern cities. *Journal of Urban Studies*, 15(3), pp. 123-145.

28) The Richmond Group of Charities (n.d.) *Movement for all: Our physical activity programme*. Available at: https://richmondgroupofcharities.org.uk/movement-all-our-physical-activity-programme-0 (Accessed: 20 September 2024).

29) Vatani, M., Kiani, K., Mahdavinejad, M., and Georgescu, M. (2024). Evaluating the effects of different tree species on enhancing outdoor thermal comfort in a post-industrial landscape. *Environmental Research Letters*, 19(6), 064051. https://doi.org/10.1088/1748-9326/ad49b7

30) Whyte, W.H. (1980). The social life of small urban spaces. Available at: https://www.pps.org/product/the-social-life-of-small-urban-spaces (Accessed: 20 September 2024).

Research Paper

Healing Cities: Integrating Virtual Reality Therapeutic Landscapes into Urban Planning for Future Well-being

Chengcheng YIN, Victoria University of Wellington, New Zealand
Bruno MARQUES, Victoria University of Wellington, New Zealand
Jacqueline MCINTOSH, Victoria University of Wellington, New Zealand

Abstract

Fast urban development poses major obstacles for city residents' emotional well-being which requires innovative solutions in urban development planning. This research investigates whether Virtual Reality (VR) therapeutic environments should integrate with urban planning strategies to build better mental health outcomes for the future. A review of relevant literature together with case study examination allows for assessment of VR therapeutic landscape effectiveness in urban mental health support. The results indicate that VR therapeutic landscapes can produce effective solutions to traditional urban planning constraints by enabling personalized design features and integrating virtual and physical interfaces while promoting social equity standards. This research creates practical guidelines that urban planners along with policymakers should follow to develop accessible VR landscape models that enable resilient healthy urban environments.

Keywords

Virtual Reality (VR), Therapeutic Landscapes, Urban Planning, Mental Health, Urban Resilience, Smart Cities, Digital Therapeutic

1. Introduction

The quick global shift toward urbanization creates serious obstacles to preserve and enhance mental health for those who live in cities. The United Nations Department of Economic and Social Affairs (2018) predicts that urban areas will house 68% of the total world population in 2050, so we urgently need new solutions for coping with psychological distress in cities (United Nations, Department of Economic and Social Affairs, Population Division, 2018). Numerous infrastructural approaches in urban planning remain useful although they fail to address the mental health requirements of varied populations living in compact urban areas (Galea, Freudenberg and Vlahov, 2005; Kondo et al., 2018). Research demonstrates that the absence of natural areas in condensed environments leads to higher stress levels and social isolation feelings which in return drives people to find urban wellness solutions.

Scientific research has determined natural settings increase mental health by creating stress reduction benefits which enhance mood and life satisfaction. (Kaplan and Kaplan, 1989; Bowler et al., 2010). However, as urban green spaces become increasingly scarce, Virtual Reality (VR) technology delivers potential

applications to create simulated natural environments which offer urban inhabitants nature experiences with healing benefits. (Riva, Wiederhold and Mantovani, 2019; Serrano et al., 2019). Virtual reality technology provides special immersive opportunities to integrate soothing naturalistic experiences inside urban environments thus overcoming mental health challenges in existing urban planning approaches.

The study examines the use of virtual reality therapeutic environments in urban design to create transformative mental health improvement systems for city dwellers. Through its immersive adaptation mechanism Virtual Reality delivers extraordinary capabilities which help tackle spatial barriers using flexible zero-bound connectivity unavailable in physical city layouts. It aims to bridge the fields of urban planning, environmental psychology, and VR technology, with a focus on the following innovative aspects: (1) interdisciplinary integration of VR within urban planning, (2) customization of VR landscapes for diverse urban populations, (3) blending virtual and physical environments to create hybrid urban spaces, (4) promoting social and spatial equity in access to therapeutic VR landscapes, and (5) exploring the long-term efficacy of VR landscapes as a sustainable mental health intervention.

This paper is structured to offer a comprehensive exploration of the topic. The framework is upon the literature review on urban mental health and therapeutic capacity of VR. Following this, the methodology will be outlined, leading to a discussion of the findings and their implications for urban planning. The paper will conclude with recommendations for future research directions.

2. Methodology

This research uses both literature review and case study analysis to evaluate how Virtual Reality therapeutic landscapes enhance mental well-being through urban planning.

The literature review establishes the theoretical foundations and empirical proof for VR therapeutic landscapes in urban planning environments. This process includes:

(1) Theories Analysis: The study examines theoretical concepts from three domains which include urban design alongside mental health together with the function of nature as a therapeutic setting. The research explores restorative environments combine with therapeutic landscapes and demonstrates their adaptable application in virtual reality dimensions.

(2) Synthesis of previous Research: A comprehensive analysis of current research concerning VR impacts on urban planning evaluates its benefits for mental health results. The evaluation will analyze the opportunities VR provides to overcome conventional urban planning limitations alongside promotion of accessible and inclusive urban environments.

(3) Identification of Research Gaps: The research identifies specific missing areas in literature focused on VR landscapes in urban planning and the requirement for personalized design methods targeting community diversity.

The analysis of VR therapeutic landscapes demonstrates practical usage potential within urban spaces through its practical application approach. This component includes:

(1) Selection of Relevant Case Studies: A review of successful case studies presents virtual reality therapeutic landscapes within contemporary urban development models. Selected case studies demonstrate diverse VR implementation examples that focus on public involvement and mental health support and environmental instructive features while showing the adaptability of VR applications in city settings.

(2) Exploration of Application Potential: Both case studies evaluate how VR therapeutic landscapes might affect mental wellness together with public awareness and social interaction patterns. This research avoids outcome metrics in favor of identifying qualitative ways through which VR applications can support urban spaces while promoting engagement.

The combination of case studies and the literature review generates practical recommendations which benefit urban planners and policymakers through a comprehensive analysis of VR therapeutic landscape implementation for improved urban health. The synthesis of theoretical insights and practical examples through this methodology reveals VR therapeutic landscapes' substantial value for urban planning which leads to more resilient and health-promoting urban areas.

3. Background Research

3.1. Foundations and Challenges of Therapeutic Landscapes

Over the past three decades urban planning together with public health policies have received significant influence throughGesler' 1992 introduction of therapeutic landscapes. Identified during the 19th-century sanatorium movement practitioners discovered natural environments hold healing properties. Today therapeutic landscapes combine physical spaces with mental environments that promote recovery and well-being. The concept gained popularity within urban design because it provides a structure to develop spaces that optimize mental and physical health in rapidly growing metropolitan areas.

Multiple complementary theories support the foundation of therapeutic landscapes. According to Kaplan and Kaplan's (1989) Attention Restorative Theory (ART), natural settings have the ability to restore depleted cognitive resources and manage mental fatigue and stress simultaneously. Stress Reduction Theory (SRT) published by Ulrich et al.'s (1991) viewing natural scenes leads to improved emotional responses which decrease stress while improving individual well-being. Wilson's (1986) Biophilia Hypothesis indicates that humans show an inherent bond with nature which forms a cornerstone for mental well-being. These frameworks create a solid theoretical base that supports the integration of therapeutic landscapes into urban design processes.

However, the application of therapeutic landscape theory faces substantial barriers when used in urban settings. Maas et al. (2006) highlighted the unequal distribution of green spaces, particularly in communities with poorer socioeconomic conditions, therefore innovative methods must be developed to ensure therapeutic spaces receive equitable distribution throughout cities. Research by Van den Berg et al. (2015) shows that health benefits stem from quality alongside quantity of green spaces; consequently, urban design requires creating spaces that restore citizens in addition to being accessible.

3.2. Expanding Concepts and Social Dimensions

The study integrates urban blue Spaces into therapeutic landscapes and demonstrates their connection to physical and mental health (White et al., 2013). Aletta and Astolfi (2018) state that urban soundscapes create environments with healing functions by using acoustic design as a way to improve urban areas. Researchers present advanced conclusions about environmental factors that promote well-being through a multisensory approach. Utilizing a multi-sensory approach, complex environmental interactions reveal the contemporary impact of environmental factors on health.

In recent years, the social dimension of the therapeutic landscape has been increasingly recognized as a fundamental component. According to Cattell et al. (2008), spatial design in public environments generates a supportive atmosphere, which leads to social communication and thus improves mental health. The field

of therapeutic land management has now moved beyond natural resources, as researchers have incorporated the human environment into therapeutic planning methods. Völker and Kistemann (2011) examine the cultural and social aspects that influence therapeutic landscape engagement before advocating urban planning that takes cultural sensitivity into account.

3.3. Virtual Reality and Emerging Trends

City development challenges have propelled Virtual Reality technology into prominence for its ability to construct therapeutic landscapes that provide augmented therapeutic experiences. Conservative healthcare applications of virtual reality in the early stage centered around pain control combined with phobia treatment (Sveistrup, 2004). These applications took their foundation from both presence theory (Slater and Wilbur, 1997) and embodied cognition theory (Wilson, 2002). These theories describe how users psychologically experience virtual environments so they can be effectively used in psychological interventions.

Studies demonstrate VR delivers encouraging results for mental health treatment across different conditions. VR delivery methods show effectiveness in treating anxiety and depression as well as PTSD according to Riva et al. (2016). The research by Powers and Emmelkamp (2008) proved that virtual reality interventions matched traditional exposure therapy effectiveness and Etchemendy, while Etchemendy, Baños and Botella (2015) showed its potential in PTSD treatment. These findings demonstrates how VR generates therapeutic environments which effectively address accessibility limitations and offers benefits similar to physical therapeutic spaces.

The use of VR to recreate natural environments for the therapeutic purpose is particularly relevant to urban planning. The combination of virtual nature environments with sound elements presented quicker stress recovery according to Ratcliffe (2021), and White et al. (2018) demonstrated that VR nature scenes decreased pain levels and anxiety in dental patients. These research findings indicate that virtual reality applications can deliver therapeutic landscape experiences while physical nature remains scarce in urban settings.

Despite its potential, VR therapeutic landscapes encounter multiple obstacles in their path. Rebenitsch and Owen (2016) identifed cybersickness as an important factor preventing widespread adoption of VR systems as Slater and Sanchez-Vives (2016) argued for better accessible yet user-friendly VR technologies. Privacy risk and emotional concerns stand as core ethical problems which demand contemplation according to Madary and Metzinger (2016). PX implementation of VR therapy systems depends on solving its operational obstacles.

Today's artificial intelligence (AI) technologies enable a transformation in virtual reality (VR) therapy by creating personalized therapeutic landscapes that fulfill specific user needs (Ribeiro de Oliveira et al., 2022; Soliman et al., 2024). Social VR groups designed for therapy allow healthcare professionals to understand therapeutic landscapes through their social elements (Kadir et al., 2023). VR platforms get smarter through biofeedback implementations that open new potential for developing intelligent therapeutic virtual landscape environments (Rockstroh, Blum and Göritz, 2019).

Research findings show definitive evidence that VR therapeutic landscapes deliver valuable mental health benefits for use in urban environments. Through the fusion of environmental psychology theory with urban planning principles and virtual reality technology effective VR therapeutic landscapes can be applied to urban domains. Research efforts need to focus on both extended outcomes and cultural adaptations together with specific implementation practices. Urban planners achieve the creation of new healing spaces by incorporating VR therapeutic landscapes into their urban planning enhancements.

4. Case Study

Several case studies demonstrate how virtual reality therapeutic landscapes are integrated into cities to create improved mental wellness alongside improved urban areas.

4.1. Case 1: TeamLab Borderless

Through its collection The TeamLab Borderless defines the process of combining technological and natural encounters using immersive artistic displays. The Tokyo-based interactive museum functions as an interstitial space which generates dynamic merged environments by using VR alongside AR to create interactive art and nature experiences. The exhibition features natural elements such as forests and water features which visitors can directly change real-time digital environments. The machine-controlled digital interactive interface enables users to strengthen their relationship with nature and build their creativity skills. TeamLab Borderless implements educational programming to foster apprentice participation which generates both environmental insight and interactive learning opportunities. Therapeutic landscapes research support metrics showing that mental recovery occurs when people engage with natural surroundings. Arcade City's experiences prove VR platforms possess potential to develop urban spaces that balance cognitive mental and emotional social benefits along with environmental interaction.

The virtual reality technology at TeamLab Borderless provides visitors with distinct emotional connections to nature. The analysis of adaptive environments teaches practitioners how to develop therapeutic urban spaces by translating the localization capabilities of VR into usable spatial designs.

4.2. Case 2: The Eden Project

The Eden project in Cornwall, UK, creates a unique eco-park by skillfully combining new technologies with natural elements. The project incorporates multiple biomes, showcasing a range of different ecosystems from tropical rainforests to Mediterranean gardens. Through interactive displays, the Eden Project engages visitors to learn about natural processes and works to develop educational community programs focused on environmental conservation.

The project cleverly combines contemporary sensor technology with data visualization methods to enable visitors to more intuitively understand the relationship between biodiversity and ecological dynamics. The educational program serves as a foundation for the creation of environmentally conscious communities and lays a solid foundation for successful urban planning. By integrating educational activities with urban development, the Eden Project demonstrates how land transformation can be guided by sustainable outcomes that lead to effective environmental education and the development of eco-citizens.

These educational and ecological projects not only focus on enhancing the public's mental health and sense of environmental responsibility, but also promote the realization of the public good while fostering the development of urban habitat.

4.3. Miraikan (The National Museum of Emerging Science and Innovation)

In this museum, virtual reality technology demonstrates its unique ability to help the public understand scientific natural phenomena.Miraikan visitors can explore different nature exhibits through interactive displays that present much challenging scientific information in a way that is easy to understand for the layperson.Miraikan focuses on ecosystems and climate change to educate the public on important environmental topics.

In addition, the museum allows visitors to learn how to address environmental challenges while gaining relevant knowledge through workshops integrated with educational programs.Miraikan demonstrates its

philosophy of healing by helping visitors gain a deeper understanding of nature and encouraging them to consciously observe the ecosystems around them. Through this design, Miraikan showed how to support urban development and, in turn, improve mental health by teaching city dwellers about important environmental knowledge.

4.4. Gardens by the Bay

Singapore's urban planning authority has created an architectural marvel that seamlessly blends technology with natural elements to drive urban planning and development. Community members experience these sustainable park initiatives first-hand by admiring the stunning Supertrees and carefully regulated indoor horticultural environments. This interactive display skillfully combines technology with botanical displays to not only innovate the tour path, but also teach visitors a wealth of botanical knowledge.

4.5. Case Summary

Different strategies for uniting therapeutic landscape concepts with urban technology emerge from the presented four cases. The key characteristics of these cases are presented via a comparative table in Table 1.

The implementation of VR therapeutic landscape integration in urban development achieves transformational outcomes according to studied case examples. Health-promoting urban initiatives show residents how to maintain resilient environments through their combination of outreach strategies and learning programs. Architects must prioritize mental health when designing urban environments, as researchers have provided strong empirical data to support the use of interactive urban technologies.

Table 1. Summary of Case Studies in VR Therapeutic Landscapes

Case Study	Location	Type	Key Features	Outcomes	Source
TeamLab Borderless (2024)	Tokyo, Japan	Digital Art Museum	-Interactive digital installations -Real time responsive environments -Nature-inspired digital art	-Enhanced visitor engagement -Improved mood states -Interactive learning experience	https://www.teamlab.art/e/tokyo/
Eden Project (2022)	Cornwall, UK	Environmental Education Center	-Indoor rainforest biomes -Educational exhibits -Sustainable design	-Environmental awareness -Nature connection -Community engagement	https://www.edenproject.com/
Miraikan (2024)	Tokyo, Japan	Science Museum	-Interactive science exhibits -Future technology showcase -Environmental education	-Scientific underdtanding -Technology awareness -Environmental learning	https://www.miraikan.jst.go.jp/en/
Garden by the Bay (2024)	Singapore	New Digital Art Experience	-Immersive digital ecosystem experience -Interactive plant exploration	-Highlighting biodiversity interdependence -Discover plant-animal relationships	https://www.gardensbythebay.com.sg/en/things-to-do/attractions/cloud-forest.html

5. Discussion and Future Directions

5.1. Discussion of Research Outcomes

While the potential to address mental health issues affecting the health status of urban communities in virtual reality therapeutic environments remains vast, public facilities such as TeamLab Borderless and the Eden Project have shown that interactive outdoor discovery can foster deep emotional connections with natural spaces, thereby improving the mental health of citizens. The findings point to a critical need for communities to integrate more natural elements into their landscapes as urbanization accelerates in areas that lack long-term sustainable green spaces. These studies also suggest that virtual reality tools have great potential to increase public environmental awareness through ecosystem education.

Miraikan engages users by providing an interactive educational experience that translates standardized techniques in urban areas into meaningful environmental action. By incorporating virtual reality therapeutic landscapes into their work, urban planners have activated a shift towards improved quality of life for residents. The research also suggests that urban planning methods urgently need to be adapted to integrate sustainable environmental regulations with mental health priorities. Planners who apply virtual reality strategies to their design work are able to create environments that meet the needs of diverse neighborhoods, thereby building strong urban systems. Integrating therapeutic land design into urban planning through virtual reality not only contributes to public policy, but also improves individual health. Government officials should utilize virtual reality to come up with affordable and scalable solutions that put mental health equity at the forefront of high-density urban areas. Future research will require the development of automated virtual characters integrated with artificial intelligence in virtual reality therapy to automatically adjust to an individual's mental health needs and maximize treatment outcomes. This workflow emphasizes the importance of interdisciplinary teamwork and reveals the great potential for the development of city-based mental health care services.

5.2. Plans for Future Investigations

Future research could evaluate the impact of virtual reality treatment environments on long-term mental health to understand their lasting effects. To determine the success of implementation in different urban cultures, researchers could explore the scalability of the intervention in a variety of settings. Additionally, the impact of virtual reality on urban health outcomes will be better understood when mental health professionals work closely with community-engaged urban planners.

6. References

Aletta, F. and Astolfi, A. (2018) 'Soundscapes of buildings and built environments', *Building Acoustics*, 25(3), pp. 195–197. Available at: https://doi.org/10.1177/1351010X18793279.

van den Berg, M. *et al.* (2015) 'Health benefits of green spaces in the living environment: A systematic review of epidemiological studies', *Urban Forestry & Urban Greening*, 14(4), pp. 806–816. Available at: https://doi.org/10.1016/j.ufug.2015.07.008.

Bowler, D.E. *et al.* (2010) 'A systematic review of evidence for the added benefits to health of exposure to natural environments', *BMC Public Health*, 10(1), p. 456. Available at: https://doi.org/10.1186/1471-2458-10-456.

Cattell, V. *et al.* (2008) 'Mingling, observing, and lingering: Everyday public spaces and their implications for well-being and social relations', *Health & Place*, 14(3), pp. 544–561. Available at: https://doi.org/10.1016/j.healthplace.2007.10.007.

Etchemendy, E., Baños, R.M. and Botella, C. (2015) 'Virtual and augmented reality as useful and efficacious tools for the psychological treatment of emotional disorders', in *Virtual reality: Technologies, medical applications and challenges*. Hauppauge, NY, US: Nova Science Publishers (Psychology research progress), pp. 31–54.

Galea, S., Freudenberg, N. and Vlahov, D. (2005) 'Cities and population health', *Social Science & Medicine*, 60(5), pp. 1017–1033. Available at: https://doi.org/10.1016/j.socscimed.2004.06.036.

Gesler, W.M. (1992) 'Therapeutic landscapes: medical issues in light of the new cultural geography', *Social Science & Medicine (1982)*, 34(7), pp. 735–746. Available at: https://doi.org/10.1016/0277-9536(92)90360-3.

Kadir, B.N. *et al.* (2023) 'Effectiveness of Virtual Reality (VR) in Improving Social Skills in Autism Spectrum Disorder Cases: A Literature Review', in D.V. Ferezagia et al. (eds) *Proceedings of the International Conference on Vocational Education Applied Science and Technology (ICVEAST 2023)*. Paris: Atlantis Press SARL (Advances in Social Science, Education and Humanities Research), pp. 45–71. Available at: https://doi.org/10.2991/978-2-38476-132-6_6.

Kaplan, R. and Kaplan, S. (1989) *The experience of nature: a psychological perspective*. Cambridge ; New York: Cambridge University Press.

Kondo, M.C. *et al.* (2018) 'Urban Green Space and Its Impact on Human Health', *International Journal of Environmental Research and Public Health*, 15(3), p. 445. Available at: https://doi.org/10.3390/ijerph15030445.

Maas, J. *et al.* (2006) 'Green space, urbanity, and health: how strong is the relation?', *Journal of Epidemiology & Community Health*, 60(7), pp. 587–592. Available at: https://doi.org/10.1136/jech.2005.043125.

Madary, M. and Metzinger, T.K. (2016) 'Real Virtuality: A Code of Ethical Conduct. Recommendations for Good Scientific Practice and the Consumers of VR-Technology', *Frontiers in Robotics and AI*, 3. Available at: https://doi.org/10.3389/frobt.2016.00003.

Powers, M.B. and Emmelkamp, P.M.G. (2008) 'Virtual reality exposure therapy for anxiety disorders: A meta-analysis', *Journal of Anxiety Disorders*, 22(3), pp. 561–569. Available at: https://doi.org/10.1016/j.janxdis.2007.04.006.

Ratcliffe, E. (2021) 'Sound and Soundscape in Restorative Natural Environments: A Narrative Literature Review', *Frontiers in Psychology*, 12. Available at: https://doi.org/10.3389/fpsyg.2021.570563.

Rebenitsch, L. and Owen, C. (2016) 'Review on cybersickness in applications and visual displays', *Virtual Reality*, 20(2), pp. 101–125. Available at: https://doi.org/10.1007/s10055-016-0285-9.

Ribeiro de Oliveira, T. *et al.* (2022) 'Systematic Review of Virtual Reality Solutions Employing Artificial Intelligence Methods', in *Proceedings of the 23rd Symposium on Virtual and Augmented Reality*. New York, NY, USA: Association for Computing Machinery (SVR '21), pp. 42–55. Available at: https://doi.org/10.1145/3488162.3488209.

Riva, G. *et al.* (2016) 'Transforming Experience: The Potential of Augmented Reality and Virtual Reality for Enhancing Personal and Clinical Change', *Frontiers in Psychiatry*, 7. Available at: https://doi.org/10.3389/fpsyt.2016.00164.

Riva, G., Wiederhold, B.K. and Mantovani, F. (2019) 'Neuroscience of Virtual Reality: From Virtual Exposure to Embodied Medicine', *Cyberpsychology, Behavior and Social Networking*, 22(1), pp. 82–96. Available at: https://doi.org/10.1089/cyber.2017.29099.gri.

Rockstroh, C., Blum, J. and Göritz, A.S. (2019) 'Virtual reality in the application of heart rate variability biofeedback', *International Journal of Human-Computer Studies*, 130, pp. 209–220. Available at: https://doi.org/10.1016/j.ijhcs.2019.06.011.

Serrano, B. *et al.* (2019) 'Virtual reality and anxiety disorders treatment: Evolution and future perspectives', in *Virtual reality for psychological and neurocognitive interventions*. Cham, Switzerland: Springer Nature Switzerland AG (Virtual reality technologies for health and clinical applications), pp. 47–84. Available at: https://doi.org/10.1007/978-1-4939-9482-3_3.

Slater, M. and Sanchez-Vives, M.V. (2016) 'Enhancing Our Lives with Immersive Virtual Reality', *Frontiers in Robotics and AI*, 3. Available at: https://doi.org/10.3389/frobt.2016.00074.

Slater, M. and Wilbur, S. (1997) 'A Framework for Immersive Virtual Environments (FIVE): Speculations on the Role of Presence in Virtual Environments', *Presence: Teleoperators and Virtual Environments*, 6(6), pp. 603–616. Available at: https://doi.org/10.1162/pres.1997.6.6.603.

Soliman, M.M. *et al.* (2024) 'Artificial intelligence powered Metaverse: analysis, challenges and future perspectives', *Artificial Intelligence Review*, 57(2), p. 36. Available at: https://doi.org/10.1007/s10462-023-10641-x.

Sveistrup, H. (2004) 'Motor rehabilitation using virtual reality', *Journal of NeuroEngineering and Rehabilitation*, 1(1), p. 10. Available at: https://doi.org/10.1186/1743-0003-1-10.

Ulrich, R.S. *et al.* (1991) 'Stress recovery during exposure to natural and urban environments', *Journal of Environmental Psychology*, 11(3), pp. 201–230. Available at: https://doi.org/10.1016/S0272-4944(05)80184-7.

United Nations, Department of Economic and Social Affairs, Population Division (2018) *World urbanization prospects: The 2018 revision*. Available at: https://population.un.org/wup/Publications/Files/WUP2018-KeyFacts.pdf.

Völker, S. and Kistemann, T. (2011) 'The impact of blue space on human health and well-being - Salutogenetic health effects of inland surface waters: a review', *International Journal of Hygiene and Environmental Health*, 214(6), pp. 449–460. Available at: https://doi.org/10.1016/j.ijheh.2011.05.001.

White, M.P. *et al.* (2013) 'Would you be happier living in a greener urban area? A fixed-effects analysis of panel data', *Psychological Science*, 24(6), pp. 920–928. Available at: https://doi.org/10.1177/0956797612464659.

White, M.P. *et al.* (2018) 'A prescription for "nature" – the potential of using virtual nature in therapeutics', *Neuropsychiatric Disease and Treatment*, 14, pp. 3001–3013. Available at: https://doi.org/10.2147/NDT.S179038.

Wilson, E.O. (1986) *Biophilia:* Cambridge, MA: Harvard University Press.

Wilson, M. (2002) 'Six views of embodied cognition', *Psychonomic Bulletin & Review*, 9(4), pp. 625–636. Available at: https://doi.org/10.3758/BF03196322.

Research Paper

Research on Spatial Planning Strategies for Community Integration of Healthcare and Physical Activity

From the Perspective of Proactive Health Interventions

Tingting YU, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Zeliang WEN, Harbin Institute of Technology, China

Abstract

Over the past 40 years, China's cities have experienced very rapid development, while rapid urbanization improves residents' material living standards and quality of life, it also brings a series of environmental issues, such as traffic congestion, uneven distribution of resources (e.g., healthcare, sports venues, parks), and air pollution. These changes have altered residents' lifestyles, with increased dependence on transportation and reduced physical activity posing new health challenges. Over the past 40 years, China's cities have experienced very rapid development.
Integrating sports and healthcare into the community to shift residents' health attitudes from passive treatment to proactive prevention is a proactive approach to addressing health threats. This study aims to establish an evaluation index system for the built environment's physical spatial elements. Using field research, resident interviews, and surveys, the study will assess the built environment across four objective dimensions—spatial layout, spatial form, spatial quality, and spatial security—and four subjective perception dimensions—convenience, comfort, safety, and cleanliness. Data on residents' behaviours and health status will be collected and analysed. Utilizing the Structural Equation Model (SEM), this research will explore the primary built environment factors affecting residents' health and investigate the mechanism of this impact. Based on these findings, spatial planning strategies will be proposed to promote the integration of sports and healthcare through spatial planning, ultimately improving residents' health.

Keywords

Community Environment, Residents' Health, Impact Mechanism, Proactive Interventions

1. Introduction

The World Cities Report 2022: Envisaging the Future of Cities notes that in 2021, more than 55% of the global population lived in urban areas, a figure projected to rise to 68% by 2050 (United Nations Human Settlements Programme, 2022). Urbanization has led to unhealthy living and working conditions, a lack of green spaces, pollution such as noise, water, and soil contamination, urban heat islands, and a scarcity of spaces for walking, cycling, and active living, contributing to an increase in non-communicable diseases (such as heart disease, asthma, cancer, and diabetes) (WHO, 2021).

The World Health Organization (WHO) and several developed countries launched the "Healthy Cities Movement" as early as the 1980s. The movement aims to improve residents' health by providing high-

quality, safe living environments, promoting active lifestyles, and addressing socio-economic factors that threaten public health (Cao, Y., 2023). In 2018, WHO released a Global Action Plan on Physical Activity, with the goal of ensuring that everyone has access to safe, enabling environments and a variety of opportunities to incorporate physical activity into their daily lives, thereby enhancing individual and community health. The specific target is to achieve a 15% relative reduction in the global prevalence of insufficient physical activity among adults and adolescents by 2030 (WHO, 2018).

To reverse the current trend of declining physical activity, effective, systematic national action is required. In response, WHO has launched a Global Action Plan on Physical Activity, proposing a universally applicable framework across more than twenty policy actions . This plan adopts a comprehensive, system-wide approach through four key areas: fostering vibrant societies, creating activity-friendly environments, building activity-oriented communities, and establishing supportive systems for physical activity.

Communities are the main settings for residents' daily lives, and achieving the "Healthy China" goal requires focusing on community environments where daily activities occur. China's urban development has entered a phase of stock adjustment, with public space construction shifting from new development to renovation and renewal. Unlike new constructions, public space renovations must carefully consider the demographics, activity needs, and exercise preferences of existing community residents. Current community public space renovation efforts primarily focus on comprehensive improvement, often following standards for newly built communities and lacking targeted recommendations. Creating a community environment conducive to exercise can help residents develop healthy habits and promote adequate physical activity levels. The second area is focused on spaces and places, which are also the focus of this research, emphasizes the need to strengthen the development of public facilities, schools, healthcare institutions, and sports and recreational facilities. It advocates for more sports fields and other open public spaces for community use, aiming to ensure that people of all ages and abilities in urban, suburban, and rural areas have convenient access to high-quality public green open spaces, green networks, leisure spaces (including rivers and coastal areas), and sports facilities.

By reviewing existing research on the impact of the built environment on health, this study finds that this field is still in its early stages. Current literature mainly comprises experiential summaries of foreign research methods and findings, with only limited exploration of impact mechanisms. This paper adopts a proactive health intervention perspective, using various communities in Nanshan District, Shenzhen, as research subjects to analyse and explore the mechanisms and influential factors of the built environment's impact on residents' health. This provides an empirical case study for further research in this field. Additionally, proactive health intervention studies focused on enhancing community residents' health are scarce, and the "sports-healthcare integration" service model is a key approach to achieving such interventions.

This study connects physical spatial data, residents' exercise data, and health data to associate community public space with residents' health. By analysing built environment features that impact health, this study integrates proactive health intervention ideas from sports and healthcare, proposing community-level public space renovation strategies. These strategies offer valuable references for future community development and renovation, enhance the feasibility of implementing sports-healthcare integration at the community level, and support healthier lifestyles for residents, contributing to the realization of the "Healthy China" strategy.

2. Theoretical analysis

2.1. Difficulties faced by the population's health

The global trend of insufficient physical activity is intensifying. In June 2024, the latest research on adult physical activity, conducted jointly by World Health Organization (WHO) researchers and the academic community, revealed that nearly one-third of adults globally (approximately 1.8 billion people) did not

meet the recommended levels of physical activity in 2022. From 2010 to 2022, the percentage of adults lacking sufficient physical activity increased by about 5 percentage points. This indicates that physical inactivity among adults has not improved, and if this trend continues, it is projected that by 2030, the percentage of physically inactive adults will further rise to 35%. Notably, China is part of this trend, with 28% of men and 19.5% of women experiencing insufficient physical activity in 2022 (Strain, T., Flaxman, S., et al., 2024).

Physical activity levels of residents in Shenzhen needs improvement. The 2023 Shenzhen National Fitness Report shows that the comprehensive fitness compliance rate among Shenzhen residents reached 91.5%, marking a 0.7 percentage point increase compared to the previous year and exceeding the national average compliance rate from the fifth National Physical Fitness Monitoring by 1.1 percentage points. The overall physical fitness of Shenzhen residents exceeds the national average, certain indicators reveal areas for improvement. For example, the average BMI for men aged 30-59 is above the overweight threshold, and the overall fitness compliance rate for older adults (60+) is 90.1%, 1.3 percentage points below the national level.

2.2. Progress of research in the disciplines

To promote public health, scholars in various countries have studied interdisciplinary frameworks (Tian, L., Li, J., Ouyang, W., et al., 2016), elements of the built environment that affect health (Wang, L., Liao, S., Zhao, X., 2016), and the promotion of physical activity (Chen, F., Zhou, S., Zhang, L., 2019), and an initial consensus has emerged on the relationship between the built environment and public health. The results are summarized in Figure 1, which shows that different disciplines have intervened in the health of the population in different ways, from the macro to the micro level.

However, research in the field of urban and rural planning on how the built environment positively intervenes in health is still in its infancy. This research will explore the mechanisms by which the environment affects health from the perspective of urban and rural planning and propose spatial intervention strategies.

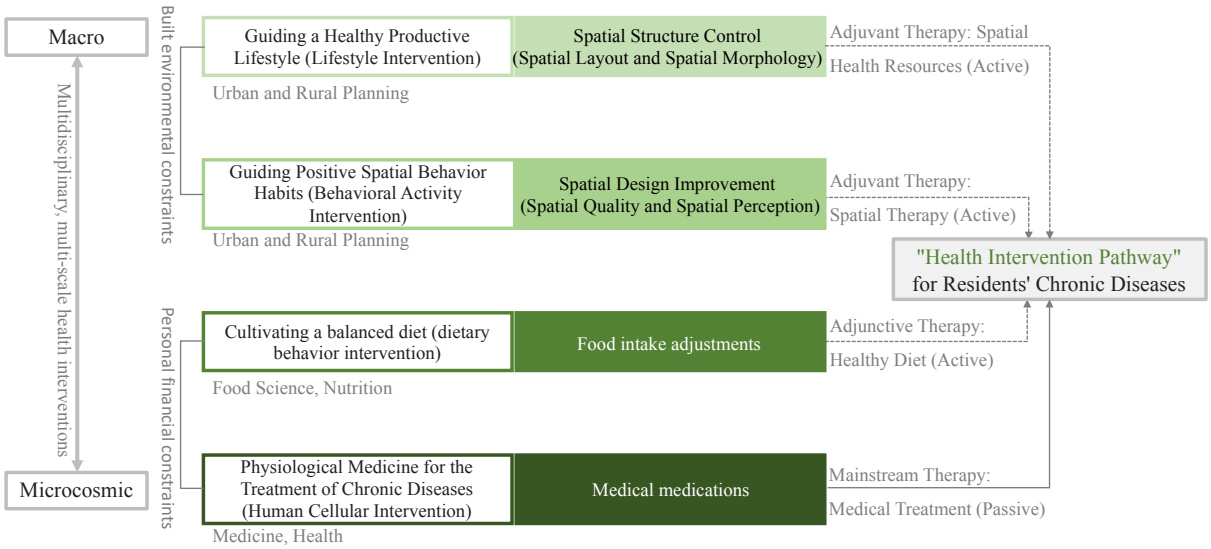


Figure 1. A multidisciplinary and multi-scale health intervention approach for residents' chronic diseases. Source: Self-drawn by the author.

2.3. Progress in the development of the sports-healthcare integration service model

Sports-healthcare integration refers to the fusion of sports and medical health resources, aiming to optimize health promotion and resource allocation. Specifically, it combines sports technology, medical techniques, and other health-promotion methods to support scientific fitness, disease prevention, treatment, and rehabilitation, creating a comprehensive approach to health across the entire lifecycle.

In Western countries, such as the United States, awareness of the negative health impacts of urbanization and motorization emerged in the late 20th century (DONALDSONA, Finch CF., 2012). Initiatives like the "Physical Activity and Public Health Guidelines" emphasized the importance of non-medical interventions to promote physical activity as a key component of health (R E Sallis., 2009). The German Government actively promotes the integration of physical medicine and health promotion through strategic planning, policy designation and human resource development (Kerr, R., 2016). Sweden's health promotion initiative "Sweden in Action" promotes the integration of physical activity into health care in primary health-care settings, the "Physical Activity Prescription" model of integrating physical and health services (Albert, F.A., Crowe, M.J., Malau, A., et al., 2020). Different countries have since established diverse sports-healthcare integration models tailored to their national needs, creating targeted services for various populations. Their construction and operational experiences offer valuable insights for further development in other regions.

The sports-healthcare integration model in China is still in its nascent stages, receiving academic attention primarily since 2016. In theoretical research, scholars have explored aspects such as implementation actors (Wang, Q., Chen, W., Wen, J., 2021), operational models (Yao, Z., Zhang, X., Fang, J., 2022), and institutional mechanisms (Huang, Li., He, H., Peng, Li., et al., 2024). Many researchers argue that embedding this model within communities, where residents' daily activities take place, supports sustained effectiveness by enabling non-medical interventions for all ages and phases of life (Dong, F., Tang, L., 2024). This approach promotes healthy lifestyle changes and enhances public health. Pilot programs are underway in cities like Beijing and Shanghai, utilizing various models based on medical institutions, communities, and hybrid approaches (Li, F., Wang, J., Cui, B., 2023). These pilot projects demonstrate both benefits and challenges, highlighting the need for further refinement to optimize these models for broader regional implementation. Further improvements are necessary to establish effective, scalable models that can support a nationwide rollout, ultimately helping to foster healthier communities.

3. Materials and methods

3.1. Research design

Our study consists of three steps: first, on the basis of multidisciplinary active health intervention research, and in conjunction with the needs of community physical and medical integration model construction, we constructed the index system of the study, which is divided into three categories, including physical environment element indicators, residents' health indicators and residents' activity indicators; second, construct and refine the research framework, use structural equation modelling to analyse the influence path of physical environment factors on residents' health, and identify the most representative indicators; third: collect and analyse the data, collect as much data as possible by time period and region to ensure the objectivity of the data, and then calculate and draw conclusions after collection.

3.2. Influencing factors

The system of research indicators is constructed from three aspects: Community Built Environment, Resident Health Indicators, and Spatial Activity Behaviour.

Urban Built Environment: By reviewing and analysing existing literature and research findings, this study examines potential physical spatial indicators within the built environment that may affect community residents' physical health, focusing on the impact of community environments on residents' well-being from a planning perspective. The dimensions of physical spatial indicators are clarified to include spatial layout, spatial form, spatial quality, and spatial security, which are further refined.

The type and description of the variable			
Objective environmental measurements	Spatial layout	F01	Land-use diversity (Yin, C., 2020)
		F02	Convenience of event venues (Wang, L., Du, Y., 2020)
		F03	Public service facilities (Domenech-Abela, J., Switsers, L., Mundo, J., et al., 2020)
		F04	Public transport stops (Yin, C., 2020)
		F05	Density of medical service facilities
	Spatial morphology	F06	Building density (Dong, W., Zhu, J., Li, H., 2023)
		F07	Morphological diversity (Cheng, H., 2021)
		F08	The enclosed state of the open space (Cheng, H., 2021)
		F09	Pedestrian street density (Namgung, M., Gonzalez, B., Park, S., 2019)
		F10	Pedestrian street connectivity (Timmermans, E.J., Schaap, L.A., et al., 2016)
	The quality of the space	F11	Green space rate (Hawkesworth, S., Silverwood, R.J., Armstrg, B., et al., 2018)
		F12	Green coverage (Peng, K., Jia. Y., Liang Y., et al., 2024)
		F13	Integrity of sanitation facilities
		F14	Space design (Wang, L., Du, Y., 2020)
	Space security	F15	Community policing (Razieh, Z., Johannes, F., Javier, M., et al., 2017)
		F16	Completeness of emergency facilities
		F17	Urban renewal projects

Figure 2. Objective environmental measurements. Source: Self-drawn by the author.

The subjective environmental perception includes 8 indicators. This set of indicators primarily focuses on the residents' perspective, aiming to understand their satisfaction with the community environment in terms of comfort, aesthetics, and convenience.

The type and description of the variable		
Subjective perception of the environment	X01	Public space appeal
	X02	A sense of security in the security situation
	X03	The cleanliness of the built environment
	X04	Walking environment comfort
	X05	Convenience of hospital treatment
	X06	Convenience of bus and subway
	X07	Accessibility of sports facilities
	X08	Convenience of activities in the park

Figure 3. Subjective perception of the environment. Source: Self-drawn by the author.

Resident Physiological Indicators: These indicators are designed to evaluate residents' health status, encompassing both physiological metrics and self-assessed health evaluations. Data on residents' health self-assessments and sleep quality evaluations will be collected through interviews and questionnaires. Physiological data such as blood pressure, blood oxygen levels, heart rate, and BMI will be gathered using devices like blood pressure monitors, pulse oximeters, weight scales, and measuring tapes. Collected data will be calculated and graded according to health standards to reflect residents' health levels.

The type and description of the variable		Quantitative methods	Data source
Physiological indicators	N01 Blood pressure	mmHg	on-site measurements
	N02 Heart rate	times/min	
	N03 Blood oxygen	%	
	N04 BMI	Kg/m2	
Health self-assessment	N05 Sleep status	1-5 (Poor-Good)	Questionnaires
	N06 Health perception	1-5 (Poor-Good)	

Figure 4. Indicators of residents' health characteristics. Source: Self-drawn by the author.

Spatial Activity Characteristics: Questionnaires will gather individual demographic information, including age and gender, while interviews will capture community residents' exercise habits, covering exercise type, frequency, and duration. These data will be quantified, and residents' physical activity levels will be graded based on the "WHO Guidelines on Physical Activity and Sedentary Behaviour" recommendations for various populations to indicate exercise intensity.

The type and description of the variable		Quantitative methods	Data source
Athletic conditions	A01 The type of Exercise	Calculate the amount of exercise in a week, compare it with the amount of exercise recommended by the World Health Organization, and score it on a scale of 1-5 (poor-good)	Questionnaires
	A02 Exercise time		
	A03 Frequency of Exercise		
Commute travel	A04 How to get around		
	A05 Commute time		
	A06 Frequency of travel		

Figure 5. Indicators of residents' activity characteristics. Source: Self-drawn by the author.

3.3. Influence path

The community environment can have a direct or indirect impact on the health of residents. The community environment can directly affect the health of residents and can also indirectly affect the health of residents through residents' health behaviours, which together constitute the comprehensive impact of the community environment on residents' health.

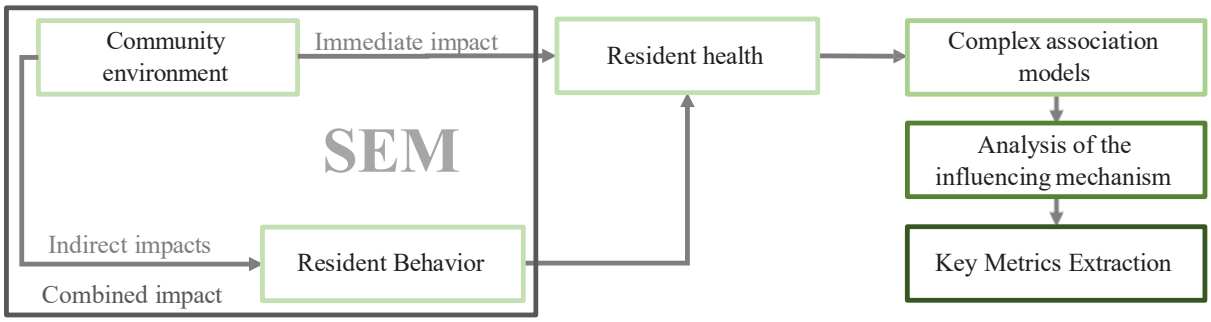


Figure 6. The comprehensive impact of community environment on residents' health. Source: Self-drawn by the author.

Based on the preliminary research route, the research method was further refined. Step 1: Explore the direct impact of community environments on residents' health and establish a structural equation model between community environments and residents' health to identify key influencing factors. Step 2: Incorporate physical activity into the model to determine if it affects the original conclusions. Step 3: If an impact is found, further explore the influence of residents' exercise and physical environmental factors on health. Finally, derive the pathways through which the environment affects health.

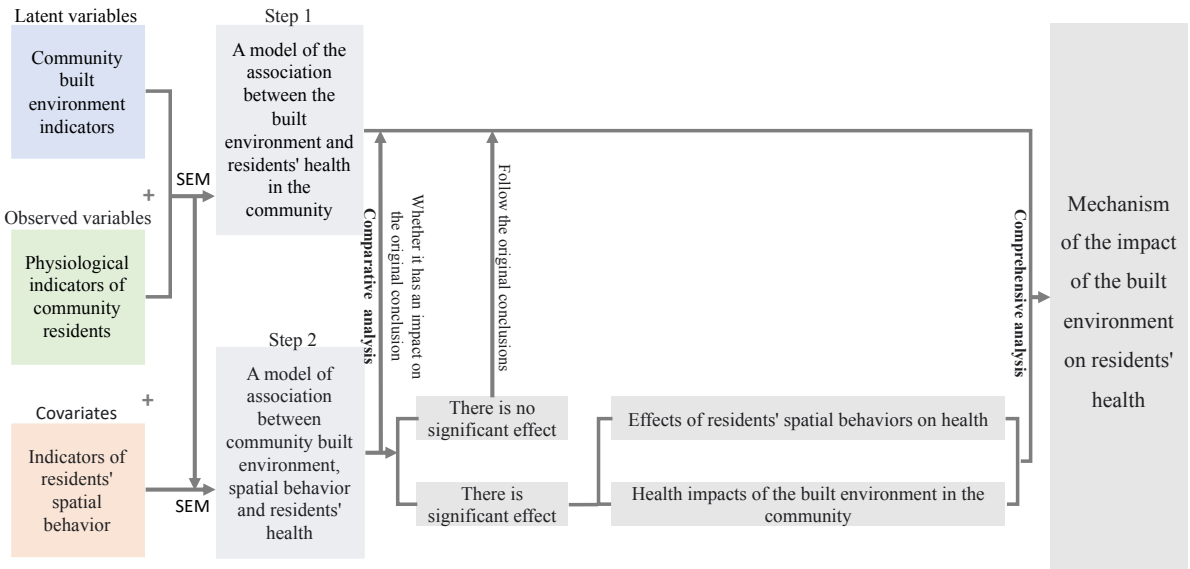


Figure 7. Research process on the mechanism of the impact of the built environment on residents' health. Source: Self-drawn by the author.

3.4. Data collection

The research location is in Shenzhen Nanshan District, Guangdong Province, China. Shenzhen covers an area of 1,997 square kilometres and has a population of 17.79 million, making it one of the largest cities in China. Nanshan District is in the central-western part of Shenzhen, Guangdong Province, bordering Yuen Long in Hong Kong across Shenzhen Bay to the southeast. By the end of 2023, the district had a permanent population of 1.8 million. Nanshan has experienced rapid urban development, excelling in cultural and ecological initiatives, with economic vitality ranking among the highest in China. In such a rapidly developing urban area, studying the impact of the community environment on residents' health is of great importance.

The research is conducted in conjunction with the "Community Health Outreach Program" organized by the *Nanshan District Private Medical Institutions Association in Shenzhen*. Suitable events are selected to facilitate in-depth community engagement, including interviews, questionnaire distribution, and physiological measurements. Based on the community's environmental quality, scale, and function, we have made a preliminary classification of the communities, which can be categorized into New Pattern Community, Comprehensive Community, and Traditional Community. This classification will aid in our subsequent research.

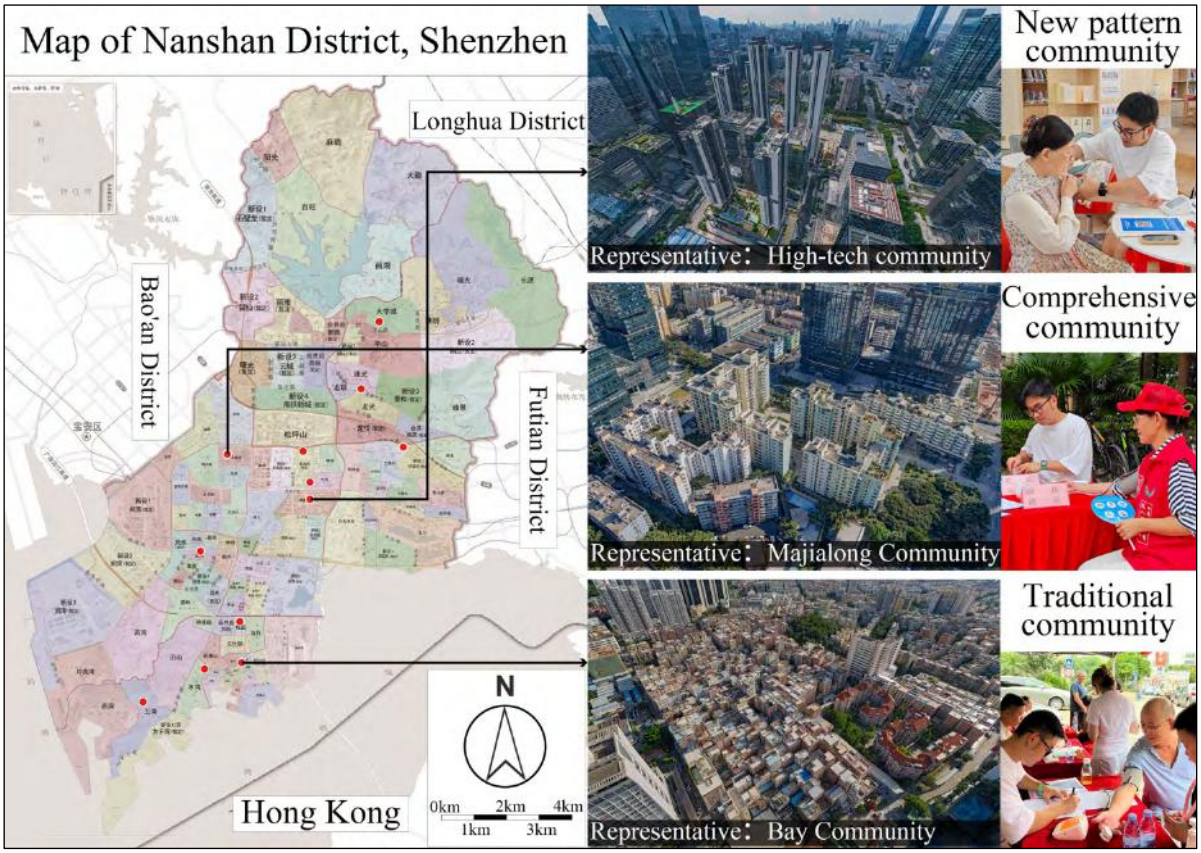


Figure 8. Results of community field research. Source: Self-drawn by the author.

4. Results and analysis

4.1. Survey results

Up to September, physiological data collection and questionnaire distribution have been completed in twelve communities (including a pilot community), resulting in approximately 580 completed questionnaires. According to the survey results, 23% of respondents are overweight, 30% rarely exercise, and 60% express a need for exercise guidance.

4.2. Calculation results

A structural equation model (SEM) was developed, incorporating detailed indicators of the objective built environment, resident health, and physical activity. This model explored the pathways by which specific aspects of the built environment influence residents' health outcomes and examined the mediating role of physical activity in linking the built environment to health. Through this analysis, the model clarified the mechanisms through which the built environment impacts health and identified how physical activity serves as an intermediary factor in this process.

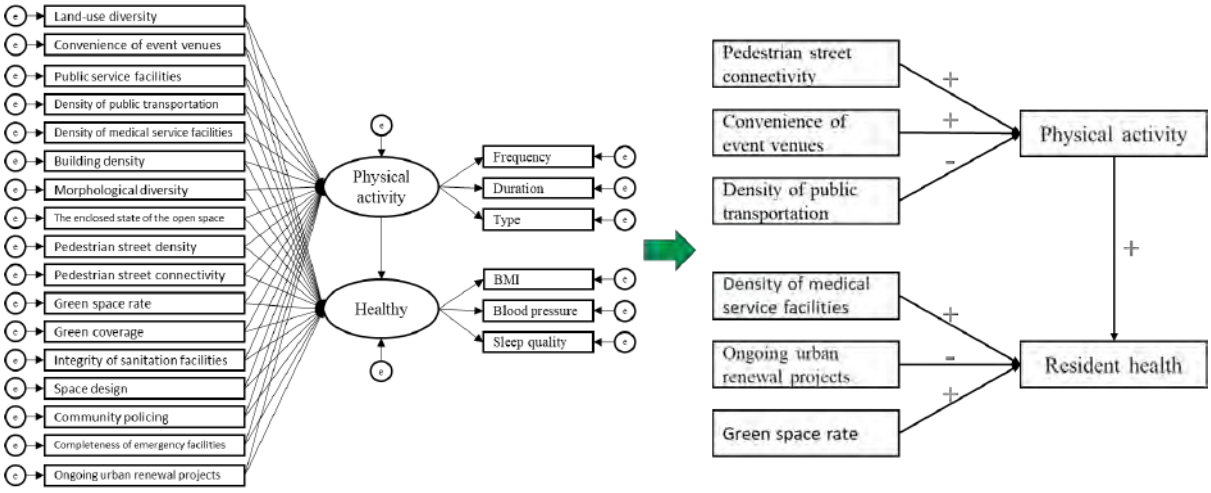


Figure 9. Use SEM to calculate the environmental factors that affect the health of residents. Source: Self-drawn by the author.

Based on the available data, we found that pedestrian street connectivity positively impacts residents' physical activity, while the density of public transportation has a negative impact on physical activity. The density of medical service facilities and the green space rate positively influence residents' health, while ongoing urban renewal projects negatively affect health. Physical activity has a positive effect on residents' health.

5. Discussion and planning strategies

5.1. Spatial layout

Optimize the layout of community sports space. The convenience of community activity spaces significantly impacts residents' willingness to exercise. Increasing the density and optimizing the layout of these spaces enhances accessibility, encouraging physical activity. To achieve this, grey spaces in the community can be utilized to create irregular, non-standardized sports areas. By strategically placing these areas, a five-minute walking coverage for activity spaces can be realized. Additionally, high-traffic parking lots can be designed as flexible spaces, serving as sports grounds during the day and as parking lots at night.

Improve the quality of community event space. The quality of community activity spaces also plays a critical role in residents' motivation to engage in physical activities. Improving the quality can involve diversifying available exercise options, strengthening facility maintenance, and ensuring adequate nighttime lighting. Enhancing comfort by providing sufficient amenities—such as seating, lockers, and washbasins—further supports use. Where feasible, adding retractable canopies can protect spaces from sun and rain, ensuring they remain usable under various weather conditions.

Integrate community medical and sports resources. Based on the study of existing cases, the practice process of sports and medicine integration in the community is summarized and designed, as shown in the figure below. It demonstrates the implementation of a community-based integrated sports and medicine service model, where the red line represents the movement flow of community residents participating in exercises, and the blue line represents the flow of fitness instructors. The exercise component can be carried out indoors or at public sports fields within the community.

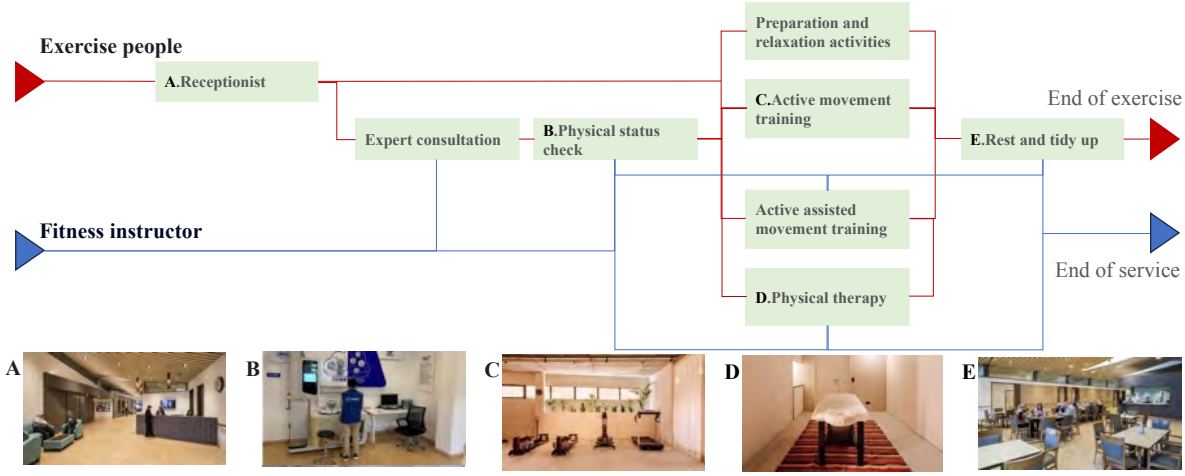


Figure 10. Main functional streamlines for the physical medicine crowd. Source: Self-drawn by the author.

5.2. Spatial morphology

Optimize the pedestrian street density. The density of streets has a significant positive effect on residents' physical activity. Higher density of walkable streets indicates greater street connectivity, pedestrian accessibility, and overall length of walkable paths, encouraging people to choose walking as a primary mode of transport. This increase in physical activity positively impacts health. Enhancing the density of pedestrian streets can effectively address issues related to insufficient physical activity while also expanding commercial space along the streets, diversifying land use, and enhancing street vitality.

5.3. Spatial quality

Increase the rate of green space. The natural environment in a community has a significant and positive direct impact on residents' health. Lush parks and tree-lined streets contribute to residents' mood, alleviating stress and anxiety. In high-density communities, grey spaces can be effectively utilized to create pocket parks, while rooftop gardens can be built on the tops of buildings. Additionally, vertical greening installations on the facades of public buildings—such as cafés and libraries—can further enhance greenery.

5.4. Spatial security

Improve emergency facilities. Providing comprehensive emergency facilities in communities can increase residents' sense of security, directly enhancing their happiness while also promoting physical activity. For instance, placing emergency medical facilities near sports areas allows for prompt first aid in case of sports injuries. Additionally, installing lighting in areas suitable for nighttime running helps ensure safety, encouraging more residents to engage in physical activities with confidence.

6. Conclusion

Based on a large amount of research, this study utilizes sufficient data to calculate the elements of the physical environment that affect the health of the residents, and then, on this basis, proposes spatial intervention strategies, which are more focused on the current situation of the city than the universal spatial planning methods, and thus more effective in promoting the health of the residents.

The data used in this paper satisfy the sampling requirements spatially, but temporally, they were collected centrally in the summer of 2024, and to avoid data bias, the data should come from different seasons. In the next step, we will continue to improve the sample data to make the results more reliable. In the long

run, we plan to implement these strategies in practice and build sample communities to validate the effectiveness of the strategies for wider implementation.

Acknowledgements

This research was funded by National Natural Science Foundation of China (grant no. 52208053, 52278056), the 66th China Postdoctoral Science Foundation (Project No. 2019M661284).

8. References

United Nations Human Settlements Programme. (2022)Envisaging the Future of Cities. Kenya: United Nations Human Settlements Programme (UN-Habitat).

World Health Organization. (2021)Urban health. [online] World Health Organization. Available at: https://www.who.int/zh/news-room/fact-sheets/detail/urban-health (Accessed 10 July 2024).

Cao, Y. (2023)The Impact of the Built Environment of Towns on the Health of Patients with Chronic Diseases and Policy Recommendations - Based on the Patient Health Behavior Perspective, PhD, Nanjing University.

World Health Organization. (2018)'Global action plan on physical activity 2018-2030: more active people for a healthier world', Geneva: World Health Organization.

Strain, T., Flaxman, S., et al. (2024)'National, regional, and global trends in insufficient physical activity among adults from 2000 to 2022: a pooled analysis of 507 population-based surveys with 5·7 million participants', The Lancet Global Health, 12(8), p1232-1243.

Tian, L., Li, J., Ouyang, W., et al. (2016)'The relationship between urban and rural planning and public health and the conceptualization of an interdisciplinary research framework', Journal of Urban Planning, 2016(2), p111-116.

Wang, L., Liao, S., Zhao, X. (2016)'Healthy city planning path and elements discernment', International Urban Planning, 2016(4), p4-9.

Chen, F., Zhou, S., Zhang, L. (2019)'Influence of built environment on residents' leisure and physical activities under life cycle perspective'. World Geography Research, 2019(5), p106-117.

DONALDSONA, FINCH CF. (2012)'Sport as a setting for promoting health', Br J Sports M-ed, 46 (1), p4-5.

R E Sallis. (2009)'Exercise is medicine and physicians need to prescribe it!', Br J Sports Med, 43, p3-4.

Kang. T., Wang, M. (2022)'Historical evolution and realistic revelation of the integration of physical medicine', Chinese Journal of Frontiers of Medicine. 14(06), p1-5.

Feng, Z., Zhang, R., Han, L. (2018)'Synergistic governance of sports-medicine integration: U.S. experience and its inspiration', Journal of Wuhan Institute of Physical Education, 52(05), p16-22.

Kerr, R. (2016)'The integration of science and medicine into sports training', Transport Plan Techn, 2016(10), p23-26.

Gansen, FM. (2018)'Health economic evaluations based on routine data in Germany: a systematic review', BMC Health Serv Res, 2018(18), p268.

Albert, F.A., Crowe, M.J., Malau, A., et al. (2020)'Functionality of Physical Activity Referral Schemes (PARS): A Systematic Review', Front Public Health, 8, p257.

Liu, X., Che, L. (2024)'Experiences and insights of the integration service model of sports medicine in Sweden', Sports Culture Journal, (01), p48-55.

Wang, Q., Chen, W., Wen, J. (2021)'Effect of community physical and medical integration exercise intervention on cardiovascular disease risk factor aggregation in middle-aged and elderly people[J]. Journal of Jilin Institute of Physical Education and Sports', 37(01), p52-57.

Yao, Z., Zhang, X., Fang, J. (2022)'Research on the functional organization of community sports and health center under the integration of physical medicine[J]. Low Temperature Building Technology', 44(02), p58-62.

Huang, Li., He, H., Peng, Li., et al. (2024)'Realistic Dilemma and Practical Path of Community Physical and Medical Integration Based on Digital Grid Management[J]. Journal of Shenyang Sports Institute', 43(04), p66-72.

Dong, F., Tang, L. (2024)'Pilot Experiences and Prospects of Practice-Based Embedded Body-Medicine Integration in the Community', Journal of Sports Culture, (4), p53-59.

Li, F., Wang, J., Cui, B. (2023)'Overseas experience and insights of body-medicine integration service model', China Health Economics, 42(10), p85-91.

Yin, C. (2020). Research on the Impact of Urban Built Environment on Residents' Health and Its Path. PhD. East China Normal University.

Wang, L., Du, Y. (2020)'Research progress on the effect of built environment on physical activity', Science and Technology Herald, 38(07), p53-60.

Domenech-Abela, J., Switsers, L., Mundo, J., et al. (2020)'The association between perceived social and physical environment and mental health among older adults: mediating effects of loneliness', Aging Ment Health, p1-7.

Dong, W., Zhu, J., Li, H. (2023)'Progress and insights of international research on the impact of community built environment on residents' social health', Shanghai Urban Planning, (03), p1-7.

Cheng, H. (2021)Research on the Impact of Built Environment in Urban Communities on the Health of Migrant Population, PhD, Wuhan University.

Namgung, M., Gonzalez, B., Park, S. (2019)'The Role of Built Environment on Health of Older Adults in Korea: Obesity and Gender Differences', Int J Environ Res Public Health, 16(18).

Timmermans, E.J., Schaap, L.A., Visser, M., et al. (2016)'The association of the neighbourhood built environment with objectively measured physical activity in older adults with and without lower limb osteoarthritis', BMC Public Health, 15, p710.

Hawkesworth, S., Silverwood, R.J., Armstrg, B., et al. (2018)'Investigating associations between the built environment and physical activity among older people in 20 UK towns', J Epidemiol Community Health, 72(2), p121-131.

Peng, K., Jia. Y., Liang, Y., et al. (2024)'Mechanisms of built environment on obesity in residents', Science and Technology Bulletin, 42(03), p107-122.

Razieh, Z., Johannes, F., Javier, M., et al. (2017)'Do Inequalities in Neighbourhood Walkability Drive Disparities in Older Adults' Outdoor Walking? ' International Journal of Environmental Research & Public Health, 14(7), p740.

Research Paper

Assessment and optimization of urban blue-green space services based on multi-source big data:

A case study of central Wuhan

Xingcan ZHOU, College of Horticulture and Forestry Sciences, Huazhong Agricultural University, China; Department of Urban Engineering, the University of Tokyo, Japan

Kojiro SHO*, Department of Urban Engineering, the University of Tokyo, Japan

Qingya CEN, College of Horticulture and Forestry Sciences, Huazhong Agricultural University, China

Hongfei QIU, College of Horticulture and Forestry Sciences, Huazhong Agricultural University, China

Abstract

Rapid urban development has exacerbated urban problems, creating an urgent need for systematic assessment of blue-green spaces as the ecological foundation, to enhance residents' well-being and guide sustainable development. Focusing on the primary functions of ecology and recreation for measuring urban blue-green space services, we selected six dimensions with twelve indicators. Using central Wuhan as a case study, we integrated diverse data sources and applied game theory to evaluate services and propose targeted optimization strategies. The results indicate that ecological attributes dominate the service scores of urban blue-green spaces, directly influencing overall rankings. The service capacity of blue-green spaces in central Wuhan exhibits a polarized distribution, with high and low service capacity spaces accounting for 41% and 36%, respectively, while moderate service capacity spaces accounting for 23%. Based on the evaluation results, the lowest-scoring Zhuyehai Park was selected as a typical site for further analysis, and optimization recommendations were made using the service measurement framework to improve external connectivity and restore ecological diversity. This study employs a data-driven dual evaluation of ecological and recreational service functions to provide practical evaluation criteria and solutions for multi-objective urban environmental planning.

Keywords

Urban blue-green space, Service function, Assessment framework, Multi-source big data

1. Introduction

Urbanization is a prominent global trend, with over 55% of the world's population currently living in cities (United Nations, 2019). The rapid development of urban areas has led to increasingly prominent problems that hinder sustainable development (Sharifi, Nygaard and Stone, 2021). Urban water systems are shrinking, and water shortages are becoming increasingly severe (Nouri, Chavoshi Borujeni and Hoekstra, 2019). At the same time, urban water bodies have experienced significant pollution and degradation, contributing to the heightened risk of flooding in some cities (Wu *et al.*, 2024). Urban blue-green spaces, especially lake parks at the intersection of urban water and green systems, provide both ecological and recreational service. These spaces contribute significantly to human well-being and life

quality (Knight, McClean and White, 2022; Zhou, Cen and Qiu, 2023). Therefore, a comprehensive study and application of urban blue-green spaces is urgently needed.

Key sustainability characteristics are central to measuring service functions (Li *et al.*, 2017; Ricci, 2022). Although some progress has been made in recent years, the potential for synergy between urban green and blue remains underexplored. Moreover, appropriate theoretical frameworks for service measurement and practical tools for assessment are still lacking (Kimic and Ostrysz, 2021; Ye and Qiu, 2021; Jiao *et al.*, 2023). Wuhan, a city with abundant water resources along the Yangtze River, has blue-green spaces play an important role in urban environment (Zhu and Zeng, 2018). Assessing the service capacity of blue-green spaces in the central Wuhan may provide valuable insights for the planning and sustainability enhancement of urban blue-green spaces.

This research aims to develop a service measurement framework for urban blue-green spaces, focusing on two primary service types: ecological and recreational. We employed multi-source big data, integrating geographic information, web data, and field surveys, to perform a multi-scale, hierarchical assessment of service functions. Through game theory, we weighted and integrated measurement dimensions to comprehensively evaluate the service functions of urban blue-green spaces in Wuhan. Based on this, we provided optimization recommendations for typical parks, offering theoretical support for blue-green space development with targeted strategies for ecological and recreational enhancement.

2. Methods

2.1. Study area

Wuhan (29°58′– 31°22′ N, 113°41′–115°05′ E), a megacity in central China with a permanent population exceeding 10 million, has a northern subtropical monsoon climate and is located in the eastern part of the Jianghan Plain. Its flat, low-lying terrain features extensive lakes and waterways, earning it the nickname “City of a Hundred Lakes”. In 2023, the Wuhan Municipal Bureau of Forestry and Parks (https://ylj.wuhan.gov.cn/) reported 38 lakes in central Wuhan, distributed over 12 water systems. There are 23 lakes already developed into parks or squares, creating 22 blue-green spaces (Figure 1, Table 1).

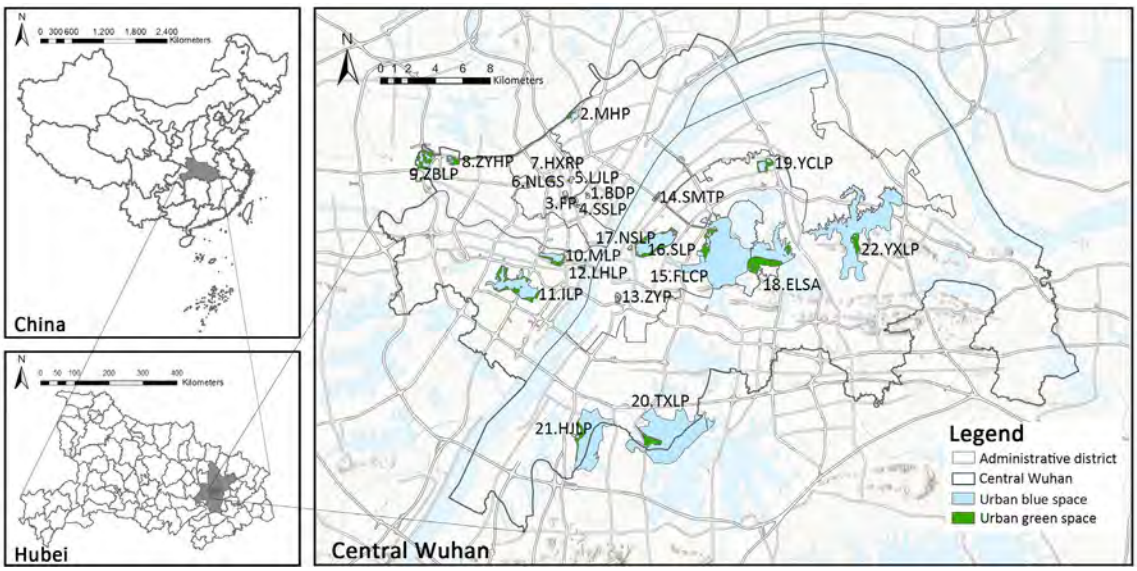


Figure 1. Distribution of 22 blue-green spaces in central Wuhan. Source: Wuhan Goverment, 2014

According to the Lake Protection Plan of Wuhan Government, based on the primary functions and specific characteristics of Wuhan's blue-green spaces, they can be classified into two main categories: ecological spaces and recreational spaces (Table 1). Recreational blue-green spaces are primarily located in the Jiang'an, Jianghan, and Wuchang districts, while ecological blue-green spaces are concentrated in the Qiaokou, Hanyang, and Hongshan districts, reflecting the current urban development trends in Wuhan.

Table 1. Selected blue-green spaces in central Wuhan and theirs functional positioning. Source: Wuhan Goverment (2014)

No.	Location	Water Body	Completed Park	Tag in Figure 1	Functiona
1	Jiang'an District	Wanzi Lake	Baodao Park	BDP	Recreational
2		Tazi Lake	Menghu Park	MHP	Recreational
3		Jiqidangzi	Fountain Park	FP	Recreational
4		Small South Lake	Small South Lake Park	SSLP	Recreational
5	Jianghan District	Lingjiao Lake	Lingjiao Lake Park	LJLP	Recreational
6		West Lake	Northwest Lake Green Square	NLGS	Recreational
7		Houxiang River	Houxiang River Park	HXRP	Recreational
8	Qiaokou District	Zhuyehai	Zhuyehai Park	ZYHP	Ecological
9		Zhangbi Lake	Zhangbi Lake Park	ZBLP	Ecological
10	Hanyang District	Moon Lake	Moon Lake Park	MLP	Ecological
11		Ink Lake	Ink Lake Park	ILP	Ecological
12		Lianhua Lake	Lianhua Lake Park	LHLP	Recreational
13	Wuchang District	Ziyang Lake	Ziyang Park	ZYP	Recreational
14		Simaitang	Simaitang Park	SMTP	Recreational
15		Fruit Lake	Fruit Lake Children's Park	FLCP	Recreational
16		Waisha Lake	Sha Lake Park	SLP	Recreational
17		Neisha Lake	Neisha Lake Park	NSLP	Recreational
18	Hongshan District	East Lake	East Lake Scenic Area	ELSA	Ecological
19		Yangchun Lake	Yangchun Lake Park	YCLP	Ecological
20		Tangxun Lake	Tangxun Lake Park	TXLP	Ecological
21		Huangjia Lake	Huangjia Lake Park	HJLP	Ecological
22		Yanxi Lake	Yanxi Lake Park	YXLP	Ecological

2.2. Framework for Measuring Blue-Green Space Services

Urban blue-green spaces provide both ecological and recreational services, these functions emphasize the environmental and social benefits of blue-green space services (Knobel, Dadvand and Maneja-Zaragoza, 2019; Ye and Qiu, 2021). We integrated findings from relevant studies on blue-green space services, utilizing ecosystem service classifications, spatial landscape dimensions, and hierarchical construction methods. Indicators reflecting the characteristics and functions of blue-green spaces were incorporated to establish evaluation criteria. Ecological service criteria include landscape connectivity, stormwater retention, and plant diversity (Andersson-Sköld *et al.*, 2018; Arthur and Hack, 2022; Wu *et al.*, 2024), while recreational service criteria encompass service area, spatial layout, and service quality (Lahoti, Lahoti and Saito, 2019; Liu and Xiao, 2021; Sharifi, Nygaard and Stone, 2021; Roberts, Glenk and McVittie, 2022). Finally, a service evaluation system based on multi-source data was developed, comprising 2 types, with 6 categories totaling 12 indicators (Figure 2).

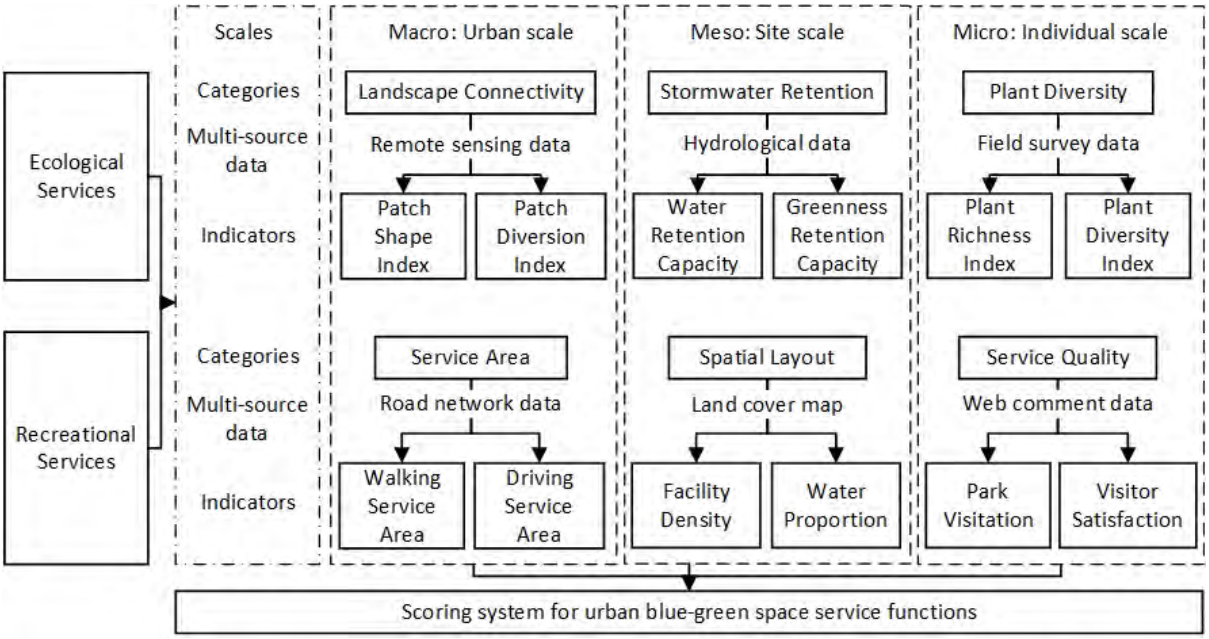


Figure 2. Evaluation framework for measuring blue-green space services. Source: Author Analysis, 2024

2.3. Measurement of Blue-Green Space Service Functions

2.3.1 Ecological Services of Blue-Green Spaces

Landscape connectivity is a critical indicator for assessing landscape structure and function, reflecting how the landscape supports or obstructs ecological flows. Using ArcGIS, lake data were extracted and imported into Fragstats software to quantify the connectivity of blue-green spaces. Two key indicators were selected to assess connectivity: the Shape Index (*SI*) which measures patch irregularity, and the Division Index (*D*) measures spatial fragmentation:

$$SI_i = P_i / minP_i$$

$$D_i = L_i / S_i$$

where P_i is the perimeter of patch *i*, and $minP_i$ is the perimeter of a circle with the same area as patch *i*. The distance index for patch *i*, L_i is calculated as $Li = \frac{1}{2}\sqrt{n/A}$, the area proportion of patch *i* is given by $S_i = A_i/A$, where *n* is the total number of all patches, *A* is the total study area, and A_i is the area of patch *i*.

To assess the stormwater retention capacity of blue-green spaces, 30-meter resolution ASTERG DEM data were used, along with field surveys and elevation data obtained from Google Earth. Hydrological analysis tools in ArcGIS were used to delineate rainfall runoff paths and lake catchment areas. The SWMM model was used to simulate surface runoff in Wuhan, calculating the water retention capacities of water bodies (V_0) and green spaces (*V*):

$$V_0 = (H_s - H_0)S$$

$$V = 10H_r\varphi F$$

where H_S is the design high water level, H_0 is the normal water level, and S represents the surface area of the water body. H_r is the design rainfall of the water body, φ is the runoff coefficient, and F represents the catchment area.

A sample-based method was used to analyze the distribution of aquatic plants along the waterfront and to assess the diversity of the plant communities. The species composition and growth patterns of aquatic plants in Wuhan's blue-green spaces were evaluated, and characteristic plant communities were identified. The study focused on biodiversity, assessing species richness with the Margalef Index and species diversity using the Shannon-Wiener Diversity Index.

2.3.2 Recreational Services of Blue-Green Spaces

To evaluate the recreational services provided by urban blue-green spaces, the primary focus is on the service area available to city residents. ArcGIS was used to create a spatial database of blue-green spaces. Road network integration (I) within a specified radius of each park, along with distance from the city center (DTC), was used to calculate walking and driving service areas. The relative asymmetry of nodes was calculated using the average shortest paths between each node and others, yielding the integration value I, which reflects connectivity and accessibility within a given radius. The higher the I value, the better the walkability and accessibility of the service area:

$$M\bar{D} = \left(\sum_{d=1}^{s} dN_d\right)/(n-1)$$

$$RA = 2(M\bar{D}-1)/(n-2)$$

$$I = 1/RA$$

where $M\bar{D}$ represents the average depth, d is the shortest angular path between nodes, N_d is the number of paths at a given depth, and n is the total number of intersection nodes. RA refers to the relative asymmetry, and its reciprocal is taken to ensure a positive correlation with the integration value I.

With respect to the mesoscale layouts, Points of Interest (POIs) serve as critical data points for understanding the intensity of public activity and the rationality of the distribution of facilities within these spaces. A web scraping tool was used to collect POI data for Wuhan's central urban area from Baidu Maps, and the number of POIs within each park was counted in ArcGIS 10.7. Density calculations were performed to show the concentration of facilities. The proportion of water bodies refers to the ratio of water area to the total park area within urban blue-green spaces, which indicates the water attractivenes. Land use data for Wuhan were collected and calculated the ratio of water to park area.

Park service quality was assessed using visitor data, focusing on visitation numbers and satisfaction levels. Web-based information was collected to analyze the recreational service levels of blue-green spaces. Data was obtained from the review website (https://www.dianping.com/), using a web scraper to collect the number of reviews and star ratings for each park between April 2017 and September 2019. The total number of reviews reflected the popularity and visitation levels of each park, while star ratings ranged from 1 to 5, with 5 stars indicating very high satisfaction and 1 star indicating dissatisfaction.

2.4. Combined Weighting Based on Game Theory

Indicator weighting methods typically include subjective, objective, and combined approaches (Li, Fan and Shen, 2018). Subjective weighting relies on the judgment of decision makers, while objective weighting uses the data-driven methods (Chen *et al.*, 2020; Ye and Qiu, 2021). As a whole, Each method

has its advantages and disadvantages: subjective methods are influenced by human biases, while objective methods may deviate from common understanding. Game theory, often used in multiobjective decision making (William, Garg and Stillwell, 2017), was applied here to integrate the entropy method and analytic hierarchy process (AHP) for combined weighting. Entropy-based weights were optimized with expert input to ensure a more objective and reasonable evaluation of urban blue-green space services.

AHP was used to construct a pairwise comparison matrix from the expert ratings. Geometric means and row normalization provided the priority vector, which was aggregated into a comprehensive weight vector. A consistency test ensured the reasonableness of the expert judgments and adjustments were made where necessary. The entropy method was also applied to calculate the value coefficient for each indicator to derive the individual weights. This process involved normalizing raw data to remove unit influence, then calculating entropy and variation to determine final indicator weights. Finally, game theory was used to integrate the subjective and objective weights (Table 2).

Table 2. Indicator weights for the evaluation system based on combined weighting. Source: Data Processing Results, 2024

Goals	Projects	Criterions	Indicators	AHP Weight	Entropy Weight	Combined Weight
Blue-Green Space Service Function	Ecological Services	Landscape Connectivity	Patch Shape Index	0.04	0.10	0.07
			Patch Diversion Index	0.06	0.13	0.09
		Stormwater Retention	Water Retention Capacity	0.12	0.15	0.14
			Greenness Retention Capacity	0.11	0.21	0.16
		Plant Diversity	Plant Richness Index	0.10	0.02	0.06
			Plant Diversity Index	0.07	0.03	0.08
	Recreational Services	Service Area	Walking Service Area	0.06	0.02	0.04
			Driving Service Area	0.03	0.02	0.02
		Spatial Layout	Facility Density	0.05	0.15	0.10
			Water Proportion	0.06	0.03	0.05
		Service Quality	Park Visitation	0.09	0.15	0.12
			Visitor Satisfaction	0.14	0.01	0.07

Given the varying scales, dimensions, and indicators, using raw values to analyze blue-green spaces in the central urban area would overemphasize indicators with higher values and underemphasize those with lower values. To address this, the commonly used z-score normalization method (Chen *et al.*, 2021) was applied to standardize the data and calculate th urban blue-green space service functions. ChatGPT (OpenAI, 2024) was used to assist in language improvement during the writing process.

3. Results

3.1. Overall Blue-Green Space Service Functions in Wuhan

3.1.1 Overall Service Function Scores

Using multi-source big data in the service function calculation model, scores for 22 urban blue-green spaces in Wuhan were calculated (Table 3).

Table 3. Service scores of blue-green spaces in Wuhan. Source: Data Processing Results, 2024

Rank	Urban Blue-Green Space	Synthesis Score	Evaluation Grade
1	Yanxi Lake Wetland Park	3264.12	High
2	East Lake Scenic Area	3149.28	
3	Tangxun Lake Wetland Park	227.98	
4	Fruit Lake Children's Park	207.68	
5	Small South Lake Park	128.80	
6	Ink Lake Park	61.98	
7	Shahu Park	53.99	
8	Neishahu Park	23.47	
9	Lingjiaohu Park	16.79	
10	Ziyanghu Park	6.16	Medium
11	Huangjiahu Wetland Park	-3.71	
12	Xibeihu Green Plaza	-5.28	
13	Baodao Park	-7.55	
14	Yangchunhu Ecological Park	-8.21	
15	Houxiang River Park	-15.99	Low
16	Simetang Park	-17.75	
17	Moon Lake Park	-21.77	
18	Zhangbihu Park	-24.45	
19	Fountain Park	-28.27	
20	Lianhuahu Park	-31.38	
21	Menghu Park	-39.73	
22	Zhuyanghai Park	-43.16	

In total, 10 parks scored above average and 12 scored below average. The distribution of synthesis score is relatively uniform, except for the two highest. The median value serves as the rating standard, defining the middle range of scores as -4.5 ± 11.38. High score parks make up 41% (9 parks), medium score parks 23% (5 parks), and low score parks 36% (8 parks). The evaluation results indicate a polarized trend. A targeted optimization of blue-green spaces can be achieved by examining the individual evaluation indicators. Specifically, Yanxi Lake Wetland Park scored the highest at 3264.12, followed by East Lake Scenic Area at 3149.28, and Tangxun Lake Wetland Park at 227.98. These scores are closely related to the high weight given to water retention capacity and the robust retention functions of these parks.

3.1.2 Categorized Service Function Scores

Given the distinct functional orientations of ecological and recreational blue-green spaces in Wuhan, the service function scores were evaluated separately. To minimize the influence of the non-targeted category, its weight was reduced by 90%, and multi-source big data was applied to the service function score calculation model. This resulted in scores for nine ecological spaces (Table 4) and thirteen recreational spaces (Table 5).

Table 4. Synthesis scores of ecological blue-green spaces in Wuhan. Source: Data Processing Results, 2024

Rank	Original Relative Rank	Ecological Blue-Green Space	Synthesis Score
1	1	Yanxi Lake Wetland Park	3566.302

2	2	East Lake Scenic Area	3451.465
3	3	Tangxun Lake Wetland Park	530.154
4	4	Ink Lake Park	364.155
5	5	Huangjiahu Wetland Park	298.468
6	6	Yangchunhu Ecological Park	293.960
7	7	Moon Lake Park	280.403
8	8	Zhangbihu Park	277.721
9	9	Zhuyanghai Park	259.017

Table 5. Synthesis scores of recreational blue-green spaces in Wuhan. Source: Data Processing Results, 2024

Rank	Original Relative Rank	Recreational Blue-Green Space	Synthesis Score
1	1	Fruit Lake Children's Park	202.811
2	3	Shahu Park	43.144
3	2	Small South Lake Park	38.478
4	5	Lingjiao Lake Park	35.267
5	7	Northwest Lake Green Square	14.662
6	11	Fountain Park	5.663
7	8	Baodao Park	4.329
8	6	Ziyang Park	1.232
9	4	Neishahu Park	-0.005
10	10	Simeitang Park	-4.982
11	13	Menghu Park	-14.809
12	9	Houxiang River Park	-22.076
13	12	Lianhua Lake Park	-27.398

The variation in scores of ecological parks is somewhat reduced compared to the overall scores, but the rankings remain the same. This may be due to the higher weight given to ecological attributes in the combined weighting scheme, which has a greater impact on ranking results than recreational attributes. It is important to analyze which indicators scored below average for the lower ranked parks and focus on improving their ecological attributes.

In contrast, the ranking of recreational spaces differs from the overall ranking. For instance, Fountain Park, which was at the bottom of the overall ranking, moved to a middle position after reducing the influence of ecological data. Meanwhile, Houxiang River Park, originally ranked in the lower-middle range, dropped to the second-lowest position without the support of ecological data. Recreational parks that experienced a relatively significant decline in ranking, such as Ziyang Park (down two positions), Neisha Lake Park (down five positions), and Houxiang River Park (down three positions), should prioritize targeted improvements in recreational attributes. Conversely, recreational parks that saw notable increases in ranking, such as Northwest Lake Green Square (up two positions), Fountain Park (up five positions), and Menghu Park (up two positions), need to enhance their ecological attributes, with greater attention required for parks exhibiting larger changes in ranking.

3.2. Evaluation System for Blue-Green Space Service Functions

The comprehensive score for blue-green spaces was calculated by aggregating the specific numerical values analyzed earlier, considering their respective weights. The original values of the calculated indicators were simplified and categorized. Using this scoring system, service function scores for urban blue-green spaces were computed, and grades were assigned to each result through a tiered approach (Table 6). This system, applying a standardized scoring method to various service function levels, facilitates the identification of multidimensional improvement directions for individual blue-green spaces and enables horizontal comparisons and evaluations of urban renewal projects.

Table 6. Scoring system for urban blue-green space service functions. Source: Data Processing Results, 2024

Criterion Level	Indicator Level	Calculated Indicator	Synthesis Score	Segmented Score
Landscape Connectivity	Patch Shape Index	Patch shape index of the landscape pattern	≤112	2
			112-187	4
			>187	6
	Patch Diversion Index	Patch diversion index of the landscape pattern (/10^4)	≤68	3
			68-113	6
			>113	9
Stormwater Retention	Water Regulation Capacity	Ratio of retention capacity to retention demand	≤4.3	5
			4.3-7.2	10
			>7.2	15
	Greenness Regulation Capacity	Green space retention capacity (×10^4 m^3)	≤103	5
			103-172	10
			>172	15
Plant Diversity	Plant Richness Index	Richness of trees, shrubs, and herbaceous plants	≤0.78	2
			0.78-0.87	4
			>0.87	6
	Plant Diversity Index	Diversity of trees, shrubs, and herbaceous plants	≤1.13	3
			1.13-1.41	6
			>1.41	9
Service Area	Walking Service Area	Road network integration within a 2000-meter radius	≤12	1
			12-80	2
			>80	3
	Driving Service Area	Road network integration within a 5000-meter radius	≤150	1
			150-350	2
			>350	3
Spatial Layout	Facility Density	POI density within the space (units/ha)	≤0.21	3
			0.21-0.34	6
			>0.34	9
	Water Proportion	Ratio of water body to total park area (%)	≤39	2
			39-64	4
			>64	6
Service Quality	Park Visitation	Number of park visitors on review websites	≤86	4
			86-143	8
			>143	12
	Visitor Satisfaction	Star rating of park visitors on review websites	≤4.3	2
			4.3-4.5	4
			>4.5	6

3.3. Service Functions of Typical Blue-Green Spaces in Wuhan

The study selected Zhuyanghai Park, which had the lowest overall score, as the evaluation target. Zhuyanghai Park is located between the Qiaokou District and Dongxihu District, bordered by Zhanggong Dike to the north and Yuanbo Avenue to the south. The scores of Zhuyanghai Park are shown in Table 7.

Table 7. Service scores of Zhuyanghai Park. Source: Data Processing Results, 2024

Indicator	Synthesis Score	Z-Score	Segmented Score
Patch Shape Index	131.68	-3.92	4
Patch Diversion Index (/10^4)	177.05	-0.65	9
Water Retention Capacity	32.03	-4.41	15
Greenness Retention Capacity (×10^4 m^3)	31.68	-7.77	10
Plant Richness Index	0.78	0.19	2
Plant Diversity Index	1.1	-10.93	3
Walking Service Area	-15.48	-5.92	1
Driving Service Area	-18.67	-2.94	1
Facility Density (units/ha)	0.27	-3.93	6
Water Proportion (%)	52.22	0.14	4
Park Visitation	17	-10.05	4
Visitor Satisfaction	4.6	6.99	6
Total Score	/	-43.20	65

Among the 12 indicators for Zhuyanghai Park, 3 had positive values and 9 had negative values, with 75% scoring below average. The three lowest scores were for the plant diversity index (-10.93), park visitation (-10.05), and green space water retention capacity (-7.77). Improvements should focus on enhancing plant diversity, increasing park visitation, and boosting the water retention capacity of green spaces. This can be achieved through optimizing park layouts, strengthening green space development, enriching recreational areas, and enhancing plant diversity to facilitate improvements.

3.3.1. Comparison of Service Functions in Typical Blue-Green Spaces

The Zhuyanghai Park (under construction) was compared with the Ziyang Park (fully constructed) in terms of Z-Scores (Figure 3) and segmented scores (Figure 4), with blue bars representing Zhuyanghai Park and red bars representing Ziyang Park.

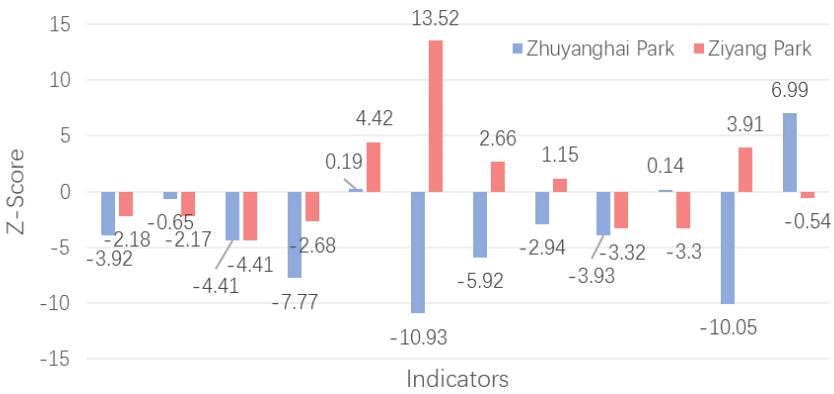


Figure 3. Comparison of z-scores between Zhuyanghai Park and Ziyang Park. Source: Author Analysis, 2024

As shown in Figure 3, the most significant differences between Zhuyanghai Park and Ziyang Park were in plant diversity, park visitation, and walking service area. This contrasts with the individual analysis of Zhuyanghai Park, which indicated that walkability was the main distinction. These differences may be due to the parks' locations and surrounding environments. Ziyang Park is located in Wuchang District, surrounded by well-established residential areas, whereas Zhuyanghai Park is located in Qiaokou District, where most residential buildings are newly constructed or still under construction. Thus, when updating the park, special attention should be given to the unique characteristics of the location and surrounding environment to enhance the area's vibrancy.

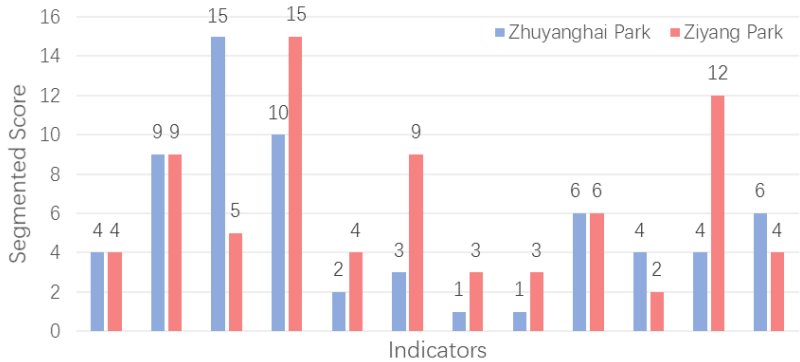


Figure 4. Comparison of segmented scores between Zhuyanghai Park and Ziyang Park. Source: Author Analysis, 2024

As shown in Figure 4, the largest differences between Zhuyanghai Park and Ziyang Park were in greenness retention capacity, park visitation, and plant diversity, which contrast with the rankings based on calculation values. Since greenness retention capacity holds significant weight in the landscape evaluation system, it plays a crucial role in determining scores. Therefore, the park's water retention capacity should be prioritized by implementing low-impact development techniques in coordination with sponge city construction to expand ecological service coverage.

3.3.2. Recommendations for the Renewal of Typical Blue-Green Spaces

Based on the comprehensive analysis of park service scores and comparative assessments, Zhuyehai Park requires enhancements in four key areas: park visitation, plant diversity, greenness retention capacity, and walking service area. Field surveys indicate that the park suffers from low visitation despite good overall ecological conditions. The park lacks basic facilities such as signage systems, resting benches, and lighting. Although the trails and boardwalks are designed for water access, some areas do not adequately considered normal water level, resulting in flooding. In summary, Zhuyehai Park is proposed to function as a bamboo culture theme park, leveraging lake ecological restoration to emphasize ecological green spaces while meeting citizens' needs for leisure, recreation, sports, and culture.

To enhance recreational accessibility, the Third Circulation Line and the Changfeng Avenue overpasses has fragmented the connection between the park and its surroundings. Thus, it is recommended to increase connectivity through pedestrian bridges and underground passages. In addition, the establishment of a primary landscape corridor will create a cohesive spatial network. From an ecological improvement perspective, the site serves as an urban green lung, and better design can enhance its role in ecological restoration. This includes constructing wetland substrates, connecting surrounding green spaces and water bodies, enhancing plant diversity, and creating microclimates to mitigate the urban heat island effect, all guided by ecological principles (Figure 5).

Figure 5. Aerial view, site plan, location map, and on-site photographs of Zhuyehai Park. Source: Wuhan Urban Construction Group, 2022

4. Conclusion

This study developed a service evaluation system for blue-green spaces in central Wuhan. Based on multi-source data, we conducted a comprehensive assessment of recreational and ecological service functions, using Zhuyehai Park as a case study to propose relevant strategies. By investigating the quantitative impact mechanisms of lake parks, we established an evaluation framework that incorporates combined weighting and score calculation. The simplification of service scoring based on data contributes additional evaluation methods and tools, facilitating practical assessment and guidance for the renovation of blue-green spaces. Future research should focus on further improving urban blue-green space services, thereby providing a foundation for enriching the research paradigm of multi-objective planning for urban environment.

Acknowledgements

The present study was supported by the National Natural Science Foundation of China (Grant No. 31770753), the China Scholarship Council (Grant No. 202306760120), and the Japan Society for the Promotion of Science KAKENHI (Grant No. 22K14390). We thank Wuhan Urban Construction Group for the basic data provided for this study.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

5. References

Andersson-Sköld, Y. *et al.* (2018) 'A framework for assessing urban greenery's effects and valuing its ecosystem services', *Journal of Environmental Management*, 205, pp. 274–285. Available at: https://doi.org/10.1016/j.jenvman.2017.09.071.

Arthur, N. and Hack, J. (2022) 'A multiple scale, function, and type approach to determine and improve Green Infrastructure of urban watersheds', *Urban Forestry & Urban Greening*, 68, p. 127459. Available at: https://doi.org/10.1016/j.ufug.2022.127459.

Chen, T. *et al.* (2021) 'Recreational Services from Green Space in Beijing: Where Supply and Demand Meet?', *Forests*, 12(12), p. 1625. Available at: https://doi.org/10.3390/f12121625.

Chen, Y. *et al.* (2020) 'Evaluation of ecological city and analysis of obstacle factors under the background of high-quality development: Taking cities in the Yellow River Basin as examples', *Ecological Indicators*, 118, p. 106771. Available at: https://doi.org/10.1016/j.ecolind.2020.106771.

Jiao, X. *et al.* (2023) 'Advances in the blue-green space evaluation index system', *Ecohydrology*, 16(3), p. e2527. Available at: https://doi.org/10.1002/eco.2527.

Kimic, K. and Ostrysz, K. (2021) 'Assessment of Blue and Green Infrastructure Solutions in Shaping Urban Public Spaces—Spatial and Functional, Environmental, and Social Aspects', *Sustainability*, 13(19), p. 11041. Available at: https://doi.org/10.3390/su131911041.

Knight, S.J., McClean, C.J. and White, P.C.L. (2022) 'The importance of ecological quality of public green and blue spaces for subjective well-being', *Landscape and Urban Planning*, 226, p. 104510. Available at: https://doi.org/10.1016/j.landurbplan.2022.104510.

Knobel, P., Dadvand, P. and Maneja-Zaragoza, R. (2019) 'A systematic review of multi-dimensional quality assessment tools for urban green spaces', *Health & Place*, 59, p. 102198. Available at: https://doi.org/10.1016/j.healthplace.2019.102198.

Lahoti, S., Lahoti, A. and Saito, O. (2019) 'Benchmark assessment of recreational public Urban Green space provisions: A case of typical urbanizing Indian City, Nagpur', *Urban Forestry & Urban Greening*, 44, p. 126424. Available at: https://doi.org/10.1016/j.ufug.2019.126424.

Li, F. *et al.* (2017) 'Urban ecological infrastructure: an integrated network for ecosystem services and sustainable urban systems', *Journal of Cleaner Production*, 163, pp. S12–S18. Available at: https://doi.org/10.1016/j.jclepro.2016.02.079.

Li, Z., Fan, Z. and Shen, S. (2018) 'Urban Green Space Suitability Evaluation Based on the AHP-CV Combined Weight Method: A Case Study of Fuping County, China', *Sustainability*, 10(8), p. 2656. Available at: https://doi.org/10.3390/su10082656.

Liu, R. and Xiao, J. (2021) 'Factors Affecting Users' Satisfaction with Urban Parks through Online Comments Data: Evidence from Shenzhen, China', *International Journal of Environmental Research and Public Health*, 18(1), p. 253. Available at: https://doi.org/10.3390/ijerph18010253.

Nouri, H., Chavoshi Borujeni, S. and Hoekstra, A.Y. (2019) 'The blue water footprint of urban green spaces: An example for Adelaide, Australia', *Landscape and Urban Planning*, 190, p. 103613. Available at: https://doi.org/10.1016/j.landurbplan.2019.103613.

OpenAI (2024) 'ChatGPT (version 4) [AI tool]'. OpenAI. Available at: https://chatgpt.com (Accessed: 15 January 2025).

Ricci, L. (2022) 'Integrated Approaches to Ecosystem Services: Linking Culture, Circular Economy and Environment through the Re-Use of Open Spaces and Buildings in Europe', *Land*, 11(8), p. 1161. Available at: https://doi.org/10.3390/land11081161.

Roberts, M., Glenk, K. and McVittie, A. (2022) 'Urban residents value multi-functional urban greenspaces', *Urban Forestry & Urban Greening*, 74, p. 127681. Available at: https://doi.org/10.1016/j.ufug.2022.127681.

Sharifi, F., Nygaard, A. and Stone, W.M. (2021) 'Heterogeneity in the subjective well-being impact of access to urban green space', *Sustainable Cities and Society*, 74, p. 103244. Available at: https://doi.org/10.1016/j.scs.2021.103244.

United Nations (2019) *World Urbanization Prospects: The 2018 Revision.* New York: United Nations, Department of Economic and Social Affairs, Population Division. Available at: https://population.un.org/wup/ (Accessed: 19 June 2024).

William, R., Garg, J. and Stillwell, A.S. (2017) 'A game theory analysis of green infrastructure stormwater management policies', *Water Resources Research*, 53(9), pp. 8003–8019. Available at: https://doi.org/10.1002/2017WR021024.

Wu, M. *et al.* (2024) 'Resilient spatial design strategies research of urban inland rivers: The case of Xinghai Lake wetland in Ningxia, China', *Ecological Indicators*, 163, p. 112075. Available at: https://doi.org/10.1016/j.ecolind.2024.112075.

Ye, Y. and Qiu, H. (2021) 'Environmental and social benefits, and their coupling coordination in urban wetland parks', *Urban Forestry & Urban Greening*, 60, p. 127043. Available at: https://doi.org/10.1016/j.ufug.2021.127043.

Zhou, X., Cen, Q. and Qiu, H. (2023) 'Effects of urban waterfront park landscape elements on visual behavior and public preference: Evidence from eye-tracking experiments', *Urban Forestry & Urban Greening*, 82, p. 127889. Available at: https://doi.org/10.1016/j.ufug.2023.127889.

Zhu, C. and Zeng, Y. (2018) 'Effects of urban lake wetlands on the spatial and temporal distribution of air PM10 and PM2.5 in the spring in Wuhan', *Urban Forestry & Urban Greening*, 31, pp. 142–156. Available at: https://doi.org/10.1016/j.ufug.2018.02.008.

Research Paper

Peri-Urbanization and Infrastructure Dynamics Strengthening Flood Resilience With Green and Grey Solutions in Developing Nations

Ayush PAWAR, Research Scholar, Maulana Azad National Institute of Technology, Bhopal India

Rajshree KAMAT, Associate Professor, Maulana Azad National Institute of Technology, Bhopal India

Abstract

Cities are constantly growing and extending their limits as a result of rising urbanization. The peri-urban interface between cities accommodates this overflow of population. Peri-urban areas are known for their transforming qualities, which are ascribed to the numerous environmental, social, and physical changes that occur there. The new investment in the periphery of the city results in a change in growth patterns, migration, land use and flood. The changing structure of the urban-rural linkages indicates the complex relationship between urbanization and capitalism. additionally, what is peri-urban now will become urban tomorrow, making it significant in terms of spatial planning. This paper aids in comprehending the meaning of peri-urban areas and flood resilience, their significance for planning, this will also address the critical need for flood resilience in these zones, especially in developing nations, where infrastructure often struggle to keep pace with rapid growth the reasons behind their importance, the different changes they experience, and their jurisdiction and governance. This paper additionally describes the characteristics and definitions of peri-urbanization, grey and green solutions, it additionally explains the methods used to identify and demarcate peri-urban zones in Indian cities. Following numerous worry areas of the peri-urban interface, the paper also presents a framework for balancing green and grey infrastructure to reduce flood vulnerability.

Keywords: Peri-Urban, Urban regions, Peri urbanization, flood resilience**,** *grey and green* **infrastructure***, Dynamism.*

1. Introduction

The first time since 2008, the pace of increase in the urban population exceeded that of the rural population. In the next 40 years, there is a projected 72% growth in the global urban population from 3.63 billion in 2011 to 6.25 billion in 2020 (Cattivelli, 2021). The increasing rate of urbanization will lead to built-up areas spreading outside of the cities, causes flood problems as well as extensive built-up land sprawl and eventually the conversion of agricultural land. Traditionally , gray infrastructure play an important role in mitigating urban flooding as a necessary stormwater drainage system.(Ahani and Dadashpoor, 2021)Because the real estate policies mostly lead to peripheral development, there is huge pressure on natural resources (Narain, Banerjee and Anand, 2014), china's storm water drainage system in typically designed to handle rainfall events that occur once every 3 to 4 year establishing peri-urban opportunity and collective pressures (Allen, 2003).

Agricultural and other undeveloped open spaces are being rapidly altered by new built-up

development.(Simon, 2008). Due to several processes occurring at the metropolitan scale, including urbanization, sprawl, or economic gentrification, flood problems, and in situ urbanization, to mention a few, both the amount of land that is urbanized and the population are growing(Meeus and GulZinck 2008). There are various spatial phenomena that occur in different geographical locations, combining it in unique ways to create diverse urban forms that cannot be effectively addressed using traditional planning methods. The negative impact of fast-paced spread urbanization in growing nations.(Kontgis et al., 2014) are that it reduces environmental sustainability and lowers quality of life.

It is now compulsory for a city to plan for peri-urban areas and interfaces to achieve sustainability and reduce flood with help of green and grey infrastructure. The Sustainable Development Goals (SDG 11) play an important role in spatial sustainability and equity within environmental sustainability. This is demonstrated by the New Urban Agenda 2020, which also highlights the importance of a plan linked between urban, peri-urban,grey and green solutions for flood resilience and rural areas as well as hinterlands, as well as improvements in transportation facilities and making public space accessible. Additionally, the spatial arrangement helps prioritize important planning and policy interventions and optimizes resource allocation for the improvement of network infrastructures which they reduce the flood risk, all of which they play a critical role in achieving or gaining sustainability from the environmental, social, and economic domains(Hillier, 2009).

The complexity of peri-urbanization and flood problem is becoming increasing day by day and the more of a challenge that requires new tools, fresh concept, and methodological frameworks to handle the various agents and elements that contribute to growth patterns, grey and green solutins and changes in land use(Gonçalves *et al.*, 2017). Peri-urban interfaces are the currently experiencing institutional changes. Consequently, in conjunction with enhancing the capacity of peri-urban areas, there is a growing need for well-structured territorial strategies supported by digital technologies and planning assistance. Systems are also needed. Therefore, Realising how these metropolitan areas are represented in detail and utilizing approaches that rely on a large number of precise indicators and factors becomes crucial. (Gonçalves *et al.*, 2017).

2. Literature Review

The literature review has Four sections that aim to deliver a basic understanding of peri-urban areas and its growth pattern grey and green infrastructure and flood resilience. The definitions of the peri-urban area and the ideas that underlie them are covered in the first section by a variety of writers and organizations. In contrast, the second section gives the theme of several research and provides an overview of how various elements have been added to the literature database.

2.1. Number of publications and citations per year

The primary data was collected from Table 1, a combination of the Wos and Scopus databases. The table includes 47 documents from 39 sources between 2011 and 2024. The publication's yearly growth rate has been -2.19% throughout the period. Having 0 references and an average of 18.43% citations per document.

In addition of total 35 articles, the retrieved data also included 209 author keywords and 284 keywords plus or index keywords. Based on the collected documents, this study field was worked on by 119 writers, with a single author contributing 9 documents. The average number of co-authors per article was 3, and the percentage of the foreign co-authorship was 29.79%.

Table 1: Result of summary following the combination of WoS and Scopus databases.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2011:2024
Sources (Journals, Books, etc)	39
Documents	47
Annual Growth Rate %	-2.19
Document Average Age	5.57
Average citations per doc	18.43
References	0
DOCUMENT CONTENTS	
Keywords Plus (ID)	284
Author's Keywords (DE)	209
AUTHORS	
Authors	119
Authors of single-authored docs	9
AUTHORS COLLABORATION	
Single-authored docs	9
Co-Authors per Doc	3
International co-authorships %	29.79
DOCUMENT TYPES	
article	35
book	1
book chapter	7
conference paper	3
review	1

Source: Author

2.2. Network analysis of author keywords:

To understand the hotspots and growth trends and flood patterns in research throughout time, keywords are important. The author's keyword patterns for 209 publications between 2011 and 2024 are investigated in this section.

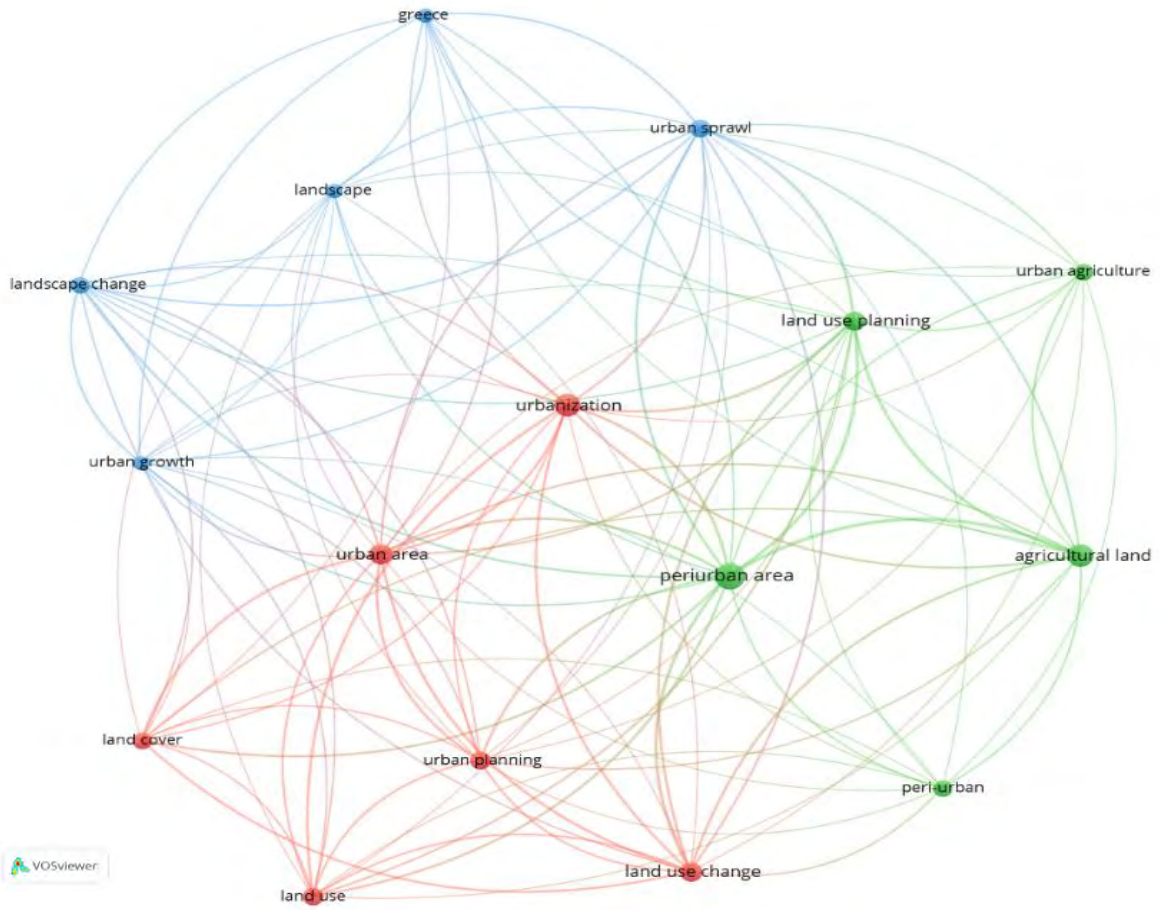


Figure 1:Author keywords co-occurrence network visualization, Source: Author

Using the entire counting procedures carried out in VOSviewer with a set of at least 4 occurrences per keyword, based on the author's keywords from the 51 articles, about 284 keywords fulfilled this criterion, and 29 keywords met the thresholds.

The keywords visualized by network mapping and document publication represent the size of nodes. A network map of authors' most frequently used keywords in peri-urban research is presented in Figure 1. The color of the groupings shows how strongly the keywords are related to one another; the size of the nodes shows how frequently a keyword occurs; and the lines connecting the nodes display the link. The keywords were categorized into three main groups based on the results.

The first grouping (red) includes author keywords: Urban area, land use planning, urbanization, land use change, and land cover. The second grouping (green) contains the per-urban area, per-urban, land use planning, agriculture land, and urban agriculture. The third cluster (blue) contains Urban sprawl, urban growth, landscape, and landscape change.

3. Peri-urban and flood resilience

The idea of peri-urban which has French origins, and it describes for a bigger area of urban sprawl surrounding a metropolitan centre. Peri-urban zone serves as a zone transition with multiple functional characteristics, in addition to dividing any given territory(Ravetz, Fertner and Nielsen, 2013), in which land uses rural and urban coexist in continuity or fragmentation Peri-urban areas are defined as those that have a variety of land uses, low density, dispersed or built areas, and scattered agricultural land, poor connectivity, flood area, grey and green infrastructures, and inadequate infrastructure and services. (Sareen and Haque, 2023), accompanied by a zone with the multifunctional ecosystem being disrupted the farmlands being quickly and arbitrarily converted into various commercial, residential, and industrial uses, according to the United Nations Environmental Program (UNEP) 2010.

Across the globe, flood resilient areas display two distinct features. Firstly, European peri-urban regions are characterized by the impact of cities, and second, in the global south, where it is claimed that peripheral areas with a constructed fabric resembling the core have evolved as a result of urbanization at the periphery(Wolff, Mdemu and Lakes, 2021). The first empirical definition of peri-urban areas, which are characterized as irregularly developed development with an average population density of at least 40 persons per square kilometres and fewer than 20,000 communities, is provided by the European Union's PLURAL (Peri-urban Land Use Relationships—Strategies and Sustainability Assessment Tools for Urban-Rural Linkages) project.(Wandl and Magoni, 2017).

Master plans are mandatory in several Asian countries to include a region of 5-8km around cities with a population of more than 30,000 people in order to account for urban spills. However, studies show that there has been peri-urban growth as far as 300 km away from the administrative boundaries of the city in some metropolitan regions of Asian countries. The lack of a generally agreed-upon definition of peri-urban areas is demonstrated by the ambiguity in their usage, as definitions vary depending on the types of cases they apply to(Mondal and Banerjee, 2021).

In addition to the multiple definitions of peri-urban and flood resilience, there have been different notions of peri-urban as a place and its location. By gathering a regional understanding and varied viewpoints of the rural-urban relationship and a combination of the peri-urban area, it is possible to better understand the peri-urban area in light of the rural hinterland and the densely populated metropolitan core.(Ravetz, Fertner and Nielsen, 2013). The production of the regional view reveals and that the peri-urban area, it has

been noted that the peri-urban area can exist anywhere in the region, characterized by extensive land-use change, varying economic activities, and distinct engagements of the population, creating an urban-rural hinterland that constitutes a rural-urban zone.

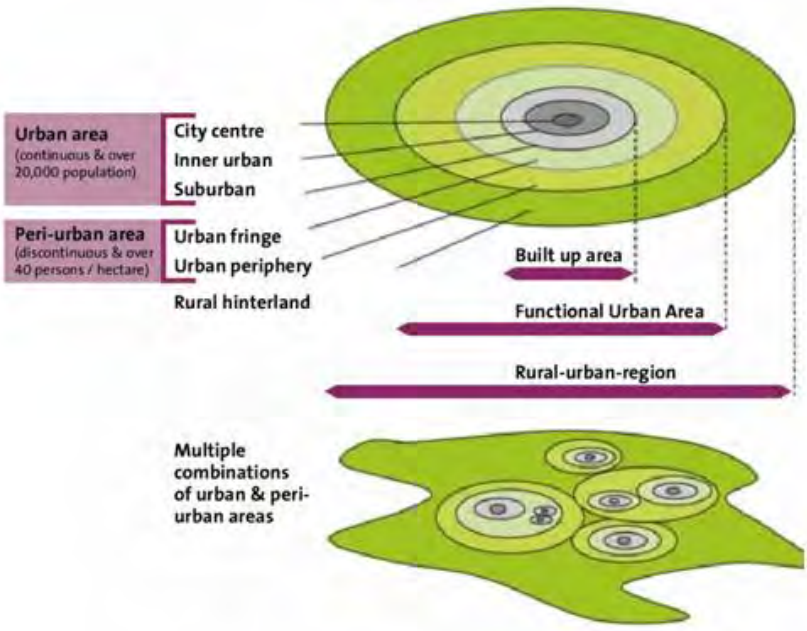


Figure 2:An emerging trend of peri urban sprawl, Source: (Tiwari, 2019)

The peri-urban interface, which discusses to the opposing and dualistic nature of the peri-urban areas and as per urban and rural represented by the interaction between the two, is another word that has been commonly linked with peri-urban (African and Asia) areas. The peri-urban interface is currently operating as a separate, dynamic area. (López-Goyburu and García-Montero, 2018). The problem of the interplay of such many urban and rural activities combine to give these locations a unique spatial and functional quality (Simon, 2008), which, in order to comprehend the fundamental spatial distinctions in the growth process, need to be contrasted with the city center. (Meeus and Gulinck, 2008).

4. Drivers of peri-urbanization

Peri-urbanization is impacted by the push and pull forces which affect the spatial pattern of any area at multiple scales. (Rauws and De Roo, 2011), changing monocentricity to polycentricity (Dadashpoor and Malekzadeh, 2020). The strong reasons, like as employment, lower crime rates, and a higher standard of living, that entice people from remote villages to cities and their outskirts are known as centripetal or pull pressures. Poor and restricted individuals are made possible by centrifugal or push pressures.

The peripheral development (NITI (National Institution for Transforming India) Aayog. 2021. Reforms in urban planning capacity in India. Gov. India. New Delhi, India.). Understanding the pattern of urbanization is crucial for comprehending the intricate system of structural, functional, and institutional driving forces that underpin expansion in a specific physical and functional form.(Ahani and Dadashpoor, 2021).

The interaction of factors often changes over time, highlighting the need to study their dynamics to enhance our comprehension of peri-urbanization phenomena (Fazal, 2013).
One of the common factors contributing to peri-urban growth is population migration to these areas. In wealthy nations, pull factors like amenity-driven in-migration affect migration; whereas, in developing

nations (Indonesia, China, Vietnam, India), push factors like low income and a low standard of life typically drive migration.(Rauws and De Roo, 2011). Moreover, in nations like China, peri-urban development reflects state-driven policies, while in Indonesia and India, rural areas may evolve by embracing new economic opportunities, resulting in a mix of varied land uses, and in the global West, the requirement of peri-urban growth is influenced by the housing demand and density(Abrantes *et al.*, 2016).
The variety of spatial changes taking place across the pan-urban region, including inner-city augmentation, redevelopment, suburbanization, and rising spatial divergence by land use, are all closely linked to urban periphery development or fringe area(Leaf, 2002). Numerous structural and functional changes are evident when the community makes decisions regarding livelihood changes. For example, The rural landscape is altered when a farmer sells their land because it is divided up into small parcels and sold separately.(Wolff, Mdemu and Lakes, 2021). The trend of city inhabitants from Latvia moving to rural areas of Germany in pursuit of larger homes has a similar effect. Therefore, peri-urban changes are usually the outcome of a push-pull dynamic including both general trends and content-specific circumstances, in the cases comprehensive research provides a basic understanding of peri-urban transition (Rauws and De Roo, 2011).

Table 2: Puss Pull Factors

PUSH FACTORS IN CITY	PULL FACTORS IN FRINGE
-HIGH LAND PRICES -CONGESTION IN THE CORE AREAS: MORE TRAFFIC -POLLUTION IN CITY -LACK OF QUALITY SERVICES AND AMENITIES	-LAND AVAILABILITY, LOWER LAND PRICES -OPPORTUNITIES FOR EMPOLYEMENT IN NEW EMERGING INDUSTRIES AND FACTORIES MOBILITY -ACCESS TO GOODS AND AFFORDABLE SERVICES -NEW EDUCATIONAL AND HEALTH FACILITIES DEVELOPING LESS POLLUTION

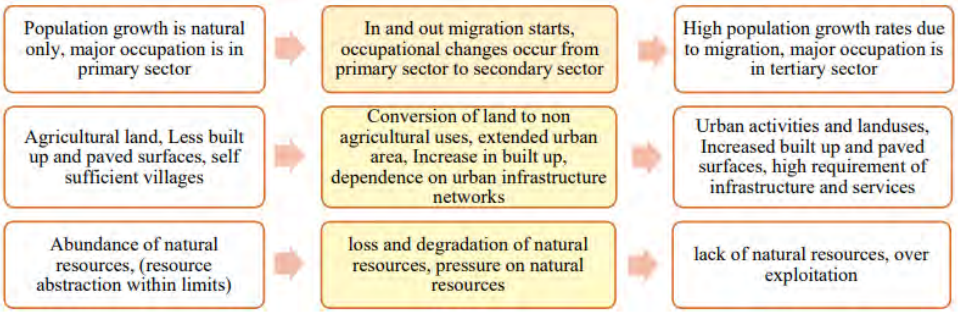
Source: (Sareen and Haque, 2023)

5. Changes and impact of peri-urban areas at flood

The regions under consideration are distinguished by their dynamic nature. The research identifies several parameters that determine the changes that take place and, it will turn to define the peri-urban boundary
a) Modification in the demography
b) Modification in socioeconomic parameters
c) Modification in the physical and infrastructural aspects
d) Modification in environmental conditions.

The main changes that may be observed in Indian cities are as follows. Despite several efforts to define a span for different indicators, the case studies and review of literature demonstrate that the limit or range of the indication is entirely contextual, reliant on the urban region where the peri-urban has to be determined. These changes have occurred in the periurban areas about the physical, environmental, and socioeconomic sectors, respectively.

Table 3: Stages of Transformation



Source: (Saxena and Sharma)

The peri-urban areas transform land use, change occupational patterns, and change it will demand for infrastructure The most apparent and possibly first stage transition observed in many Indian cities is the alteration in land cover. The land cover changes in the case study cities over 20 years are shown below. It is noted that all of the cities have seen a considerable rise in built-up area, while practically all of the case study cities have seen decreases in areas with water bodies, vegetation or forest land, and agricultural land. (*Peri-Urban Interface of Indian Cities: Growth, Governance and Local Initiatives on JSTOR*,).

Table 2: Landuse changes in Indian Cities for two decades

Landuse	Chennai	Ahmedabad	Patna	Guwahati	Chandigarh
Builtup	41%	173%	97%	40%	14.5%
Water Bodies	-13%	167%	-51%	-	0.37%
Fallow Land	-0.5%	-50%	-77%	-	25.84%
Vegetation/ Forest	-15%	-32%	-64%	-10%	0.03%
Agriculture	-3%	-86%	-40%	-10%	-24.5%

Source: (Tiwari, 2019)

Table 4:Drivers of peri urbanization in Indian Cities

GROWTH	CHENNAI	AHMEDABAD	CHANDIGARH	PATNA	GUWAHATI
Direction	Southward expansion.	Along transport routes	expansion towards Mohali, Panchkula	Growth and reorganization of internal space	More pronounced on the southern side
Drivers of growth	Growing as an IT corridor engulfing several fishing and agricultural villages and hamlets	Construction along transport routes lucrative for real estate developers. New industrialization along the roads	Development of information technology park and the Himalayan express-way.	People of the rural poor, migrating to the area and the slum dwellers being resettled from the city.	Construction of institutions, apartments, industries

Source(Wadduwage, 2021)

The peri-urban growth in Indian cities brings about multifaceted impacts across various domains, underscoring the necessity for comprehensive and sustainable approaches to address the challenges it poses. Physically, urban expansion and land use changes result in the loss of agricultural land, diminishing

water bodies, vegetation, and forests, while encroachment on ecologically sensitive areas disrupts local flora and fauna. Industrial activities and improper waste disposal contribute to the pollution of surface water bodies and groundwater, further exacerbating environmental degradation(Wisnubroto *et al.*, 2021). Additionally, urbanization often leads to the displacement of tribal populations and disrupts natural habitats. Economically, while peri-urban areas may offer employment opportunities in emerging industries and real estate development(Akbari and khosravaninezhad, 2014), the loss of agricultural land and challenges in solid waste management and water resource competition can hinder economic activities.

Moreover, inadequate governance and coordination impede the efficient management of peri-urban areas, affecting economic development. Infrastructure-wise, the increase in built-up areas necessitates new infrastructure development, posing challenges in planning and provision, particularly in rapidly growing peri-urban regions(Chakraborty *et al.*, 2021). Transportation corridors are impacted, and upgrades become essential to accommodate the development of new industrial and residential complexes. Environmentally, haphazard development in the peri-urban areas leads to the loss of open spaces, vegetation, and agricultural land, coupled with declines in groundwater tables and salinity intrusion, impacting water resources and ecosystems.
Urban flooding and environmental pollution further compound the health risks for residents and ecosystems alike. Combating these challenges requires holistic strategies encompassing sustainable land use planning, environmental conservation measures, economic diversification, efficient governance, and infrastructure development to ensure the long-term viability and resilience of peri-urban areas in Indian cities(Mondal and Banerjee, 2021).

6. Peri-urban growth pattern and grey and green infrastructure in india

India is an growing trend in urbanization, which it includes an increase in the proportion of its population are living in cities, the geographic extension of its current urban centers, the regular birth of new cities, and the advancement of urban economies. For example, according to census data, From 1971 to 2011 , the percentage of the national population residing in urban areas increased from 19.91 % to 31.16%.(Saxena and Sharma, no date).
The number of new towns increased from 5161 in 2001 to 7935 in 2011; Peri-urban areas are regions where land uses transition from well-known urban land uses to agicultural areas. This growth is largely due to an increase in the number of censuses conducted in this area.(Sahu and Vaidya, 2020).

7. Issues and problems in peri-urban areas and flood resilience

There is sufficient data to conclude when an ecosystem's carrying limit is exceeded, something bad will finally happen. This also applies to peri-urban locations. The stresses brought on by urbanization are causing India's periurban areas to change and become extremely stressed.

Table 5:ISSUES AND CAUSES OF PERI-URBAN AREA

ISSUES	CAUSES
• Uncontrolled growth • Underegulated / haphazard development • Poor quality services will increase day by day (water, sanitation)	• Lack of land use maps, legislation approving development plans, and land monitoring systems.

• Increase the no. of buildings and population density	Lack of regulations related to land, building, and development
• High-rise built structures are unsafe • Land mafia forced to acquire land	Fragmented and haphazard planning
• Non-availability of spaces • Forced land acquisition by the land mafia	Lack of information in administrative boundaries and extended area
• Project execution delays brought on by unauthorized settlement and land disputes	Prohibition and forcibly to applied urban bye-laws
• Native population Displacement • Decreased in production of food grain and vegetable; in result rising food grain prices and scarcity of resources	Irregularities in the industries and other economic activities in the city

SOURCE:(Peri-Urban Interface of Indian Cities: Growth, Governance and Local Initiatives on JSTOR)

8. Peri-urban growth and case study

India has seeing an increasing trend in urbanization, which includes an also increase in the proportion of its population which are living in cities, the geographic extension of its current urban centers, the regular birth of new cities, and the advancement of urban economies. For example, according to the census of data, Between 1971 and 2011, the proportion of the country's population living in cities grew from 19.91% to 31.16%. From 5161 in 2001 to 7935 in 2011, there were more new towns; this growth is mostly to a attributable to an increase in Census data of the Periurban area, which is the area where well-grow urban land uses transition into areas used for agriculture(Saxena and Sharma, no date).

Peri-urban regions are found to be at distance between 5 and 25 kilometers from the urban boundary, taking into account the census town's expansion beyond the municipal limit and the range of connectivity to the core city area and urbanity value. The urban index approach, to one of the delineation techniques, it is used in the case study of to determine the boundaries of the peri-urban zones and fringe area. The case study covers four aspects in the designated areas. The city's overall expansion, important pull forces, peri-urban area changes, and satellite map analysis are also the factors. The comparison is carried out using a table.(Sahu and Vaidya, 2020).

Table 6:CASE STUDY OF PERI-URBAN AREAS

TOPICS		CASE STUDY-1	CASE STUDY-2
GROWTH OF THE CITY AND THE PERI-URBAN AREAS		There are just one industrial town in Jamshedpur in 1951, following the existence of several census towns.1951-3 Census Town. 1961-1964 Census Town.	Chhattisgarh's capital, Raipur, had just one municipal corporation in 1951. 1991–1971 expand close to the municipal corporation 2001 had a single census town.

		1971-1977 Census Town. 1991-2000 Census Town. 2001-14 Town of Census or The district head quarter's highest influence distance is 85 km, while the minimum is 4. However, taking it into account the maximum area, the Jamshedpur urban agglomeration's impact distance ranges from 4 to 15 km.	2011: Four census towns 2021: There will be two census towns: Mana, which is 12 kilometers from the district headquarters, and Siltara, which is 15 kilometers away.
FACTOR OF GROWTH OF ANY CITY		Jamshedpur is an industrial city and has an industrial settlement with significant industry growth increasing over a period of time. It has good interconnection with other places, NH-33 connects Adityapur. Rail connectivity The two rivers Subarnarekha and Kharkai serve as the city's natural borders, while the Dalma hills are located on one side. The city is expanding towards the national highway and state highway as well as along railway lines according and map study and site survey	Raipur are major industrial expansion in Birgaon along with national highways Moreover, the city growth can be seen towards the Abhanpur and Dhamtari roads because of the Atal Nagar, Patan, and land availability of the area. People move from adjacent villages to nearby villages mostly because of the Kharun River and the ease of access to the ring road. It is only 15 km to Atal Nagar. Away from Raipur, the whole region expanding quickly between these two places draws people in because of the possibility of future expansion and the presence of the important Mumbai-Calcutta rail line.
SATELLITE MAP STUDY		The area's growth situation is explained by the satellite map analysis. The mango area, which is closest to Adityapur and rail lines and has the most	A satellite map depicts the increase that can occurring in the direction of the industrial region and the ongoing conversion of agricultural

		amount of undeveloped land, is initially appropriate for house growth since its land use is continuously changing from agricultural to residential.	land to other uses. Major land use changes are visible along the Abhanpur and Dhamtari roads as well as in the Raipura to Patan area.
POLICIES GOVERNMENT		Jamshedpur has an urban agglomeration plan for 2027 that calls for the urban growth of municipal borders and the creation of 13 census towns.	In the masterplan of Raipur 2021 the Birgaon area is considered and comes under planning area and its outgrowth of the municipal corporation AMRUT and JNNURM policy are also working on the development of the area

SOURCE:(Sahu and Vaidya, 2020)

9. Tolls/Method

The study draws from a wide range of sources of information using a number of instruments and techniques. To achieve this, numerous sources of data were gathered, covering a broad spectrum including the Indian Metrological Department, Survey of India Toposheet NO. 73 M/15 and M/16, of census data from various years, village income records, and the United States Geological Survey's LANDSAT series.(Saradar, no date). The present paper provides a tools/method to delineate the peri-urban areas near the metropolis and the megalopolis area in India.

The Optimum Index Factor (OIF) has been used to classify land use and land cover (LULC). Seven separate indices (viz. NDPI, NDVI, NDBI, NDBAI, SAVI, MNDWI, and UBI) have been applied to depict different land use components in this study area there is no single index is sufficient to explain the existing design. (Arif and Gupta, 2020).

To determine which locations are peri-urban principal component Analysis has been conducted, and classification has been done using a "maximum likelihood classification algorithm" with ground trothing (Saradar, no date). This was the built-up expansion spatial data analysis done with ArcGIS (v. 10.2.1) software. Therefore, a zoning plan was prepared that addresses number of environmental and socioeconomic concern and it will help to mitigate the effects of the declining quality of the peri-urban space. (Arif and Gupta, 2020).

10. Governance of peri-urban areas and flood resilience

As per the 73rd Amendment to the Constitution, several institutions and organizations oversee the growth and development of peri-urban areas. These include Panchayats, Nagar Panchayats, the state government's Town & Country Planning Department, district administrations, MPCs, DPCs, and Development Authorities. (Tiwari, 2019).

India is becoming more urbanized, raising concerns about the unfavorable conditions brought about by the peri-urban areas' unchecked growth and development. The following policy documents—such as the

former Planning Commission Five-Year Plans—legislation (such as the Seventy-fourth Constitution Amendment Act, 1992); programs and schemes—such as the Jawaharlal Nehru National Urban Renewal Mission, 2005; the Atal Mission for Rejuvenation and Urban Transformation, 2015; the National Urban Mission, 2016—and initiatives of town and country planning departments, regional planning and development authorities, and state and local governments—have shaped the government's approach and response over the years. (Tiwari, 2019)

The Planning for peri-urban areas is to establish a sensible regional and land use pattern, create an efficient regulatory framework, establish Metropolitan Planning Committees (MPCs), offer affordable housing it also provide some basic services, and regional transportation corridors and facilities, In addition to expanding a number of growth hubs and the rural settlements, such as census towns, are some of the recommendations for better peri-urban region governance.(Saxena, Engineering and 2015, no date).

According to reports of state government of Uttarakhand is during the process of combining of both peri-urban areas and urban local bodies. As a result, these regions will be eligible for municipal services such as solid waste management, a sewer network, and piped water supplies. The Asian Development Bank (ADB) and the Indian government are providing funds for this project, which is projected to cost approximately INR 35 billion. The plan also includes regulating the construction of commercial buildings in 29 peri-urban regions. Additionally, the state administration is collaborating with the World Bank and the federal government to increase access to better water supply services in the state's of peri-urban areas, home to more than seven lakh people. To improve the food supply to cities, the Union Ministry of Agriculture and Farmers Welfare action to improve peri-urban agricultural output. Peri-urban agriculture and the expanding of food sources for the urban inhabitants, and according to the Ministry, it will help or support to stabilize prices and adapt to climate change. (Sahu and Vaidya, 2020)

The rural communities' development decisions are made by the panchayats, the local self-governing body. However, the peri-urban area combines elements of the rural and urban settings, and here is where the panchayat is inadequate in addressing the urban aspect. This can be linked to several factors, including a lack of funding and the independence in raising it, the ability to control the local dynamics, and the knowledge to steer land use change and urbanization-related challenges.

11. Assessment of the Effectiveness of Comprehensive Gray–Green Practice

We conducted a coupled grey–green facility practice and assessed the impact of the enhanced measures on rainfall and flood management in the study area. The outlet J61 was chosen to examine the flow of water through the pipeline during a rainfall return period of 1 year (Fig. 3). Based on Fig. 3, the area covered by the curves reflects the overall volume of outflow.

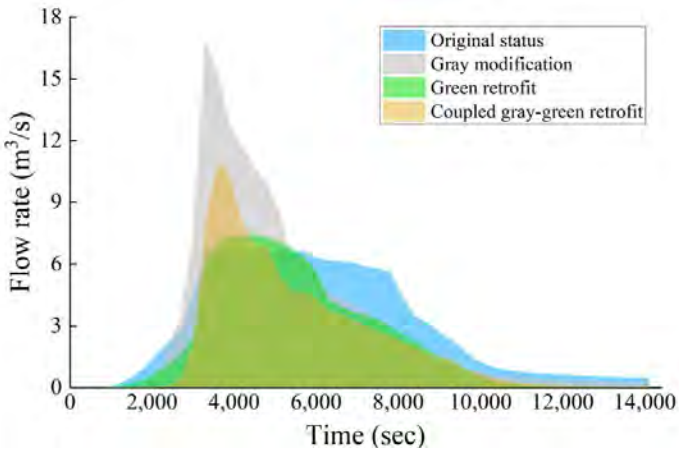


Figure 3: Comparison of outflow processes for different retrofitting methods at a typical outlet (J61) under a 1-year return period rainfall

The total outflows are approximately the same for the status quo situation and the gray retrofit, and approximately the same for the green retrofit and the grey-green retrofit. Furthermore, the first group contains a larger quantity of water compared to the second group. The level of peak flow reflects the drainage capacity of the pipeline to a certain extent. The peak of the curve associated with the status quo situation is not high, but it remains so for an extended duration, suggesting that the pipeline system has been consistently operating at maximum capacity for a long time. The shape of the flow curve for the green retrofit and the status quo situation exhibits overall similarity, although Fig.3 Inundation for coupled gray–green retrofit versus current state under different rainfall scenarios the time at which the peak occurred is postponed. The gray renovation has significantly increased the drainage capacity of the pipe network, with a peak of 16.86 m3/s, demonstrating its ability to rapidly drain rainwater. The peak flow rate of the integrated gray–green retrofit is 11.11 m3/s, which is much lower compared to the gray pipe network renovation. Meanwhile, it is considerably higher than both the current state and the green retrofit. Implementing a gray-green retrofit can simultaneously decrease water volume and enhance the drainage capacity of the pipe network. This helps alleviate pressure on the drainage pipes and ensures a smoother flow of water.

12. Conclusion

The purpose of this paper is to increase awareness and gain knowledge of the method and technique considered as a spatial planning of peri-urban areas and their growth patterns. It is evident that there is considerable expansion occurring in both the urban centre and the main cities. Due to the low land prices in the outskirts, peri-urban areas become appealing to real estate developers, leading to profitable development in these regions and encouraging the expansion of peri-urban regions. Additionally, the development of industry, IT hubs, Transportation networks and Real estate projects all act as stimulants for these sector's growth and contribute to the dynamic evolution of peri-urban growth Therefore, the study of peri-urban areas is best approached by considering the different development factors that influence the scale and character of growth. The concept of peri-urbanization is inherently contextual, varying based on the direction and factors propelling growth in these areas. These regions accommodate the expanding population, including the overflow from urban sprawl, which poses challenges such as resource depletion, environmental degradation, and social and ecological issues in peri-urban areas. Nevertheless, Comprehensive studies and case studies show that these expanding areas present chances for well-thought-out planned interventions to reduce traffic in urban cores and create a more harmonious

relationship between rural and urban areas. deteriorating city environments on a global scale can also find solutions in the peri-urban interface, where development is still in its early stages and under the control of authorities. Implementing context-specific, evidence-based development frameworks and introducing environmentally friendly regulations in these areas during initial transformations can not only mitigate degradation but also aid in restoring the equilibrium of urban areas.

Therefore, more research is necessary to find out how these areas respond to urban expansion and city growth in terms of growth and development, activity, and environmental resources. Consequently, preparing for the peri-urban areas transforming ecosystem needs to be sensitive., and this can be achieved by implementing an environment-sensitive, holistic approach early in the development process.

13. References

1. Abrantes, P. *et al.* (2016) 'Compliance of land cover changes with municipal land use planning: Evidence from the Lisbon metropolitan region (1990-2007)', *Land Use Policy*, 51, pp. 120–134. Available at: https://doi.org/10.1016/j.landusepol.2015.10.023.
2. Ahani, S. and Dadashpoor, H. (2021) 'A review of domains, approaches, methods and indicators in peri-urbanization literature', *Habitat International*, 114, p. 102387. Available at: https://doi.org/10.1016/J.HABITATINT.2021.102387.
3. Akbari, R. and khosravaninezhad, samaneh (2014) 'Application of environmental justice concept in urban planning, the peri- urban environment of Tehran as the case study', *Iran University of Science & Technology* [Preprint].
4. Allen, A. (2003) 'Environmental planning and management of the peri-urban interface: Perspectives on an emerging field', *Environment and Urbanization*, 15(1), pp. 135–148. Available at: https://doi.org/10.1630/095624703101286402.
5. Arif, M. and Gupta, K. (2020) 'Spatial development planning in peri-urban space of Burdwan City, West Bengal, India: statutory infrastructure as mediating factors', *SN Applied Sciences*, 2(11), pp. 1–19. Available at: https://doi.org/10.1007/S42452-020-03587-0/FIGURES/14.
6. 'Balanced Urban Development: Options and Strategies for Liveable Cities', Springer Nature, 2016.
7. Cattivelli, V. (2021) 'Planning peri-urban areas at regional level: The experience of Lombardy and Emilia-Romagna (Italy)', *Land Use Policy*, 103, p. 105282. Available at: https://doi.org/10.1016/J.LANDUSEPOL.2021.105282.
8. Chakraborty, S. *et al.* (2021) 'Spatio-temporal patterns of urbanization in the Kolkata Urban Agglomeration: A dynamic spatial territory-based approach', *Sustainable Cities and Society*, 67. Available at: https://doi.org/10.1016/J.SCS.2021.102715.
9. Dadashpoor, H. and Malekzadeh, N. (2020) 'Driving factors of formation, development, and change of spatial structure in metropolitan areas: A systematic review', *Journal of Urban Management*, 9(3), pp. 286–297. Available at: https://doi.org/10.1016/J.JUM.2020.06.005.
10. Fazal, S. (2013) 'Conceptualizing Peri-Urban Interface', pp. 15–25. Available at: https://doi.org/10.1007/978-94-007-5255-9_3.
11. Gonçalves, J. *et al.* (2017) 'Differentiating peri-urban areas: A transdisciplinary approach towards a typology', *Land Use Policy*, 63, pp. 331–341. Available at: https://doi.org/10.1016/J.LANDUSEPOL.2017.01.041.
12. Hillier, B. (2009) 'Spatial sustainability in cities: organic patterns and sustainable forms', *In: Koch, D. and Marcus, L. and Steen, J., (eds.) Proceedings of the 7th International Space Syntax Symposium. (pp. p. 1). Royal Institute of Technology (KTH): Stockholm, Sweden. (2009)* [Preprint]. Available at: http://www.sss7.org/Proceedings_list.html (Accessed: 14 April 2024).
13. Jiayue Li, Jiajun Zeng, Guoru Huang, WenjieChen. (2024) 'Urban Flood Mitigation Strategies with Coupled Gray–Green Measures: A Case Study in Guangzhou City, China', International Journal of Disaster Risk Science.
14. Kontgis, C. *et al.* (2014) 'Monitoring peri-urbanization in the greater Ho Chi Minh City metropolitan

area', *Applied Geography*, 53, pp. 377–388. Available at: https://doi.org/10.1016/j.apgeog.2014.06.029.

15. Leaf, M. (2002) 'A tale of two villages: Globalization and peri-urban change in China and Vietnam', *Cities*, 19(1), pp. 23–31. Available at: https://doi.org/10.1016/S0264-2751(01)00043-9.
16. López-Goyburu, P. and García-Montero, L.G. (2018) 'The urban-rural interface as an area with characteristics of its own in urban planning: A review', *Sustainable Cities and Society*, 43, pp. 157–165. Available at: https://doi.org/10.1016/j.scs.2018.07.010.
17. Meeus, S.J. and Gulinck, H. (2008) 'Semi-Urban Areas in Landscape Research: A Review', *Living Reviews in Landscape Research*, 2. Available at: https://doi.org/10.12942/LRLR-2008-3.
18. Mohammad Arif, Krishnendu Gupta. (2020) 'Spatial development planning in peri-urban space of Burdwan City, West Bengal, India: statutory infrastructure as mediating factors', SN Applied Sciences.
19. Mondal, D. and Banerjee, A. (2021) 'Exploring peri-urban dynamism in India: Evidence from Kolkata Metropolis', *Journal of Urban Management*, 10(4), pp. 382–392. Available at: https://doi.org/10.1016/j.jum.2021.06.004.
20. Narain, V., Banerjee, P. and Anand, P. (2014) 'The Shadow of Urbanization: The Periurban Interface of Five Indian Cities in Transition', (68).
21. *NITI (National Institution for Transforming India) Aayog. 2021. Reforms in urban planning capacity in India. Gov. India. New Delhi, India: National Institution for Transforming India Government of India.* - (Accessed: 14 April 2024).
22. Peri-urban futures Scenarios and models for land use change in Europe, 2013.
23. *Peri-Urban Interface of Indian Cities: Growth, Governance and Local Initiatives on JSTOR* (no date). Available at: https://www.jstor.org/stable/4416042 (Accessed: 3 April 2024).
24. Rauws, W.S. and De Roo, G. (2011) 'Exploring transitions in the peri-urban area', *Planning Theory & Practice*, 12(2), pp. 269–284. Available at: https://doi.org/10.1080/14649357.2011.581025.
25. Ravetz, J., Fertner, C. and Nielsen, T.S. (2013) 'The dynamics of peri-urbanization', *Peri-Urban Futures: Scenarios and Models for Land use Change in Europe*, pp. 13–44. Available at: https://doi.org/10.1007/978-3-642-30529-0_2
26. Sahu, P. and Vaidya, S. (2020) 'Study of growth pattern at peri-urban areas and identifying challenges: A case study', *International Research Journal of Engineering and Technology* [Preprint]. Available at: www.irjet.net (Accessed: 14 April 2024).
27. Saradar, J. (no date) 'Delineation of Peri urban Area using Modern Techniques a case study of North 24 Parganas'. Available at: https://www.academia.edu/13876669/Delineation_of_Peri_urban_Area_using_Modern_Techniques_a_case_study_of_North_24_Parganas (Accessed: 21 April 2024).
28. Sareen, S. and Haque, M. (2023) 'The Dynamics of Peri-Urban Spatial Planning: An Overview', *Journal of Urban Planning and Development*, 149(3), p. 03123002. Available at: https://doi.org/10.1061/JUPDDM.UPENG-4275.
29. Saxena, A.M. and Sharma, A.S. (no date) *Periurban Area: A Review of Problems and Resolutions*. Available at: www.ijert.org.
30. Saxena, M., Engineering, S.S.-I.J. of and 2015, undefined (no date) 'Periurban area: a review of problems and resolutions', *academia.eduM Saxena, S SharmaInternational Journal of Engineering Research & Technology, 2015•academia.edu* [Preprint]. Available at: https://www.academia.edu/download/66979655/ijertv4is090051.pdf (Accessed: 3 April 2024).
31. Simon, D. (2008) 'Urban environments: Issues on the peri-urban fringe', *Annual Review of Environment and Resources*, 33(Volume 33, 2008), pp. 167–185. Available at: https://doi.org/10.1146/ANNUREV.ENVIRON.33.021407.093240/CITE/REFWORKS.
32. Somi Sareen, Mazharul Haque. (2023) 'The Dynamics of Peri-Urban Spatial Planning: An Overview', Journal of Urban Planning and Development.
33. Tiwari, P. (2019) 'Dynamics of Peri Urban areas of Indian Cities', in. Available at: http://www.ijser.org.

34. Wadduwage, S. (2021) 'Drivers of peri-urban farmers' land-use decisions: an analysis of factors and characteristics', *Journal of Land Use Science*, 16(3), pp. 273–290. Available at: https://doi.org/10.1080/1747423X.2021.1922525.
35. Wandl, A. and Magoni, M. (2017) 'Sustainable Planning of Peri-Urban Areas: Introduction to the Special Issue', *Planning Practice and Research*, 32(1), pp. 1–3. Available at: https://doi.org/10.1080/02697459.2017.1264191.
36. Wisnubroto, E.I. *et al.* (2021) 'The dynamic changes in peri-urban agricultural area and typology of multi-function agriculture in Batu City, Indonesia', *IOP Conference Series: Earth and Environmental Science*, 667(1), p. 012093. Available at: https://doi.org/10.1088/1755-1315/667/1/012093.
37. Wolff, S., Mdemu, M. V. and Lakes, T. (2021) 'Defining the Peri-Urban: A Multidimensional Characterization of Spatio-Temporal Land Use along an Urban–Rural Gradient in Dar es Salaam, Tanzania', *Land 2021, Vol. 10, Page 177*, 10(2), p. 177. Available at: https://doi.org/10.3390/LAND10020177.

Research Paper

Identification and cause analysis of food deserts in the old town

A case study of the old town of Nanjing

Li Chenhui,Southeast University,China

Abstract

Amidst the backdrop of an aging population, accessing healthy food has become a critical issue for maintaining food security. Areas where residents face difficulties in obtaining healthy food are termed "food deserts." For old urban areas, studying and identifying food deserts issues are vital for promoting health equity, planning the future development of old cities, and stimulating market vitality. With the support of big data, research on food deserts can now be analyzed at the street level. This paper takes the old city of Nanjing as an example to identify and analyze the formation of food deserts.Utilizing population data, food supply point data, this study first conducts a descriptive statistical analysis of the proximity and density of food supply points from communities to food supply points in the old urban area. It then employs the Two-Step Floating Catchment Area (2SFCA) method, considering the impact of age on food acquisition, to determine food deserts from both the supply and demand perspectives. Subsequently, the study uses the Mann-Whitney U test to explore the differences and connections between the proximity and density of food supply and built environmental characteristics such as the number of buildings in the block, the degree of land use mix, and public service facilities. Finally, Geographically Weighted Regression (GWR) is applied to investigate the relationship between the formation of food deserts and built environmental variables such as the number of buildings in the block, the degree of land use mix, and public service facilities. All data used in this study are publicly available online.The study reveals that there is a negative correlation between the number of buildings in the block and food deserts phenomena in most areas of the old city, while the degree of land use mix and the density of public service facilities are mostly positively correlated with food deserts. These findings provide valuable insights for urban planning and policy-making aimed at enhancing food accessibility and promoting health equity in old urban areas.

Keywords

Food deserts, old city,built environment

1. Introduction

In the mid-1990s, academia defined "food deserts" as geographical areas where a lack of healthy food retail outlets results in residents struggling to access healthy and affordable food within a certain distance.[1]

According to the World Health Organization (WHO), a healthy diet can help prevent all forms of malnutrition, as well as non-communicable diseases (NCDs), including diabetes, heart disease, stroke and cancer. An unhealthy diet is one of the major risks to global health. In the context of China's aging population, access to healthy food has become an important issue to maintain food safety. For the old city, the research and identification of food deserts is of great significance for promoting health and equity, planning the future development of the old city, and stimulating the vitality of the old city market.

Properly distributed food supply points help reduce food waste and carbon emissions during transportation, supporting sustainable urban development. Urban planning should consider the reasonable distribution of food supply points, residential areas and work areas to reduce the impact on the environment. At present, with the support of big data, the study of food deserts have reached the street scale for analysis and research.

The current research on food deserts are mainly concentrated in the field of quantitative analysis. Traditional analysis methods mainly analyze the accessibility of food supply points, including buffer analysis [2-3]、kernel density analysis [4] and other methods for density and proximity analysis. Some scholars also use network analysis[5] to divide the arcs of street networks into homogeneous linear units for analysis, or use geographic grid methods to assign equal weights to grid population density. Thus, it is associated with the distribution of food deserts.[6] In addition, some scholars used road data to build a network analysis model and studied the accessibility of demand areas to food retail points through network analysis. [7]

The current research on food deserts are mainly concentrated in the field of quantitative analysis. Traditional analysis methods mainly analyze the accessibility of food supply points, including buffer analysis, kernel density analysis and other methods for density and proximity analysis. Some scholars also use network analysis to divide the arcs of street networks into homogeneous linear units for analysis, or use geographic grid methods to assign equal weights to grid population density. Thus, it is associated with the distribution of food deserts. In addition, some scholars used road data to build a network analysis model and studied the accessibility of demand areas to food retail points through network analysis.

This study mainly studies the following issues. First, how to identify areas with weak food supply capacity (food deserts) in the old urban areas with high population density. In addition, with the support of big data, how to better consider the needs of the elderly population. Whether the relationship between food supply capacity and the number of block buildings, the mixing degree of block land use and the density of public service facilities is close at the block scale, and on this basis, how the built environment factors at the block scale affect the food supply capacity.

This study has theoretical and practical significance. First, an interdisciplinary approach is used, combining statistical and geographic data with urban planning. At the same time, the needs of vulnerable groups are taken into account, which in turn contributes to the construction of more equitable and harmonious cities. The distribution of food supply points is related to the health and quality of life of urban residents, and the rationality of the distribution of food supply points is related to the health and quality of life of urban residents, and is an important part of urban sustainable development. In addition, the rational distribution of food supply points is an important part of urban renewal and community development, and research can promote the sustainable development of old urban areas and the enhancement of community cohesion.

2. Research scope and data source

2.1. Research object and scope

The research object of this paper is the main block of the old city of Nanjing. According to the relevant documents on the protection of historical and cultural cities, the old city is within the three administrative regions of Xuanwu, Gulou and Qinhuai, and the core area of the ancient city basically covers this scope. Therefore, the main block of these three administrative regions is selected for research when the data is selected. Nanjing is one of the four ancient capitals of China, with a history of more than two thousand years. Located in the southwest of Jiangsu Province and the lower reaches of the Yangtze River, Nanjing is

rich in historical, cultural and natural landscapes. There are four distinct seasons, abundant rain, belonging to the north subtropical humid climate. In 2023, the population of the elderly aged 60 and above in Gulou District is 307,100, and the population of the elderly aged 60 and above in Qinhuai District is 266,700, which is one of the regions with the largest elderly population in Nanjing. The aging of population in Gulou District, Qinhuai District and Xuanwu District is obvious.

2.2. Data Sources

The population density data comes from data shared by Professor Chen Yuehong's team on the figshare platform[8]。 A 100-m gridded population dataset of China’s seventh census in 2020 was generated by stacking ensemble learning and geospatial big data.

The population age data used in this study came from the website "worldpop", and the original data was raster data with a resolution of 100m. The site contains both 'Constrained' and 'Unconstrained' data, covering the years 2000 to 2020. This study extracted the number of people over 70 years old in each neighborhood within the 2020 study area of the 'Unconstrained' type.

The block data comes from the public data set "41 Urban blocks in 63 Chinese cities" released by Beijing City Lab, which extracts the largest construction land plots in the city as the range.Eleven attributes are available in the data, including ID of the block (PARCEL_ID), name of cities (CITY_NAME), number of buildings (BLD_Count), average floor number (BLD_FLOORN), average floor area ratio (BLD_FAR), average building density (BDL_bldDen)and so on。 [9] The block data comes from the public data set "41 Urban blocks in 63 Chinese cities" released by Beijing City Lab, which extracts the largest construction land plots in the city as the range.

POI food supply point data from AmAP API2022 edition. The data content includes latitude and longitude, the name and type of the point. The food supply points in this study are defined as supermarkets, which are divided into department stores, supermarkets, convenience stores and shopping centers according to types, with a total of 2,567 stores. The food supply points and distribution involved in this study are shown in the figure below. In addition, POI data of interest points of public service facilities are also obtained. This study selects educational facilities, medical and health institutions, cultural and entertainment institutions, transportation stations, sports venues, social welfare and security facilities as public service points, so as to calculate the number variable of public service facilities in blocks.

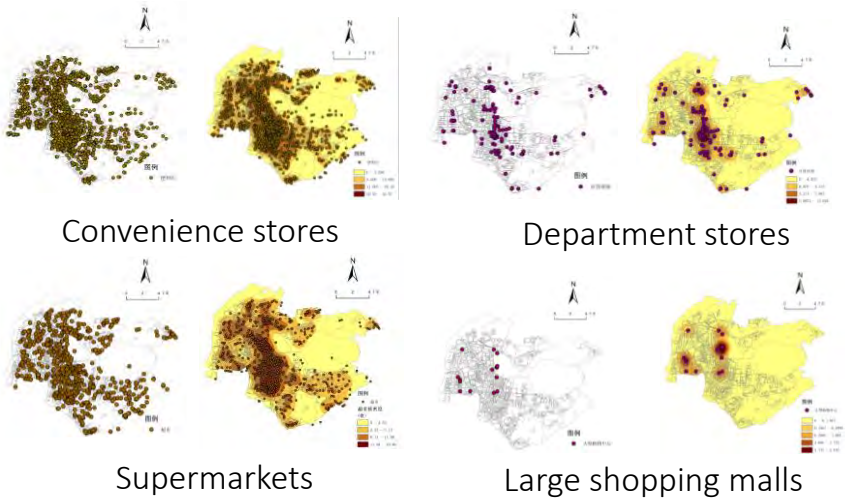


Figure 1. Distribution and kernel density estimation of four types of food supply points. Source: author.

Table 1 Statistical quantity, classification and proportion of four types of food supply points

Type	Number	Grade	Proportion
Large shopping malls	16	4	0.01
Department stores	134	3	0.05
supermarket	766	2	0.30
Convenience store	1650	1	0.64

3. Methodology

3.1. Food deserts identification based on two-step floating catchment area method (2SFCA)

$$A_i^F = \sum_{j\epsilon\{d_{ij}\leq d_0\}} R_j = \sum_{j\epsilon\{d_{ij}\leq d_0\}} \left[\frac{S_j}{\sum_{k\epsilon\{d_{kj}\leq d_0\}} D_k}\right]$$

The 2SFCA method was first proposed by Radke et al. (2000), further improved by Luo et al. (2003) and named as the Two-Step Floating Catchment Area (2SFCA) me*thod*. The method is to search the supply point and the demand point respectively in two steps. The first step is to focus on the food supply point, search the demand point within the threshold range, and then calculate the supply and demand ratio. The second step is to search all supply points within the threshold range, and then calculate the sum of the demand ratio of all supply points found.

In the formula, i represents the block and forms the central demand point k of the block; j represents the food supply point, which has been divided into four levels according to the food supply capacity; AiF represents the food supply capacity of block i calculated according to the Two-Step Floating Catchment Area (2SFCA) method, that is, the sum of the supply and demand ratio of food supply points in the corresponding search range of block i; dij is the radius of distance between block i and food supply point j; Rj is the ratio of the food supply capacity level corresponding to food supply point j to the population served within the search radius d0; Sj represents the supply scale of supply point j, which has been expressed as their respective supply grade according to their respective supply capacity; Dk represents the scale of demand at point k, which in this study refers to the number of people covered.

3.2. Mann-Whitney U test

The Mann-Whitney U test, also known as the Wilcoxon rank sum test, is a non-parametric statistical method used to compare the distribution of two independent samples. It is especially suitable for cases where the data does not meet the normal distribution or there are outliers, and is a non-parametric alternative to the T-test. This study uses this method to measure whether the number of buildings in the block, the degree of functional mixing of land use, and the number of public service facilities will affect the proximity and density of food supply points in the block.

3.3. Geographically weighted regression analysis

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i) x_{ik} + \varepsilon_i$$

Geographically Weighted Regression (GWR) is a local linear regression model that allows the regression coefficient to vary spatially, so as to capture the non-stationarity of spatial data. This model, proposed by Professor A. Stewart Fotheringham in 1996, is mainly used to deal with the problem of heterogeneity in spatial data, that is, the relationship between spatial variables may change with the change of spatial location. In the formula, yi is the dependent variable value at the block position (ui,vi), which in this study refers to the food supply capacity; xikis the KTH independent variable value at the location (ui,vi). This study selected three variables: number of buildings, mixed degree of land use functions, and number of public service facilities. βk(ui,vi) is the KTH regression coefficient at the block location (ui,vi), which is a function of geographical location; ϵi is the error term.

4.Results and conclusions

4.1. Results of food deserts identification

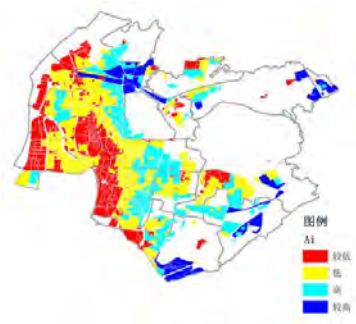


Figure 2. Map of district food supply capacity distribution. Source: author.

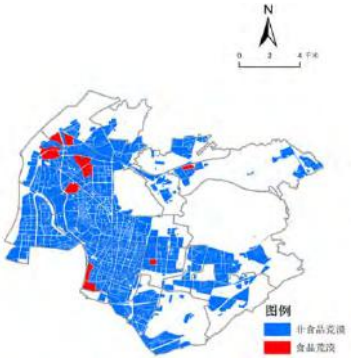


Figure 3. Results of food deserts analysis. Source: author.

As shown in Figure 1, it can be seen that the distribution and quantity of the four food supply points are different. The higher the supply capacity level, the smaller the quantity. Convenience stores and supermarkets are generally concentrated in the most densely populated areas of Qinhuai District and Gulou District, and large shopping malls with the highest food supply capacity can only be found in some streets of Gulou District. Next, department stores are the most dispersed.

The Two-Step Floating Catchment Area (2SFCA) method was used to obtain the distribution diagram of food supply capacity (Ai value), and the Ai value was divided into four hierarchical segments according to the natural breakpoint method of Arcgis: 0.28, 0.51, 0.98 and 1.91. Among them, below 0.28 is very low supply capacity, below 0.51 is low supply capacity, between 0.51 and 0.98 belongs to high food supply capacity, between 0.98 and 1.91 belongs to high food supply capacity. The areas with high food supply

capacity are mainly distributed in Xiaoshi street, east of Xuanwuhu Street, south of Xiaoling Wei Street and south of Honghua Town.

The distribution of food supply capacity in blocks with more than 300 elderly people under the age of 70 was superimposed to screen out the distribution map of food deserts. It can be seen that Baotaqiao Street, Xiaguan Street, Jianning Road Street and Shuangtang Street in the southwest of Nanjing Old City have a small number of blocks belonging to the food deserts. Other blue areas are non-food deserts areas.

4.2. The result of cause analysis

The proximity of food supply points in a block is defined as: the distance between the center point of the block and the nearest food supply point; The density of food supply points in a block is defined as the number of supply points within a unit buffer area. The original hypothesis is that there is no significant difference in food supply density and proximity of blocks with different building numbers, different functional mixing degree and different public service density.

According to Mann-whitney Test, the food supply density and proximity of blocks with different building numbers, different functional mixing degree and different public service density are significantly different, which rejects the original hypothesis. Both sets of data do not satisfy the hypothesis of normal distribution. Firstly, descriptive statistical analysis is made on the data. In the following table, the quartile, average value and other values of food supply proximity and density corresponding to the three variable groups are counted respectively, and the difference in density and proximity between different groups can be clearly seen.

Table 2 Descriptive statistics of Mann-whitney Test

	Proximity			Density		
	Not stratified	Low number of buildings	High number of buildings	Not stratified	Low number of buildings	High number of buildings
25%	0	0	0	33	36	35
50%	29	67	50.8	56	77	58
Mean	79	90.6	67.3	69	82.3	103
75%	109	145.4	232.2	99	119	97
std.dev	126	8.5	47.8	44	15.2	35.9
		Low mixing degree of function	High mixing degree of function		Low mixing degree of function	High mixing degree of function
25%		0	0		31	43
50%		41	0		52	68
Mean		88.6	49		66	78
75%		125	60		93	110
std.dev		135.6	89		44.3	43.3
		Low number of public service facilities	High number of public service facilities		Low number of public service facilities	High number of public service facilities
25%		0	99		28	99
50%		54.6	126		43.5	126

Mean	100	21	48	121
75%	150.6	146	64	146
std.dev	141	39	27	36

The test results show (FIG. 4) that all the P values of the three groups of variables after the test of "high and low number of buildings", "high and low mixing degree of land use functions", and "high and low number of public service facilities" are less than 0.05 significance level, which means that statistically it can be proved that the above three groups of variables have significant differences in food supply density and proximity of blocks. In other words, the food supply density and proximity of blocks with different number of buildings, different functional mixing degree and different public service density are significantly different.

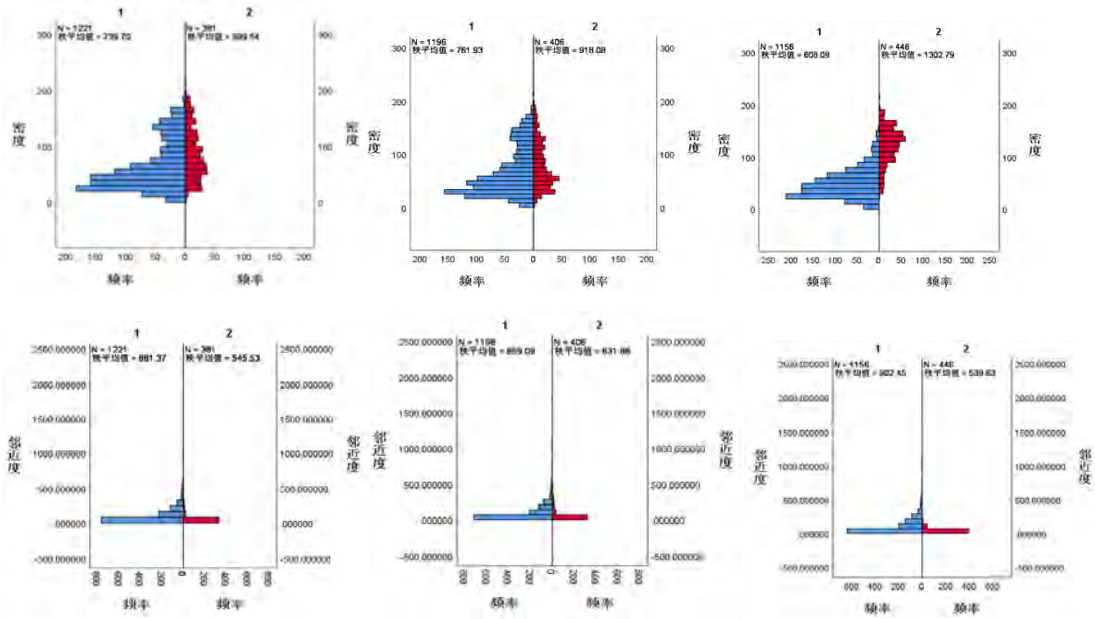


Figure 4. Three groups of inspection results of "high and low number of buildings", "high and low mixing degree of land use functions" and "high and low number of public service facilities". Source: author.

After the multicollinearity (VIF) test, the multicollinearity of the variable is excluded. A geographically weighted regression model (GWR) was used to further verify the possibility of significant differences caused by the above three variables.

First, as shown in Figure 6 (a), the relationship between the functional mixing degree coefficient of blocks and the food supply capacity shows obvious spatial heterogeneity, and the correlation is mainly positive, that is, the higher the functional mixing degree of blocks, the stronger the food supply capacity. There is no significant difference in the spatial variation of absolute value of regression coefficient. The negative regression coefficient is mainly distributed in the southern part of the old city. It is speculated that the reason for this distribution relationship is that the functional mixing in the southern part of the city brings space congestion and land shortage, thus weakening the food supply capacity. And the positive is mainly distributed in the old city of Gulou district, especially the central gate street, Hunan Road street.

As shown in Figure 6 (b), the number of buildings and the food supply capacity are mainly negatively correlated, that is, the more buildings there are, the weaker the food supply capacity of the block.

Speculation may be associated with the negative effects of more densely populated neighborhoods with a high number of buildings. The positive regression coefficient is mainly distributed in Xiaolingwei Street in the eastern part of the old city, which belongs to the science and innovation sector and has a moderate population distribution. The more buildings, the more food supply points, the stronger the supply capacity.

As shown in Figure 6 (c), the density of public service facilities and food supply capacity are mainly positively correlated, that is, the higher the density of public service facilities, the higher the food supply capacity. However, the negative regression coefficient is mainly distributed in the southeast of Xuanwu District, which may be due to the mismatch between public service facilities and residents' actual needs. Public service facilities may focus more on providing entertainment or leisure services, while the facilities related to food supply, such as supermarkets and wet markets, are insufficient. As a result, the more public service facilities, the weaker the food supply capacity.

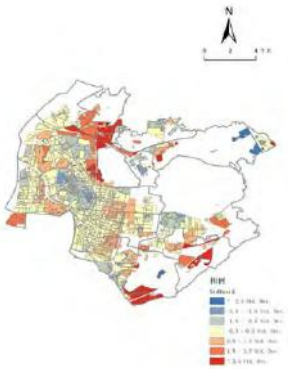


Figure 5. Global standard error. Source: author

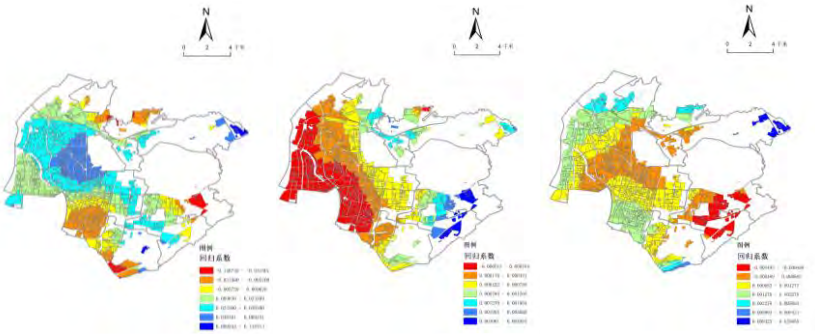


Figure 6. Mixed-degree coefficient of block function (a), regression coefficient of building number (b), regression coefficient of public service facility density (c). Source:author.

5. References

[1]Cummins, S. and Macintyre, S. (2002) '"Food deserts" – evidence and assumption in health policy making', *BMJ (Clinical research ed.)*, 325(7361), pp. 436-438.

[2]Kristian, L. and Jason, G. (2008) 'Mapping the evolution of "food deserts" in a Canadian city: Supermarket accessibility in London, Ontario, 1961–2005', *International Journal of Health Geographics*, 7(1), p. 16.

[3]Clarke, G. (2002) 'Deriving Indicators of Access to Food Retail Provision in British Cities: Studies of Cardiff, Leeds and Bradford', *Urban Studies*, 39(11), pp. 2041-2060.

[4] Moore, L.V., Roux, A.V.D., et al. (2008) 'Associations of the local food environment with diet quality - a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis', *American Journal of Epidemiology*, 167(8), pp. 917-924.

[5]He, Y.K., Wang, L., Ai, T.H. (2019) 'A Study on Food Accessibility Supported by Street Network Linear Partition Model', Geography and Geo-Informatics Science, 35(1), pp. 50-57+1. (Chinese)

[6]Moore, L.V., Diez Roux, A.V. and Brines, S. (2008) 'Comparing Perception-Based and Geographic Information System (GIS)-based characterizations of the local food environment', *J Urban Health*, 85(2), pp. 206-216. doi: 10.1007/s11524-008-9259-x.

[7]Smoyer-Tomic, E.K., Spence, C.J. and Amrhein, C. (2006) 'Food Deserts in the Prairies? Supermarket Accessibility and Neighborhood Need in Edmonton, Canada*', *The Professional Geographer*, 58(3), pp. 307-326.

[8]Chen, Y., Xu, C., Ge, Y., et al. (2024) 'A 100-m gridded population dataset of China's seventh census using ensemble learning and geospatial big data', *Earth System Science Data Discussions*, 2024, pp. 1-19.

[9]Long, Y., Li, P., Hou, J.X. (2019) 'Three-Dimensional Urban Form at the Block Level in Major Chinese Cities', Shanghai Urban Planning Review, (3), pp. 10-15. (Chinese)

Research Paper

Identification and cause analysis of food deserts in the old town

A case study of the old town of Nanjing

Li Chenhui, Southeast University, China

Abstract

Amidst the backdrop of an aging population, accessing healthy food has become a critical issue for maintaining food security. Areas where residents face difficulties in obtaining healthy food are termed "food deserts." For old urban areas, studying and identifying food deserts issues are vital for promoting health equity, planning the future development of old cities, and stimulating market vitality. With the support of big data, research on food deserts can now be analyzed at the street level. This paper takes the old city of Nanjing as an example to identify and analyze the formation of food deserts.Utilizing population data, food supply point data, this study first conducts a descriptive statistical analysis of the proximity and density of food supply points from communities to food supply points in the old urban area. It then employs the Two-Step Floating Catchment Area (2SFCA) method, considering the impact of age on food acquisition, to determine food deserts from both the supply and demand perspectives. Subsequently, the study uses the Mann-Whitney U test to explore the differences and connections between the proximity and density of food supply and built environmental characteristics such as the number of buildings in the block, the degree of land use mix, and public service facilities. Finally, Geographically Weighted Regression (GWR) is applied to investigate the relationship between the formation of food deserts and built environmental variables such as the number of buildings in the block, the degree of land use mix, and public service facilities. All data used in this study are publicly available online.The study reveals that there is a negative correlation between the number of buildings in the block and food deserts phenomena in most areas of the old city, while the degree of land use mix and the density of public service facilities are mostly positively correlated with food deserts. These findings provide valuable insights for urban planning and policy-making aimed at enhancing food accessibility and promoting health equity in old urban areas.

Keywords

Food deserts, old city,built environment

1. Introduction

In the mid-1990s, academia defined "food deserts" as geographical areas where a lack of healthy food retail outlets results in residents struggling to access healthy and affordable food within a certain distance (Cummins,2002).

According to the World Health Organization (WHO), a healthy diet can help prevent all forms of malnutrition, as well as non-communicable diseases (NCDs), including diabetes, heart disease, stroke and cancer. An unhealthy diet is one of the major risks to global health. In the context of China's aging population, access to healthy food has become an important issue to maintain food safety. For the old city, the research and identification of food deserts is of great significance for promoting health and equity, planning the future development of the old city, and stimulating the vitality of the old city market.

Properly distributed food supply points help reduce food waste and carbon emissions during transportation, supporting sustainable urban development. Urban planning should consider the reasonable distribution of food supply points, residential areas and work areas to reduce the impact on the environment. At present, with the support of big data, the study of food deserts have reached the street scale for analysis and research.

The current research on food deserts are mainly concentrated in the field of quantitative analysis. Traditional analysis methods mainly analyze the accessibility of food supply points, including buffer analysis (Kristian et al,2008; Clarke,2002)、kernel density analysis (Moore et al,2008) and other methods for density and proximity analysis. Some scholars also use network analysis (He et al,2019) to divide the arcs of street networks into homogeneous linear units for analysis, or use geographic grid methods to assign equal weights to grid population density. Thus, it is associated with the distribution of food deserts(Moore et al,2008). In addition, some scholars used road data to build a network analysis model and studied the accessibility of demand areas to food retail points through network analysis.

The current research on food deserts are mainly concentrated in the field of quantitative analysis. Traditional analysis methods mainly analyze the accessibility of food supply points, including buffer analysis, kernel density analysis and other methods for density and proximity analysis. Some scholars also use network analysis to divide the arcs of street networks into homogeneous linear units for analysis, or use geographic grid methods to assign equal weights to grid population density. Thus, it is associated with the distribution of food deserts. In addition, some scholars used road data to build a network analysis model and studied the accessibility of demand areas to food retail points through network analysis.

This study mainly studies the following issues. First, how to identify areas with weak food supply capacity (food deserts) in the old urban areas with high population density. In addition, with the support of big data, how to better consider the needs of the elderly population. Whether the relationship between food supply capacity and the number of block buildings, the mixing degree of block land use and the density of public service facilities is close at the block scale, and on this basis, how the built environment factors at the block scale affect the food supply capacity.

This study has theoretical and practical significance. First, an interdisciplinary approach is used, combining statistical and geographic data with urban planning. At the same time, the needs of vulnerable groups are taken into account, which in turn contributes to the construction of more equitable and harmonious cities. The distribution of food supply points is related to the health and quality of life of urban residents, and the rationality of the distribution of food supply points is related to the health and quality of life of urban residents, and is an important part of urban sustainable development. In addition, the rational distribution of food supply points is an important part of urban renewal and community development, and research can promote the sustainable development of old urban areas and the enhancement of community cohesion.

2. Research scope and data source

2.1. Research object and scope

The research object of this paper is the main block of the old city of Nanjing. According to the relevant documents on the protection of historical and cultural cities, the old city is within the three administrative regions of Xuanwu, Gulou and Qinhuai, and the core area of the ancient city basically covers this scope. Therefore, the main block of these three administrative regions is selected for research

when the data is selected. Nanjing is one of the four ancient capitals of China, with a history of more than two thousand years. Located in the southwest of Jiangsu Province and the lower reaches of the Yangtze River, Nanjing is rich in historical, cultural and natural landscapes. There are four distinct seasons, abundant rain, belonging to the north subtropical humid climate. In 2023, the population of the elderly aged 60 and above in Gulou District is 307,100, and the population of the elderly aged 60 and above in Qinhuai District is 266,700, which is one of the regions with the largest elderly population in Nanjing. The aging of population in Gulou District, Qinhuai District and Xuanwu District is obvious.

2.2. Data Sources

The population density data comes from data shared by Professor Chen Yuehong's team on the figshare platform(Chen et al,2024).A 100-m gridded population dataset of China’s seventh census in 2020 was generated by stacking ensemble learning and geospatial big data.

The population age data used in this study came from the website "worldpop", and the original data was raster data with a resolution of 100m. The site contains both 'Constrained' and 'Unconstrained' data, covering the years 2000 to 2020. This study extracted the number of people over 70 years old in each neighborhood within the 2020 study area of the 'Unconstrained' type.

The block data comes from the public data set "41 Urban blocks in 63 Chinese cities" released by Beijing City Lab, which extracts the largest construction land plots in the city as the range.Eleven attributes are available in the data, including ID of the block (PARCEL_ID), name of cities (CITY_NAME), number of buildings (BLD_Count), average floor number (BLD_FLOORN), average floor area ratio (BLD_FAR), average building density (BDL_bldDen)and so on (Long et al, 2019).The block data comes from the public data set "41 Urban blocks in 63 Chinese cities" released by Beijing City Lab, which extracts the largest construction land plots in the city as the range.

POI food supply point data from AmAP API2022 edition. The data content includes latitude and longitude, the name and type of the point. The food supply points in this study are defined as supermarkets, which are divided into department stores, supermarkets, convenience stores and shopping centers according to types, with a total of 2,567 stores. The food supply points and distribution involved in this study are shown in the figure below. In addition, POI data of interest points of public service facilities are also obtained. This study selects educational facilities, medical and health institutions, cultural and entertainment institutions, transportation stations, sports venues, social welfare and security facilities as public service points, so as to calculate the number variable of public service facilities in blocks.

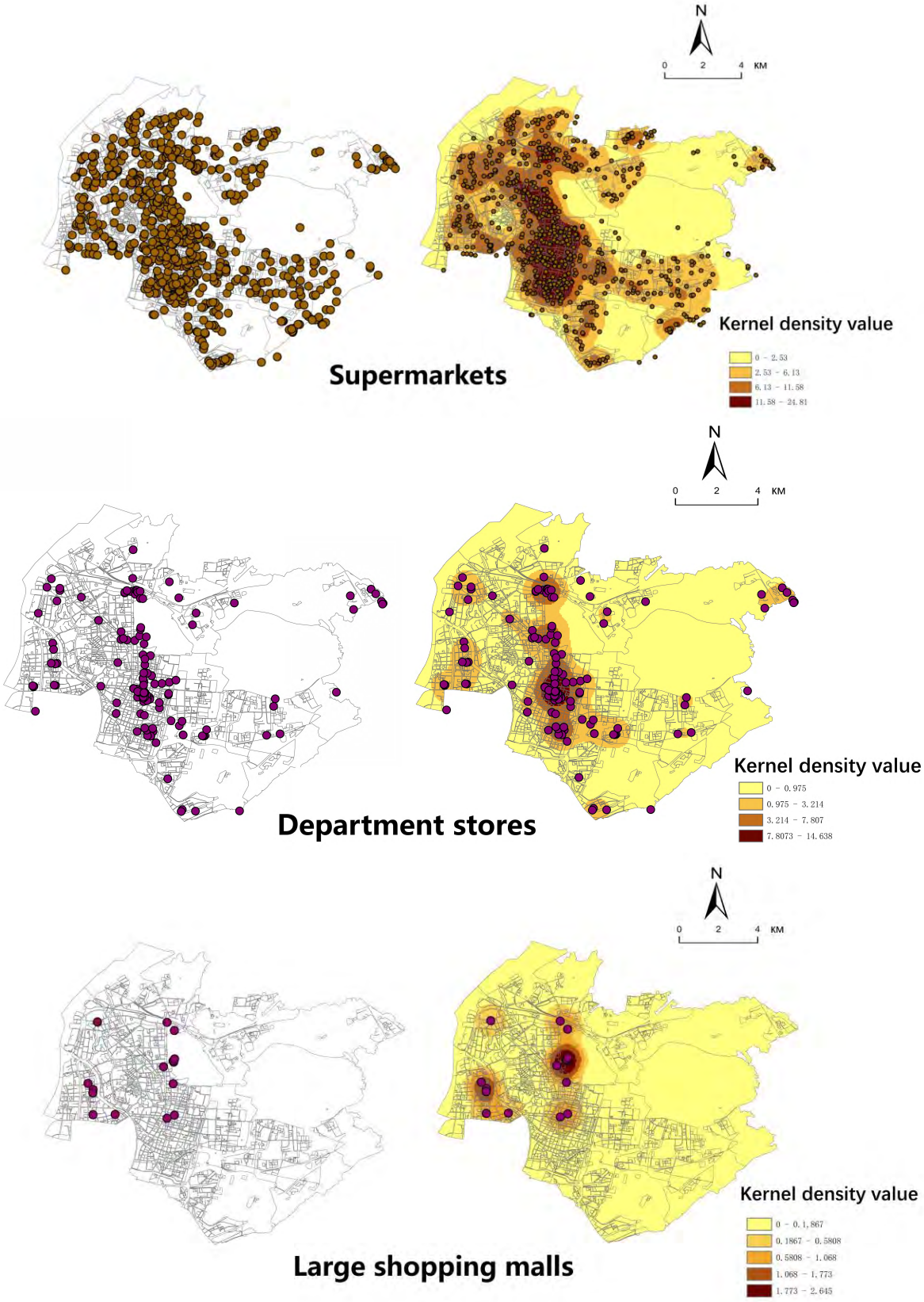


Figure 1. Distribution and kernel density estimation of four types of food supply points. Source: Author's own work.

Table 1. Statistical quantity, classification and proportion of four types of food supply points. Source: Author's own work.

Type	Number	Grade	Proportion
Large shopping malls	16	4	0.01
Department stores	134	3	0.05
supermarket	766	2	0.30
Convenience store	1650	1	0.64

3. Methodology

3.1. Food deserts identification based on two-step floating catchment area method (2SFCA)

$$A_i^F = \sum_{j\epsilon\{d_{ij}\leq d_0\}} R_j = \sum_{j\epsilon\{d_{ij}\leq d_0\}} \left[\frac{S_j}{\sum_{k\epsilon\{d_{kj}\leq d_0\}} D_k}\right]$$

The 2SFCA method was first proposed by Radke et al. (2000), further improved by Luo et al. (2003) and named as the Two-Step Floating Catchment Area (2SFCA) me*thod*. The method is to search the supply point and the demand point respectively in two steps. The first step is to focus on the food supply point, search the demand point within the threshold range, and then calculate the supply and demand ratio. The second step is to search all supply points within the threshold range, and then calculate the sum of the demand ratio of all supply points found.

In the formula, i represents the block and forms the central demand point k of the block; j represents the food supply point, which has been divided into four levels according to the food supply capacity; AiF represents the food supply capacity of block i calculated according to the Two-Step Floating Catchment Area (2SFCA) method, that is, the sum of the supply and demand ratio of food supply points in the corresponding search range of block i; dij is the radius of distance between block i and food supply point j; Rj is the ratio of the food supply capacity level corresponding to food supply point j to the population served within the search radius d0; Sj represents the supply scale of supply point j, which has been expressed as their respective supply grade according to their respective supply capacity; Dk represents the scale of demand at point k, which in this study refers to the number of people covered.

3.2. Mann-Whitney U test

The Mann-Whitney U test, also known as the Wilcoxon rank sum test, is a non-parametric statistical method used to compare the distribution of two independent samples. It is especially suitable for cases where the data does not meet the normal distribution or there are outliers, and is a non-parametric alternative to the T-test. This study uses this method to measure whether the number of buildings in the block, the degree of functional mixing of land use, and the number of public service facilities will affect the proximity and density of food supply points in the block.

3.3. Geographically weighted regression analysis

$$y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i) x_{ik} + \varepsilon_i$$

Geographically Weighted Regression (GWR) is a local linear regression model that allows the regression coefficient to vary spatially, so as to capture the non-stationarity of spatial data. This model, proposed by Professor A. Stewart Fotheringham in 1996, is mainly used to deal with the problem of heterogeneity in spatial data, that is, the relationship between spatial variables may change with the change of spatial location. In the formula, yi is the dependent variable value at the block position (ui,vi), which in this study refers to the food supply capacity; xikis the KTH independent variable value at the location (ui,vi). This study selected three variables: number of buildings, mixed degree of land use functions, and number of public service facilities. βk(ui,vi) is the KTH regression coefficient at the block location (ui,vi), which is a function of geographical location; ϵi is the error term.

4.Results and conclusions

4.1. Results of food deserts identification

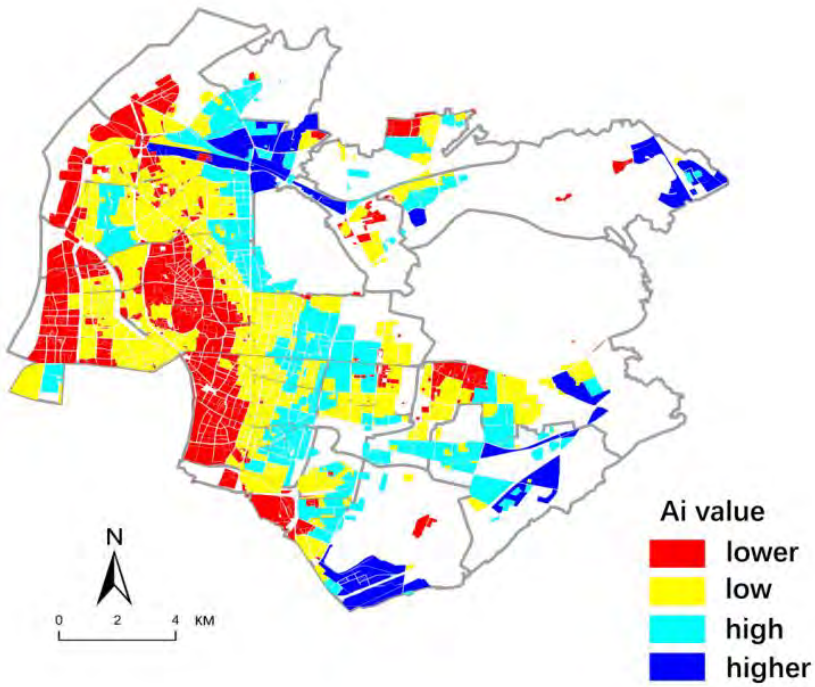


Figure 2. Map of district food supply capacity distribution. Source: Author's own work.

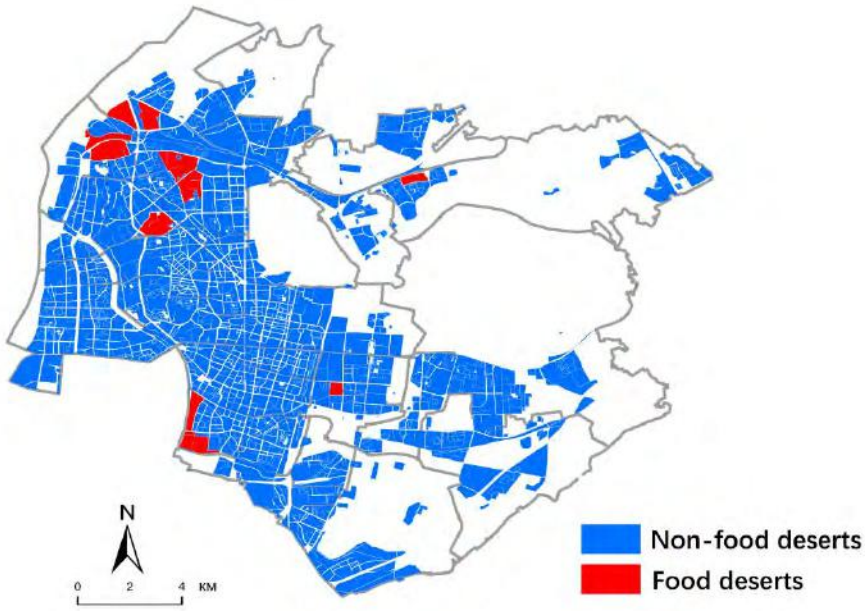


Figure 3. Results of food deserts analysis. Source: Author's own work.

As shown in Figure 1, it can be seen that the distribution and quantity of the four food supply points are different. The higher the supply capacity level, the smaller the quantity. Convenience stores and supermarkets are generally concentrated in the most densely populated areas of Qinhuai District and Gulou District, and large shopping malls with the highest food supply capacity can only be found in some streets of Gulou District. Next, department stores are the most dispersed.

The Two-Step Floating Catchment Area (2SFCA) method was used to obtain the distribution diagram of food supply capacity (Ai value), and the Ai value was divided into four hierarchical segments according to the natural breakpoint method of Arcgis: 0.28, 0.51, 0.98 and 1.91. Among them, below 0.28 is very low supply capacity, below 0.51 is low supply capacity, between 0.51 and 0.98 belongs to high food supply capacity, between 0.98 and 1.91 belongs to high food supply capacity. The areas with high food supply capacity are mainly distributed in Xiaoshi street, east of Xuanwuhu Street, south of Xiaoling Wei Street and south of Honghua Town.

The distribution of food supply capacity in blocks with more than 300 elderly people under the age of 70 was superimposed to screen out the distribution map of food deserts. It can be seen that Baotaqiao Street, Xiaguan Street, Jianning Road Street and Shuangtang Street in the southwest of Nanjing Old City have a small number of blocks belonging to the food deserts. Other blue areas are non-food deserts areas.

4.2. The result of cause analysis

The proximity of food supply points in a block is defined as: the distance between the center point of the block and the nearest food supply point; The density of food supply points in a block is defined as the number of supply points within a unit buffer area. The original hypothesis is that there is no significant difference in food supply density and proximity of blocks with different building numbers, different functional mixing degree and different public service density.

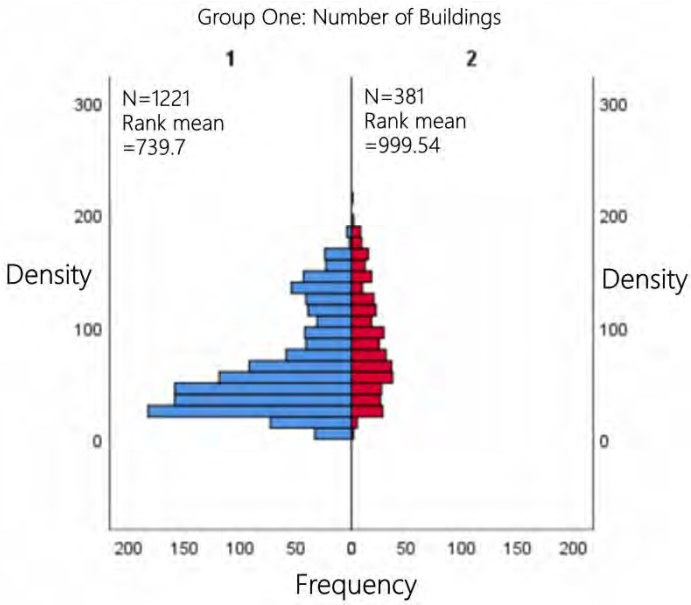
According to Mann-whitney Test, the food supply density and proximity of blocks with different building numbers, different functional mixing degree and different public service density are significantly different, which rejects the original hypothesis. Both sets of data do not satisfy the hypothesis of normal distribution. Firstly, descriptive statistical analysis is made on the data. In the following table, the quartile,

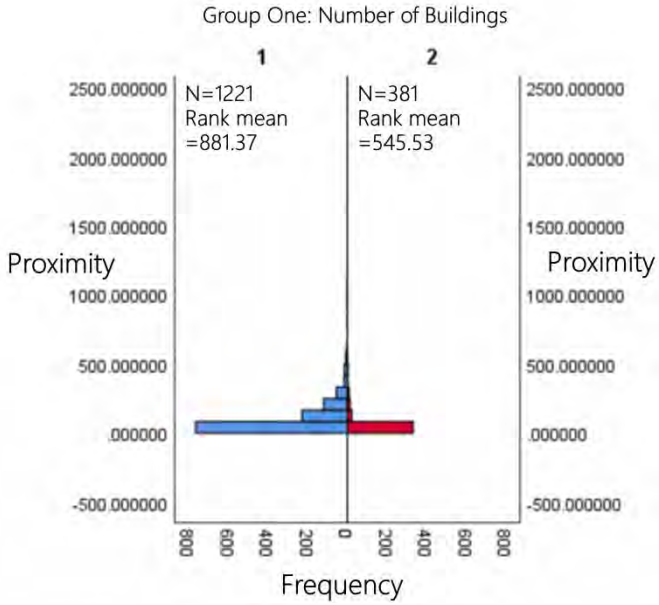
average value and other values of food supply proximity and density corresponding to the three variable groups are counted respectively, and the difference in density and proximity between different groups can be clearly seen.

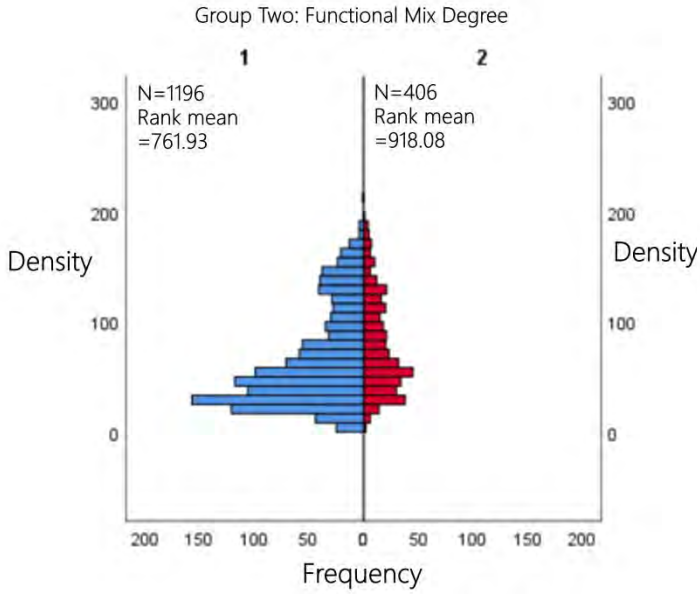
Table 2. Descriptive statistics of Mann-whitney Test. Source : Author's own work.

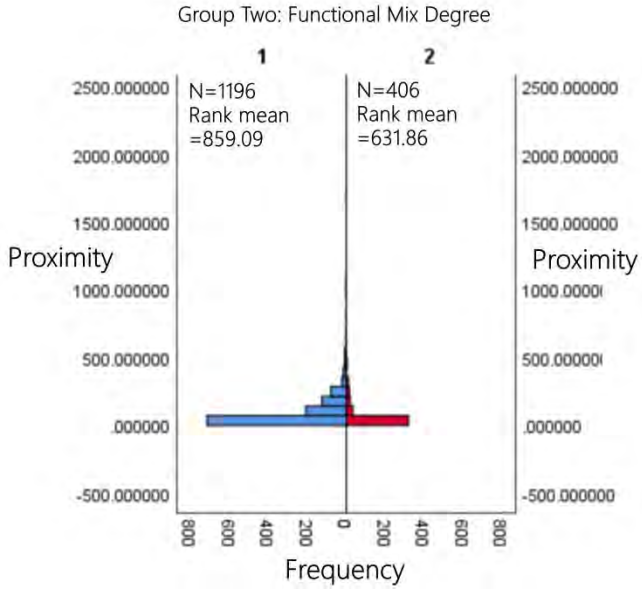
	Proximity			Density		
	Not stratified	Low number of buildings	High number of buildings	Not stratified	Low number of buildings	High number of buildings
25%	0	0	0	33	36	35
50%	29	67	50.8	56	77	58
Mean	79	90.6	67.3	69	82.3	103
75%	109	145.4	232.2	99	119	97
std.dev	126	8.5	47.8	44	15.2	35.9
		Low mixing degree of function	High mixing degree of function		Low mixing degree of function	High mixing degree of function
25%		0	0		31	43
50%		41	0		52	68
Mean		88.6	49		66	78
75%		125	60		93	110
std.dev		135.6	89		44.3	43.3
		Low number of public service facilities	High number of public service facilities		Low number of public service facilities	High number of public service facilities
25%		0	99		28	99
50%		54.6	126		43.5	126
Mean		100	21		48	121
75%		150.6	146		64	146
std.dev		141	39		27	36

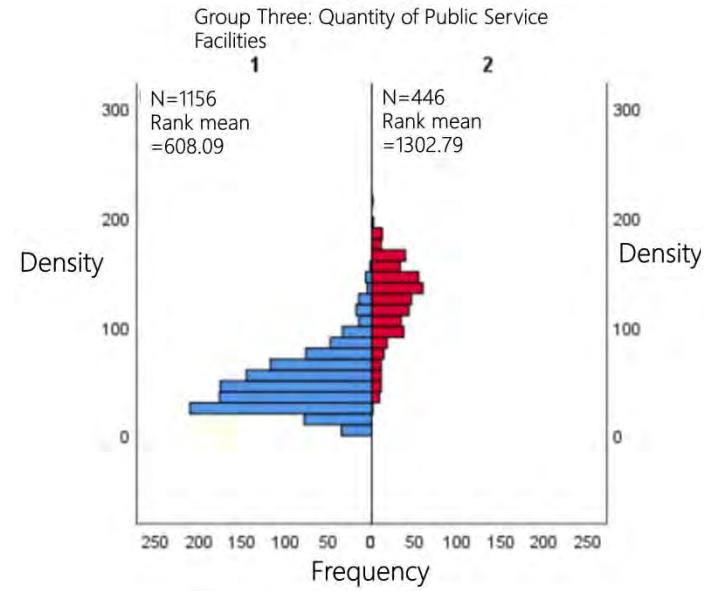
The test results show (FIG. 4) that all the P values of the three groups of variables after the test of "high and low number of buildings", "high and low mixing degree of land use functions", and "high and low number of public service facilities" are less than 0.05 significance level, which means that statistically it can be proved that the above three groups of variables have significant differences in food supply density and proximity of blocks. In other words, the food supply density and proximity of blocks with different number of buildings, different functional mixing degree and different public service density are significantly different.


Group One: Number of Buildings
1
2
N=1221
Rank mean
=739.7
N=381
Rank mean
=999.54
Density
Frequency


Group One: Number of Buildings
1
2
N=1221
Rank mean
=881.37
N=381
Rank mean
=545.53
Proximity
Frequency


Group Two: Functional Mix Degree
1
2
N=1196
Rank mean
=761.93
N=406
Rank mean
=918.08
Density
Frequency


Group Two: Functional Mix Degree
1
2
N=1196
Rank mean
=859.09
N=406
Rank mean
=631.86
Proximity
Frequency


Group Three: Quantity of Public Service Facilities
1
2
N=1156
Rank mean
=608.09
N=446
Rank mean
=1302.79
Density
Frequency

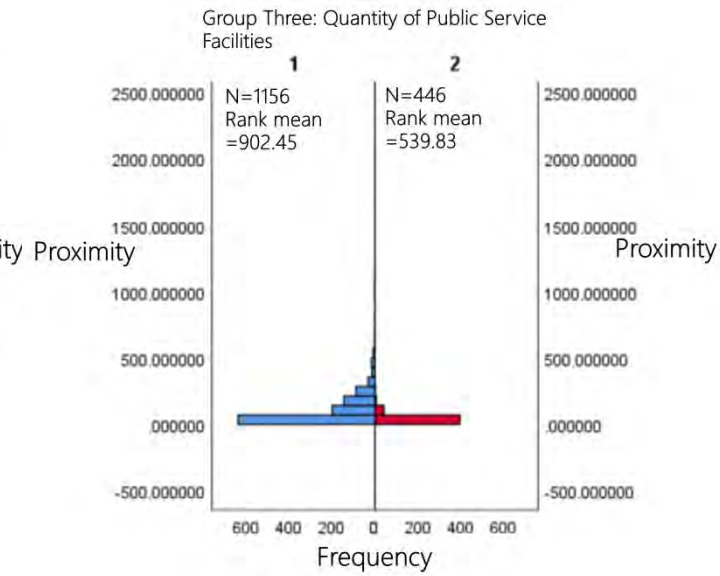

Group Three: Quantity of Public Service Facilities
1
2
N=1156
Rank mean
=902.45
N=446
Rank mean
=539.83
Proximity
Frequency

Figure 4. Three groups of inspection results of "high and low number of buildings", "high and low mixing degree of land use functions" and "high and low number of public service facilities". Source: author.

After the multicollinearity (VIF) test, the multicollinearity of the variable is excluded. A geographically weighted regression model (GWR) was used to further verify the possibility of significant differences caused by the above three variables.

First, as shown in Figure 6 (a), the relationship between the functional mixing degree coefficient of blocks and the food supply capacity shows obvious spatial heterogeneity, and the correlation is mainly positive, that is, the higher the functional mixing degree of blocks, the stronger the food supply capacity. There is no significant difference in the spatial variation of absolute value of regression coefficient. The negative regression coefficient is mainly distributed in the southern part of the old city. It is speculated that the reason for this distribution relationship is that the functional mixing in the southern part of the city brings space congestion and land shortage, thus weakening the food supply capacity. And the positive is mainly distributed in the old city of Gulou district, especially the central gate street, Hunan Road street.

As shown in Figure 6 (b), the number of buildings and the food supply capacity are mainly negatively correlated, that is, the more buildings there are, the weaker the food supply capacity of the block. Speculation may be associated with the negative effects of more densely populated neighborhoods with a high number of buildings. The positive regression coefficient is mainly distributed in Xiaolingwei Street in the eastern part of the old city, which belongs to the science and innovation sector and has a moderate population distribution. The more buildings, the more food supply points, the stronger the supply capacity.

As shown in Figure 6 (c), the density of public service facilities and food supply capacity are mainly positively correlated, that is, the higher the density of public service facilities, the higher the food supply capacity. However, the negative regression coefficient is mainly distributed in the southeast of Xuanwu District, which may be due to the mismatch between public service facilities and residents' actual needs. Public service facilities may focus more on providing entertainment or leisure services, while the facilities related to food supply, such as supermarkets and wet markets, are insufficient. As a result, the more public service facilities, the weaker the food supply capacity.

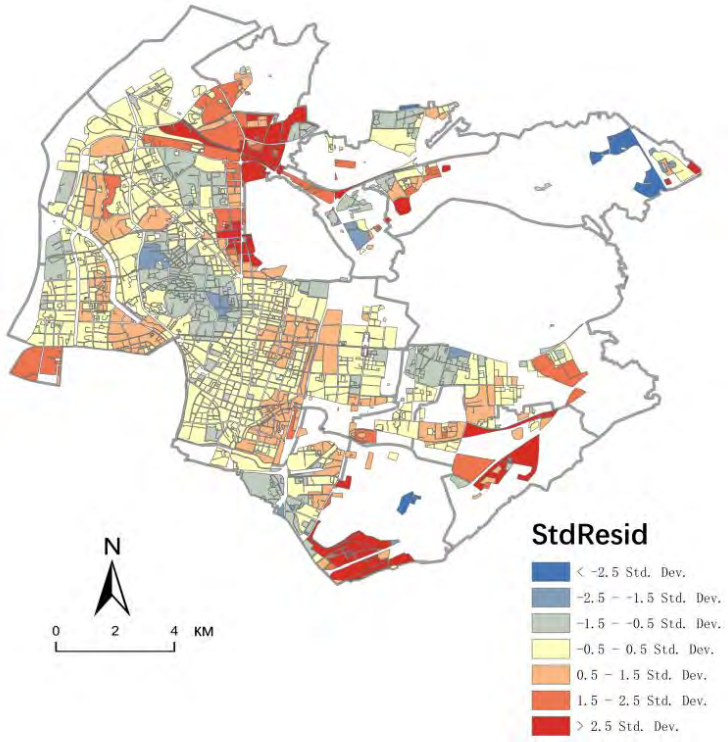
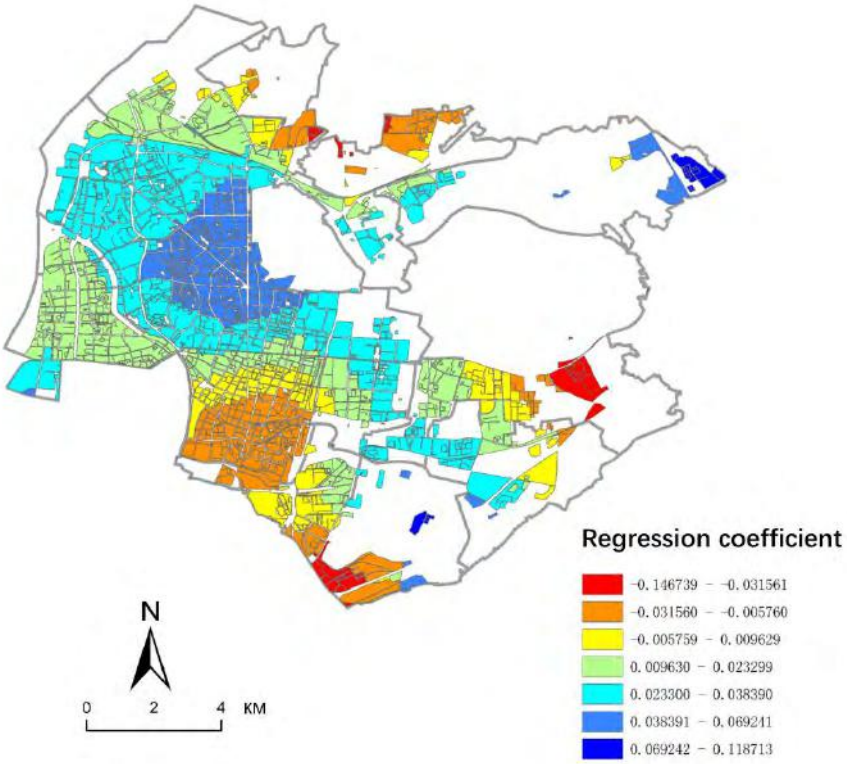


Figure 5. Global standard error. Source: Author's own work.



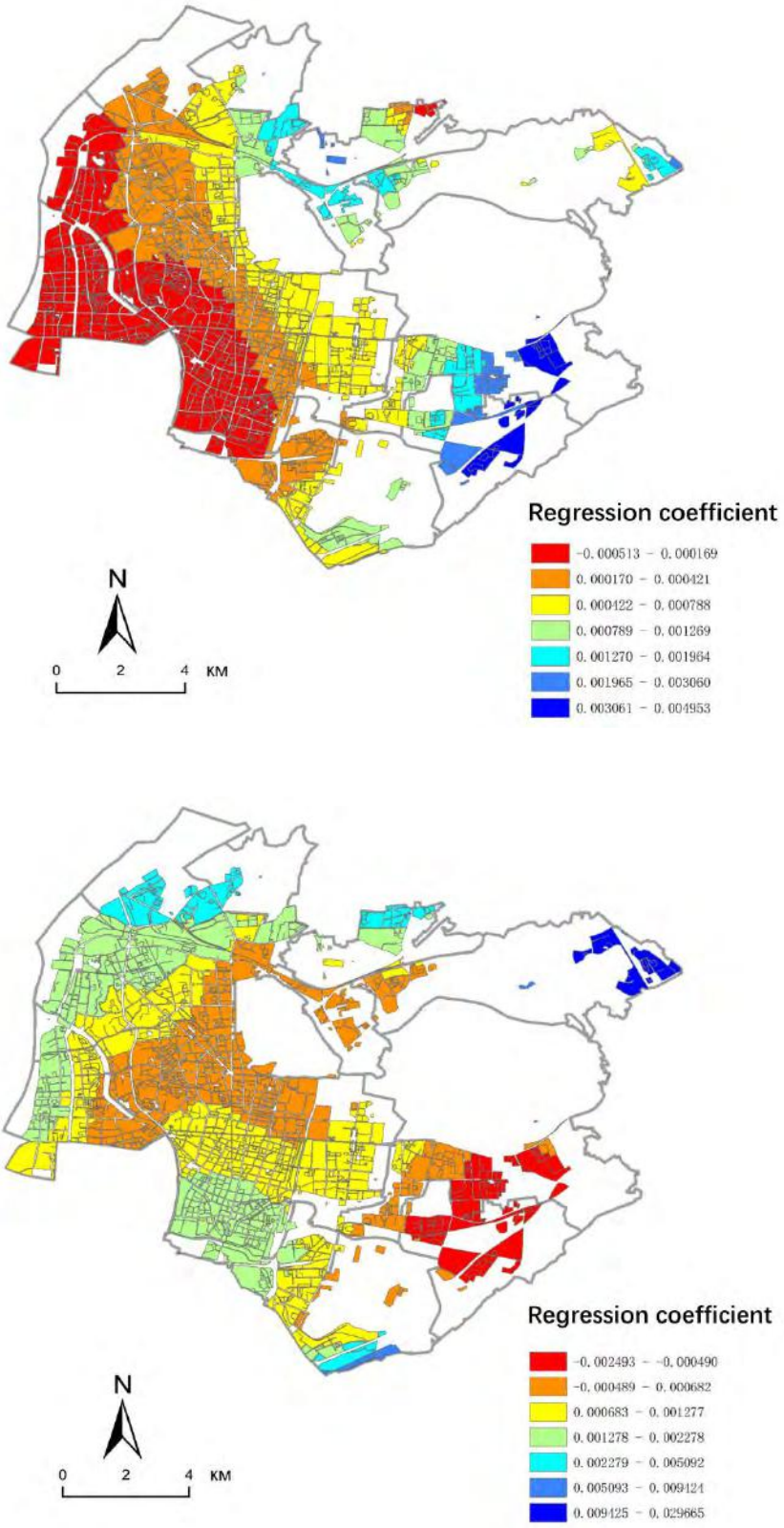


Figure 6. Mixed-degree coefficient of block function (a), regression coefficient of building number (b), regression coefficient of public service facility density (c). Source :Author's own work.

5. References

Chen, Y., Xu, C., Ge, Y., et al. (2024) 'A 100-m gridded population dataset of China's seventh census using ensemble learning and geospatial big data', Earth System Science Data Discussions, 2024, pp. 1–19.

Clarke, G. (2002) 'Deriving Indicators of Access to Food Retail Provision in British Cities: Studies of Cardiff, Leeds and Bradford', Urban Studies, 39(11), pp. 2041–2060.

Cummins, S. and Macintyre, S. (2002) '"Food deserts" – evidence and assumption in health policy making', BMJ, 325(7361), pp. 436–438.

He, Y.K., Wang, L. and Ai, T.H. (2019) 'A Study on Food Accessibility Supported by Street Network Linear Partition Model', Geography and Geo-Informatics Science, 35(1), pp. 50–57+1. [in Chinese]

Kristian, L. and Jason, G. (2008) 'Mapping the evolution of "food deserts" in a Canadian city: Supermarket accessibility in London, Ontario, 1961–2005', International Journal of Health Geographics, 7(1), p. 16.

Long, Y., Li, P. and Hou, J.X. (2019) 'Three-Dimensional Urban Form at the Block Level in Major Chinese Cities', Shanghai Urban Planning Review, (3), pp. 10–15. [in Chinese]

Moore, L.V., Diez Roux, A.V. and Brines, S. (2008) 'Comparing Perception-Based and Geographic Information System (GIS)-based characterizations of the local food environment', Journal of Urban Health, 85(2), pp. 206–216. doi:10.1007/s11524-008-9259-x.

Moore, L.V., Roux, A.V.D., et al. (2008) 'Associations of the local food environment with diet quality - a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis', American Journal of Epidemiology, 167(8), pp. 917–924.

Smoyer-Tomic, E.K., Spence, C.J. and Amrhein, C. (2006) 'Food Deserts in the Prairies? Supermarket Accessibility and Neighborhood Need in Edmonton, Canada', The Professional Geographer, 58(3), pp. 307–326.

Research Paper

Exploring indicators of economic resilience in South African towns and cities

Ockert PRETORIUS, Department of Urban and Regional Planning, University of Johannesburg, South Africa

Abstract

The consideration of economic resilience is growing in prominence among policymakers in the Global South. The ability of towns and cities to prevent, absorb, and adapt to economic disturbances, as well as catalyse long-term structural transformation, is anchored in a context of social, economic, and environmental pressures. A lack of economic resilience of South African towns and cities may affect the stability of economic growth and output over the short- and long-term, and thus sustained socio-economic development and wellbeing improvement. Vulnerability to disturbances may also negatively impact national economic convergence objectives. The aim of this paper is to explore indicators of economic resilience in the South African context, with the objective of analysing the performance of cities and towns and delineate potential interventions toward mitigating potential vulnerabilities. A mixed-method research approach is applied to analyse numerous variables associated with the identified indicators and review relevant development policy. The findings indicate that there are significant differences in performance in the indicators across South African municipalities and urban and rural areas. Relevant here are variables such as the Tress Index, capital and labour productivity, and the Human Development Index. There is a need to prioritise policy interventions specific to fostering economic resilience, with reference to the spatial interventions delineated in the National Spatial Development Framework.

Keywords

Economic resilience; South African towns and cities; mixed-method approach; regional convergence.

1. Introduction

The concept of economic resilience is gaining prominence among spatial planners and policymakers in the Global South, where towns and cities face increased pressure to prevent, absorb, and adapt to economic disturbances while ensuring long-term economic output growth (Dzigbede et al., 2022). In developing countries, including South Africa, the stability of economic growth and output – essential for sustained socio-economic development and improvement in wellbeing – depends on mitigating the vulnerability of municipalities to short- and long-term economic shocks and disturbances (Arreza, 2024). A lack of economic resilience in towns and cities may negatively impact national economic convergence effects and progress toward creating an inclusive space economy (Oprisan et al., 2023). Efforts toward supporting economic resilience is in line with global objectives, with specific reference to Sustainable Development Goal 11 (SDG11) of the United Nations (UN), which seeks to "make cities and human settlements inclusive, safe, resilient and sustainable" (UN, 2024). However, fostering economic resilience in the context of the South African built environment is complicated by the continued legacy of apartheid spatial planning, which has brought about spatial fragmentation, marginalisation, and inequality (Ramatlo, 2021). Said

challenges may exacerbate economic vulnerability and hinder broader spatial objectives of integrated and sustainable human settlements.

The aim of the paper is to provide an overview of economic resilience indicators and explore how differences in these indicators are spatially distributed across South African towns and cities. The objectives are the following:

1. Identify potential indicators of economic resilience.
2. Analyse performance of municipalities against these indicators to provide insight on their resilience.
3. Provide an overview of spatial policies that seek to foster economic resilience.

Current research is predominantly focussed on determining variables that influence economic resilience (Laubscher, 2017; Ngouhouo & Nchofoung, 2021; Van Aswegen & Retief, 2021; Duan et al., 2022; Joseph et al., 2024), which is utilised in this study to identify potential indicators in this regard (as per the research objectives). The contribution of this paper is providing initial indications of potential the economic resilience and vulnerability of certain towns and cities, reflected through municipal-level data, as well as insights into the positioning of urban and rural areas and related municipalities in this regard. Central hereto is comparing the relative performance of metropolitan and non-metropolitan areas in nine provinces to identify areas of prioritisation, both spatial and sectoral. Toward this end, the paper applies a mixed-method research approach that includes a quantitative analysis of secondary data, as well as a qualitative policy review. The structure of the paper is centred on a literature review, an overview of the research methodology, the findings and discussion, and the concluding section.

2. Literature review

The following section presents the literature review. The subsections are centred on an 'overview of economic resilience', 'economic resilience in South Africa', and a 'policy review'.

2.1. Overview of economic resilience

From a systems perspective, economic resilience relates to the capacity of production systems to catalyse structural and functional changes in response to economic shocks and their impact (Sutton & Arku, 2022). This adaptive capacity, which includes continuous transformation, evolves over time to enable long-term economic resilience to dynamic and multifaceted shocks and disturbances. Trippl et al. (2023) underline the need for transformative resilience in which economic crises are leveraged to place production systems on new, more sustainable, and inclusive growth paths. This transcends the resist and recovery aspects of economic resilience and presents shocks as opportunities for transformation over time (Trippl et al., 2023). In addition to resistance (reduced impact of shocks) and recovery (returning to pre-shock outcomes), Mayor and Ramos (2020) identify reorientation (identify alternative growth paths), and renewal (innovation to strengthen resilience going forward) as two additional dimensions of economic resilience. This is indicative of the dynamic nature of economic resilience – one that evolves with time and in response to different shocks. This illustrates the requirement for responses to economic shocks to be multi-dimensional for regions to maintain optimal function (Sutton et al., 2023).

2.2. Economic resilience in South Africa

Table 1 provides an overview of the select current research on economic resilience with reference to South Africa, and identifies determining factors that may influence said resilience. The latter is in line with the research objectives of this paper.

Table 1. Overview and factors in economic resilience. Source: Author (2024).

Source	Overview	Important factors
Van Aswegen & Retief (2021)	Role of economic structure on economic resilience in South African regions; balance between adaptation and adaptability; sectoral diversification may support economic resilience; policy should support sectoral competitive advantage of regions on a national level.	Competitive advantage; economic diversity.
Duan et al. (2022)	Role of industrial structure and foreign direct investment (FDI) in economic resilience; robustness of industrial ecosystems, supply chain connections, and exchange rate volatility influences responses to economic shocks; policy consideration of green energy investment to support resilience.	Industrial structure.
Joseph et al. (2024)	Economic resilience index for comparative analysis; South Africa economic resilience changes over time.	Economic diversity; institutional strength.
Laubscher (2017)	Province-scale economic resilience in South Africa; diverse factors in economic resilience; focus on Western Cape province.	Economic diversity; industrial structure; competitive advantage.
Ngouhouo & Nchofoung (2021)	South Africa is economically resilient in comparison to other Sub-Saharan African countries, while performance varies over time; identifies the role of institutions, employment creation, and human development in supporting economic resilience; economic diversification needs to be supported through the reinvestment of natural resource revenue in other sectors.	Human development; economic diversity.

Accordingly, as indicated in Table 1, factors that may influence economic resilience include economies having a competitive advantage, its economic and sectoral diversity, industrial structure, institutions, and extent of human development. These inform the indicators to be utilised in the quantitative analysis.

2.3. Policy review

The National Spatial Development Framework (NSDF), promulgated in 2022, is the highest-level spatial planning instrument in South Africa and delineates the country's spatial development vision and objectives. Central objectives include addressing socio-economic disparities and the promotion of sustainable and inclusive development (DALRRD, 2022). The NSDF integrates all sectors and stakeholders in the development process and seeks to coordinate resource allocation in this regard. The NSDF places the built environment central to the achievement of economic resilience through highlighting the need to create polycentric systems of nodes, which is "a functionally integrated system of settlements/nodes of varying size that co-exist and collaborate in mutually beneficial ways, and in doing so, enhance the resilience of the system and its constituent parts" (DALRRD, 2022:18). The centrality of resilience in the NSDF is also indicated through the following objectives delineated in the policy:

- Maintaining biodiversity and natural ecosystems "for global, national and local resilience" (DALRRD, 2022:82).
- Create more compact settlement footprints, enabled by "development forms and patterns, housing types, building materials and construction methods, and transport and service networks", to reduce the impact of climate change (DALRRD, 2022:87).
- Improved "resilience of rural areas through diversification" and ensuring their reduced dependence on single economic sectors (DALRRD, 2022:91).
- Economic diversification is dependent on "the availability of viable, real economic opportunities" sourced from the primary, secondary, and tertiary sectors (DALRRD, 2022:96).
- Physical infrastructure is required "to enhance the development prospects, and strengthen the resilience of" metropolitan growth centres and rural nodes (DALRRD, 2022:136).
- The capacity for regional adaptation "to ensure greater resilience of livelihoods" is linked to economic diversification and agri-innovation (DALRRD, 2022:178).

Accordingly, the NSDF has the potential to guide economic resilience interventions in South African towns and cities, with the latter informed by potential vulnerability that negate the adaptive capacity of economies.

3. Research methodology

This paper applies a mixed-method research approach to (i) provide an overview of economic resilience indicators and (ii) explore how differences in these indicators are spatially distributed across South African towns and cities. The quantitative approach includes the analysis of secondary data in the form of four indicators delineated based on the factors that influence economic resilience as identified in Table 1. These are the Human Development Index (HDI), Labour Productivity (2015 base), Capital Productivity (2015 base), and the Tress Index. Said indicators measure the extent of economic diversification, quality of life, competitive advantages, and productivity. The Quantec EasyData database was utilised to access the secondary data related to the various indicators for 205 non-metropolitan (local) municipalities and eight metropolitan municipalities in South Africa. These represent respective rural and urban contexts relevant to the paper. To measure comparative performance, data for the year 2022 was utilised. The policy review, which constitutes the qualitative component of the methodology, is centred on the NSDF. This document informs spatial development in South Africa. The analysis delineates the respective policy components and their role in supporting economic resilience in towns and cities. Artificial Intelligence (AI) software (i.e. ChatGPT from OpenAI) was utilised to provide an initial scoping of relevant publications. This select information was verified and expanded upon by the author within the delineated parameters of the study and analysis.

4. Findings and discussion

The topics of the findings and discussion section include the 'regional overview of indicator performance', 'comparative analysis of urban and rural regions', and 'policy review'.

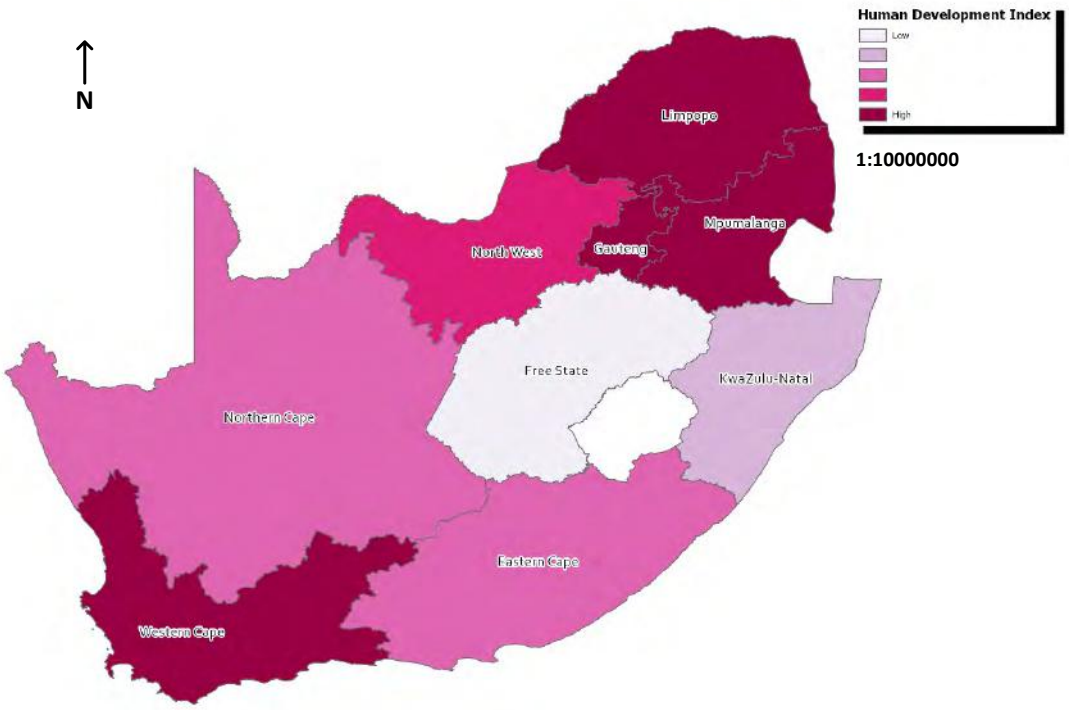
4.1. Regional overview of indicator performance

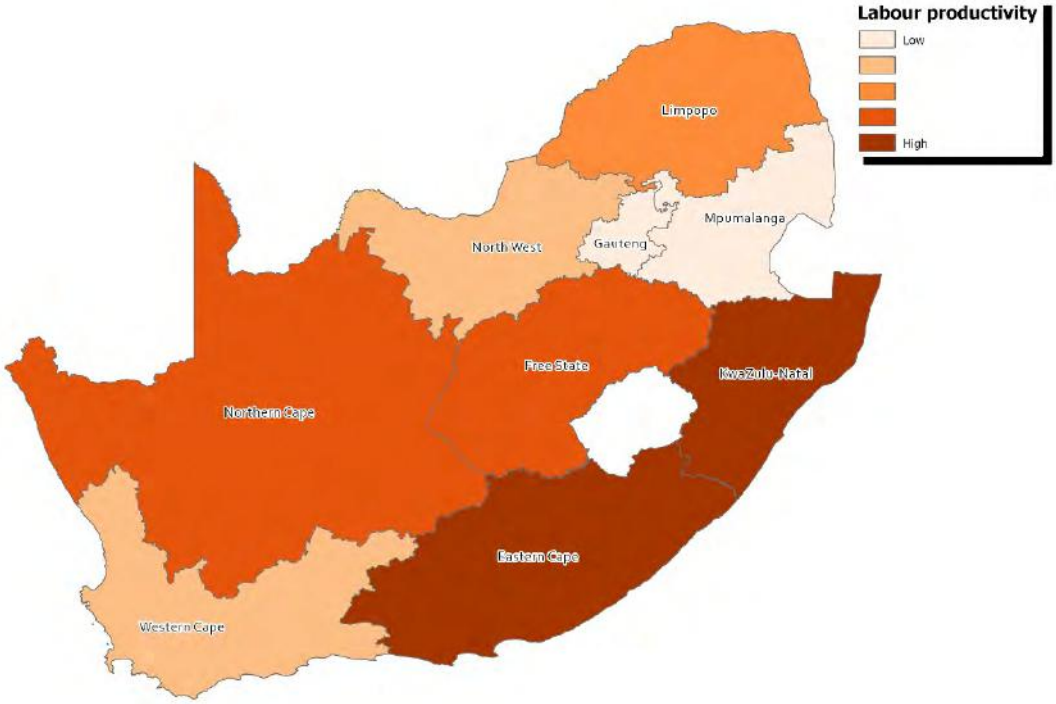
The following section provides a regional overview of municipal performance for the delineated indicators. Toward this end, Table 2 indicates the percentage of municipalities in each province that perform higher than the national average in the four indicators.

Table 2. Municipal performance per province. Source: Quantec EasyData (2024).

Province	HDI	Labour Productivity (2015 base)	Capital Productivity (2015 base)	Tress Index
1. Western Cape	100,00%	72,00%	96,00%	100,00%
2. Eastern Cape	42,42%	96,15%	38,46%	100,00%
3. Northern Cape	46,15%	88,46%	84,62%	100,00%
4. Free State	5,26%	89,47%	73,68%	100,00%
5. KwaZulu-Natal	9,09%	93,18%	63,64%	93,18%
6. North West Province	66,67%	72,22%	83,33%	100,00%
7. Gauteng	100,00%	33,33%	55,56%	44,44%
8. Mpumalanga	100,00%	29,41%	41,18%	100,00%
9. Limpopo	100,00%	72,73%	31,82%	100,00%

Figure 1 illustrates the spatial distribution of related performance on a provincial level.


N
Human Development Index
Low
High
1:10000000
Limpopo
Mpumalanga
North West
Gauteng
Free State
KwaZulu-Natal
Northern Cape
Eastern Cape
Western Cape


Labour productivity
Low
High
Limpopo
Mpumalanga
North West
Gauteng
Free State
KwaZulu-Natal
Northern Cape
Eastern Cape
Western Cape

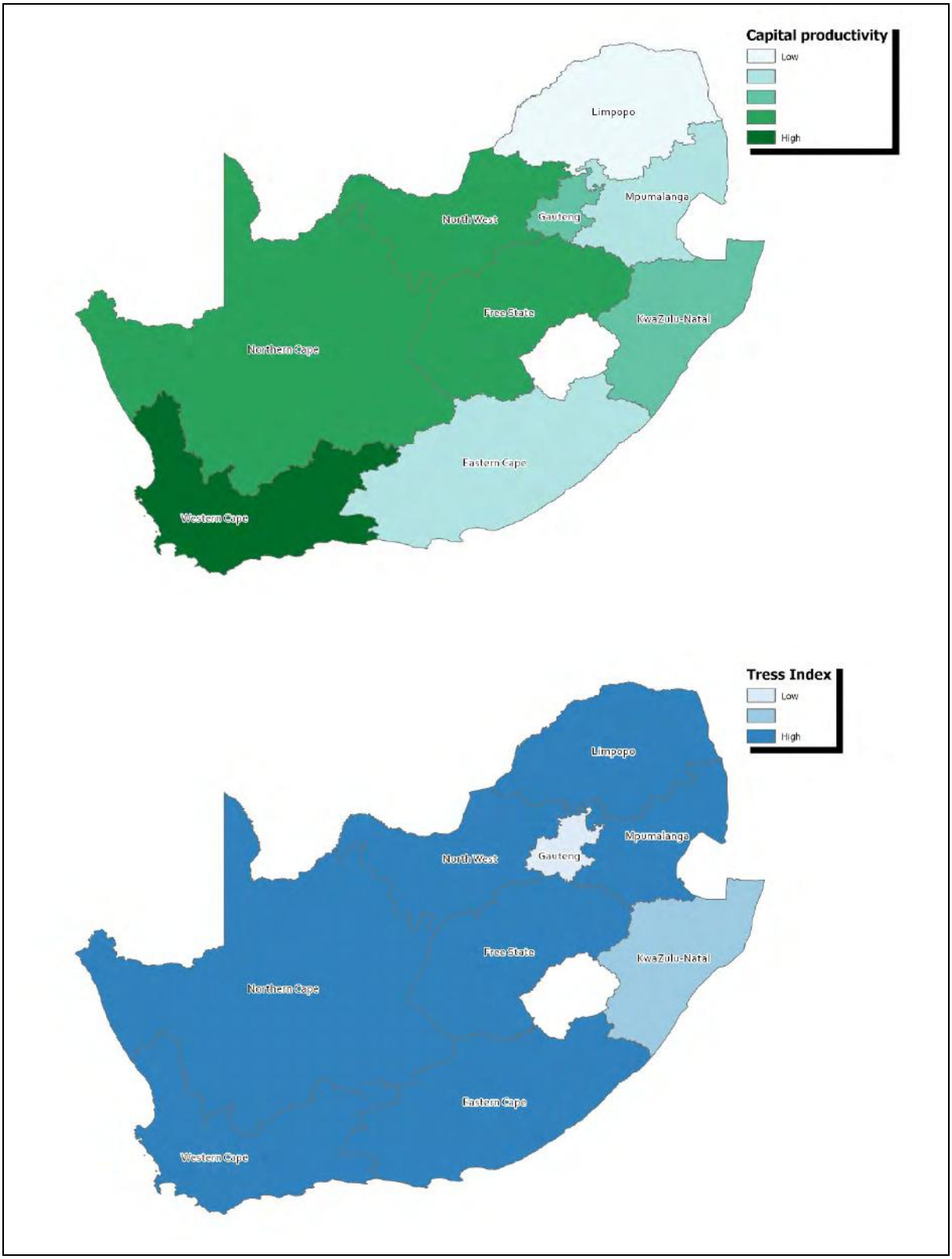


Figure 1. Spatial distribution of performance among indicators. Source: Author (2024).

As indicated in Table 2 and Figure 1, there are significant differences among the municipalities in the various provinces with regard to performance in the four indicators. With regard to HDI, in four provinces 100,00% of municipalities perform higher than the national average, including Western Cape, Gauteng,

Mpumalanga, and Limpopo. This is followed by 66,67% in North West Province, 46,15% in the Northern Cape, and 42,42% in the Eastern Cape. KwaZulu-Natal (9,09%) and the Free State (5,26%) have the lowest percentage of municipalities that perform higher than the national average in the HDI. In terms of labour productivity, the highest percentage of municipalities that exceed the national average in terms of performance are the Eastern Cape (96,15%), KwaZulu-Natal (93,18%), Free State (89,47%), and the Northern Cape (88,46%). Gauteng and Mpumalanga are the two provinces with the least amount of municipalities that exceed the national average, with 33,33% and 29,41% respectively. In terms of capital productivity, the Western Cape (96,00%), the Northern Cape (84,62%), and the North West Province (83,33%) have the highest percentage of municipalities that that exceed the national average performance. This is contrasted to Limpopo (31,82%), Mpumalanga (41,18%), and Gauteng (55,56%), who have the least amount of municipalities in this regard. In terms of the tress index, all municipalities in seven provinces have a higher concentration of economic activity compared to the national average. In KwaZulu-Natal, 93,18% of municipalities have a higher tress index than the national average, while 44,44% of municipalities in Gauteng exceed this national average.

4.2. Comparative analysis of urban and rural regions

The following section provides a comparison of the average performance of urban and rural areas in the four delineated indicators, which is summarised in Table 3.

Table 3. Metropolitan and non-metropolitan performance. Source: Quantec EasyData (2024).

Indicator	Metropolitan	Non-metropolitan
1. HDI	0,71	0,67
2. Labour Productivity (2015 base)	106,95	112,69
3. Capital Productivity (2015 base)	96,74	98,75
4. Tress Index	74,46	79,34

As indicated in Table 3, there are differences between metropolitan and non-metropolitan in the four delineated indicators. Metropolitan municipalities (0,71) have on average higher HDI in comparison with non-metropolitan municipalities (0,67). This may be indicative of regional disparities in quality of life and the social, economic, and environmental outcomes associated with the index, including health, education, and basic service delivery. In addition, this may indicate economic inequality, with urban areas characterised by more employment and higher income opportunities. The latter may constitute push and pull factors that influence migration and urbanisation trends between regions, which further exacerbates inequality (Gumede, 2021). Increased HDI may also catalyse increased domestic investment in said regions. Disparities in HDI between regions may also be due to disparities in education and health investment (Ngwakwe, 2020) – influencing broader socio-economic outcomes. Said disparities are due to structural inequality catalysed by historical and current public policy (Ogujiuba et al., 2024). The latter interventions need to prioritise improved education, health outcomes, and income distribution. Human development inequality is spatially reflected (also in Table 3) due to more inclusive development policy in urban areas, contrasted to rural areas being ensnared in cycles of low economic growth and opportunities (Ogujiuba et al., 2024).

Furthermore, Table 3 indicates that non-metropolitan municipalities (112,69) have higher labour productivity (2015 base) compared to metropolitan municipalities (106,95). This is also reflected in capital productivity (2015 base), with metropolitan municipalities scoring 96,74 in comparison with 98,75 in non-metropolitan municipalities. This may indicate the more productive use of labour and capital in rural areas, which is potentially centred on economies comprised of higher productivity sectors. This may include activities related to agriculture, mining, and energy. Cognisant of their comparatively lower HDI performance, high productivity in rural areas may not result on high employment or income. However, said productivity may also indicate opportunities for innovation and technology integration in non-metropolitan municipalities (Moyo et al., 2024). Higher productivity in rural areas may also be attributed to their adaptive capacity in a milieu of limited resource availability (Zhou & Gumbo, 2021). This is despite challenges related to infrastructure and access to markets. Phiri and Mbaleki (2022) state that increased public investment, with specific reference to education and health, may catalyse improved productivity. However, while rural areas (as per Table 3) illustrate higher productivity, the lack of targeted fiscal interventions limits potential growth and exacerbates the disconnect between productivity and employment (Phiri and Mbaleki (2022).

Table 3 does, however, indicate that metropolitan municipalities have, on average, a lower tress index score (74,46) than non-metropolitan municipalities (79,34). This translates into the economies of rural regions being concentrated in fewer economic sectors, with specific reference to primary and secondary activities, whereas urban regions house a larger tertiary sector through the provision of services activities, including finance and trade (Meyer, 2020). Further to these findings, Marais et al. (2023) analyse the dependence of rural regions in South Africa on primary sectors, including mining activities, which increases their vulnerability to economic downturns. The latter is relevant in the case of mine closures, which destabilise local economies. According to Van Aswegen et al. (2020), diversification strategies are required in regions that display significant concentration and specialisation in a narrow array of economic activities. This may support economic resilience and mitigate the potential for economic stagnation. This forms part of the broader need for local governance and policy interventions in rural areas as emphasised by Marais and Nel (2024).

4.3. Policy review

Table 4 indicates the policy components inherent to the NSDF, which may be applied to mitigate vulnerabilities and support economic resilience in the context of the South African space economy.

Table 4. NSDF policy components. Source: Author (2024).

Policy component	Overview	Relevance to economic resilience
1. Sectoral diversification	More balanced economy by lowering dependence on primary sectors	Support resilience to downturns in specific sectors.
2. Infrastructure investment	Infrastructure investment to improve linkages between regions.	Economic resilience in rural areas.
3. Spatial integration and growth nodes	Promotes development of various growth nodes; more balanced regional development strategy.	Reduced dependence on a few metropolitan centres.
4. Human capital and social infrastructure	Investment in education and health infrastructure.	Adaptive human capital to support diversified regional economies and adapt to economic shocks.

5. Natural resources and sustainability	Sustainable resource use; green economy development.	Relationship between economic and environment resilience.
6. Governance and institutional support	Effective governance and stakeholder collaboration is central to related policy development and implementation.	Intra-government and sectoral alignment important in fostering economic resilience.
7. Inclusive development	Inclusive development policy and access to economic opportunities toward the reduction of spatial inequality.	Social resilience is dependent on inclusive development and policy.

Accordingly, as indicated in Table 4, the implementation of the policy components in the NSDF may reduce vulnerability to sector-specific downturn, strengthen economic resilience to rural areas, reduce dependence on a few metropolitan centres, enable adaptive human capital to support diversified regional economies and adapt to economic shocks, develop the nexus between economic and environmental resilience, align policies in different spheres and sectoral are central to achieving economic resilience, and insure inclusive development that supports economic – and societal – resilience.

5. Conclusion

This paper has sought to identify potential indicators of economic resilience, analyse performance of municipalities against these indicators to provide insight on their resilience, and provide an overview of spatial policies that seek to foster economic resilience. The findings indicate that there are inequalities in the performance of municipalities, as well in between urban and rural regions in terms of performance in the indicators of economic resilience. Municipalities in the Free State and KwaZulu-Natal (HDI), Mpumalanga and Gauteng (labour productivity), the Eastern Cape and Limpopo (capital productivity) are positioned among the lowest performing in the context of the indicators. Only Gauteng and KwaZulu-Natal have municipalities that are more economically diverse (Tress Index) than the national average. Furthermore, rural areas perform lower than their urban counterparts in the HDI and Tress Index, while positioned higher in both labour and capital productivity. While the former illustrates the potential vulnerability of these areas, economic productivity may be leveraged to foster improved outcomes in broader economic indicators, including economic resilience. The latter may be achieved through the implementation of the diverse policy components incorporated in the NSDF, including sectoral diversification, infrastructure provision and spatial integration, human capital development, and governance and institutional support. This needs to form part of a holistic approach toward mitigating vulnerability to economic shocks, while fostering equal spatial diffusion of resilience and adaptation. Said approach ought to consider the productivity of factors of production, structural change, intra- and inter-regional interactions, connecting infrastructure, and governance capacity. In light of these findings in this exploratory study, future research initiatives ought to incorporate additional indicators to expand on the potential scope of the analysis, as well as analyse their growth trends over time; incorporate the direct measurement of economic resilience during shocks and disturbances on a local level in South Africa; and incorporate a broader review of development policies over diverse planning scales.

References

Arreza, M.K.B. (2024) 'Informal economy eatery owner's resilience: a recovery strategy', *Pak. j. life soc. Sci,* 22(2), p.4168-4179.

Department of Agriculture, Land Reform and Rural Development (DALRRD). (2022) 'National Spatial Development Framework'. Available at: https://www.gov.za/sites/default/files/gcis_document/202302/47999gen1594.pdf (Accessed: 31 October 2024).

Duan, W., Madasi, J.D., Khurshid, A. and Ma, D. (2022) 'Industrial structure conditions economic resilience', *Technological Forecasting & Social Change*, 183, p1-16.

Dzigbede, K.D., Pathak, R. and Muzata, S. (2023) 'Budget systems and post-pandemic economic resilience in developing countries', *Journal of Public Budgeting, Accounting & Financial Management*, 35(3), p333-353.

Gumede, V. (2021) 'Revisiting poverty, human development and inequality in democratic South Africa', *Indian Journal of Human Development*, 15(2), p1-17.

Joseph, T., Awolaja, O. and Ajibola, O. (2024) 'Measuring Sub-Saharan Africa economic resilience to external shocks: The role of adaptive policy space', *Applied Journal of Economics, Management and Social Sciences*, 5(1), p1-28.

Jumiyati, S., Nurdin, R., Rahman, I., Alam, A.S. and Akkas, N. (2021) 'Economic and ecological adaptation to changes in agricultural land use to increase sustainable economic resilience', In *IOP Conference Series: Earth and Environmental Science* (Vol. 800, No. 1, p. 012049). IOP Publishing.

Laubscher, P. (2017) 'The business cycle resilience of the Western Cape economy: a regional analysis of the 2009 recession and subsequent recovery', *J.Stud.Econ.Econometrics,* 41(3), p1-34.

Marais, L., Burton, J., Campbell, M. and Nel, E. (2023) 'Mine closure in the coal industry: global and national perspectives', in Marais, L., Burger, P., Campbell, M., Denoon-Stevens, S.P. and Van Rooyen, D. (eds.) *Coal and energy in South Africa: considering a just transition*. Great Britain: Edinburgh University Press, pp. 34-43.

Marais, L. and Nel, V. (2024) 'Governance in South African secondary cities', in Matamanda, A.R., Chakwizira, J., Chatiza, K. and Nel, V. (eds.) *Secondary cities and local governance in Southern Africa*. Switzerland: Springer, pp. 71-84.

Mayor, M. and Ramos, R. (2020). Regions and economic resilience: New perspectives. *Sustainability*, 12(11), p1-4.

Meyer, D. (2020) 'Does the diversification of the economy matter? : an assessment of the situation in South Africa', *EuroEconomica*, 39(2), p181-194.

Moyo, C., Mishi, S. and Ncwadi, R. (2024) 'The determinants of labour productivity in the Eastern Cape Province: A sectoral and industry analysis', *Development Southern Africa*, 41(2), p371-387.

Ngouhouo, I. and Nchofoung, T.N. (2021) 'Economic resilience in Sub-Saharan Africa: evidence from composite indicators', *Journal of the Knowledge Economy*, p1-22.

Ngwakwe, C.C. (2020) 'Measuring the interdependence between economic growth and human development in South Africa', *EuroEconomica*, 39(2), p94-103.

Ogujiuba, K., Maponya, L. and Stiegler, N. (2024) 'Determinants of human development index in south africa: a comparative analysis of different time periods', *World*, 5, p1-24.

OpenAI. (2023) 'ChatGPT'. Available at: https://chatgpt.com/ (Accessed: 21 January 2025).

Oprisan, O., Pirciog, S., Ionascu, A.E., Lincaru, C. and Grigorescu, A. (2023) 'Economic Resilience and Sustainable Finance Path to Development and Convergence in Romanian Counties' *Sustainability*, 15(19), p.1-24.

Phiri, A. and Mbaleki, C. (2022) 'Fiscal expenditures, revenues and labour productivity in South Africa', *Cogent Economic & Finance*, 10(1), p1-18.

Quantec EasyData. (2024) 'The EasyData Service'. Available at: https://www.quantec.co.za/easydata/ (Accessed: 31 October 2024).

Ramatlo, T. (2021) 'Boxed in: Challenges of escaping the inherited spatial realities of apartheid from the centre to the periphery', *Astrágalo. Cultura de la Arquitectura y la Ciudad*, 1(29), p157-174.

Sutton, J., Arcidiacono, A., Torrisi, G. and Arku, R.N. (2023) 'Regional economic resilience: A scoping review', *Progress in Human Geography*, 47(4), p500-532.

Sutton, J. and Arku, G. (2022) 'Regional economic resilience: towards a system approach', *Regional Studies, Regional Science*, 9(1), p497-512.

Trippl, M., Fastenrath, S. and Isaksen, A. (2024) 'Rethinking regional economic resilience: Preconditions and processes shaping transformative resilience', *European Urban and Regional Studies*, 31(2), p101-115.

United Nations (UN). (2024) 'Department of Economic and Social Affairs'. Available at: https://sdgs.un.org/goals/goal11 (Accessed: 31 October 2024).

Van Aswegen, M., Retief, F.P. (2021) 'The role of economic sectoral structure as a policy mechanism towards more resilient peripheral regions: the case of South Africa', *GeoJournal*, 86, p2823-2843.

Van Aswegen, M., Retief, F.P. and Drewes, E. (2020) 'Regional resilience in peripheral South Africa: the Northern Cape case', *Town and Regional Planning*, 77, p1-17.

Zhou, H. and Gumbo, V. (2021) 'Rural-urban comparison of manufacturing SMMEs performance in KwaZulu Natal Province, South Africa', *African Journal of Development Studies*, 11(1), p7-31.

Research Paper

Transforming Small Anatolian Cities
Insights from Student-Driven Urban Change in Amasya, Türkiye

Selin ASLAN ŞENOL, Gebze Technical University, Türkiye
Burcu SOYGÜZELOĞLU, Gebze Technical University, Türkiye
Melis OĞUZ ÇEVİK, Gebze Technical University, Türkiye

Abstract

Studentification refers to the urban transformation driven by student influx, with universities playing a pivotal role. Students boost city appeal, enrich social and cultural life, and drive real estate profitability. Students adopt local customs and engage with residents as they integrate, gaining valuable experience. In Türkiye, many cities under 750,000 have seen universities established post-2006 to stimulate local economies. Despite criticisms of these "provincial universities," little research exists on their urban impacts. This study explores studentification in Amasya, focusing on Amasya University's influence on urban development, socio-economic vitality, and challenges like gentrification and housing pressures. Using a participatory action research (PAR) approach, students collaborated with residents and tradespeople to explore these changes. This research involves desk studies, city visits, semi-structured interviews, and creative student-led fieldwork, along with an ongoing survey gathering broader insights from students across departments. A two-day workshop in Amasya synthesised data from stakeholders and experts, revealing the university's positive influence on local life, though it also created housing pressures. While residents near the university appreciate economic growth and diversity, those farther away express concerns about cultural shifts and housing affordability. These preliminary findings will first inform ongoing survey results and, subsequently, contribute to a broader study involving six Anatolian cities by aiding urban planning and policy-making in effectively addressing studentification's impacts.

Keywords

Studentification, Urban transformation, Türkiye, Amasya, University

Introduction

In recent years, the establishment of new universities in Turkey, particularly since 2006, has marked a significant shift in the landscape of higher education and its impact on smaller urban areas. With cities like Amasya now home to universities, the influence of these institutions extends beyond education, affecting local economies, social structures, and urban spaces. Amasya, a historically and culturally rich small city in the Black Sea region, represents a unique setting for examining these transformations. The city, contributing 0.02% to Turkey's GDP and showing a moderate economic performance with a GDP per capita of $19,907, is an example of how smaller urban centres can experience both benefits and challenges due to the presence of a university (TUIK, 2022). However, the role of these institutions in smaller cities is underexplored in the literature, especially concerning the social, economic, and spatial interactions between students and local communities. .

This research examines the increasingly larger student population at Amasya University, which has impacted on the socio-economic and cultural landscape of the city. This aims to comprehensively analyze the student-driven change focusing on how the presence of students affects the economy, social dynamics, and physical infrastructure at the local level. By focusing on a smaller city rather than the more studied urban centres, the research contributes to the limited available academic insight in the understanding of "studentification" within the Turkish context.

The methodology of this paper involves the collection of qualitative data, mainly through semi-structured interviews and student-led workshops. Semi-structured interviews were conducted by students of Amasya University with the support of local tradespeople and residents in order to understand the economic, social, and physical impacts attributed to the student population sensitively. These interviews provided a spectrum of insights into how locals perceive the changes, from economic benefits, such as increased commerce in service sectors, to cultural adjustments and tensions associated with a younger, transient population. Complementing this, a workshop involving students from Amasya University was conducted, incorporating SWOT analysis and mapping techniques. This workshop allowed students to evaluate interview outcomes, reflect on their interactions with the city, and assess the strengths and weaknesses of the urban landscape from a student's perspective.

Key findings show major changes in Amasya, an economic activity led by students' demands, and shifting dynamics within the community. Students and locals alike have different views of the city: though some residents view the growth of students as economically and culturally enriching, others raise concerns about the effects of housing pressures, infrastructure, and traditional values. These socio-cultural changes have brought all sorts of opinions to the fore, which underlines the city's adaptive capability. This adaptability is enabled through a 'cultural leak' between students and locals by merging traditional and new influences in ways that will help Amasya balance its historical identity with today's changes.

In all, this study contributes to the academic discourse on universities' effects in smaller cities by offering insights into student-driven urban transformation and adaptive capacity. It expands the discussion on urban sociology and planning in Turkey, while providing an understanding of socio-spatial dynamics introduced by higher education institutions in non-metropolitan settings. Therefore, the case of Amasya

provides an important model for analysing how universities can reshape smaller urban centers and fills a gap in the current literature on urban adaptation and studentification.

1. Town-Gown Relations in Transition

1.1. Exploring Student-Driven Urban Change: A Review of Existing Perspectives

Universities are multi-dimensional systems expected to contribute to the integrated development of urban areas that encompass social, economic, and environmental dimensions. They are recognized as catalysts for socio-economic growth, and transform the cultural and demographic fabric of their host cities (Akengin and Kaykı, 2013; Erilli, 2018; Gürsoy, 2018; Huggins and Cooke, 1997; Işık, 2008; Öztürk, Torun and Özkök, 2011). The presence of universities triggers transformation through the behaviour of students, academic staff, and administrative personnel, who introduce new consumption patterns and daily life practices that reshape the social, economic, and spatial fabric of cities.

Studies in international literature often focus on the concept of studentification (Smith, 2005)—urban transformation driven by the influx of students, which mainly impacts housing demand, retail, and services. Key factors for a city to accommodate students discussed in the literature include housing availability, transportation, and essential services (Ateş & Tunçel, 2023; Harris, 1943). Local governance plays a crucial role in integrating universities with urban development (Glasson, 2003; van den Berg & Russo, 2004).

In national literature, the emphasis has largely been on the economic impacts of universities. Studies (Akçakanat, Çarıkçı, and Dulupçu, 2010; Arslan, 2014; Gürsoy and Erjem, 2019) often examine how student expenditures benefit the local economy, particularly through housing and services. For instance, Akçakanat, Çarıkçı, and Dulupçu (2010) discuss the positive effects on employment and housing markets. These studies commonly use surveys and economic impact analysis, but they tend to overlook the broader spatial and social dimensions. The spatial transformation introduced by universities, such as infrastructure development and land use changes, is underexplored.

From a social perspective, universities foster cultural diversity and social interaction, and reshape cities' socio-cultural landscapes (Bourdieu, 1984; Tüysüz, 2020). Students from diverse socio-cultural backgrounds create new social spaces in cities, and enrich local culture and diversity. Koh and Harris (2020) emphasise universities as key sites for such interactions, especially for students transitioning into adulthood. Through integration into urban life, students adopt local customs, contribute to local culture, and form lasting relationships with the cities they inhabit. Although some studies have explored the social contributions of universities, few systematically examine how universities reshape urban spaces. While Akengin and Kaykı (2013), Arlı (2013), and Keçeli (2016) examined socio-spatial impacts, they mainly focused on student numbers and quality of life indicators. The interaction between students and the urban environment remains an underexplored area in both national and international studies.

Discussions on land use and spatial impacts remain relatively underdeveloped in the literature. Limited studies by Abar and Karaaslan (2013) and Çalışkan and Sarış (2008) have used multiple correspondence analysis and surveys to explore how universities affect urban planning. However, these studies often fail to fully capture how universities reshape cities through their demand for housing, services, and infrastructure.

Both international and national literature highlight the need for more comprehensive approaches to studying universities' roles in urban development. While economic impacts are well-documented, the social and spatial dimensions require deeper exploration, particularly in Türkiye. This project aims to address this gap by providing a holistic framework to analyse the diverse impacts of universities on urban transformation.

1.2. Multi-Dimensional Impacts of Universities in Türkiye: The Case of Amasya

In Türkiye, the rapid expansion of universities, particularly after the 2006 reforms, has significantly influenced both urban development and local economies, especially in small and medium-sized cities. Many cities with populations under 750,000 established universities as part of a national strategy to boost regional development. Although these universities contribute only 0.00% to 0.02% of Türkiye's GDP (TUIK, 2022), their local economic and socio-cultural impacts are substantial.

Amasya, the case study area of this research, exemplifies this dynamic by contributing 0.02% to the national GDP with a total GDP of $6.7 billion in 2022 (TUIK, 2022). Its GDP per capita stands at $19,907, moderate compared to other cities with universities founded post-2006, where GDP per capita ranges from $5,000 to $20,000 (TUIK, 2022). However, Amasya's local economy, particularly in education, housing, and services, has experienced significant growth due to the presence of students. Yet, preliminary results of the ongoing surveys with Amasya University students within this research show that despite this growth, 72% find shopping options inadequate, and 69% feel a lack of suitable social spaces. This highlights a gap between economic growth and the city's ability to meet the social and cultural needs of its student population.

Economic impacts of universities are often viewed through the lens of student expenditures. In cities like Burdur and Erzincan, student spending on housing and local goods stimulates business growth and employment (Gürsoy, 2018). Amasya also benefits from increased spending, but this economic boost coincides with rising rents and gentrification, leading to socio-spatial tensions. Arslan (2014) and Kaşlı and Serel (2008) noted that housing markets in university cities, like Amasya, struggle to balance growing student demand with affordability, creating pressures on long-term residents. This pattern reshapes neighbourhoods both physically and socially.

Beyond economics, universities like Amasya University have sparked significant social and cultural changes. Akengin and Kaykı (2013) discuss how universities enrich cities by fostering cultural activities, events, and increased social engagement. However, tensions between students and long-term residents often emerge, particularly concerning the availability of affordable housing and cultural shifts (Ergun, 2014). Preliminary results of the ongoing survey with Amasya University students showed that 60% of respondents do not plan to remain in Amasya after graduation by referring to limited job opportunities and a lack of cultural vibrancy.

Furthermore, the socio-spatial impact of universities extends to infrastructure and urban planning. These cities often struggle to keep pace with their rapidly growing student populations. Sankır and Sankır (2017) highlighted housing shortages and inadequate social services in smaller cities. In these cities, urban infrastructure, such as public spaces and transportation, has not evolved to match the city's needs, leading to issues like traffic congestion. Abar and Karaaslan (2013) emphasise that these small-sized cities experience unplanned urban growth, leading to reactive measures rather than proactive, strategic urban planning.

In conclusion, universities in Türkiye, especially the ones in smaller cities such as Amasya, usually have a significant contribution to strengthening local economies and social structures. However, their impact on urban development processes has been less investigated by concerning socio-spatial and cultural transformations. For this reason, this research aims to encompass these aspects from many different perspectives and contains comprehensive analysis about the impacts.

2. Methodology

This research uses a qualitative research design to capture the complex and layered impact of the student population on Amasya's socio-economic and spatial landscape. It was undertaken by following a methodology in two main steps: (1) semi-structured interviews and (2) a student-led workshop comprising mapping activities and discussions with various actors. Such methods, put together, ensure an in-depth analysis of local perspectives and student-driven urban analyses that helped gain a better understanding of the adaptive processes of this city.

First, semi-structured interview question sets were created to obtain negative and positive views about the impacts of the student population in Amasya. For this, 20 students from the Architecture Faculty at Amasya University volunteered for the interviews. Between May 7–20, 2024, each student interviewed a tradesperson and a resident locally, which amounts to 20 tradespeople and 20 residents in the sample. The interview recordings were transcribed and processed by using OpenAI's Whisper API, which provides an accurate textual dataset and streamlines transcription tasks for qualitative research.The transcriptions were then analysed using OpenAI's Qualitative Analysis Tools, which enabled systematic coding, thematic identification, and categorization of key ideas across responses (OpenAI, n.d.).

The second step involved a workshop, held on May 25-26, 2024, with the same group of volunteer students, including faculty academicians, municipality representatives, and experts in urban planning. The workshop was organized in such a way as to extend insights from the interviews through participatory mapping activities. Students were to map some of the core elements of Amasya's urban structure, such as transport and land use patterns, by integrating interview findings into their personal observations and experiences. Then, in groups of three students, they presented their SWOT analyses-the strengths, weaknesses, opportunities, and threats of the city. The outcome was discussed in a concluding discussion led by the faculty members and experts in planning, which allowed reflection and synthesis of critical observations.

A comparative analysis was finally conducted by combining the results from the interviews with those of the workshop. It focused on the spatial aspects identified through the mapping and SWOT outputs by comparing these against the local perspectives from the interviews. These multiple levels collectively provided a broad frame for Amasya's adaptive capacity and its socio-spatial dynamic in relation to its student population by offering important insights for the study of small cities being influenced by higher-education institutions.

3. Results

3.1. Community Perspectives: Insights from Semi-Structured Interviews

Semi-structured interviews conducted by the volunteer students of Faculty of Architecture at Amasya University showed significant outcomes in terms of impacts of university students to the socio-economic,

socio-cultural and physical fabric of the Amasya city. Socio-economic impacts were perceived significant from both demographic groups. Local tradespeople, especially those operating in the service sector, note that the influx of students has favoured commercial activity, providing a steady increase in sales. For many tradespeople, the student population translates directly into revenue, with one interviewee stating:

"Students mean direct cash flow for tradesmen, so the benefit is great" (T1-IOD).

Increasing number of cafes and social spaces around the city is one visible outcome, with establishments multiplying in both number and scope to meet student demand:

"Cafes have increased. There were cafes before, but they were neither this many nor this widespread" (T1-IOD).

This economic stimulus is not only limited to direct sales but also generates new job opportunities, as observed by local residents who recognize the positive impact on employment and local business diversity. The presence of students has prompted the opening of new businesses catering specifically to their needs, leading to an expanded job market within the city:

"Dormitories were established, local businesses profited. Many businesses catering to the university opened. A lot of people found new job opportunities" (R1-IP).

Together, these perspectives reflect how the university has become a key aspect in Amasya's economic landscape, driving growth in both commercial transactions and employment, thus enriching the local economy.

The university has also brought socio-cultural change to Amasya by making the social environment of the city more heterogeneous and open. This had reflection on different kinds of responses from the community. To the local tradespeople, this impact is very positive, since they see more tolerance and openness in their social interaction, which they associate with students who come into their town. Even the social behaviors have changed, and one of the trades-people says:

"This situation has also changed our perspective, people have become more polite" (T13-IBK)

Moreover, tradespeople appreciate the role of the university in boosting the quality of demographics in the city and facilitating cultural integration, adding to the cosmopolitan environment:

"The university increases the quality of the demographic structure in the city and provides cultural integration" (T5-IAG).

In contrast, local residents hold more complex views on the university's socio-cultural influence. While some residents appreciate the city's new modern face with a student population, others express concern about the erosion of traditional values. For certain residents, the diverse cultural influx associated with the student population is seen as a threat to Amasya's conservative identity and spiritual values:

"By bringing the culture of 81 provinces here, they ruined Amasya's spiritual values and the level of morality has declined" (L1-IP).

Yet, others perceive the university's presence as a positive force for social change, gradually normalising ideas that previously may not have been accepted in the community:

"Amasya is a conservative city, but thanks to the university, certain ideas have started to become normalised" (L5-HH).

These perspectives underscore the dual impact of the university, as it facilitates cultural integration and openness while simultaneously challenging deeply held values and sparking a nuanced discourse on tradition and modernity in Amasya.

The physical effects brought different views to the eyes of local tradespeople and residents in terms of improvements and challenges to the infrastructure of the university. For example, local tradespeople mentioned that the increasing number of students has burdened the demand for housing, mainly due to the scarcity of state-provided dormitories, therefore, a rise in the need for private accommodation was felt:

"The insufficiency of the state dormitories increases the demand for housing" (T1-IOD).

This has driven up rental prices and, over time, increased competition for housing among both locals and students. Besides housing, the tradespeople report that the transportation infrastructure has also suffered. In this respect, one stated:

"It has caused a housing problem and transportation issues have worsened over the years" (T5-IAG).

The local residents give a wider perspective to the physical changes by appreciating the positive infrastructural development in light of resource pressures. With the university, new building complexes, including cafes and social spaces for student life have been constructed in the city. These developments added to the social and recreational infrastructure of the city, which makes it more lively. The expansion of public transportation, including an increase in the number of taxis has increased the accessibility for all:

"The university added to the infrastructure of Amasya; the roads and public transportation became better" (L1-IP).

The increase in cafes and social venues reflects also the tendency of the town to adapt to its younger population with one resident notes that:

"The number of cafes and social venues has gone up, and there has also been an increase in the number of taxis" (L18-SA).

Together, these views reveal the university's role in the physical transformation of Amasya and how it balances infrastructural benefits with increased demands on housing and transit systems.

3.2. Student Perspectives: Insights from the Workshop

In the research, a student workshop was organized to include students directly into the assessment of Amasya's urban dynamics. It is a participative methodology that gives students the ability to engage

themselves with the city by using a mental mapping technique to analyze main issues in land use, transportation, distribution of the population, relationships between the regions, and the main set of plans/ projects distribution inside the city (Figure 1).

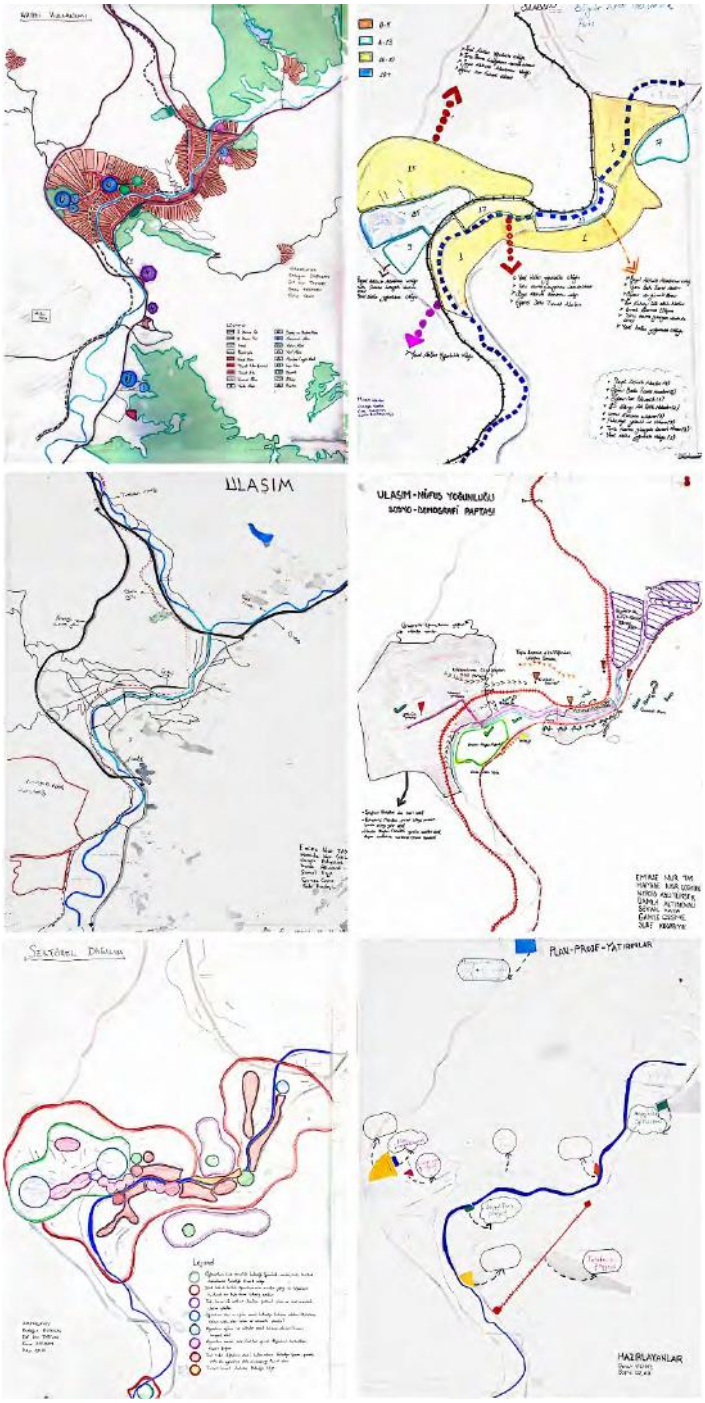


Figure 1. Student workshop outcomes: mental mapping on land-use, inter-region relationship, transportation, socio-demographic distribution, sectoral distribution, distribution of plans and projects, respectively) (Created by participant students).

Through this hands-on approach, the workshop aimed to bridge the gap between academic knowledge and real-world urban challenges, offering students a role in shaping their environment. The workshop provided valuable insights into Amasya's strengths, weaknesses, opportunities, and threats from the perspective of students (Figure 2). Students' findings reflected their understanding of the city's physical layout and socio-spatial challenges, particularly the relationship between the university and the city.

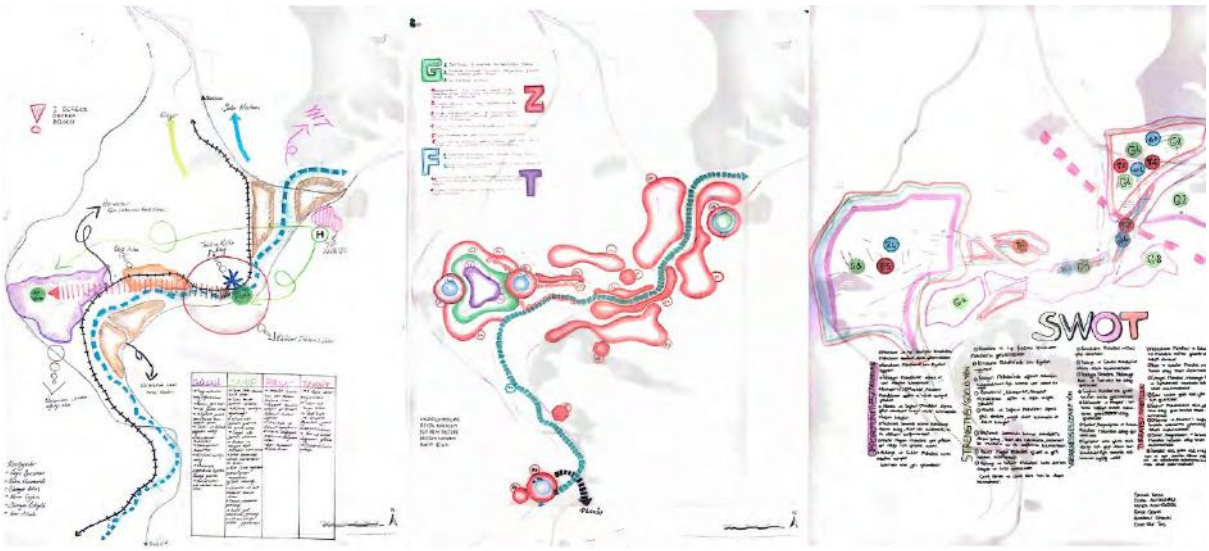


Figure 2. Student workshop outcomes: SWOT analysis (From left to right: S1, S2 and S3, created by the participant students).

The SWOT analysis revealed both strengths and weaknesses, and highlighted Amasya's historical and cultural value, pedestrian accessibility, and the vitality of the university sub-center, including Şeyhcui and Akbilek Neighbourhoods as key strengths (Table 1). The relationship between the city and the river was also seen as a major asset for urban accessibility and aesthetics. However, weaknesses included inadequate public transportation, insufficient intercity connections, and a lack of social facilities for students. Many students pointed out the disconnection between the university and the city centre, which further contributes to these challenges.

In terms of opportunities, students emphasised Amasya's potential to leverage its historical and cultural heritage for economic growth and to position the university as a focal point for cultural and academic activities (Table 2). However, threats included unplanned urban expansion, environmental degradation, and economic disparities between neighbourhoods, which pose significant challenges to sustainable development of the city.

Table 1. Perceived strengths and weaknesses of Amasya from the mental maps of participant students (Summarised by the authors).

	Factors Stated In Mappings	S1	S2	S3
Strengths	Historical and cultural value	x	x	
	Relationship between water and the city	x		x

	Pedestrian access to focal points	x	x	x
	Cultural diversity/ variety	x		
	Cultural flexibility/adaptability	x		
	Economic accessibility	x		
	Safety in residential streets		x	
	Airport/ Air transportation		x	
	Vitality of university sub-center		x	
	Adequacy of social facilities			x
	Accessibility to housing			x
	Train station			x
Weaknesses	Inadequacy of intercity transportation		x	
	Inadequacy of public transportation facilities	x	x	x
	Cultural diversity/ variety (adaptation problems)		x	
	Inadequacy of social facilities		x	
	Insecurity within the central area	x	x	x
	Lack of connection between the university and the city		x	

Table 2. Perceived opportunities and threads of Amasya from the mental maps of participant students (Summarised by the authors).

	Factors Stated In Mappings	S1	S2	S3
Opportunities	Historical-cultural attraction center	x		x

	University campus as a new focal area	x	x	
	Increasing cultural events with the university	x	x	x
	Railway as an essential transportation mode		x	x
	Employment opportunities for university students		x	
	Accessible housing for university students			x
Threads	Unplanned expansion of the urban macroform	x		
	Lack of communication between the university and the city	x	x	x
	Economic differences between neighborhoods	x		
	Destruction of green areas	x		
	Social insecurity within the train station	x		x
	Uncontrolled increase in the immigrant population	x	x	x
	Need for urban transformation		x	
	Need for planning regulations about flood risk		x	
	Insecurity caused by lack of lighting in residential areas			x

One of the key insights from the workshop was the lack of integration between the university and the city. Students observed that the university operates in isolation, limiting its potential to contribute to Amasya's socio-cultural life. This disconnect was linked to accessibility challenges, as public and intercity transport systems were seen as inadequate, impacting both the student population and the broader community. Regarding land use, students highlighted the unplanned expansion of the urban macroform and the urgent need for better coordination in infrastructure projects. The increasing demand for housing driven by the student population was another key issue. Although the university sub-center has developed, students noted that social facilities remain insufficient, which reflects concerns raised in the semi-structured interviews.

When considering the workshop outcomes with the semi-structured interviews together, several parallels and differences emerge. Both highlight the significant economic impact of students on Amasya's local

economy. It is agreed by local tradespeople and participants of workshops that students enhance the housing and service sectors, hence accelerating business and providing employment opportunities. For example, the increase in cafes and social spots identified by the local business also reflects the view of students that there is development in the growth of the university sub-center.

However, whereas both groups identified the economic benefit, socio-cultural and physical impacts were perceived differently by each group. The cultural effect of the university was seen to be very different by local residents, with some believing it had a positive effect, while others felt it was damaging to Amasya's traditional values. Students, however, perceived the university to create cultural tolerance and increase the diversity of cultural activities. This generational divide is illustrative of differing attitudes toward the perception of the university's role in reshaping the city's social fabric.

4. Conclusion

This study provides significant insights into the transformative role that universities play in smaller cities with respect to the case of Amasya. Among its key findings is that students and locals have different conceptions regarding the changing character of Amasya. There is a distinction in the student conceptions, which express that their presence enriches this city, since it contributes to the existing diversity and dynamism. In contrast, locals are more ambivalent. While some welcome the economic and cultural vibrancy brought by the presence of students, others worry about erosion of traditional values and urban mores. Such divergent perceptions point to the socio-cultural changes accompanying university-related urban transformation.

The socio-cultural change that took place in Amasya underlines different ideas concerning the impact of students on local life. Among them, local tradespeople are inclined to consider the growth of students as positive since it gives a greater driving force to the local economic life. Demand for goods, services, and housing created by these students has stimulated the service industry and helped the local traders by providing jobs. This economic benefit creates a generally positive disposition from tradespeople, distinctly different from residents who do not have an economic benefit from the presence of students.

What we have called "cultural leak" further underscores the adaptive capacity of Amasya to such changes in a process whereby students and locals interactively affect each other's social behaviors, cultural norms, and urban lifestyles. In this interaction, a mixture of traditional and modern influences develops which essentially helps the city adapt, changing yet retaining its core cultural entity. This cultural leak has allowed Amasya to embrace new cultural dynamics introduced by students without fully losing its traditional character, providing a model of adaptive resilience in small cities with growing university populations.

This study serves as a pilot for exploring the impacts of universities in small Turkish cities, and offers preliminary insights into Amasya's spatial, socio-cultural and economic shifts as a framework for further research. While this research in Amasya is still ongoing (October 2024), initial findings highlight important dynamics, and survey efforts are still underway with students from multiple departments at Amasya University. Following the conclusion of the Amasya study, the same multi-dimensional, participatory methodology will be applied to other selected small Turkish cities hosting universities. By conducting

similar analyses, we aim to identify both common patterns and unique characteristics in each setting, and contribute to a broader understanding of student-driven urban transformation across diverse regions in Türkiye. Ultimately, these findings will inform urban planning and policy, and aid in the management of the complex dynamics of university-induced urban change in Türkiye's small cities.

Acknowledgements

We would like to thank Assoc. Prof. Dr. Aslı Altanlar and Assist. Prof. Dr. Zeynep Özdemir from Amasya University for their invaluable support in facilitating the research, field visit, and workshop, and all the participating students for their active participation and contributions.

References

Abar, H. and Karaaslan, A. (2013) 'Konut talep edenlerin özellikleriyle talep edilen konutun özellikleri arasındaki ilişkinin çoklu uyum analizi yöntemi ile incelenmesi: Atatürk üniversitesi personeli örneği', Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 27(3), pp.323-339.

Akçakanat, T., Çarıkçı, İ. and Dulupçu, A. (2010) 'Üniversite öğrencilerinin bulundukları il merkezine ekonomik katkıları ve harcama eğilimleri: Isparta 2003-2009 yılları örneği', SDÜ Fen Edebiyat Fakültesi Sosyal Bilimler Dergisi, 22, pp.165-178.

Akengin, H. and Kaykı, A. (2013) 'Şehirleşme üniversite ilişkisine bir örnek: Gazimağusa', Marmara Coğrafya Dergisi, 28, pp.501-525.

Arlı, E. (2013) 'Barınma yerinin üniversite öğrencilerinin kişisel ve sosyal gelişim ve akademik başarı üzerindeki etkilerinin odak grup görüşmesi ile incelenmesi', Yüksek Öğretim ve Bilim Dergisi, 3(2), pp.173-178.

Arslan, H. (2014) 'Çankırı Karatekin Üniversitesi'nin kente ekonomik katkısı ve öğrenci harcamalarının farklı değişkenler açısından analizi', Dicle Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 12, pp.114-127.

Ateş, D. and Tunçel, H. (2023) 'Üniversite şehri kriterleri: Eskişehir örneği', Coğrafi Bilimler Dergisi, 21(2), pp.198-234.

Bourdieu, P. (1984) Distinction: A social critique of the judgement of taste. Cambridge, MA: Harvard University Press.

Çalışkan, V. and Sarış, F. (2008) 'Çanakkale şehrinde üniversite-konut ilişkisi', Doğu Coğrafya Dergisi, 20, pp.215-237.

Ergun, C. (2014) 'Üniversite ve kent ilişkisi üzerine görüşler: Mehmet Akif Ersoy Üniversitesi örneği', Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi, 31, pp.216–237.

Erilli, N.A. (2018) 'Üniversite öğrencilerinin bulundukları il ekonomisine katkıları: Cumhuriyet Üniversitesi örneği', Uluslararası Ekonomi İşletme ve Politika Dergisi, 2(1), pp.79-96.

Glasson, J. (2003) 'The widening local and regional development impacts of the modern universities: A tale of two cities (and north-south perspectives)', Local Economy, 18(1), pp.21–37.

Gürsoy, M. (2018) 'Üniversitelerin içinde doğdukları kentlere yönelik sosyal ve kültürel işlevleri: Adıyaman örneği', OPUS Uluslararası Toplum Araştırmaları Dergisi, 9(16), pp.1369-1414.

Gürsoy, M. and Erjem, Y. (2019) 'Kent perspektifinden ekonomik boyutuyla üniversite algısı: Adıyaman örneği', İdealkent, 10(27), pp.679-713.

Harris, C. (1943) 'A functional classification of cities in the United States', Geographical Review, 33(1), pp.86-99.

Huggins, R. and Cooke, P. (1997) 'The economic impact of Cardiff University: Innovation, learning and job generation', GeoJournal, 41(4), pp.325-337.

Işık, Ş. (2008) 'Türkiye'de üniversitelerin kentleşme üzerine etkileri', Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 10(3), pp.159-181.

Kaşlı, M. and Serel, A. (2008) 'Üniversite öğrenci harcamalarının analizi ve bölge ekonomilerine katkılarını belirlemeye yönelik bir araştırma', Yönetim ve Ekonomi, 15(2), pp.99-113.

Keçeli, K. (2016) Isparta şehrinde uluslararası öğrencilerin kentsel mekân algısı. Yüksek Lisans Tezi, Süleyman Demirel Üniversitesi, Sosyal Bilimler Enstitüsü, Coğrafya Anabilim Dalı.

Koh, S.Y. and Harris, A. (2020) 'Multicultural reflexivity: University students negotiating 'pockets' and 'strings' of multiculturalism in Malaysia', Children's Geographies, 18(6), pp.712–725.

OpenAI. (n.d.) *Qualitative Analysis Tools*. [online]. Available at: https://openai.com (Accessed: 14 August 2024).

Öztürk, S., Torun, İ. and Özkök, Y. (2011) 'Anadolu'da kurulan üniversitelerin illerin sosyo-ekonomik yapılarına katkıları', Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 8(16), pp.145-158.

Sankır, H. and Sankır, Ş. (2017) 'Toplumsal değişim açısından üniversite-kent etkileşimi ve algısı: Bülent Ecevit Üniversitesi örneği', Yükseköğretim ve Bilim Dergisi, 7(3), pp.473-483.

Smith, D. P. (2005). "Studentification": The Gentrification Factory?, 73–90; Der.: Atkinson R. ve Bridge G. (2005). *Gentrification in a Global Context: The New Urban Colonialism*, Taylor & Francis, New York

Turkish Statistical Institute (TUIK) (2023) *İl Bazında Gayrisafi Yurt İçi Hasıla 2022*. Available at: https://data.tuik.gov.tr/Bulten/Index?p=Il-Bazinda-Gayrisafi-Yurt-Ici-Hasila-2022-45867 (Accessed: 27 October 2024).

Tüysüz, S. (2020) 'Dönüştürücü bir mikro-coğrafya alanı olarak üniversiteler ve yerellik-evrensellik paradoksu', Ege Coğrafya Dergisi, 29(2), pp.179-199.

van den Berg, L. and Russo, A. (2004) The student city: Strategic planning for student communities in EU cities. London: Routledge. Available at: https://doi.org/10.4324/9781315236919 (Accessed: 15 October 2023).

Research Paper

A fuzzy approach for critical quality assessment of neighbourhood risk factors in historic city centres

Empirical evidence from Kolkata, India

Barnali CHAKRABORTY, Indian Institute of Technology, Kharagpur, India
Priyanka DEY, Indian Institute of Technology, Kharagpur, India

Abstract

Historic city centres, which are essential socio-economic and cultural assets, are increasingly being threatened due to rapid urbanisation, climate change, and inadequate development, management, and conservation practices. This research made an empirical assessment of the compounding risks present in historic city centres by taking the case of Kolkata, India. A fuzzy approach was employed to quantify the critical qualities of the physical, functional, environmental, economic, and social dimensions, elucidating how these inherent characteristics govern the riskscapes in historic city centres. The findings revealed the presence of physical degradation and socio-economic decline in the selected study areas, which exacerbate their vulnerabilities and increase their overall risk. This research puts forward a stratified risk assessment approach using factors that are intrinsic to historic city centres and thus provides comprehensive knowledge about their ground realities. The research offers a pragmatic framework aiming to guide evidence-based decision-making to foster a more resilient and sustainable future for heritage management and urban development.

Keywords

Historic city centre, risk assessment, vulnerability, intangible heritage, built-environment

1. Introduction (800)

Industrialisation and technological advancements have steered a massive outflow of population, where people from rural hinterlands are rapidly migrating to urban centres in search of job opportunities and better quality of life. The world urban population has increased fourfold, from 0.8 billion in 1950 to 4.2 billion in 2018, and is expected to account for more than half of the total global population by 2050 (United Nations 2018). The impacts of rapid urbanisation are experienced in the form of changing demographic, spatial, and functional dynamics that inadvertently introduce significant transformation in the social, economic, and environmental base of a country (Bodo, 2019; Kuddus, Tynan and McBryde, 2020). The multifaceted urban challenges are predominantly concentrated in historic city centres in the form of housing shortages, inadequate and ageing infrastructures, overcrowding, congestion, environmental deterioration, and other socio-cultural and public health challenges, exceeding the carrying capacity of these historic centres (Picard, 1939; Hemer *et al.*, 2003).

Urban heritage, largely concentrated in historic districts, constitutes a vital asset for socio-economic development in rapidly evolving global cities. These districts hold great symbolic importance for city

dwellers and are pivotal in determining the liveability, well-being, and quality of life of residents (UNESCO, 2010). However, the tangible and intangible heritage inherent to these historic centres is being increasingly altered due to rapid urbanisation and globalisation, which introduces several risks in these sensitive areas. These historic areas are being subjected to additional pressures due to ineffective development, management, and conservation practices, exposing them to various degrees of vulnerability and compounding risks, thereby restricting their tourism and future development potential. These factors significantly diminish the potential of these invaluable heritage assets, further threatening their resilience and sustainability (Ferreira and Ramírez Eudave, 2022).

To elevate the cultural experiences in historic areas and promote their tangible and intangible heritage for sustainable development, it is vital to have high-quality and well-rounded development in these areas. Historic centres are dynamic in nature, where multiple stakeholders converge to shape their physical, environmental, social, and economic developmental trajectories. As such, successful management of historic districts mandates institutional frameworks and regulatory assessment tools. However, the intricate and constantly changing dynamics among the various urban components complicate empirical assessments in historic districts (Quesada-Ganuza *et al.*, 2021). There is a need for pragmatic approaches that combine qualitative and quantitative narratives to explore the systemic risks underlying these vulnerable historic areas. Therefore, this research aims to assess the criticality of historic neighbourhoods and identify their risks, extending a comprehensive understanding of the present urban dynamics in these historic centres. By taking the case of Kolkata, which is also known as the cultural capital of India, this study explores the various intensities of risk associated with the spatial, environmental, economic, and social conditions of these historic districts. This research puts forward an approach for quantitative risk assessment of historic districts using factors that are intrinsic to historic areas and thus provides comprehensive knowledge about their ground realities. The fuzzy risk assessment of historic areas underscored in this research took cognizance of the perturbations resulting from various socio-economic, physical, and infrastructural conditions. The findings of this research provide crucial insights for decision-makers to identify gaps in the functionality of municipal services and the quality of spatial, environmental, and socio-economic aspects. The theoretical and practical contribution of this research will assist in understanding the potential future threats and thereby guide evidence-based decision-making for streamlining heritage development towards a more resilient and sustainable future.

The remainder of the study has been structured as follows: Section 2 presents a brief background of the existing literature. Section 3 explains the methodology and selected study areas for the research, followed by section 4, which presents the result and discusses the research outcome. Section 5 presents the final inferences and conclusion of the research and describes the scope of future research.

2. Background

The *International Council on Monuments and Sites (ICOMOS)* has recognised historic city centres as human settlements that have a historical blueprint of their past physical structures and way of life, reflecting the spatio-temporal evolution of the settlement. These historic centres have a high concentration of business, cultural, recreational, and residential functions with buildings and structures of significant historic and cultural values (Asian Development Bank, 2008). These centres are cauldrons where physical, social, and functional attributes interact and influence each other to form an integral part of everyday city life. As a result, these centres hold profound symbolic and emotional significance for the city dwellers, as they extensively showcase the rich historical backdrop of the cities and their intangible heritage, accumulated over the years in the form of diverse traditions, values, and cultural practices

(UNESCO, 2010). These historic centres have distinct morphological, physical, functional, social, perceptual, and visual characteristics and nuanced shades of temporal evolution, fostering a unique urban identity and enriching the genius loci of these places (UNESCO, 2016; Shehab El-Deen, Aboulsaadat and Nour, 2024). The United Nations has previously recognised the importance of historic cities in advancing socio-economic development (UNESCO, 2010). They are an invaluable part of the socio-cultural and economic assets of countries and play a pivotal role in shaping the sustenance of societies and communities at large. In addition to their monumental values, these centres have social and community attributes that contribute towards the development of cultural capitals (Romão and Bertolin, 2022). Along the same line, previous literature has noted their significance in driving sustainable and inclusive development and boosting the economy of a country by promoting tourism opportunities (Deacon, 2018; UNESCO, 2023).

However, the unprecedented rate of population expansion and uncontrolled urban densification have subjected these historic city centres to pressures of varying degrees. The rapid commercialisation, market exploitation of these sensitive areas, and overexploitation of their tangible and intangible resources for promoting mass tourism have exponentially increased the vulnerabilities of these areas (Castronuovo, 2023; Shehab El-Deen, Aboulsaadat and Nour, 2024). Moreover, these historic centres often undergo natural ageing and dilapidation in addition to experiencing climate-induced disasters, contributing to significant depreciation in the natural adaptive capacities of these historic centres. The impacts of these externalities extend beyond the built environment, bearing considerable ramifications on the cultural landscape of these areas by inducing profound shifts in socio-economic dynamics, thereby resulting in dilution of community cohesion and increased fragmentation, marginalisation, and gentrification (Castronuovo, 2023; Fu *et al.*, 2023). Owing to these profound anthropogenic pressures and climate-induced challenges, the debate over resilient planning, development, and preservation of historic centres and their heritage assets have intensified over the decades. Global forums on heritage conservation like *ICOMOS* and *UNESCO* have been persistently focusing on addressing these challenges threatening the integrity and sustenance of these heritage assets (Quesada-Ganuza *et al.*, 2021). The *Recommendations on Historic Urban Landscape* was formulated by the *UNESCO World Heritage Committee* in 2003 followed by the *Vienna Memorandum* in 2005 to collectively align heritage conservation approaches with urban development aspirations (Francini and Rozochkina, 2024). The *European Union* similarly manifested a cultural heritage risk assessment through their *EU Work Plan for Culture 2019-2022* (Quesada-Ganuza *et al.*, 2021). However, risk assessment in historic areas often proves to be challenging, given the intricacies and the presence of overlapping physical, environmental, economic, and social dynamics (Ferreira and Ramírez Eudave, 2022). Existing studies on risk assessment of historic city centres have predominantly focused on hazard and vulnerability assessments within the context of disaster risk and climate change. Studies on the inherent attributes of these historic city centres, which play a crucial role in shaping their vulnerabilities and adaptive capacities, remain underexplored. There is a distinct gap in addressing how these intrinsic characteristics influence the overall risk associated with these sensitive areas, independent of external hazards. Thus, this research aims to critically evaluate the inherent characteristics of historic city centres by taking the case of historic city centre of Kolkata, the cultural capital of India. By employing a fuzzy approach, this research undertakes a multi-level and multi-factorial risk assessment of the selected study areas to better inform decision-makers about the diverse challenges present in these areas. The risk profiling incorporates both tangible and intangible attributes of the study areas, offering a comprehensive overview of their combined vulnerabilities.

The contributions of this study are twofold. Firstly, this study presents a participatory approach by integrating multiple stakeholders in the quality assessment of the study areas. This bottom-up methodology ensures that the place-based concerns and the subjective perceptions of key stakeholders

are adequately reflected in the overall risk assessment, as these aspects are often undermined when relying solely on census-based data. Secondly, the proposed framework enables policymakers to identify lacunae in existing development plans and policies, thereby fostering evidence-based policy initiatives.

3. Methodology

Data collection for this research was conducted in two parts consisting of expert opinion surveys and stakeholders' perception mapping using structured questionnaires. The stakeholders' perception mapping was conducted in two wards of Kolkata, which are parts of the historic centre of the city and a total of 160 samples were collected. A multi-factor and multi-level risk assessment was then conducted at three levels by employing fuzzy logic. In the first level, the critical quality assessment of individual risk factors within each subsystem was undertaken followed by the criticality assessment of the subsystems in the second level. Finally, the overall risk scores of the study areas was computed based on the values obtained in the first two levels. To determine the weights of the factors for the risk assessment, an expert opinion survey was conducted using structured questionnaire. A panel of 15 experts were invited for the expert opinion survey to rate the relevance of the selected indicators in 5-point Likert Scale and the final weight of the indicators was obtained using the normalised mean method as per the following equation:

$$w_i = \frac{M_i}{\sum_{i=1}^{n} M_i}, \; 0 < w_i < 1 \text{ and } \sum_{i=1}^{n} w_i = 1 \qquad \text{(Eq. 1)}$$

where, w_i is the weight of the factors/subsystems, M_i is the mean score of each factor/subsystem . The critical quality scores of the individual risk factors in each subsystem were calculated as the membership function (MF) using the following equation:

$$MF_i = \frac{x_1}{LT_1} + \frac{x_2}{LT_2} + \frac{x_3}{LT_3} + \frac{x_4}{LT_4} + \frac{x_5}{LT_5} \qquad \text{(Eq. 2)}$$

where, x_1 to x_5 are the percentage of responses received under the five linguistic terms and LT_1 to LT_5 are the grade alternatives adopted for the linguistic terms in the Likert scale. The fuzzy matrix was then computed for the criticality assessment of the subsystems in the second level as follows:

$$S_i = \begin{matrix} MF_1 \\ MF_2 \\ MF_3 \\ \dots \\ \lfloor MF_m \rfloor \end{matrix} = \begin{matrix} C_{11} & C_{21} & C_{31} & C_{41} & C_{51} \\ C_{12} & C_{22} & C_{32} & C_{42} & C_{52} \\ C_{13} & C_{23} & C_{33} & C_{43} & C_{53} \\ \dots & \dots & \dots & \dots & \dots \\ C_{1m} & C_{2m} & C_{3m} & C_{4m} & C_{5m} \end{matrix} \qquad \text{(Eq. 3)}$$

where, S_i is the fuzzy matrix showing the membership functions of the factors, C_{11} to C_{5m}, within a defined subsystem.

The fuzzy evaluation matrix D_i was calculated as:

$$D_i = W_i \circ S_i = \{w_1, w_2, w_3, \dots, w_n\} * \begin{vmatrix} C_{11} & C_{21} & C_{31} & C_{41} & C_{51} \\ C_{12} & C_{22} & C_{32} & C_{42} & C_{52} \\ C_{13} & C_{23} & C_{33} & C_{43} & C_{53} \\ \dots & \dots & \dots & \dots & \dots \\ C_{1m} & C_{2m} & C_{3m} & C_{4m} & C_{5m} \end{vmatrix} \qquad \text{(Eq. 4)}$$

where, D_i is the degree of membership of the grade alternative for a given subsystem (Wuni *et al.*, 2022). The scores of the critical quality of the subsystems in the second level was calculated as the product of the fuzzy evaluation matrix (D_i) of the subsystem and the grade alternatives adopted for the linguistic terms (LT) in the Likert scale. The critical scores of each subsystem were given by:

$$C_i = \sum_{i=1}^{5} (D_i \times LT) \qquad \text{(Eq. 5)}$$

The overall risk scores (RS_{sa}) of the study areas were calculated using the fuzzy evaluation matrices of the subsystems and their associated total weights.

$$R = \begin{matrix} MF_{S_1} \\ MF_{S_2} \\ MF_{S_3} \\ \dots \\ \lfloor MF_{S_n} \rfloor \end{matrix} = \begin{vmatrix} s_{11} & s_{21} & s_{31} & s_{41} & s_{51} \\ s_{12} & s_{22} & s_{32} & s_{42} & s_{52} \\ s_{13} & s_{23} & s_{33} & s_{43} & s_{53} \\ \dots & \dots & \dots & \dots & \dots \\ s_{1n} & s_{2n} & s_{3n} & s_{4n} & s_{5n} \end{vmatrix} \quad \text{(Eq. 6)}$$

The final fuzzy evaluation matrix (D_{sa}) for the study areas were computed as:

$$D_{sa} = W \circ R = \{W_1, W_2, W_3, \dots, W_n\} * \begin{vmatrix} s_{11} & s_{21} & s_{31} & s_{41} & s_{51} \\ s_{12} & s_{22} & s_{32} & s_{42} & s_{52} \\ s_{13} & s_{23} & s_{33} & s_{43} & s_{53} \\ \dots & \dots & \dots & \dots & \dots \\ s_{1n} & s_{2n} & s_{3n} & s_{4n} & s_{5n} \end{vmatrix} \quad \text{(Eq. 7)}$$

where, W is the weight of the subsystems S_1 to S_n.

$$RS_{sa} = \sum_{i=1}^{5} (D_{sa} \times LT) \quad \text{(Eq. 8)}$$

3.1. Study Area

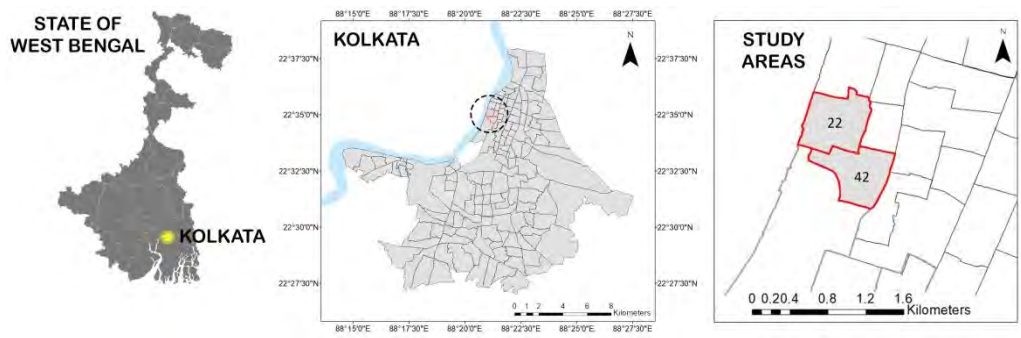


Figure 1. Location of the study areas. Source: Authors

The city of Kolkata, situated on the eastern bank of River Hoogly, is the business and financial hub of eastern India. The city is presently the 7th largest city in the country, with a population of approximately 45 lakhs (Directorate of Census Operation West Bengal, 2011). As the capital of British India until 1911, it developed as a port city, and the earliest settlements came up in the northern and central parts. Known as the cultural capital of India, this city has a diverse demographic population and an urban fabric that reflects the historical and cultural evolution. The historic centre of the city has rich colonial architectural heritage and a unique sense of place, deeply rooted in traditions and cultural practices. However, since the last few decades, the historic centre of the city is undergoing rapid decline due to population exodus from these areas. The city centre is more than 300 years old and has started exhibiting significant signs of ageing and degradation (Chakraborty and Dey, 2024a). The Kolkata Municipal Corporation has estimated that the city has presently more than 2000 dilapidated buildings, out of which 721 buildings pose a serious threat to the lives of the inhabitants.

Figure 2. Condition of the study areas. Source: Authors

Wards 22 and 42, which are parts of the earliest settlement of the city, were selected as study areas for this research. The census data revealed a high proportion of unemployed population, indicating signs of economic decline in these wards. Similarly, these wards have more than 70% rented buildings and 10% of the buildings are vacant (Figure 3), proving the exodus of the original inhabitants from these historic centres. As shown in Figure 2, these wards are undergoing severe functional and physical depreciation owing to ageing infrastructure and housing, and associated socio-economic decline, which compromises the adaptive capacity of the residents and further increases their vulnerabilities. In the presence of these multiple threats, these wards were realised to be the right case examples for carrying out a comprehensive risk profiling to elucidate how these inherent factors govern the riskscapes in historic city centres. The overlapping socio-cultural dynamics and the physical fabric of the built environment provides an ideal setting for assessing the resulting risks, as the interaction between socio-cultural capitals with the physical environment of these wards significantly impacts their adaptive capacities.

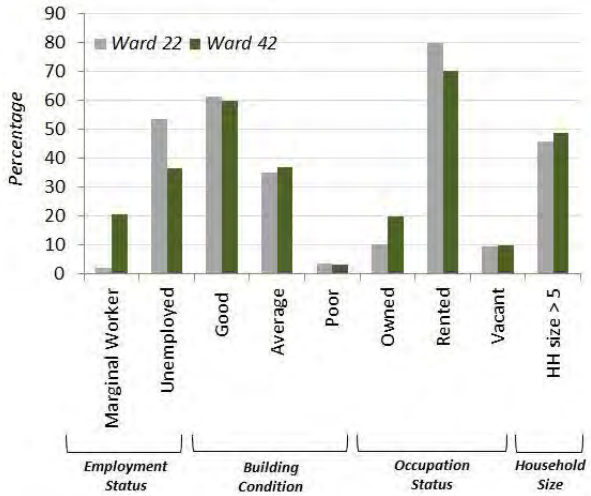


Figure 3. Demographics of the study areas. Source: Census of India, 2011

4. Results and Discussions

The results of the risk analysis were computed based on the data collected from expert opinion surveys and stakeholder perception mapping. The weights of the risk factors, deduced from the expert opinion surveys using the normalised mean method, show the relative importance of the identified factors (Table 1).

Table 1. Weights of the factors and subsystem. Source: Authors

Risk Factors	Mean Score of the Factors	Factor Weights	Total Mean Score of each Subsystem	Subsystem weights
Physical Quality			38.212	0.307
P1 Abandoned buildings	4.358	0.114		
P2 Vacant plots	2.860	0.075		
P3 Degraded building conditions	4.290	0.112		
P4 Presence of demolished buildings	3.569	0.093		
P5 Substandard and unsanitary living conditions	4.067	0.106		
P6 Temporary structures made of makeshift materials	2.783	0.073		
P7 Graffiti	2.357	0.062		
P8 Overgrown vegetation and weeds	3.286	0.086		
P9 High building density	2.783	0.073		
P10 Abandoned vehicles on streets	4.072	0.107		
P11 Poor visual appearance	3.787	0.099		
Functional Quality			17.213	0.138
F1 Decline in public health	4.285	0.249		
F2 Nonconformity with byelaws	2.782	0.162		
F3 Poor road infrastructure	3.572	0.208		
F4 Parking problems	2.786	0.162		
F5 Inadequate and poor public infrastructural services	3.788	0.220		
Environmental Quality			14.929	0.12
EN1 Environmental contamination	3.787	0.254		
EN2 Degraded outdoor areas	3.784	0.253		
EN3 Improper waste disposal	4.215	0.282		
EN4 Air pollution	3.143	0.211		
Economic Quality			14.354	0.115
EC1 High rate of mortgage foreclosure	3.643	0.254		
EC2 Low per capita income	3.425	0.239		
EC3 Low property values	3.643	0.254		
EC4 Tax delinquency	3.643	0.254		
Social Quality			39.782	0.32
S1 Feeling of exclusion	3.855	0.097		
S2 Less sense of community	3.146	0.079		
S3 Contested notion of safety and security	3.787	0.095		
S4 Social stigmatization	3.856	0.097		
S5 Antisocial behaviour and immoral activities	3.426	0.086		
S6 Conflicting land ownership	3.07	0.077		
S7 Socio-economic segregation	3.497	0.088		
S8 Lack of social cohesion	3.072	0.077		
S9 Violence and crime	4.287	0.108		
S10 Social unrest	4.216	0.106		
S11 Population exodus	3.57	0.09		

Based on the commonality between the factors, they were grouped under five subsystems, namely *physical, functional, environmental, economic*, and *social*, to represent distinct qualities of the study areas. According to the computed weights, the most important risk factors were identified to be *abandoned buildings (P1), degraded building conditions (P3), violence and crime (S9), decline in public health (F1), social unrest (S10), improper waste disposal (EN3), abandoned vehicles on streets (P10)*, and *substandard and unsanitary living conditions (P5)*. This indicates that physical and social dimensions have the most important role in determining risks in historic city centres.

Table 2. Membership function of ward 22. Source: Authors

Risk Factors	*Factor Weights*	*Membership Function (Level 1)*	*Membership Function (Level 2)*
Physical Quality			(0.06 0.27 0.19 0.38 0.09)
P1 Abandoned buildings	0.114	(0.00 0.21 0.10 0.60 0.09)	
P2 Vacant plots	0.075	(0.00 0.06 0.09 0.40 0.46)	
P3 Degraded building conditions	0.112	(0.20 0.36 0.14 0.24 0.06)	
P4 Presence of demolished buildings	0.093	(0.00 0.07 0.04 0.73 0.16)	
P5 Substandard and unsanitary living conditions	0.106	(0.07 0.36 0.17 0.39 0.01)	
P6 Temporary structures made of makeshift materials	0.073	(0.00 0.10 0.21 0.60 0.09)	
P7 Graffiti	0.062	(0.07 0.50 0.30 0.13 0.00)	
P8 Overgrown vegetation and weeds	0.086	(0.01 0.40 0.26 0.33 0.00)	
P9 High building density	0.073	(0.27 0.36 0.34 0.03 0.00)	
P10 Abandoned vehicles on streets	0.107	(0.00 0.20 0.14 0.46 0.20)	
P11 Poor visual appearance	0.099	(0.09 0.36 0.39 0.17 0.00)	
Functional Quality			(0.11 0.39 0.40 0.11 0.00)
F1 Decline in public health	0.249	(0.20 0.46 0.26 0.09 0.00)	
F2 Nonconformity with byelaws	0.162	(0.00 0.23 0.64 0.13 0.00)	
F3 Poor road infrastructure	0.208	(0.10 0.51 0.39 0.00 0.00)	
F4 Parking problems	0.162	(0.19 0.34 0.24 0.20 0.03)	
F5 Inadequate and poor public infrastructural services	0.220	(0.03 0.33 0.50 0.14 0.00)	
Environmental Quality			(0.11 0.43 0.41 0.05 0.00)
EN1 Environmental contamination	0.254	(0.01 0.29 0.54 0.16 0.00)	
EN2 Degraded outdoor areas	0.253	(0.16 0.49 0.36 0.00 0.00)	
EN3 Improper waste disposal	0.282	(0.11 0.47 0.39 0.03 0.00)	
EN4 Air pollution	0.211	(0.19 0.49 0.33 0.00 0.00)	
Economic Quality			(0.03 0.25 0.37 0.34 0.02)
EC1 High rate of mortgage foreclosure	0.254	(0.00 0.13 0.16 0.67 0.04)	
EC2 Low per capita income	0.239	(0.07 0.26 0.36 0.27 0.04)	
EC3 Low property values	0.254	(0.00 0.27 0.49 0.24 0.00)	
EC4 Tax delinquency	0.254	(0.04 0.33 0.47 0.16 0.00)	
Social Quality			(0.01 0.17 0.49 0.30 0.03)
S1 Feeling of exclusion	0.097	(0.00 0.11 0.39 0.46 0.04)	
S2 Less sense of community	0.079	(0.03 0.31 0.59 0.07 0.00)	
S3 Contested notion of safety and security	0.095	(0.01 0.24 0.57 0.17 0.00)	
S4 Social stigmatization	0.097	(0.03 0.26 0.39 0.29 0.04)	
S5 Antisocial behaviour and immoral activities	0.086	(0.00 0.17 0.34 0.44 0.04)	
S6 Conflicting land ownership	0.077	(0.00 0.00 0.30 0.57 0.13)	
S7 Socio-economic segregation	0.088	(0.00 0.04 0.59 0.37 0.00)	
S8 Lack of social cohesion	0.077	(0.06 0.39 0.54 0.01 0.00)	
S9 Violence and crime	0.108	(0.00 0.11 0.67 0.21 0.00)	
S10 Social unrest	0.106	(0.00 0.13 0.59 0.27 0.01)	
S11 Population exodus	0.09	(0.00 0.16 0.34 0.44 0.06)	

The membership function of the risk factors and their associated subsystems were computed based on the data collected using stakeholder perception mapping (Table 2 and Table 3). These membership functions gave the primary inputs for estimating the critical qualities of the risk factors and their subsystems in *level 1* and *level 2* respectively, which were then used to estimate the overall risk scores of the study areas in *level 3*. Conducting the stakeholder perception mapping was pivotal in determining the criticality of the study areas in real time, as historic city centres often undergo transformations that remain unnoticed by external observers. As such, data collected from the primary stakeholders enabled an in-depth understanding of the intrinsic conditions of these areas based on community knowledge, collective memories, and lived experiences of the inhabitants.

Table 3. Membership function of ward 42. Source: Authors

Risk Factors	*Factor Weights*	*Membership Function (Level 1)*	*Membership Function (Level 2)*
Physical Quality			(0.07 0.19 0.25 0.41 0.08)
P1 Abandoned buildings	0.114	(0.00 0.17 0.03 0.69 0.11)	
P2 Vacant plots	0.075	(0.00 0.00 0.14 0.63 0.22)	
P3 Degraded building conditions	0.112	(0.16 0.32 0.17 0.33 0.02)	
P4 Presence of demolished buildings	0.093	(0.00 0.03 0.11 0.68 0.18)	
P5 Substandard and unsanitary living conditions	0.106	(0.10 0.32 0.21 0.34 0.02)	
P6 Temporary structures made of makeshift materials	0.073	(0.01 0.14 0.21 0.60 0.03)	
P7 Graffiti	0.062	(0.17 0.40 0.29 0.14 0.00)	
P8 Overgrown vegetation and weeds	0.086	(0.00 0.14 0.41 0.43 0.01)	
P9 High building density	0.073	(0.38 0.21 0.38 0.03 0.00)	
P10 Abandoned vehicles on streets	0.107	(0.00 0.06 0.33 0.34 0.27)	
P11 Poor visual appearance	0.099	(0.07 0.32 0.48 0.13 0.00)	
Functional Quality			(0.17 0.26 0.48 0.07 0.01)
F1 Decline in public health	0.249	(0.32 0.20 0.32 0.16 0.00)	
F2 Nonconformity with byelaws	0.162	(0.01 0.30 0.60 0.07 0.02)	
F3 Poor road infrastructure	0.208	(0.14 0.28 0.57 0.01 0.00)	
F4 Parking problems	0.162	(0.24 0.28 0.33 0.12 0.02)	
F5 Inadequate and poor public infrastructural services	0.220	(0.09 0.29 0.61 0.01 0.00)	
Environmental Quality			(0.12 0.30 0.56 0.03 0.00)
EN1 Environmental contamination	0.254	(0.01 0.24 0.68 0.07 0.00)	
EN2 Degraded outdoor areas	0.253	(0.13 0.30 0.53 0.03 0.00)	
EN3 Improper waste disposal	0.282	(0.09 0.39 0.52 0.00 0.00)	
EN4 Air pollution	0.211	(0.27 0.26 0.48 0.00 0.00)	
Economic Quality			(0.03 0.22 0.31 0.42 0.02)
EC1 High rate of mortgage foreclosure	0.254	(0.00 0.07 0.30 0.60 0.03)	
EC2 Low per capita income	0.239	(0.04 0.26 0.29 0.37 0.04)	
EC3 Low property values	0.254	(0.01 0.20 0.29 0.50 0.00)	
EC4 Tax delinquency	0.254	(0.07 0.36 0.36 0.21 0.01)	
Social Quality			(0.01 0.18 0.46 0.32 0.04)
S1 Feeling of exclusion	0.097	(0.00 0.08 0.36 0.49 0.08)	
S2 Less sense of community	0.079	(0.03 0.31 0.53 0.11 0.01)	
S3 Contested notion of safety and security	0.095	(0.01 0.26 0.58 0.14 0.01)	
S4 Social stigmatization	0.097	(0.03 0.28 0.23 0.41 0.04)	
S5 Antisocial behaviour and immoral activities	0.086	(0.00 0.21 0.41 0.36 0.02)	
S6 Conflicting land ownership	0.077	(0.00 0.01 0.52 0.36 0.11)	
S7 Socio-economic segregation	0.088	(0.00 0.10 0.50 0.39 0.01)	
S8 Lack of social cohesion	0.077	(0.00 0.32 0.54 0.12 0.01)	
S9 Violence and crime	0.108	(0.00 0.09 0.64 0.26 0.01)	
S10 Social unrest	0.106	(0.01 0.28 0.48 0.23 0.00)	
S11 Population exodus	0.09	(0.00 0.03 0.28 0.58 0.11)	

The critical quality assessment of the risk factors, computed using the membership functions, highlights the present condition of the subsystems, as shown in Figure 4. The research findings suggest that the *physical* quality, *social* quality, and *economic* quality in ward 22 and ward 42 have surpassed the average critical value of 2.5, indicating that the present state of these subsystems is quite critical. Using equation 8, the overall risk score of ward 22 was found to be *2.975* while the risk score of ward 42 was *3.023*, suggesting that ward 42 poses more risk as compared to ward 22. The critical quality assessment of the risk factors highlights that these historic city centres are significantly experiencing the risk of physical decay and socio-economic decline. This can be attributed to the fact that these wards have been experiencing exodus of the original inhabitants over the last few decades, leading to housing abandonment and renting of these centuries-old buildings. The basic amenities in these historic areas are presently in a deplorable state, resulting in low rental charges in these areas and thereby attracting tenants from the economically weaker section of society. In the absence of the original caretakers, these areas undergo further decay and decline due to lack of maintenance and upkeep (Chakraborty and Dey, 2024b). Furthermore, the frequent change in tenancy often destabilises the neighbourhood cohesion in these areas and contributes to segregation and exclusion, significantly lowering the sense of community and social quality of these areas.

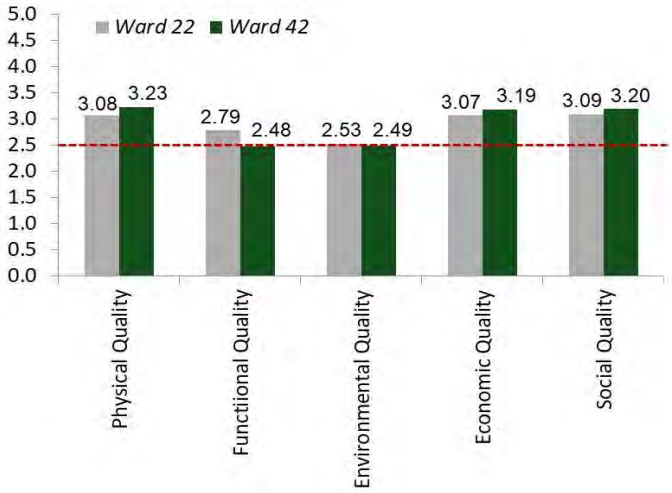


Figure 4. Critical Quality Assessment of the Subsystems. Source: Authors

Previous literature has highlighted that the presence of these factors often make historic centres susceptible to urban blight, which might trigger the exodus of affluent people from the historic core, contributing to building abandonment and further decline in the social structure of these areas. The presence of these factors inevitably lowers the tourism potential of the historic cores in addition to impacting their socio-economic growth. Moreover, the ineffectiveness in maintenance and conservation practices often exacerbates the existing vulnerabilities in historic city centres, thereby necessitating an integrated effort to safeguard these areas. In line with this, the findings of the research extended a nuanced understanding of the various vulnerabilities and risk profiles of the study areas, resulting from the present state of their intrinsic physical, functional, spatial, and socio-economic conditions.

5. Conclusion

Historic city centres and landscapes are reflections of tangible and intangible heritages. They have buildings of exemplary architectural values, showing traditional ways of construction and living and simultaneously showcasing the socio-cultural identities of these places embedded in their traditions, values, and cultural practices. The tangible and intangible assets present in historic urban centres are invaluable in advancing sustainable economic development alongside fostering social cohesion and uplifting community well-being and liveability of urban dwellers. It thus becomes crucial to preserve not just these tangible assets but their intangible counterparts as well, retaining their connection to the past that are pivotal for the sustenance of these historic precincts and communities living therein. However, rapid urbanisation and frequent threats due to climate change have destabilised these sensitive historic centres and further exacerbated their vulnerabilities and limited their adaptive capacities, necessitating a comprehensive analysis of the various dynamics that govern the riskscapes of these sensitive areas. The inherent complexities and challenges present in these historic centres demand an integrated approach that combines the built environment analyses with the socio-economic dimensions.

This research thus made an attempt to underscore the various physical, functional, environmental, economic, and social factors that determine the overall risk in historic city centres. A stratified fuzzy approach was used to evaluate the criticalities of the identified risk factors and overall risks of the selected areas resulting from the combined effects of these risk factors. The research methodology integrated expert opinion surveys with stakeholder perception mapping to derive insights into the local conditions of these areas. The stakeholder perception mapping enabled a participatory approach to understand the subjective and objective attributes associated with these historic areas, predominantly reflecting the aspects that are vital for their healthy functionality and sustenance. It further provided a new perspective on the lived experiences of the residents in these historic neighbourhoods by capturing the social-spatial factors that define and shape the vulnerabilities and management in these areas. The research findings highlighted the current state of these wards alongside the prevailing lacunas in developmental and socio-economic conditions, providing a discourse on prioritising developmental needs based on empirical evidence drawn from the fuzzy analysis.

This research puts forward an empirical approach to assess risks associated with historic city centres based on their inherent conditions and characteristics. The research concludes that risk assessment should be at the centre of policy discussions concerning the preservation and development of historic centres. The intrinsic characteristics of the historic districts, both tangible and intangible, should be carefully incorporated into the overall risk profile of cities to better prepare them for unprecedented events. Future development efforts should carefully address the preservation of these tangible and intangible resources, which are vital assets that enrich the historic identity and spirit of these places and are an important aspect of community development. Future research should conduct similar investigations into the multifaceted risks in historic city centres, enabling policymakers to take informed decisions for redirecting cities towards a more sustainable future, where new development will co-exist alongside historical heritage.

6. Acknowledgement

We thank the Indian Institute of Technology, Kharagpur, and the Ministry of Education, Government of India, for providing assistance for this research under the Prime Minister's Research Fellowship Scheme.

7. Reference

Bodo, T. (2019) 'Rapid Urbanisation: Theories, Causes, Consequences and Coping Strategies', *Annals of Geographical Studies*, 2(3), pp. 32–45.

Castronuovo, V. (2023) 'Losing Cultural Heritage due to Anthropic Environmental Disasters: An Application of the DPSIR Spiral Framework', *Sustainability (Switzerland)*, 15(3). doi: 10.3390/su15031978.

Chakraborty, B. and Dey, P. (2024a) 'A Composite Urban Blight Identification and Evaluation Index (CUBIE): A Systems-Driven Approach Based on Empirical Evidence from Kolkata, India', *Social Indicators Research*. doi: 10.1007/s11205-024-03494-6.

Chakraborty, B. and Dey, P. (2024b) 'Spatial characterisation of blighted urban areas using space syntax analysis: the case of historic city centre of Kolkata, India', *GeoJournal*, 89(5), p. 231. doi: 10.1007/s10708-024-11221-4.

Deacon, H. J. (2018) 'Conceptualising Intangible Heritage in Urban Environments: Challenges for Implementing the HUL Recommendation', *Built Heritage*, 2(4), pp. 72–81. doi: 10.1186/BF03545685.

Dey, T. (2022) 'Dwelling in Decay: Analysing the SpatioPsychological Paradigm of Dilapidated Dwellings in Kolkata', in *Habitat, Ecology and Ekistics Case Studies of Human-Environment Interactions in India*, pp. 135–146. doi: 10.1007/978-3-030-49115-4.

Directorate of Census Operation West Bengal (2011) *District Census Handbook Kolkata Village and Town Wise Primary Census Abstract*.

Ferreira, T. M. and Ramírez Eudave, R. (2022) 'Assessing and Managing Risk in Historic Urban Areas: Current Trends and Future Research Directions', *Frontiers in Earth Science*, 10(March), pp. 1–17. doi: 10.3389/feart.2022.847959.

Francini, C. and Rozochkina, T. (2024) 'Cultural Heritage and Urban Development: Embracing the Historic Urban Landscape Approach', in, pp. 105–113. doi: 10.1007/978-3-031-54816-1_7.

Fu, L. *et al.* (2023) 'Assessment of urbanization impact on cultural heritage based on a risk-based cumulative impact assessment method', *Heritage Science*, 11(1), p. 177. doi: 10.1186/s40494-023-01024-0.

Hemer, O. *et al.* (2003) *A FUTURE FOR THE PAST Historic Cities in Development*. Available at: www.supervisual.se (Accessed: 23 April 2023).

Kuddus, M. A., Tynan, E. and McBryde, E. (2020) 'Urbanization: A problem for the rich and the poor?', *Public Health Reviews*, 41(1), pp. 1–4. doi: 10.1186/s40985-019-0116-0.

Picard, R. (1939) 'The Challenge of Urban Blight', *Journal of the American Planning Association*, 5(1), pp. 1–5. doi: 10.1080/01944363908978808.

Quesada-Ganuza, L. *et al.* (2021) 'Risk Assessment Methodologies to Safeguard Historic Urban Areas from the Effects of Climate Change', in *12th International Conference on Structural Analysis of Historical Constructions SAHC 2020*. doi: 10.23967/sahc.2021.214.

Romão, X. and Bertolin, C. (2022) 'Risk protection for cultural heritage and historic centres: Current knowledge and further research needs', *International Journal of Disaster Risk Reduction*, 67. doi: 10.1016/j.ijdrr.2021.102652.

Shehab El-Deen, A. S., Aboulsaadat, A. H. and Nour, W. A. (2024) 'Reviving the past: urban strategies for renovating historic commercial streets in city centers', *Journal of Engineering and Applied Science*, 71(1), p. 155. doi: 10.1186/s44147-024-00488-6.

Steinberg, F. (2008) *Revitalization of historic inner-city areas in Asia : the potential for urban renewal in Ha Noi, Jakarta, and Manila*. Asian Development Bank.

UNESCO (2010) *Historic districts for all - India: a social and human approach for sustainable revitalisation; brochure for local authorities; 2010*. Available at: http://publishing.unesco.org.

UNESCO (2016) *Global Report on Culture for Sustainable Urban Development Heritage and Creativity Culture*. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000245999%0Ahttp://unesdoc.unesco.org/images/0024/002459/245999e.pdf.

UNESCO (2023) *Urban Heritage for Resilience*.

United Nations (2019) *World Urbanization Prospects The 2018 Revision*.

Wuni, I. Y. *et al.* (2022) 'Modelling the critical risk factors for modular integrated construction projects', *International Journal of Construction Management*, 22(11), pp. 2013–2026. doi: 10.1080/15623599.2020.1763049.

Case Study Report

Petites Villes de Demain: revitalizing small cities for a sustainable future

Clotilde HAVARD, France

Abstract

Developed at the national scale, Petites Villes de Demain is an urban planning program aiming at improving living conditions in small cities facing the devitalization of their city-centers. The 1600 targeted cities have been identified on the criteria that they are a center for their broader territory, providing smaller cities and villages with employment, services and commerce. 36% of the French population is estimated to be impacted by these cities' situation. This program focuses on creating a long-term strategy for each city, designed to ensure economic and commercial dynamism, patrimonial valorization and amelioration of housing and public space.*

**Petites Villes de Demain translates to "Small Cities of Tomorrow"*

Keywords

Urban shrinkage, revitalization, innovation, master plan

Introduction :

In 2020, France launched the Petites Villes de Demain (PVD) program, a six-year initiative designed to revitalize small towns that historically served as centers for their territories. These towns have faced significant challenges, weakened by urban sprawl, shifting consumption patterns, and the centralization of resources in major cities. They were at the center of the post-COVID "Yellow Jackets" protests, fueled by rising fuel costs and a sense of neglect from national policies. PVD aims to reverse this decline by providing tailored support, dedicating fundings, and resources to help these towns create sustainable, locally-driven development strategies.

It is an innovative program, from the way it has shifted France's national urban policies, to its organization and the multiple partners it involves. It has led to a new vision for small cities's planning, from the relationship between state and cities to the connection between cities themselves. Finally, this program has been used as a real size experiment, as some of the changes it has brought have been implemented at the national scale, for new policies as well as for new fundings methods.

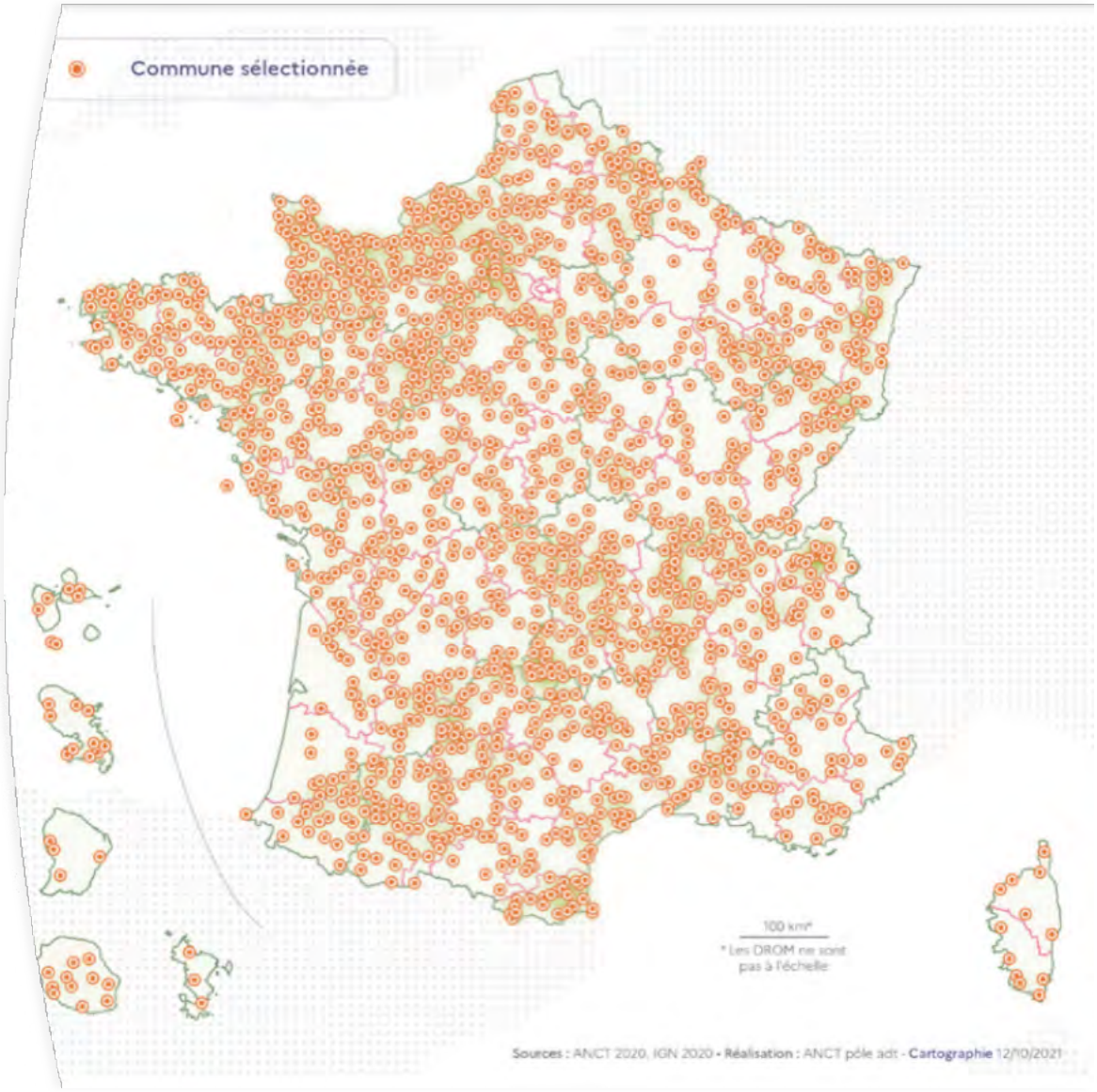
1. 1. Petites Villes de Demain : an innovative national program

1.1. A program designed to address devitalization of small cities

Representing all regions of France, 1600 cities have been selected to participate in the program. They face depopulation, linked to the abandonment of ancient buildings in favor of suburban houses. This vacancy impacts local businesses, which also face competition from commercial zones near main roads. Additionally, these cities lack resources to maintain their historical heritage, leading to a negative urban

ambiance. From this situation was created Petites Villes de Demain, aiming to improve the everyday life of the cities' inhabitants. The 1,600 cities selected were chosen based on several criteria to target those most in need of support and with significant development potential:

- They are the center of their functional area;
- They have less than 20 000 inhabitants (50% have less than 3 500 inhabitants);
- They have low socio-economic indicators (high poverty rates, unemployment, economic decline);They



have shown political will and revitalization potential

These cities were selected to revitalize their centers and restore the attractiveness for housing, commerce, and services that was often lost to urban sprawl and changing economic conditions.

The phenomenon of devitalization was partly due to the absence of a long-term development strategy. Many of these cities lacked dedicated teams for strategic urban planning and did not have the resources to hire urban planners. This absence of planning led to a "project-by-project" approach, dependent on available national funding, resulting in unconnected initiatives that failed to address the overall shrinkage

phenomenon. Additionally, the lack of local teams made it difficult for these cities to apply for national funding, creating territorial inequalities compared to larger cities (Bonnin-Oliveira and Reigner, 2024).

1.2. A program designed to support locally-based improvement

Petites Villes de Demain has aslo been developed as a way to compensate for decades of urban policies aimed toward major cities.

During the Reconstruction period (1945-1960), the state acted as a central planner, focusing on rebuilding major cities and creating large housing projects in their outskirts. From 1960 to 1980, the state continued to balance population distribution by creating new towns.

In the 2000s, initiatives targeted metropolitan areas, emphasizing urban sustainability. Programs like the Grand Paris Metropolis aimed to enhance the attractiveness and competitiveness of large urban areas. The MAPTAM Law (2014) and the NOTRe Law (2015) further strengthened metropolitan competencies to boost their international competitiveness. These were part of a broader strategy to ensure that France's largest cities could thrive on the global stage, driving innovation and growth. Recent Programs like "Petites Villes de Demain" reflect a shift towards supporting local development. In order to achieve this goal, Petites Villes de Demain has been structured around three main pillars :

- **Technical Support**: assisting towns in defining and implementing a master plan, enabling effective actions.
- **Funding**: allocating funds for specific projects or studies.
- **Networking**: creating local and national networks to promote innovation, share experiences, and exchange best practices.

The primary focus has been on enhancing the towns' technical skills. Participating cities are provided with:

- **Funding for Chief Projecs**: covering up to 75% of the chief project position, with access to a national hiring platform. Chief projects are responsible for developing and implementing the city's master plan and executing various pre-identified actions.
- **Funding for City-Center Managers**, designed to accompany the dynamism and attractiveness of the center, as well as support new business establishments;
- **National Training Programs**: organized for chief projects and for mayors or their teams.
- **Co-founding of strategic studies :** providing up to 50% of studies designed to help them conceive a master plan or define a future project.
- **Pre-arranged Studies and Consulting**: access to studies and consulting firms for analyses on specific topics like post-COVID retail dynamics or citizen participation.

1.3. A program designed to encourage networks and national partnerhips

Alongside these measures to address the lack of technical skills in these cities, the ANCT[1], with support from local prefectures, has established local, regional, and national networks for these cities:

[1] National Agency for Territories' Cohesion

In each “département” have been organized meetings of the chief projects, to allow them to share and discuss on the challenges they faced in completing their tasks and the possible solutions. These meetings also provide information on the program’s evolution, national funding, laws or specific upcoming stages of the cities’ projects. In the Lot-et-Garonne “department”, these meetings were organized for a day every 6 to 8 weeks by the departmental coordinator of the program; they evolved depending on the needs expressed by the chief projects. Besides these local networks, the ANCT organized a national network using an online platform design to facilitate discussion on various topics.

The program relied on numerous partnerships, with its organization involving various institutional actors such as different ministries and national organizations. These partners were crucial for funding the program and providing cities with studies and project.

Additionally, national-level partnerships were established with entities like “*gendarmerie*”, the Patrimony Foundation, and regional health agencies. Through these national partnerships, cities could create their own partnership agreements, enabling collaboration on specific themes such as security and heritage valorization.

2. A new vision for a town's planning

2.1. A shift in posture in the relation between cities and state and the diffusion of new norms in city-making policies .

Petites Villes de Demain is, as a program, an innovation on French urban planning policy. It has marked a transition in the relationship between the state and the territories. Until its creation, most urban policies were considered as "top-down" policies, where PVD has been created as a partnership between the state and the cities, designed to maintain their autonomy and support them into creating their own revitalizing solutions. Since the program's creation, local representatives have communicated the needs of chief projects, which has influenced the national webinars and training offered to cities.

The program led to organizational and operational innovations: the ANCT created new tools to facilitate planning and operational actions. Through one-on-one conventions, it funds project managers and strategic studies, ensuring adherence to methods and objectives. It also identifies and spreads information on innovative urban practices.

One key aspect of the Petites Villes de Demain program is its specific methodology designed to ensure logical and coherent actions for each city. This includes:

- **Operation for Territorial Revitalization (ORT):** within 18 months of the initial contract, cities must sign an ORT, involving main program partners, the prefecture, and the city itself. The ORT includes a diagnosis, master plan, and action plan. This document pushes cities to strategize their future development and aim for the revitalization of their city-center.
- **Housing Improvement Program**: participating cities are required to establish a housing improvement program, co-financed by the public sector and landlords, to aid the revitalization process.

This methodology encourages the development of local partnerships, as the partners of each action can be identified in the action-plan and can sign the "ORT". The ORT also facilitates the city's applications for regional or national funding, as each action is clearly identified and detailed in the plan. It helps demonstrate the coherence between the project and the city's strategy to funding bodies.

2.2. Example of Sainte-Livrade-sur-Lot

Sainte-Livrade-sur-Lot is a 6500 inhabitants city situated in the south-west of France, between two main cities : Bordeaux and Toulouse.

Its selection to the program has notably allowed the city to launch several studies, some of them concerning already-started projects and allowing to improve them:

- A first study on the city-center businesses, that analyzed the strengths and weaknesses of city-center businesses and the impact of COVID. It served as a foundation for the city-center manager, facilitating the establishment of new businesses and the organization of events to promote existing ones and create a business network.
- The main urban study of the city. This comprehensive study aimed to create the city's master plan and action plan, in order to lead to the redaction of its ORT. It was the first time the city had conducted a prospective reflection for the redevelopment of its city center. It has helped giving the mayor's team a new vision on the city, as well as providing them with solutions to connect independent projects and give a coherence to future and current projects.

- A programmatory study for the renovation of a 3 000m2 abandoned factory in the city center, for which the operational phase of the project had already been planed by the city, without any programmatory study. Funded at 50% by the program, this study helped design the renovation of the factory into a "tiers-lieu" (multiple use building) with diverse uses like a restaurant, public services, coworking spaces, and a social center. The inclusion of the social center allowed for an open use from the public, and secured additional funding for the project. Finally, in Sainte-Livrade-sur-Lot, the program has helped the city develop an inclusive project on an abandoned factory located in its city center. It has partly financed studies, helped build financial partnerships and unlock specific founds for urban renewal and soil pollution

- The launch of an housing program, design to fight vacancy in the city center as well as improve living conditions of inhabitants

2.3. A program designed to improve networking and sharing good practices at the national scale

By the organization of meetings, webinars and events designed to create a national network of "professionals of revitalizing cities", the diffusion of good practices and possible partnerships have helped mayors and chiefs projects to learn from other cities' experiences and follow possible solutions. From those webinars, some mayors or chief projects have been approached by other sharing similar challenges and interested by learning about innovative solutions or interesting failures.

This network also extend to national partners of the project, that propose possible solutions of local matters : for example, the "foundation du patrimoine"[2] offers cities to intervene and train citizens and professionals for the rehabilitation of patrimonial buildings within the city centers, while the Regional Health Agencies propose fundings and support on health-focused city planning

By the way it has been created and managed, the program allows and facilitate local innovations: participating cities are encouraged to develop local networks, collaborations and partnerships and to use national and local resources (local assets, associative sector, patrimonial and cultural heritage, …), to build creative ad-hoc solutions.

3. Petites Villes de Demain as a real size experiment

3.1. A program that has helped create "à la carte" development

Each city participating in the "Petites Villes de Demain" program has identified the challenges, objectives and solutions adapted to its specific territorial context. Despite the common methodology and resources, the program has not led to a uniformity of projects but rather to the creation of tailored strategies and projects.

Plombières-les-Bains (1700 inhabitants) revitalized its 1800-year historical patrimony through a storytelling focused on "elegance à la campagne", aiming to adapt its built patrimony with modern functionality to welcome new inhabitants, diversify the local economy via tourism, art, and brocante and enhancing connections with its surroundings.

[2] Patrimony fundation

Carrouges (629 inhabitants) implemented an innovative participatory approach to co-design the public spaces in the city-center, involving residents, children, shopkeepers, in tactical urbanism to balance different uses. Local stakeholders developed a program of activities to reclaim the square, fostering community interactions and conviviality, while allowing for feedbacks.

Charlieu (6500 inhabitants) : launched the "Permis de Végétaliser" in 2023 to improve its city-center, create cool zones, reduce impermeability, and establish biodiversity refuges. This project actively involves residents, who can request a project tot he city, which then conduct necesary work and provides material to the citizen, enhancing community engagement and environmental quality.

Brantôme (2500 inhabitants) : collaborated with the association “Le Tri-cyle Enchanté” to establish a resource center focused on solidarity, ecological actions, job creation, and alternatives to overconsumption. The “community of communes” economically and politically supported the project and provided a building. The association provided its expertise in reuse, environmental education, sustainability and social cohesion, engaging the community through environmental awareness activities.

3.2. A now prioritized methodology for public fundings

Petites Villes de Demain has also been the starting point of a change in public fundings distribution, as the participating cities have been prioritized when applying to national fundings. Public funding has become more targeted and adapted to the specific needs of small towns.

The program has encouraged a culture of innovation and citizen participation, leading to an increase in project calls at both national and local levels. Cities are encouraged to propose innovative and tailored projects and has promoted partnerships between local authorities and private actors, such as local businesses, associations, and foundations. These partnerships help mobilize additional resources and diversify funding sources

Futhermore, In order to encourage cities to develop strategies and master plan in the same way that what the “Petites Villes de Demain” are doing, any application to a national funding will be strengthen by having an ORT.

3.3. A program developed for smaller cities : villages d’avenir

More recently, a new program has been launched in France. Called “Villages d’avenir”, it aims to provide rural communities with the technical assets they are equally missing. It aims to support towns with less than 3,500 inhabitants in realizing their development projects to enhance the attractiveness and dynamism. Each community receives comprehensive and personalized support:

- An initial Assessment with the ANCT helps identify the projects to support
- A dedicated project manager (1 to 2 per “departement”, 120 at national scale) assists the communities in advancing their initiatives, working with local teams to define a roadmap and identify the necessary steps. They also guide the towns identifying financial partners and fundings.

Regular monitoring and continuous support to ensure the progress of projects.

Conclusion

Petites Villes de Demain has allowed mayors facing a lack of urban planning culture and specialized staff to access trained professionals and develop a long-term perspective on the city's development. The normalization of long-term planning, creation of action plans and organized urban management has been one of the main objectives and success of the program, as the participation (and fundings) on the program depends on creating and following a master plan. Through this policy as well as through the organization of professional training for project managers and conferences for mayors, Petites Villes de Demain has improved small cities' technical planning skills.

The program has also promoted local innovations and initiatives by organizing webinars, departmental and national meetings designed to ease good-practice and idea sharing. It has succeeded in creating a network among small cities and towns who felt isolated facing those issues.

Apart from the strategy, skills and networking aspects, PVD has contributed to the improvement of life conditions in those cities. It generalized the opening of "France Services" offices, to compensate the lack of interlocutors on various subjects (tax, legal issues, social security…). It also partly finances and eases housing improvement programs, designed to fight vacancy.

However, the ORT concept and its connexion to future fundings has led mayors to adapt part of the action plan to include projects that might be included in future national fundings, which limits the « à la carte » aspect of the program and leads elected officials to feel an increased centralization, perceiving state control through funding requirements.

4. References

Ministère de la Cohésion des Territoires. (2017) *Dossier de présentation : Action cœur de ville*. Paris : Ministère de la Cohésion des Territoires.

Avise. (2023) *10 projets d'économie circulaire sur des Petites villes de demain*. Available at: https://www.avise.org/actualites/10-projets-deconomie-circulaire-sur-des-petites-villes-de-demain Accessed: 31 October 2024).

Bonnin-Oliveira, S., et Reigner, H. (2024) *Le programme Petites villes de demain : vers un État start-up*. Métropolitiques. Available at: https://metropolitiques.eu/Le-programme-Petites-villes-de-demain-vers-un-Etat-start-up.html Accessed: 31 October 2024).

Coppin, S (2021) *Les trois temps de l'aménagement du territoire en France*. Dunkerque: Université du Littoral-Côte d'Opale

Agence nationale de la cohésion des territoires (ANCT). (2023) *Petites villes de demain*. Available at https://agence-cohesion-territoires.gouv.fr/petites-villes-de-demain-45 Accessed: 31 October 2024).

Agence nationale de la cohésion des territoires (ANCT). (2024) *La Projetothèque*. Available at: https://agence-cohesion-territoires.gouv.fr/la-projetotheque-15 Accessed: 31 October 2024).

Agence nationale de la cohesion des territoires (ANCT).(2024) *'Une nouvelle ambition pour les petites communes rurales'*. Available at: **https://agence-cohesion- territoires.gouv.fr/une-nouvelle-ambition-pour-les-petites-communes-rurales-1305** (Accessed: 31 October 2024).

To increase the readability of this paper, the AI tool *Copilot* was used as a translating tool.

Research Paper

Unveiling City Images through Social Media

A Data-Driven Approach for Inclusive Planning and Heritage Conservation in Nanjing

Xiliu HE, Southeast University, China
Jintu XU, Southeast University, China
Ziqi WU, Chongqing University, China

Abstract

This study explores city image analysis methods based on social media data, focusing on the central urban area of Nanjing. By collecting and analyzing geo-tagged data from Weibo platform, combined with GIS spatial analysis and natural language processing techniques, the research establishes a data-driven analytical framework for virtual space urban imagery. The findings reveal that Nanjing's virtual space image exhibits a "core-periphery" spatial distribution pattern, identifying 27 effective urban district clusters, 14 major landmarks, 36 significant nodes, and various paths and boundaries. Comparative analysis with planning documents reveals significant differences between virtual space imagery and planned spatial structures: social media data shows more concentrated spatial patterns, highlighting areas of public interest; regarding landmarks and nodes, planning documents emphasize historical and cultural elements, while virtual space underscores the importance of modern functional spaces; in terms of paths and boundaries, planning presents a systematic and complete network, while virtual space demonstrates a more fragmented but intensively used path system. The research results provide data support and policy recommendations for promoting inclusive planning and heritage conservation.

Keywords

City Image; Social Media Data; Platform Urbanism; Inclusive Planning; Virtual Space; Nanjing

1. Introduction

In recent years, social media platforms have become increasingly important as channels for public knowledge and participation in urban affairs. As these platforms gain popularity, they are profoundly changing how people perceive, experience, and engage with urban spaces. This shift presents both challenges and opportunities for urban planning and research.

1.1. Social Media Platforms as New Interfaces for Urban Knowledge and Public Participation

Social media platforms have emerged as critical new interfaces for public knowledge and participation in urban affairs (Iosifidis, 2011; Simonofski et al., 2021). With the widespread adoption of social media, people are now able to share their urban experiences, perceptions, and knowledge in real-time and on a massive scale. These platforms provide a wealth of user-generated content (UGC), including text, images, and

videos with geographic tags. This data offers unprecedented insights into how people interact with and understand their urban environments (Kim & Johnson, 2016; Narangajavana et al., 2019).

The richness and real-time nature of social media data make it an invaluable resource for studying urban perceptions and public engagement (Park et al., 2022). Unlike traditional survey methods, which are often limited in scope and frequency, social media data provides a continuous stream of information about how people experience and perceive their cities. This wealth of data allows researchers to gain insights that were previously difficult or impossible to obtain, opening up new avenues for understanding urban dynamics and public sentiment (Osorio-Arjona et al., 2021; Yue et al., 2022).

1.2. Platform Urbanism and the Reshaping of Urban Experiences

The concept of "Platform Urbanism" has emerged to describe how digital platforms are fundamentally reshaping our experience of cities (Repette et al., 2021). These platforms are blurring the lines between virtual and physical urban spaces, creating new forms of urban experience that exist at the intersection of digital and physical realms. This phenomenon is transforming how people navigate, understand, and interact with urban environments (Repette et al., 2021).

Platform Urbanism is creating a feedback loop between virtual perceptions and physical urban experiences. As people share their experiences on social media, they shape the virtual image of the city. This virtual image, in turn, influences how others perceive and interact with the physical urban space. This dynamic interplay between virtual and physical urban experiences offers new perspectives for urban research and planning (Van der Graaf & Ballon, 2019; Williamson & Ruming, 2019).

This dynamic interplay between virtual and physical urban experiences forms the foundation of our research framework. By examining how Platform Urbanism manifests in Nanjing's central urban area, we aim to understand not only the characteristics of its virtual space urban image but also how this bottom-up perspective differs from traditional top-down planning approaches (Burns & Welker, 2023).

1.3. The Rise of Data-Driven Approaches in Urban Studies

Advancements in big data analytics and artificial intelligence technologies have enabled new data-driven approaches to urban research. Techniques such as natural language processing, machine learning, and spatial clustering are now being widely applied to analyze vast amounts of social media data (Park et al., 2022; Balaji et al, 2021; Fan et al., 2021). These methods allow researchers to extract valuable urban perception information from unstructured social media content, providing data-driven support for urban planning and management.

These new research methodologies are driving innovation in urban studies. By leveraging the power of big data and AI, researchers can now uncover patterns and insights that were previously hidden, leading to a more nuanced and comprehensive understanding of urban dynamics and public perceptions (Park et al., 2022; Lei et al., 2018; Liu et al., 2023).These developments raise important questions about how we can effectively utilize social media data to understand urban dynamics. Specifically, this research seeks to address four interconnected questions:

1. How can we construct a scientifically sound and robust data-driven analytical framework for urban image analysis?

2. What are the characteristics of the virtual space urban image of Nanjing's central urban area derived from this framework?
3. How does the bottom-up perspective of the virtual space urban image differ from the top-down spatial structure outlined in official planning documents?
4. What implications and guidance does this research provide for inclusive planning and heritage conservation?

This research aims to explore how social media data can be used to unveil city images and inform more inclusive planning and heritage conservation strategies. By analyzing the virtual space imagery of Nanjing, we seek to demonstrate the value of social media data in understanding public perceptions of urban spaces and identify potential discrepancies between planned and perceived urban structures.

The remainder of this paper is structured as follows. Section 1 introduces the research background and context, discussing the emergence of social media platforms as new interfaces for urban knowledge, the concept of Platform Urbanism, and the rise of data-driven approaches in urban studies. Section 2 outlines the research methodology, detailing the study area of central Nanjing, data sources from social media platforms, research workflow, and two key methods for identifying virtual and physical space imagery. Section 3 presents an empirical case study of Nanjing's central urban area, examining the spatial distribution patterns of virtual space image elements and analyzing their characteristics through social media data. Finally, Section 4 discusses the implications of our findings and concludes with reflections on the relationship between virtual space imagery and urban planning practices, offering insights for inclusive planning and heritage conservation.

2. Research data and methodology

2.1. Study Area

This research focuses on the central urban area of Nanjing (Figure 1), a city with profound historical and cultural significance in China. As one of China's most historically significant cities, Nanjing has served as the capital for multiple dynasties over its 7000-year history, with nearly 500 years as an imperial capital. This rich heritage has left the city with abundant historical and cultural resources, including one UNESCO World Heritage site and numerous cultural relics.

The study area encompasses Nanjing's central urban district, which demonstrated strong economic vitality with a total GDP of 907.85 billion yuan in 2022 and a permanent resident population of 949.17 million. According to the "Nanjing Urban Development Strategy (2023)" and "Nanjing Territory Spatial Plan (2021-2035)", the city center is strategically positioned to showcase the integration of "Innovation, Culture, and Ancient Capital" characteristics, embodying a unique blend of ancient capital charm and modern metropolitan vitality.

The central urban area is a typical and representative area for the study of virtual space imagery, functioning as the core zone for economic and social development while preserving significant historical and cultural landmarks. This dual role makes it an ideal setting for examining how historical urban spaces are perceived and represented in social media, as it combines rich cultural heritage with modern urban development. The area serves as a demonstration of how historical preservation can coexist with contemporary urban functions, offering a unique opportunity to study the interaction between traditional and contemporary urban elements in both physical and virtual spaces.

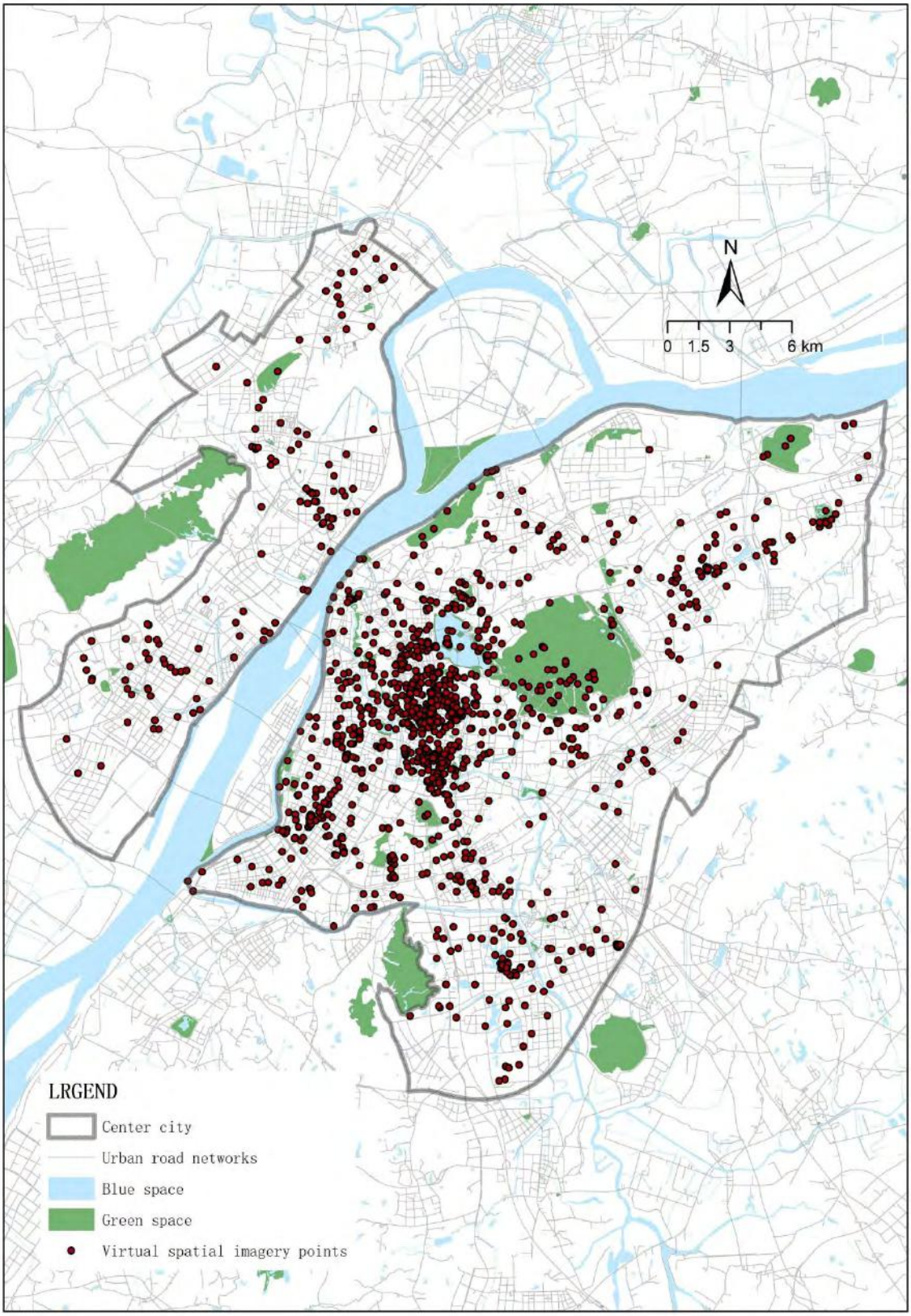


Figure 1. Study area and data. Source: Authors.

2.2. Research Data

This study leverages the open data ecosystem that has emerged through various open initiatives - including open government data, open knowledge, open resources, and open APIs - from citizens, government agencies, academic institutions, and commercial organizations (Attard et al., 2015). The rise of Data Augmented Design (DAD) has particularly influenced our data collection approach in urban studies, emphasizing the importance of incorporating diverse data sources to understand urban dynamics (Long & Zhang, 2021).

Among various urban data sources, social media data provides unique insights into how people perceive and experience urban spaces. In this research, we utilize Weibo data as our primary data source, which represents one of the most widely used social media platforms in China. Weibo serves as a rich repository of user-generated content where people actively share their daily urban experiences through text, images, and videos, offering valuable insights into public perceptions of urban spaces (Rizwan et al., 2018).

Weibo data is particularly valuable for urban perception research due to its short-form textual content, terminal-based distribution, and rich multimedia content including images and location information (Kwak et al., 2010). With its massive user base and high engagement rates, Weibo provides clear spatial-temporal attributes that have been widely applied in urban cognition, vitality, and perception studies (Zhen et al., 2017; Lu et al., 2019; Chen et al., 2022). By integrating Weibo's textual content and spatial data, we can apply space-time analysis and quantitative methods to systematically understand public perceptions of the city. This approach allows us to analyze how people experience and interpret urban spaces through their social media expressions, providing insights into the collective urban imagination and experience.

2.3. Research Methods

2.3.1. Research Workflow

This research follows a systematic four-stage workflow to analyze virtual space imagery through social media data (Figure 2). The first stage focuses on data acquisition and preprocessing, where we collect social media data from Weibo platform and conduct necessary data cleaning and filtering procedures. The second stage involves virtual space imagery measurement, which includes the analysis of geographical districts, landmarks, nodes, pathways and edges within the study area. In the third stage, we conduct spatial structure analysis through document analysis in field research and categorization of spatial functions. The final stage encompasses comparative analysis and application, where we compare our findings with existing urban structures and develop practical application strategies.

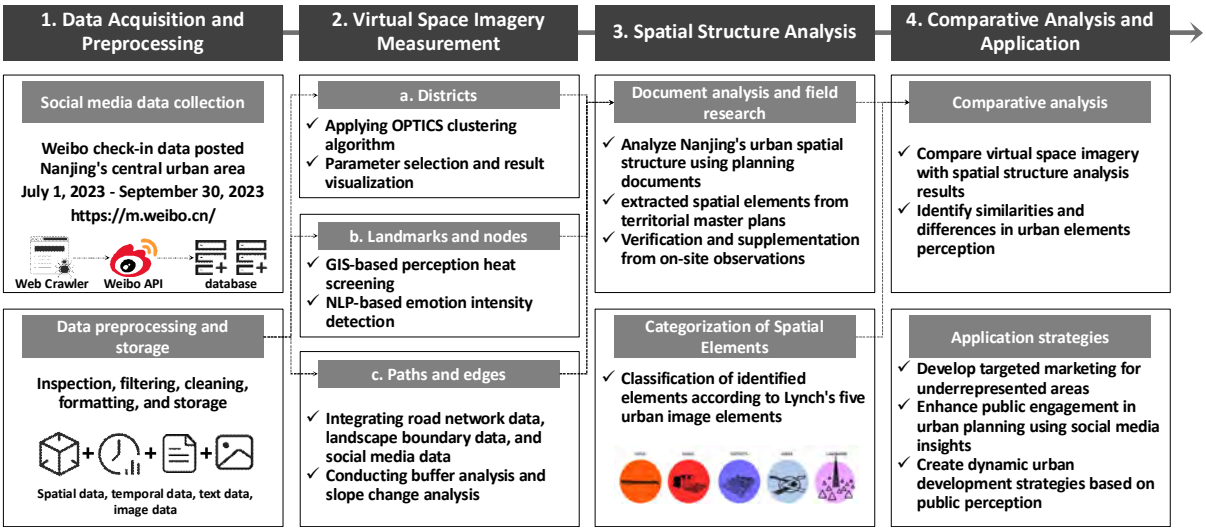


Figure 2. Frameworks and workflows. Source: Authors.

2.3.2. Virtual Space Image Identification Method Based on GIS and NLP

This study employs an integrated approach combining Geographic Information Systems (GIS) and Natural Language Processing (NLP) to identify and analyze urban images in virtual space. We collect geo-tagged social media data from Weibo platform through its API and web crawling techniques. After data cleaning and preprocessing, we conduct spatial analysis using GIS software. Through hotspot analysis and density mapping, we can directly visualize the spatial distribution of key urban image elements. We also apply NLP techniques to conduct in-depth analysis of textual data, identifying public concerns and sentiment levels regarding specific urban elements. By incorporating Lynch's key elements of city image theory, we categorize the NLP analysis results and integrate them with GIS findings to construct a comprehensive virtual space urban image model.

2.3.3. Urban Spatial Structure Extraction Method Based on Document Analysis and Field Research

To extract the urban spatial structure from planning documents, this research combines document analysis with field research. We collect Nanjing's territorial spatial master planning documents and extract key spatial structure information, including major functional zones, development axes, and central systems. The analysis of these elements is conducted according to Lynch's urban image theory to ensure theoretical consistency.

3. Case study

3.1. Virtual Space Image Element Extraction Based on Social Media Data

3.1.1. Spatial Distribution Pattern of Virtual Space Image Hotspots

The data collection focused on Nanjing's central urban area, utilizing Python programming to extract Weibo posts with geographic tags. We collected data from January 1, 2023, to September 30, 2023, obtaining 67,601 initial records. The collected data included posting time, text content, number of photos, number of reposts, number of comments, and urban location tags. After filtering for content relevance through five dimensions including integrity, purity, and text content relevance, and clearing check-in data that could

not support subsequent analysis due to unknown address, unknown gender, and confusing check-in text content, we retained 56,151 valid records for analysis.

From the spatial distribution perspective, the data reveals a "core + periphery" pattern (Figure 3a). Major hotspots are concentrated in areas such as Xinjiekou, Confucius Temple, Old South Gate, and Olympic Center, forming a multi-core spatial structure. Secondary clusters are distributed in outer layers, including places like Nanjing Railway Station, Zijinhua Palace, Purple Mountain, Xuanwu Lake, and Xianlin University Town.

Analysis of user check-in frequency at these locations shows significant differences in popularity. The top 20 locations account for approximately 45% of all check-ins, with the Nanjing Olympic Sports Center area receiving the highest number of check-ins. Other popular locations include Xinjiekou Business District, Confucius Temple Scenic Area, Xuanwu Lake Park, Zijin Mountain, Zhonghua Gate Castle, Presidential Palace, Nanjing Museum, Old Dongmen Street, Yuejiang Tower, and various university campuses such as Nanjing University (Xianlin Campus).

The Moran's Index analysis ($I = 0.065$, $P = 0.000$, $Z = 9.66 > 2.58$) confirms significant spatial clustering effects among these virtual space image elements (Figure 3b). When compared with the city's master plan (2021-2035), these clusters align with existing urban centers while demonstrating unique characteristics. The internal virtual space image elements show a clustered distribution, with particularly high concentration in the old city center. The external virtual space image hotspots are primarily distributed across several sub-centers, including the western center (Olympic Center), eastern sub-center (Xuanwu Lake), Xianlin sub-center (University Town), and various emerging nodes like Nanjing South Railway Station and Yangtze River Park.

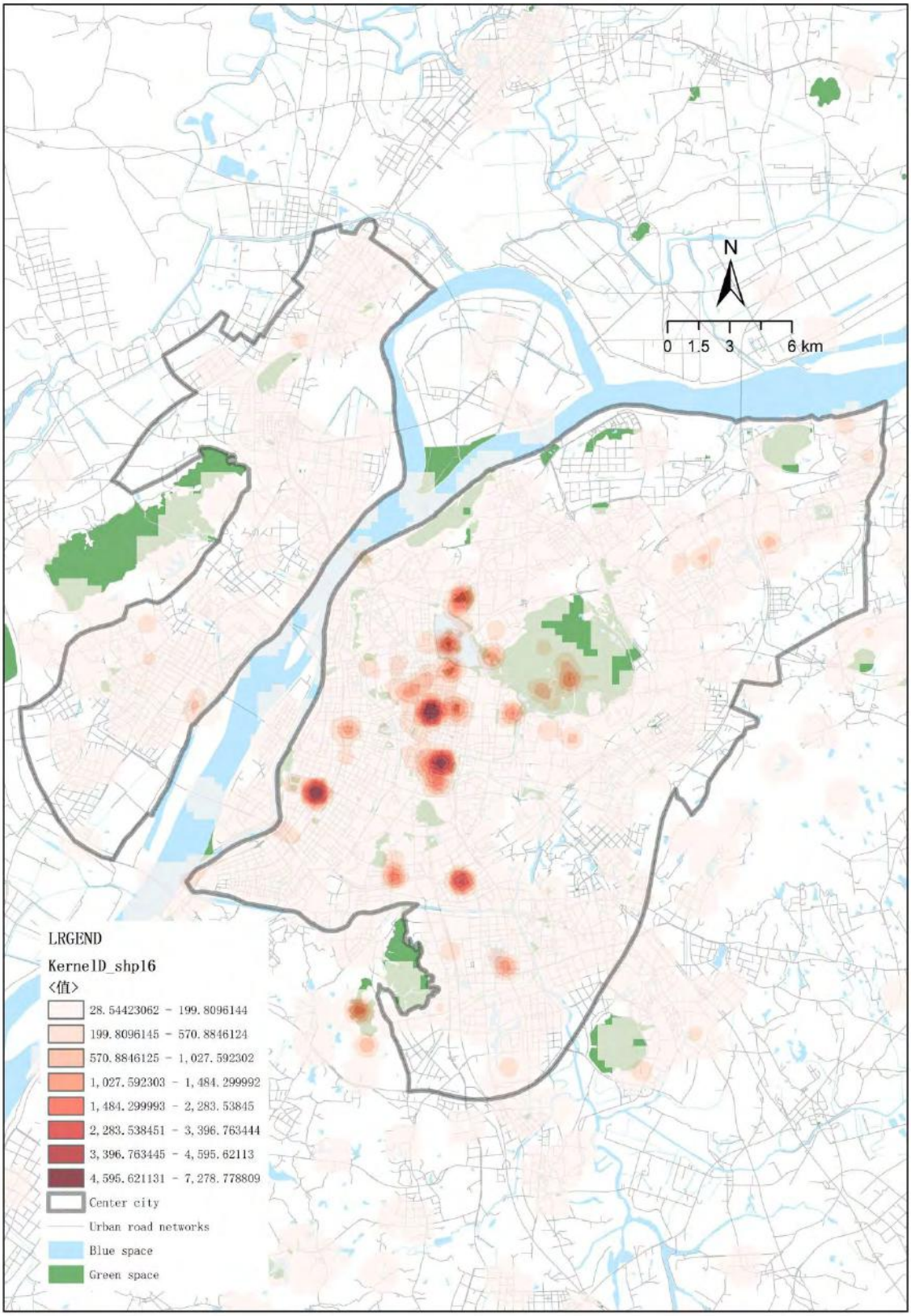
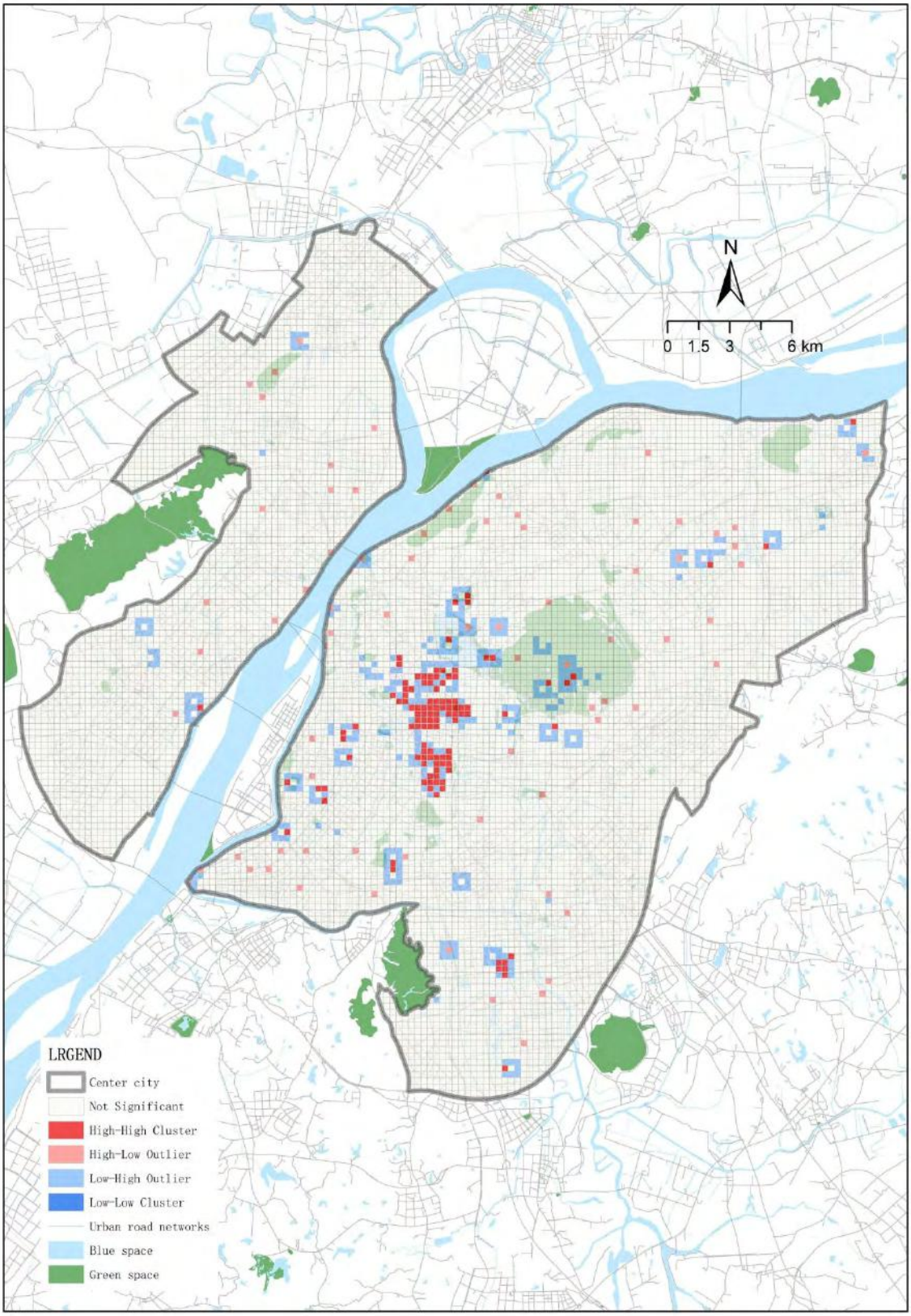


Figure 3. (a) Results of kernel density analysis



(b) Results of local spatial autocorrelation analysis. Source: Authors.

3.1.2. Analysis of Virtual Space Image District Elements

The identification of district elements followed a systematic analytical process using the OPTICS algorithm combined with distance curves and multi-perspective verification. First, we applied the OPTICS method to generate reachability curves, which helped identify key parameters and potential clustering areas. The analysis revealed varying degrees of clustering across different urban zones. Based on the k-dist graph and reachability curve analysis, we determined the optimal neighborhood radius (E) to be 600m, which corresponds to a 5-10 minute walking distance that aligns with typical urban perception patterns. The minimum points parameter (M) was set to 6 to ensure meaningful cluster formation. This parameterization allowed us to effectively identify significant district-level elements while filtering out isolated points.

The spatial analysis results identified 27 effective clusters, revealing a clear hierarchical structure in Nanjing's virtual space imagery (Figure 4). The Old City area centered around Xinjiekou and the Hexi New Town anchored by the Olympic Sports Center emerged as the primary image districts. These are complemented by several secondary image districts including the South City center, Xianlin sub-center, Longjiang area, Xiaolingwei district, and Hongshan area. These identified districts largely correspond to the city's public center system, though with some notable differences. The virtual space imagery effectively captures the dual-core structure of Nanjing's urban area, with the Old City and Hexi New Town emerging as the most prominent districts.

Through ArcGIS and Python programming implementation, we classified and visualized these districts based on their clustering characteristics and POI densities. The analysis reveals that the strongest virtual space imagery elements are concentrated in historically and culturally significant areas as well as modern commercial centers, reflecting the public's collective recognition of these urban spaces. However, some officially designated district-level centers, particularly in the Jiangbei area, show limited presence in the virtual space imagery. This disparity suggests a potential gap between planning intentions and public perception of these areas, highlighting the need for further investigation into the factors influencing public recognition and usage of urban spaces.

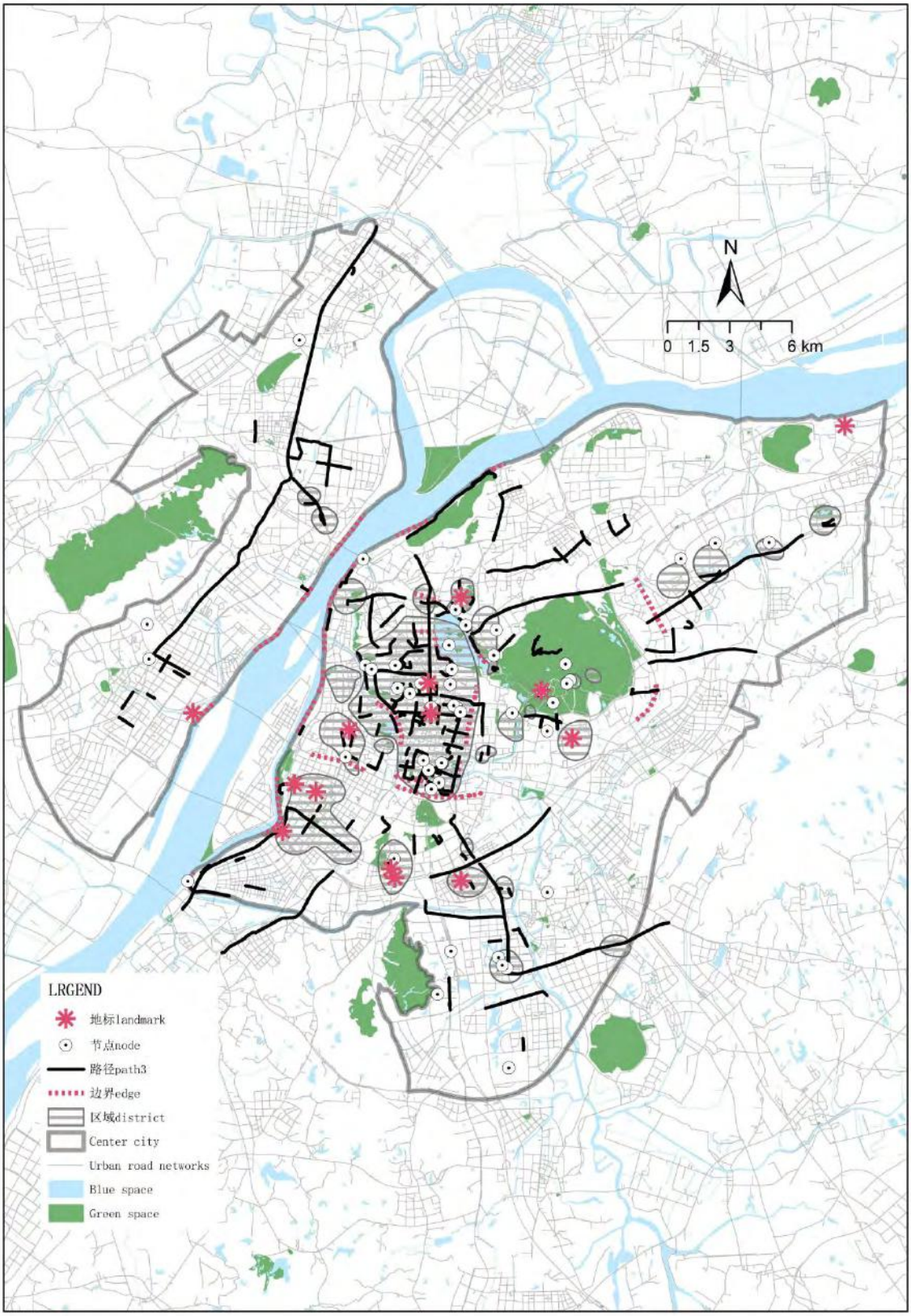


Figure 4. Virtual spatial imagery. Source: Authors.

3.1.3. Analysis of Virtual Space Image Landmarks and Nodes

The identification of landmarks and nodes followed a systematic screening process based on perception heat and emotional intensity. We first extracted POI data and applied a two-stage filtering method. The first stage evaluated perception heat through check-in frequency and user interaction levels. The second stage incorporated emotional intensity assessment by analyzing text sentiment and user engagement. These two metrics were weighted equally (50:50) in the final evaluation to ensure a balanced consideration of both quantitative popularity and qualitative significance.

Through this analysis process, we identified 14 major landmarks and 36 significant nodes in Nanjing's virtual space imagery (Figure 4). The landmarks include prominent locations such as the Nanjing Olympic Sports Center, Nanjing South Railway Station, Presidential Palace, Sun Palace Theater, 1701 LIVE HOUSE MAX, Nanjing Massacre Memorial Hall, Hongshan Zoo, Nanjing South Station, and several major universities. These landmarks demonstrate diverse characteristics in terms of both function and historical significance.

The analysis reveals several interesting patterns in how these urban elements are perceived in virtual space. Some landmarks and nodes align well with traditionally planned structures, such as Xinjiekou, the Olympic Sports Center, and Nanjing South Station, carrying high perception heat and emotional intensity in both physical and virtual realms. However, unexpected locations like the Nanjing Massacre Memorial Hall, Hongshan Zoo, Sun Palace Theater, and various entertainment venues have emerged as significant virtual landmarks due to their strong emotional resonance and high user engagement, despite not being conventional urban landmarks in traditional planning contexts.

The node analysis particularly highlights the importance of educational and cultural institutions in Nanjing's virtual space imagery. Many significant nodes include universities and historical-cultural sites, which aligns well with Nanjing's positioning as both an educational center and ancient capital. Notable examples include Deji Plaza, KINGMO Shopping Mall, Nanjing Museum, Laomen East, Fish Head Wetland Park, and various university campuses. This distribution pattern reflects the city's unique characteristic as a hub of education and culture while also showcasing its modern urban vitality.

3.1.4. Analysis of Virtual Space Image Paths and Boundaries

The identification of paths and boundaries employed an integrated analysis approach combining urban road network data, landscape boundary data, and social media data. For path analysis, we first created buffer zones around the roads and overlaid social media data within these zones. Through kernel density analysis, we extracted paths that demonstrated high perception heat, particularly focusing on segments with significant user activity. The path selection criteria considered both spatial distribution and usage intensity, with a minimum length threshold of 300 meters to align with typical Chinese block lengths.

The analysis revealed several distinctive characteristics in Nanjing's virtual space path system (Figure 4). The spatial distribution shows a clear "dense in the old city, sparse outside" pattern, reflecting the perception intensity difference between the historic core and peripheral areas. High-profile paths that emerged from the analysis include the road in front of Jiming Temple, Yihe Road, Zhongshan North Road, Central Road, and the mountain road to Zhongshan. While paths of 300 meters or longer were primarily selected during analysis to match typical urban block scales, the results also identified numerous shorter paths within the central urban area, as well as some exceptionally long paths extending over 24 kilometers.

For edge elements, we first compiled a comprehensive list of traditional physical boundaries including railways, highways, and riverbanks (Figure 4). We then analyzed kernel density maps of social media data, particularly focusing on areas with steep gradients that might indicate perceived boundaries. The results show that virtual space boundaries partially overlap with physical boundaries such as railways, highways, riverbanks, and mountains. The ancient city walls of Nanjing demonstrate particularly strong boundary characteristics, especially in the central and southern areas around Zhongyang Gate and Zhonghua Gate.

A notable finding is that virtual edges display strong discontinuity characteristics - the linear boundaries are not continuous, which differs from physical boundaries. This fragmentation may be attributed to the nature of social media perception patterns and user behavior. The analysis also reveals that some traditional physical boundaries may not necessarily function as strong perceptual boundaries in virtual space, suggesting a complex relationship between physical urban form and its digital representation in public perception.

3.2. Urban Spatial Structure Extraction Based on Planning Documents

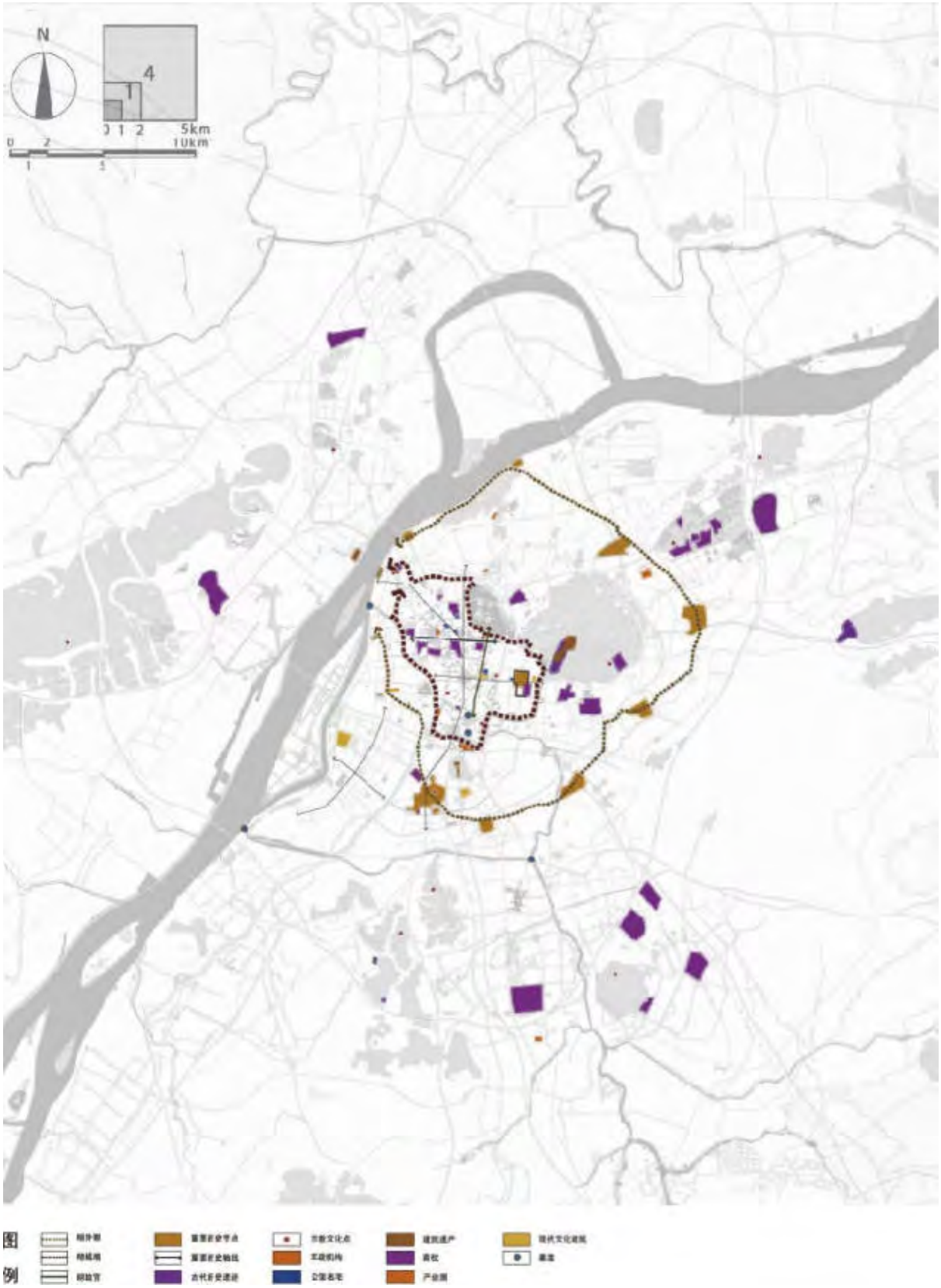
Through a comprehensive analysis of Nanjing's territorial spatial planning documents and field research, we systematically extracted the city's planned spatial structure. The analysis focused on three characteristic intention areas - green, cultural, and urban - to understand how official planning envisions the city's spatial organization and development (Figure 5a-b-c).

In terms of districts, the planning documents highlight several key spatial elements. These include urban parks, university campuses, industrial parks, significant historical areas, commercial centers, gateway areas, and the confluence zones of rivers. These districts form the fundamental spatial framework of Nanjing's planned urban structure, reflecting the city's emphasis on balancing modern development with historical preservation.

The landmarks and nodes identified in planning documents primarily consist of mountain entrances, important historical nodes, religious and cultural points, guild halls, notable residences, architectural heritage sites, military and government institutions, and strategic viewpoints. These elements serve as key spatial anchors in the city's planned structure, emphasizing Nanjing's rich cultural and historical heritage while accommodating contemporary urban functions.

The paths and edges system outlined in the planning documents is characterized by several distinct elements. These include tree-lined avenues, important historical axes, the Ming Palace complex, Ming City Wall, Ming Outer City Wall, streets with distinctive commercial characteristics, and significant urban development axes. This network of paths and boundaries not only facilitates urban movement but also helps define the city's spatial character and historical continuity.

Figure 5. (a) Green characteristic intention



(b) Cultural characteristic intention

(c)Urban characteristic intention. Source: Nanjing's territorial spatial planning documents.

3.3 Comparative Analysis

Through a systematic comparison between virtual space imagery derived from social media data and urban spatial structure from official planning documents, we identified several significant patterns and disparities across different urban elements.

For district elements, we observed a distinct contrast in spatial coverage. Planning documents present a comprehensive arrangement of diverse urban areas, including residential, commercial, industrial, and ecological zones. However, social media data reveals a more concentrated pattern, highlighting popular spots with high public engagement. This disparity suggests potential gaps in public awareness and utilization of certain planned districts, particularly in newly developed areas. The contrast provides valuable insights for future development strategies and promotional efforts to enhance public awareness of underutilized urban spaces.

In terms of landmarks and nodes, the analysis reveals different emphasis points between planning intentions and public perception. While official plans prioritize historical landmarks and traditional cultural sites, social media data demonstrates stronger public engagement with high-profile modern locations and contemporary cultural venues. This divergence indicates the need for strategies that can enhance the visibility of secondary landmarks while better integrating historical elements with modern urban functions to create more engaging public spaces.

The comparison of path and edge elements shows notable differences in spatial networks. Planning documents present systematic and comprehensive networks emphasizing historical axes and planned connectivity. In contrast, social media data reflects more fragmented but intensively used routes, particularly around popular attractions and commercial areas. This difference suggests opportunities for revitalizing historical features by incorporating modern functions and improving connectivity between popular destinations. The analysis also indicates the importance of aligning future planning decisions with actual user preferences and movement patterns to create more vibrant and well-utilized urban spaces.

Table 1. Comparative analysis.

	Official Urban Structure	Virtual Space Image Structure
Data Source	Planning documents	Social media data
Analysis Methods	Document analysis, field research, summary and integration	GIS spatial analysis, NLP sentiment analysis, OPTICS clustering algorithm
Participants	Planners, government departments	Citizens
Perspective	Top-down	Bottom-up
Overall Characteristics	Systematic, comprehensive coverage of elements, structured spatial organization	Non-systematic, heat-driven elements, fragmented spatial patterns
District Elements	Focus on functional urban areas regardless of activity levels	Focus on high-activity and emotionally significant areas
Landmark Elements Node Elements	Priority given to historical landmarks and traditional cultural sites	Emphasis on popular contemporary locations and historical-cultural sites
Path Elements	Formal systematic road network, emphasizing historical axes and planned connections	Fragmented but highly-used paths, particularly around commercial areas and popular attractions
Edge Elements	Continuous boundaries defined by water systems, mountains, roads, railways, and historical city walls	Discontinuous boundaries, partly combined with physical and functional boundaries
Conclusions and Implications	1. Planning Recognition: Acknowledge differences in perception between public and government; focus on actual user preferences and movement patterns 2. Planning Implementation: Integrate public feedback, optimize key urban elements; focus on redevelopment potential of popular areas; focus on spatial creation, commercial and cultural reorganization and promotion of secondary areas	

Source: Authors.

4. Discussion and Conclusion

4.1. Research Findings and Contributions

This study presents several significant findings and methodological contributions to urban spatial analysis. First, we successfully developed a novel methodology that integrates GIS spatial analysis, OPTICS clustering algorithm, and sentiment analysis to map virtual space imagery. This integrated approach provides a comprehensive framework for understanding public perception of urban spaces through social media data.

Our analysis revealed notable divergences between virtual and physical urban structures, particularly in paths and edges, where public perception patterns often differ from planned spatial arrangements. We also discovered unexpected locations with high emotional intensity in virtual space, challenging traditional urban landmark concepts. The spatial perception patterns showed an uneven distribution of virtual imagery elements, with significant concentration in the old city area. The research demonstrated the significant influence of social media data in understanding public perception of urban spaces. Historical

and cultural sites proved particularly important in shaping the city's virtual image, highlighting their continued relevance in contemporary urban life (Park et al., 2022).

4.2 Research Limitations and Future Directions

Despite its contributions, this study has several limitations that suggest directions for future research. A primary concern is data bias in social media representation, as certain demographic groups may be underrepresented in the dataset. Future studies should address these sampling limitations and explore methods to ensure more comprehensive demographic coverage.

The temporal dynamics of virtual space imagery deserve further investigation through longitudinal studies to understand how public perception changes over time. Cross-platform analysis incorporating data from multiple social media platforms could provide a more comprehensive view of urban perception patterns.

To enhance the methodology's robustness, future research should conduct comparative studies across different cities to identify common patterns and unique characteristics. Integration with traditional urban studies techniques could enrich the analysis framework, while causality exploration could help understand the factors influencing virtual space imagery formation.

Finally, application testing in real urban planning projects is crucial to assess practical impacts and refine the methodology. This practical implementation would help validate the approach's effectiveness in supporting urban planning and heritage conservation decisions.

4. References

Iosifidis, P. (2011). 'The public sphere, social networks and public service media', *Information, Communication & Society*, 14(5), 619-637.

Simonofski, A., Fink, J., & Burnay, C. (2021). 'Supporting policy-making with social media and e-participation platforms data: A policy analytics framework', *Government Information Quarterly*, 38(3), 101590.

Kim, A. J., & Johnson, K. K. (2016). 'Power of consumers using social media: Examining the influences of brand-related user-generated content on Facebook', *Computers in human behavior*, 58, 98-108.

Narangajavana Kaosiri, Y., Callarisa Fiol, L. J., Moliner Tena, M. Á., Rodríguez Artola, R. M., & Sánchez García, J. (2019). 'User-generated content sources in social media: A new approach to explore tourist satisfaction', *Journal of Travel Research*, 58(2), 253-265.

Park, J. Y., Mistur, E., Kim, D., Mo, Y., & Hoefer, R. (2022). 'Toward human-centric urban infrastructure: Text mining for social media data to identify the public perception of COVID-19 policy in transportation hubs', *Sustainable Cities and Society*, 76, 103524.

Osorio-Arjona, J., Horak, J., Svoboda, R., & García-Ruíz, Y. (2021). 'Social media semantic perceptions on Madrid Metro system: Using Twitter data to link complaints to space', *Sustainable Cities and Society*, 64, 102530.

Yue, A., Mao, C., Chen, L., Liu, Z., Zhang, C., & Li, Z. (2022). 'Detecting changes in perceptions towards smart city on Chinese social media: A text mining and sentiment analysis', *Buildings*, 12(8), 1182.

Repette, P., Sabatini-Marques, J., Yigitcanlar, T., Sell, D., & Costa, E. (2021). 'The evolution of city-as-a-platform: Smart urban development governance with collective knowledge-based platform urbanism', *Land*, 10(1), 33.

Van der Graaf, S., & Ballon, P. (2019). 'Navigating platform urbanism', *Technological Forecasting and social change*, 142, 364-372.

Williamson, W., & Ruming, K. (2020). 'Can social media support large scale public participation in urban planning? The case of the# MySydney digital engagement campaign', *International Planning Studies*, 25(4), 355-371.

Burns, R., & Welker, P. (2023). 'Interstitiality in the smart city: More than top-down and bottom-up smartness', *Urban Studies*, 60(2), 308-324.

Balaji, T. K., Annavarapu, C. S. R., & Bablani, A. (2021). 'Machine learning algorithms for social media analysis: A survey', *Computer Science Review*, 40, 100395.

Fan, T., Guo, N., & Ren, Y. (2021). 'Consumer clusters detection with geo-tagged social network data using DBSCAN algorithm: a case study of the Pearl River Delta in China', *GeoJournal*, 86(1), 317-337.

Lei, C., Zhang, A., Qi, Q., Su, H., & Wang, J. (2018). 'Spatial-temporal analysis of human dynamics on urban land use patterns using social media data by gender', *ISPRS International Journal of Geo-Information*, 7(9), 358.

Liu, M., Luo, X., & Lu, W. Z. (2023). 'Public perceptions of environmental, social, and governance (ESG) based on social media data: Evidence from China', *Journal of Cleaner Production*, 387, 135840.

Attard, J., Orlandi, F., Scerri, S., & Auer, S. (2015). 'A systematic review of open government data initiatives', *Government information quarterly*, 32(4), 399-418.

Long, Y., & Zhang, E. (2021). 'Data augmented design (DAD): definitions, dimensions, performance, and applications', *Data Augmented Design: Embracing New Data for Sustainable Urban Planning and Design*, 15-33.

Rizwan, M., Wan, W., Cervantes, O., & Gwiazdzinski, L. (2018). 'Using location-based social media data to observe check-in behavior and gender difference: Bringing weibo data into play', *ISPRS International Journal of Geo-Information*, 7(5), 196.

Kwak, H., Lee, C., Park, H., & Moon, S. (2010, April). 'What is Twitter, a social network or a news media?', In Proceedings of the 19th international conference on World wide web (pp. 591-600).

Zhen, F., Cao, Y., Qin, X., & Wang, B. (2017). 'Delineation of an urban agglomeration boundary based on Sina Weibo microblog 'check-in'data: A case study of the Yangtze River Delta', *Cities*, 60, 180-191.

Lu, S., Shi, C., & Yang, X. (2019). 'Impacts of built environment on urban vitality: Regression analyses of Beijing and Chengdu, China', *International journal of environmental research and public health*, 16(23), 4592.

Chen, S., Meng, B., Liu, N., Qi, Z., Liu, J., & Wang, J. (2022). 'Cultural perception of the historical and cultural blocks of beijing based on weibo photos', *Land*, 11(4), 495.

AI Methodological Note:

When translating and polishing the paper, advanced artificial intelligence language model Claude 3.5 was used to assist with data analysis, content structuring, and language refinement. However, all final explanations, conclusions, and editorial decisions are made by the authors to ensure the accuracy and completeness of the research. Careful monitoring was conducted on the use of Claude 3.5 to meet research objectives and maintain the quality of research results.

Research Paper

Research on Healthy Street Identification and Evaluation Based on Social Media Data and Street View Imagery

LIU Siqi, School of Architecture, South China of Technology, State Key Laboratory of Subtropical Building and Urban Science, China

LI Han, School of Architecture, South China of Technology, State Key Laboratory of Subtropical Building and Urban Science, China

ZHANG Chunyang, School of Architecture, South China of Technology, State Key Laboratory of Subtropical Building and Urban Science, China (corresponding author)

Abstract

Improving urban health is a significant challenge of the 21st century and a common good that concerns all people. Streets are important public spaces for public walking, and walking helps maintain physical and mental health and prevent infectious diseases. Therefore, it is necessary to identify and evaluate healthy streets that promote active public walking. The current construction of healthy streets lacks technical means and feedback platforms for public participation, while public active walking willingness and behavior information on social media can fill this gap. This study proposes a healthy street evaluation method based on social media data and street view images, which is used to evaluate the walking environment from the public perspective. This paper retrieves social media "Xianghongshu" posts related to "Citywalk", uses natural language processing to extract street samples, uses semantic segmentation and deep learning to process street view image data, and uses SPSS and LightGBM models to explore the predictive ability and correlation of healthy street elements and spatial perception with social media attention. The results show that the correlation between various spatial elements and social media attention is weak or insignificant, while spatial perception "safety" and "wealthy" have a significant positive correlation with social attention. Some spatial elements have a correlation with spatial perception, such as "lighting" and "greening" are positively correlated with "beautiful". In terms of social media attention prediction ability, the importance of spatial elements is lower than spatial perception. This may mean that in the dissemination and interaction of social media content, spatial perception features are more important than spatial elements. Therefore, when urban planners evaluate streets from the perspective of public participation, they can first clarify the design objectives from the perspective of improving spatial perception, and then focus on the spatial elements related to such perception.

Keywords

Health Street, Citywalk, Deep learning, Social Media, SVI, Public Engagement

1. Introduction

Health is supposed to be integrated into all policies so as the development of urban area should be centred on people's health, declaring by the World Health Organization inspired by Ottawa Charter for Health Promotion. Urban built environment affects health, so how to reduce health risks and enhance health potential through urban design has become a hot topic. Optimising the walking environment and building healthy streets are good to reduce the risk of non-communicable diseases caused by unhealthy lifestyles such as sedentary behaviour and reduced physical activity (Rosenberg, P. et al., 2016).

Public participation is a method that can be used to evaluate and optimise street design. The American-Canadian theorist Jane Jacobs was the first to advocate for public participation in the construction of safe and vibrant urban streets in the 20th century. Her approach to understanding urban space and her perspective have been revisited and have inspired urban development for different contexts and needs (Hirt & Zahm, 2012). For example, many social organisations promote community environmental improvement by organising urban walking events (e.g. Jane's Walk) and conducting bottom-up neighbourhood environmental and built environment assessments (Gómez-Varo, I. et al., 2022). Existing design research has shown the improvement of urban pedestrian environment can promote community participation (Hassen, N. and Kaufman, P., 2016), such as improving sidewalks, increasing connectivity, and optimising lighting and street furniture (Rogers, S.H. et al., 2013). Street design optimisation and promoting public participation are mutually reinforcing.

In today's Chinese social media, urban walking activities represented by "Citywalk" have become a way of exploring the built environment of the streets. At the end of 2023, Xiaohongshu and Chinese Academy of Social Sciences jointly released the "2023 Annual Life Trend Observation Report." "Citywalk" was selected as one of the top ten lifestyle keywords, and related topics were viewed more than 2.1 billion times. Citywalk is an active physical activity that integrates walking into leisure and entertainment, which can promote health. The preference for Citywalk in social media can to some extent reflect people's willingness and spatial tendency to engage in active walking activities. For a long time, due to the high cost of communication and limited public participation channels, the public voice for improving the health of the built environment has been weak. Current healthy street assessments rely heavily on traditional methods such as questionnaires and scoring assessments. The application of big data is still in its infancy, and fewer attention has focused on the potential contribution of social media to optimise the walking environment and healthy street assessments. Therefore, studying social media data related to "Citywalk" topics can supplement the long-standing lack of public participation in street design and the insufficient basis for healthy street assessments. It can also provide a good sample for summarising the characteristics of healthy street spatial elements, which is of positive significance for the construction of refined healthy cities.

2. Conceptual framework

2.1. Literature review

The impact of streets on public health has become a consensus. Healthy streets shift the focus from cars to people by limiting health risks, promoting healthy behaviours and enriching health resources, so as to meet people's needs for physical and mental health development. The streets walkability is crucial factor that promotes physical activity in the built environment . Integrating physical activity into daily life leads to better health (Sallis, J.F. et al., 2012). As one of the most important evaluation criteria to characterize healthy streets, walkability measurement is helpful to identify and evaluate healthy streets. Related research (Jensen, W.A. et al., 2014) has identified the difference between audited walkability as an

objective standard for assessing the walking environment and perceived walkability as a subjective standard for assessing the walking experience, and advocates combining the two to better identify and assess the quality of streets. Objective evaluations are often based on surveys and assessments by professionals and institutions, such as surveys on land use diversity, number of street intersections, traffic flow, public transport connectivity, linearity of walking routes, width of pavements, lighting, number of residents or commuters and vegetation coverage, to assess whether a street is convenient, accessible, has a sense of community, is comfortable and safe(Baobeid, A. et al., 2021； Cerin, E. et al., 2006; Frank, L.D. et al., 2005). Subjective evaluation focuses more on the experience and feelings of pedestrians and residents. It assesses the convenience, safety, walkability, thermal comfort, aesthetic attributes and infrastructure quality of the street through surveys, group discussions, interviews, etc (Cerin, E. et al., 2006; Ewing, R. et al., 2009; Kim, S. et al., 2014; Baobeid, A. et al., 2021). Some scholars combine objective and subjective evaluations, using psychological greenery, visual congestion, outdoor enclosure and visual walkways indicators to form a framework for walkability that combines the feature extraction techniques of objective evaluation and the perception of subjective evaluation (Zhou, H. et al., 2019). The combination of subjective and objective evaluations can more comprehensively and accurately identify and assess the pedestrian environment on the street, providing a basis for subsequent healthy street construction.

2.2. SVI in Healthy Streets Assessment

Compared to other data, street view images are closer to the perspective of a person's perceptual experience of a space and have unique advantages in healthy street assessment. Taking green space exposure metrics as an example, open, standardised, geo-referenced, wide-coverage streetscape views can provide new exposure measures for epidemiological studies, and the measured exposure measures are less correlated with traditional methods such as NDVI, and are better able to exclude interferences such as community-based socio-economic factors in health studies (Larkin, A. and Hystad, P., 2019). For street users, daily exposure to greenery is more important than greenness metrics, with visual levels of street greenery (rather than HDVI) being positively correlated with cycling probability (Lu, Y. et al., 2019)，and more strongly associated with propensity to choose practical walking activities.

Developments in deep learning and computer vision have provided significant support for understanding street scene images, with large-scale models and large-scale image datasets facilitating the execution of tasks such as scene classification, target detection, and semantic analysis (Zhang, F. et al., 2024). With the help of datasets trained on a large number of labelled images, such as Place 2 and ADE20K, the spatial elements of street view images are segmented, extracted, classified, and become the basis for quantitative analysis. Previous studies on health related to environment relies on field surveys and questionnaire interviews to collect information about the physical environment (Gullón, P. et al., 2015), which is quite time-consuming and the evaluation is susceptible to subjective factors. Street view images, which are captured in abundant quantities over short periods of time, are also more advantageous in identifying health-related visual elements such as greenery, pavements, food advertising lights, etc (Chen, J. et al., 2023).

Machine learning algorithms provide an effective and high-performing approach for information extraction in complex street environments（Zhou, H. et al., 2019). Numerous studies have showed how to audit and assess the impact of the built environment through street view imagery. Some studies have demonstrated how street view imagery act in assessing the impact on public health. For example, street view imagery assessments have identified ways to improve the walking experience and safety (Wu, Y.T. et al., 2014; Wang, R. et al., 2019) to promote physical health, identify unhealthy food and drink advertising to warn of poor dietary environments (Boyland, E.J . et al., 2016), and the natural

environment can also be identified to guide psychological recovery (Quinn, J.W. et al., 2019; Hyam, R., 2017), improve mental health such as depression (Wu, Y.T. et al., 2014).

2.3. Social Media Data for Healthy Streets Assessment

People's perceptions of streets are critical to assessing their health. Traditional survey methods for spatial assessment rely on long-term fieldwork and limited survey samples, such as Kevin Lynch's cognitive maps, Jane Jacobs' observation records, and William White's behavioural observations. In recent years, with the help of social media and online platforms, a large amount of individual spatial preference and perception information has been collected, and the sample size and credibility of spatial assessments have greatly increased. (1) Social media data can reflect health behaviours. Lu et al. (2021) observed an association between the use of urban nature parks and the severity of epidemics during Covid-19 and noted that large, inexpensive urban green spaces can strengthen the resilience of communities in coping with crises and epidemics. (2) Social media data can foretell health risks. Peng C. (2020) used machine learning techniques to build models that can assess and analyse HPV vaccination issues and individual depression and anorexia through social media data. (3) Social media data can optimise health resources. Zhang R. (2020) used social media data and facial expression reading as technical support to explore the mechanism of blue space on public physical and mental health, and put forward a proposal to enhance the accessibility and openness of the space to promote the public's physical activity and positive emotions. Social media is a good source of data for the Healthy Streets Assessment because it can reshape the power structure in urban planning, engaging citizens, professionals, and third parties in communication and collaboration (Lin, Y., 2023). Based on this, this paper hopes to explore the correlation between social media data and healthy spatial elements and spatial perception.

3. Healthy Streets Assessment

3.1. Research framework

This paper constructs a conceptual framework to identify and evaluate healthy spatial elements in street view images that promote walking by reflecting walking intentions using data from social media-related topics and simulating walking experiences using street view image data. The information provided by this study can help inform design decisions for healthy streets.

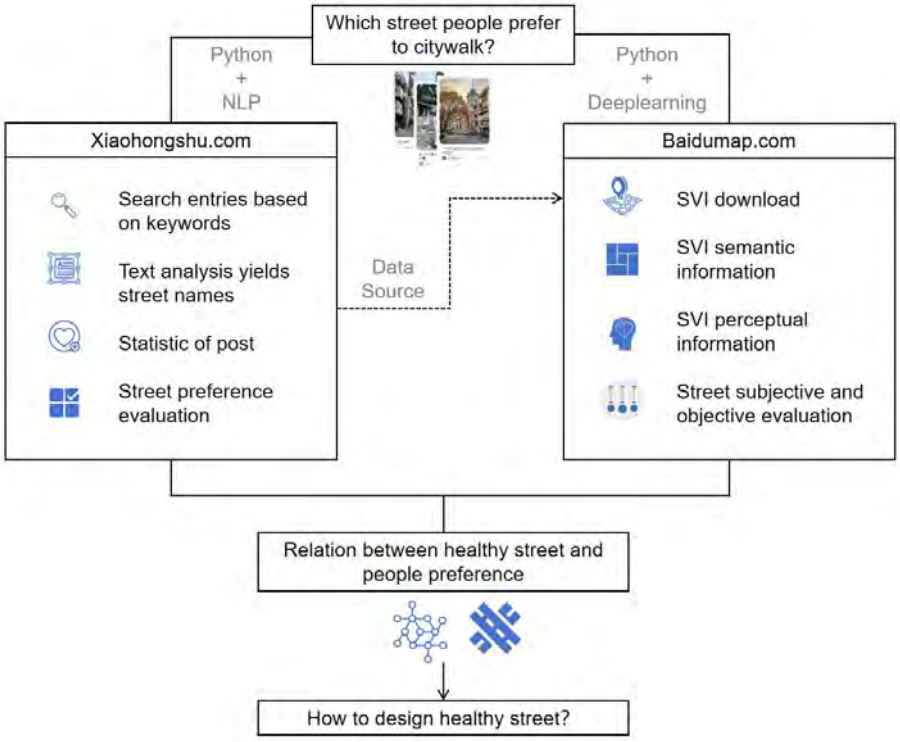


Figure 1. Conceptual framework. Source: Author.

3.2. Assessment system

The aim of this paper is to construct a system for identifying and evaluating healthy street elements based on SVI images. As there are many dimensions and indicators to characterise healthy streets, the research is based on a literature review and divides the street space into three types of space: architectural interface, motorized space and non-motorized space, and screens 12 spatial elements as quantitative indicators. Among them, the architectural interface focuses on the spatial enclosure of the street, the motorised space focuses on the degree of motorisation and the friendliness to slow traffic, and the non-motorised space focuses on whether it is suitable for walking, cycling and staying.

Building a healthy street element recognition and evaluation system based on street view imagery is the purpose of this study. Because there are many dimensions and indicators to characterize healthy streets, based on literature review, the street space is divided into three categories: architectural interface, motorized space and non-motorized space. 12 spatial elements are screened as quantitative indicators of audited walkability and their positive and negative impacts on health are discriminated (Table 1) .Among them, the architectural interface is concerned with the spatial enclosure of the street, the motorized space is concerned with the degree of motorization and the friendliness of walking, while the non-motorized space is concerned with whether it is suitable for walking, cycling and staying. Spatial elements in street view images can be identified by semantic segmentation, and corresponding parameters can be formed by calculating the percentage of elements in the image, which provides a basis for subsequent analysis (Table 2). At the same time, in order to better identify and evaluate the quality of streets, the man-machine confrontation scoring framework proposed by Yao Yao et al to describe perceived walkability is adopted in this study, and 6 parameters on street spatial perception are formed: "beautiful", "safety", "depressing", "wealthy", "lively", "boring".

Classification	Street elements	Health effect	Content
Architectural Interface	Building	+	Buildings, walls, fences, etc. can form visual enclosures (Wang, R. et al., 2019), which have a positive health impact on special groups with reduced walking ability, such as the elderly and children (Vanwolleghem, G. et al.,
	Wall	+	
	Fence	+	
	Sky	-	Higher visual enclosure (i.e. lower sky ratio) makes pedestrians feel safer and more comfortable, thus increasing the likelihood of walking (Ewing, R. & Handy, S., 2009). In addition, due to the street thermal effect, the proportion of the sky in the SVI is moderately negatively correlated with pedestrian flow and the walking index (Yin, L. & Wang, Z., 2016).
Motorised Space	Road	-	Motor vehicle speed is negatively correlated with road safety (Lee H et al., 2019)
	Motor vehicle	-	Obstacles in the street, such as parked cars and billboards, are a source of traffic congestion and reduce the willingness of pedestrians to walk (Lee, He, & Sohn, 2017).
	Crossing facilities	+	Pedestrians are willing to spend more time using signalised crossings and less time using footbridges and underpasses, especially women and older people (Anciaes, P.R. & Jones, P., 2018).
	Traffic signs	+	Traffic signs increase the orderliness of the environment, reduce cognitive load, and alleviate negative emotions caused by the environment (Yin, L. & Wang, Z., 2016).
Non-motorised Space	Lighting	+	Street lighting improves the visibility of spaces and increases the psychological safety of pedestrians (Li W., 2016)
	Street furniture	+	The length of street furniture is positively correlated with the social behaviour of pedestrians and negatively correlated with commercial activity (Xu, L. & Kang, Q., 2014).
	Sidewalk	+	The ratio of road area to sidewalk area in the pedestrian's field of vision affects the pedestrian's feelings and behaviour (Zhou, H. et al., 2019).
	Greening	+	The quality and quantity of street greenery are positively correlated with leisure physical activity, and the higher the street greenery rate, the healthier the street (Lu, Y., 2019).

Table 1. The health effects of spatial elements in SVI. Source: Author.

Classification	Definition	Elements	Symbols	Content	Data type
Architectural Interface	Architectural interface enclosure	Building	B_n	The proportion of the pixel area of walls, fences and buildings to the total pixel area	percentage
		Wall fence	I_n		
		Sky	K_n	The proportion of the pixel area of the sky in the SVI	percentage
Motorised Space	The degree of motorisation and the degree of friendliness to pedestrians in motorised spaces	Road	R_n	The proportion of the pixel area of the road in the SVI	percentage
		Motor vehicle	V_n	The proportion of the area of the pixels of the motor vehicle in the SVI	percentage
		Crossing facilities	C_n	Presence or absence of pedestrian crossings, overpasses and other facilities for crossing the street in SVI	Boolean (0 or 1)
		Traffic signs	P_n	Presence or absence of traffic signs in SVI	Boolean (0 or 1)
Non-motorised Space	The degree to which non-motorised spaces are suitable for walking, cycling and staying	Lighting	L_n	The proportion of the pixel area of the lighting facilities in the SVI	percentage
		Street furniture	F_n	The proportion of the pixel area of the street furniture in	percentage
		Sidewalk	D_n	The proportion of the pixel area of the sidewalk in the SVI	percentage
		Greening	T_n	The proportion of the pixel area of the greening in the SVI	percentage

Table 2. Measurement of spatial elements in SVI. Source: Author.

3.3. Data source and processing

The study selected Xiaohongshu, a Chinese platform with 300 million monthly active users, as the data source. On January 25, 2024, the author retrieved a total of 1,918 posts related to the theme of street walking by searching for keywords such as "Citywalk", "Jane's Walk", "city observation". The data of the related posts includes basic information of the posts (title, post link, text, post cover, publication time, IP address, location information, keywords), post influence (number of shares, likes, and comments), author information (gender, author's age, author's occupation), and author influence (number of followers, fans, and likes and collections). Since posters often publish their posts a few days after their outings, the obtained "IP address" and "location information" do not accurately reflect the specific locations and streets mentioned in the text. Therefore, this study prioritized natural language processing for text recognition, determining the locations described in the posts by analyzing the 'title' and 'text'. As the "post cover" photos are taken from various angles and do not adequately reflect the street scenery, Baidu Maps' street view was chosen as a supplement. Based on the street names, panoramic images of all sample streets were obtained using Python and the Baidu API. The study employs the algorithm inplace-ABN (Bulò, Porzi, and Kontschieder 2018) and the pre-trained dataset Label mapping in the Mapillary Vistas dataset (Neuhold et al. 2017) for semantic segmentation of the data. After data cleansing, natural language processing, and summary statistics, a total of 894 streets were obtained as research samples.

Number	Elements	Type	Remark
1	Building	Construction	independent variable
2	Wall	Construction	independent variable
3	Fence	Construction	independent variable
4	Sky	Sky	independent variable
5	Road	Flat	independent variable
6	Motor vehicle	Vehicle	independent variable
7	Crossing facilities	Construction	independent variable
8	Traffic signs	Object	independent variable
9	Lighting	Object	independent variable
10	Street furniture	Object	independent variable
11	Sidewalk	Flat	independent variable
12	Greening	Object	independent variable

Table 3. Segmentation items in this research dataset. Source: Author.

4. Results and discussions

4.1. Topic trend

From the perspective of time distribution, the topic of "Citywalk" began to attract attention from April 2021, and the topic popularity continued to rise from 2023 and reached the peak of discussion in August 2024, after which the topic popularity declined (Figure 2).

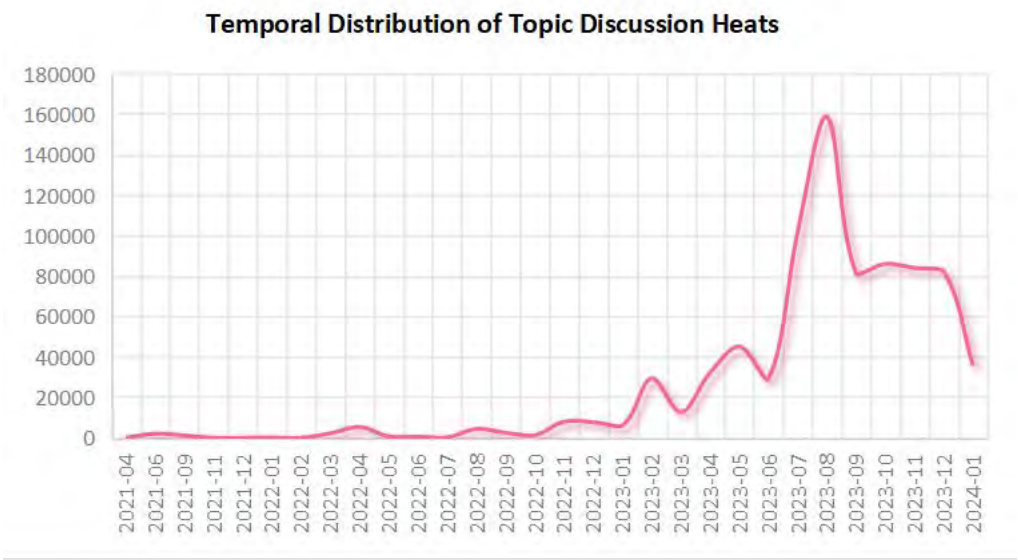


Figure 2.Time heat of the topic. Source: Author.

Natural language processing (NLP) has improved the accuracy of the description of the social information source region (IP) (Figure 3), and Shanghai is the city with the highest output of relevant social content. Regions such as Jiangsu, Zhejiang and Shanghai saw the most posts, while eastern and central China saw higher interest in the topic.

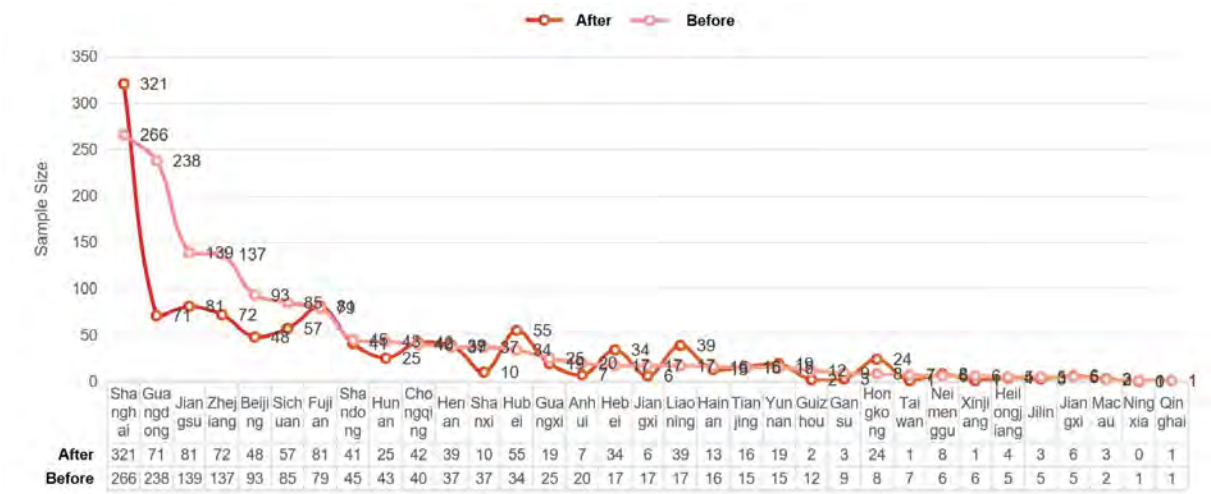


Figure 3. Provinces distribution using natural language processing. Source: Author.

From the perspective of regional differences, there are differences in the interaction amount of content published in different regions at different time points. Posts from Shanghai, Zhejiang, Guangdong and other places have a higher volume of interaction since May 2023, indicating that these cities have a higher social focus on the walkability of urban streets (Figure 4). In terms of gender differences, Shanghai,

Henan and Zhejiang provinces had higher interaction volume for male content posts, while most other regions had lower interaction volume. The regions with the highest interaction volume of women's content are Shanghai, Jiangsu, Hubei, Zhejiang, Guangdong and Beijing. The overall trend shows that women post more interactive content than men, especially in Shanghai, Zhejiang and Guangdong (Figure 5).

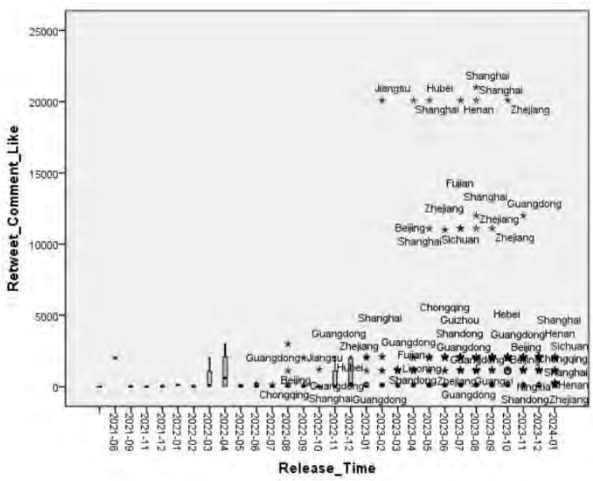


Figure 4. Discussions in different places at different times. Source: Author.

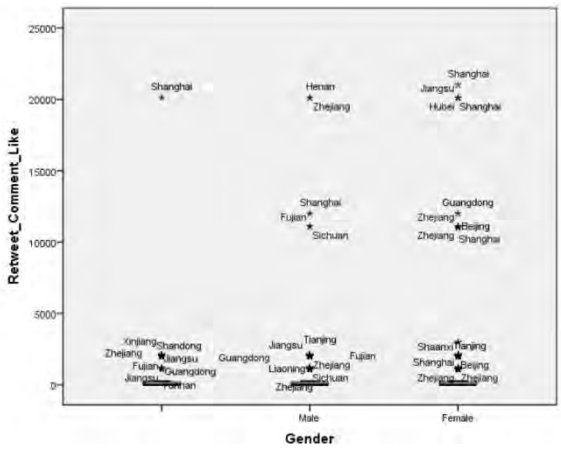


Figure 5. Discussion of different genders in different regions. Source: Author.

4.2. Correlation analysis

The study leveraged SPSS version 22 to perform one-tailed Pearson correlation tests on a spectrum of feature values, and subsequently employed Python to generate the correlation matrix heatmap (**Figure 6**). The findings reveal that while correlations between various spatial elements and social attention are generally weak or non-significant, perceptions of "safety" and "wealthy" are notably correlated with social attention at a significant level ($p<0.01$). Furthermore, among the spatial elements, the correlation coefficient between buildings and the sky is 0.215 ($p<0.01$), between roads and traffic signs is 0.233 ($p<0.05$), and between sidewalks and greening is 0.325 ($p<0.01$), all of which point to significant positive correlations. This implies that these pairs of elements act as common influencers in street scenes, collectively impacting environmental quality. Additionally, there exists a correlation between spatial elements and spatil perception; for instance, the correlation coefficient between lighting and the perception of beauty is 0.139 ($p<0.05$), indicating a significant positive correlation. This suggests that adequate lighting may enhance the aesthetic appeal of the environment. In a similar vein, the correlation coefficient between greening and the perception of beauty is 0.325 ($p<0.01$), which suggests that the extent of greenery significantly influences the environment's aesthetic appeal positively.

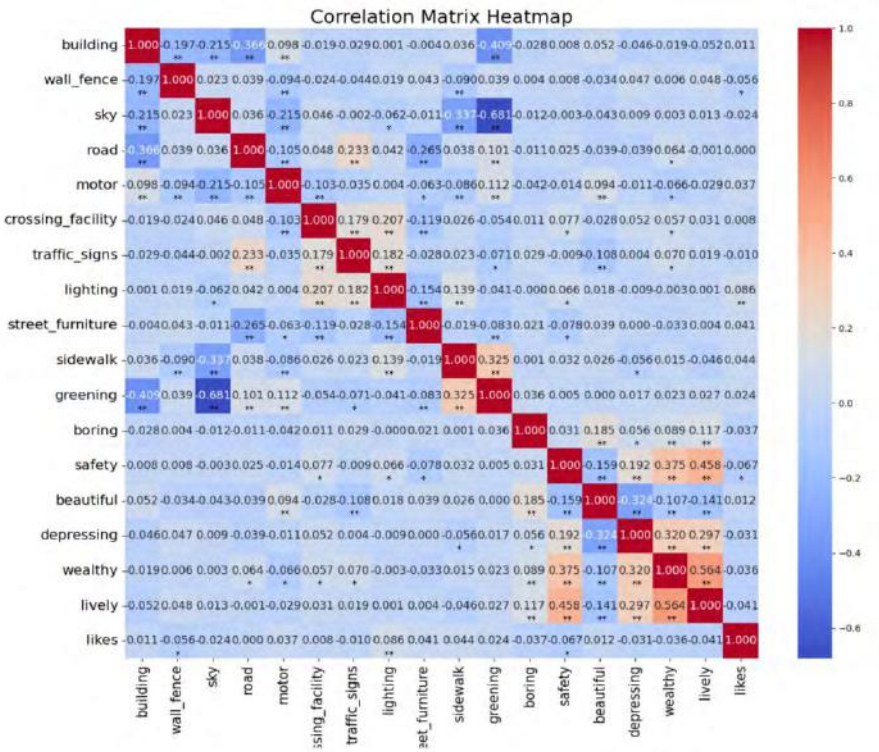


Figure 6. Correlation matrix heat map. Source: Author.

4.3. Weight analysis

To explore the predictive power of various spatial elements and spatial perceptions on social attention, the study employed the LightGBM model to learn from the data. The SHAP values, which elucidate the outcomes of the LightGBM model, are depicted in the following figure (Figure 7). Arranging the spatial perceptions that positively influence social media content attention according to their feature importance, they are, in order: a high "beautiful" value, a low "oppressive" value, a high "active" value, a high "wealthy" value, a high "safety" value, and a low "boring" value. In contrast, the feature importance of spatial elements is lower than that of spatial perceptions. The spatial elements that positively influence social media content attention are, in order: a high "street furniture" value, a low "road" value, a low "motor vehicle" value, a high "lighting" value, a high "greening" value, and a high "crosswalk facilities" value, while "traffic signs," "sky," "fences," and "buildings" have little impact on the predictive results. This is in line with the previous judgments on the health impacts of various spatial elements and also indicates that some elements has no influence on the predictive outcomes of health street attention based on the street view and social media. This may imply that in the dissemination and interaction of social media content, spatial perception features are more important than spatial element features. This finding challenges the inherent cognition of urban planners, who tend to believe that simply increasing or decreasing a single spatial element can enhance the walkability of streets, neglecting the fact that assessments of streets should first focus on spatial perceptions.

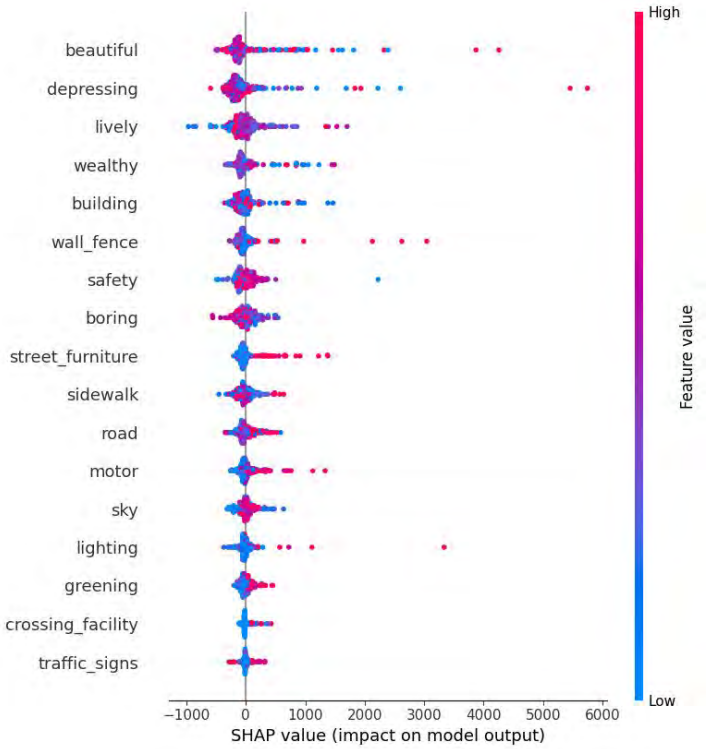


Figure 7. SHAP values of various elements. Source: Author.

4.4. Academic innovation

From the perspective of data sources, the study utilized Xiaohongshu, one of the most popular Chinese social media platforms among young people, as its data source. Compared to other social media platforms, posts on Xiaohongshu regarding urban space topics typically feature more detailed textual descriptions and a higher level of interactive influence, with address information also being more readily available. In terms of information processing methods, the study employed natural language processing based on textual descriptions to extract location information from the text, thereby enhancing the accuracy of the sample street information. Methodologically speaking, the study explored the correlation between social media content attention and spatial elements as well as spatial perceptions, proposing a strategy that prioritizes spatial perceptions over the improvement of spatial elements in the assessment of healthy streets.

4.5. Existent insufficiency

Although street view imagery shows great potential for assessing healthy streets, there are problems with the temporal and spatial coverage of the data (Larkin, A. and Hystad, P., 2019). It is challenging to randomly selecting a street view from a human perspective to represent the average level, as there are differences in the years and seasons when different streets are photographed. For elements with seasonal distribution differences, such as greenery, it is difficult to eliminate this part of the error. At the same time, for elements with spatial distribution differences, such as crossing facilities, streetlights, and street furniture, the reliability of street view images may be reduced. There is controversy over the positive or negative health effects of individual spatial element indicators. For example, in different climatic regions, pedestrians' sensitivity to the proportion of sky area varies, and even within the subtropical region, preferences differ across seasons. As a result, the final model fitting shows that such

elements have no predictive power. Looking at the coverage of the study population, the main users of the social media platform Xiaohongshu are young people aged 18-34, with a user ratio of about 30% male and 70% female, thus our results have certain limitations. The time span of our data collection is from April 2021 to January 2024, with a limited sample size, and the model fit and related trends await further refinement with an increase in sample size.

5. Conclusions

Our research findings indicate that integrating spatial elements and perceptions from street view images with social media data constitutes an effective method for street assessment. Social media data offers subjective evaluations of popular streets, while objective parameters relies on street view imagery. By comparing subjective and objective data, we can analyze the correlation between the two, providing a reference for the weighting and revision of indicators in a healthy street assessment system, and facilitating the implementation of design practices. This study aids governments and relevant designers in quickly grasping the dynamics of internet data while saving labor and material costs, and in reviewing and guiding the construction of healthy cities in a context-specific and gradual manner.

Funding/Support: This study was supported by the Project on Theories and Methods of Green Construction for Large-scale Projects in Subtropical Meso-scale Cities (Grant No. 2022KA01), which is a self-directed research topic of the National Key Laboratory of Subtropical Architecture and Urban Science, South China University of Technology.

6. References

Anciaes, P.R. and Jones, P. (2018) 'Estimating preferences for different types of pedestrian crossing facilities', *Transportation research part F: traffic psychology and behaviour*, *52*, pp.222-237.

Baobeid, A., Koç, M. and Al-Ghamdi, S.G. (2021) 'Walkability and its relationships with health, sustainability, and livability: elements of physical environment and evaluation frameworks', *Frontiers in Built Environment*, *7*, p.721218.

Boyland, E.J., Nolan, S., Kelly, B., Tudur-Smith, C., Jones, A., Halford, J.C. and Robinson, E. (2016) ' Advertising as a cue to consume: a systematic review and meta-analysis of the effects of acute exposure to unhealthy food and nonalcoholic beverage advertising on intake in children and adults', *The American journal of clinical nutrition*, *103*(2), pp.519-533.

Bulo, S.R., Porzi, L. and Kontschieder, P. (2018) 'In-place activated batchnorm for memory-optimized training of dnns', In *Proceedings of the IEEE conference on computer vision and pattern recognition* (pp. 5639-5647).

Cerin, E., Saelens, B.E., Sallis, J.F. and Frank, L.D. (2006) 'Neighborhood Environment Walkability Scale: validity and development of a short form', *Medicine and science in sports and exercise*, *38*(9), p.1682.

Ewing, R. and Handy, S. (2009) 'Measuring the unmeasurable: Urban design qualities related to walkability', *Journal of Urban design*, *14*(1), pp.65-84.

Chen, J., Chen, L., Li, Y., Zhang, W. and Long, Y. (2023) 'Measuring physical disorder in urban street spaces: a large-scale analysis using street view images and deep learning', *Annals of the American Association of Geographers*, *113*(2), pp.469-487.

Frank, L.D., Schmid, T.L., Sallis, J.F., Chapman, J. and Saelens, B.E. (2005) 'Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ', *American journal of preventive medicine*, *28*(2), pp.117-125.

Gómez-Varo, I., Delclos-Alio, X. and Miralles-Guasch, C. (2022) 'Jane Jacobs reloaded: A contemporary operationalization of urban vitality in a district in Barcelona', *Cities*, *123*, p.103565.

Gullón, P., Badland, H.M., Alfayate, S., Bilal, U., Escobar, F., Cebrecos, A., Diez, J. and Franco, M. (2015) 'Assessing walking and cycling environments in the streets of Madrid: comparing on-field and virtual audits', *Journal of urban health*, *92*, pp.923-939.

Hassen, N. and Kaufman, P. (2016) 'Examining the role of urban street design in enhancing community engagement: A literature review', *Health & place*, *41*, pp.119-132.

Hirt, S. and Zahm, D. eds. (2012) *The urban wisdom of Jane Jacobs*. Routledge.

Hyam, R. (2017) 'Automated image sampling and classification can be used to explore perceived naturalness of urban spaces', *PLoS One*, *12*(1), p.e0169357.

Jensen, W.A., Brown, B.B., Smith, K.R., Brewer, S.C., Amburgey, J.W. and McIff, B. (2017) 'Active transportation on a complete street: Perceived and audited walkability correlates', *International journal of environmental research and public health*, *14*(9), p.1014.

Kim, S., Park, S. and Lee, J.S. (2014) 'Meso-or micro-scale? Environmental factors influencing pedestrian satisfaction', *Transportation Research Part D: Transport and Environment*, *30*, pp.10-20.

Larkin, A. and Hystad, P. (2019) 'Evaluating street view exposure measures of visible green space for health research', *Journal of exposure science & environmental epidemiology*, *29*(4), pp.447-456.

Lee, H. and Kim, S.N. (2019) 'Shared space and pedestrian safety: Empirical evidence from pedestrian priority street projects in Seoul, Korea', *Sustainability*, *11*(17), p.4645.

Lee, J., He, S.Y. and Sohn, D.W. (2017) 'Potential of converting short car trips to active trips: The role of the built environment in tour-based travel', *Journal of Transport & Health*, *7*, pp.134-148.

Li, W. (2016) '*Research on urban street landscape based on daily safety (psychological safety and behavioral safety)*', Shenyang Agricultural University.

Lin, Y. (2023) 'How can social media reshape power relations in urban planning?: Discover how social media transforms power relations in urban planning as Dr. Yanliu Lin examines its impact on government-society relation and collaborative practices in the Chinese context', *The Project Repository Journal*, *17*, pp.64-67.

Lu, Y. (2019) 'Using Google Street View to investigate the association between street greenery and physical activity', *Landscape and Urban Planning*, *191*, p.103435.

Lu, Y., Yang, Y., Sun, G. and Gou, Z. (2019) 'Associations between overhead-view and eye-level urban greenness and cycling behaviors', *Cities*, *88*, pp.10-18.

Lu, Y., Zhao, J., Wu, X. and Lo, S.M. (2021) 'Escaping to nature during a pandemic: A natural experiment in Asian cities during the COVID-19 pandemic with big social media data', *Science of the total environment*, *777*, p.146092.

Neuhold, G., Ollmann, T., Rota Bulo, S. and Kontschieder, P. (2017) 'The mapillary vistas dataset for semantic understanding of street scenes', In *Proceedings of the IEEE international conference on computer vision* (pp. 4990-4999).

Peng C. (2020) '*Research on health problem analysis method based on social media data*', Tianjin University.

Quinn, J.W., Mooney, S.J., Sheehan, D.M., Teitler, J.O., Neckerman, K.M., Kaufman, T.K., Lovasi, G.S., Bader, M.D. and Rundle, A.G. (2016) 'Neighborhood physical disorder in new york city', *Journal of maps*, *12*(1), pp.53-60.

Rogers, S.H., Gardner, K.H. and Carlson, C.H. (2013) 'Social capital and walkability as social aspects of sustainability', *Sustainability*, *5*(8), pp.3473-3483.

Rosenberg, P., Kano, M., Ludford, I., Prasad, A. and Thomson, H. (2016) '*Global report on urban health: equitable, healthier cities for sustainable development*', World Health Organization.

Sallis, J.F., Floyd, M.F., Rodríguez, D.A. and Saelens, B.E. (2012) 'Role of built environments in physical activity, obesity, and cardiovascular disease', *Circulation*, *125*(5), pp.729-737.

Vanwolleghem, G., Van Dyck, D., Ducheyne, F., De Bourdeaudhuij, I. and Cardon, G. (2014) 'Assessing the environmental characteristics of cycling routes to school: a study on the reliability and validity of a Google Street View-based audit', *International Journal of Health Geographics*, *13*, pp.1-9.

Wang, R., Lu, Y., Zhang, J., Liu, P., Yao, Y. and Liu, Y. (2019) 'The relationship between visual enclosure for neighbourhood street walkability and elders' mental health in China: Using street view images', *Journal of Transport & Health*, *13*, pp.90-102.

Wu, Y.T., Nash, P., Barnes, L.E., Minett, T., Matthews, F.E., Jones, A. and Brayne, C. (2014) 'Assessing environmental features related to mental health: a reliability study of visual streetscape images', *BMC Public Health*, *14*, pp.1-10.

Xu, L. and Kang, Q. (2014) 'The impact of spatial and interface characteristics of commercial streets on pedestrian staying activities: A case study of Nanjing West Road in Shanghai', *Urban Planning Forum*, (03), pp. 104–111.

Yin, L. and Wang, Z. (2016) 'Measuring visual enclosure for street walkability: Using machine learning algorithms and Google Street View imagery', *Applied geography*, *76*, pp.147-153.

Zhang R. (2020) '*Urban blue spatial characteristics affecting public health under social media data*', Harbin Institute of Technology.

Zhang, F., Salazar-Miranda, A., Duarte, F., Vale, L., Hack, G., Chen, M., Liu, Y., Batty, M. and Ratti, C. (2024) 'Urban Visual Intelligence: Studying Cities with Artificial Intelligence and Street-Level Imagery', *Annals of the American Association of Geographers*, *114*(5), pp.876-897.

Zhou, H., He, S., Cai, Y., Wang, M. and Su, S. (2019) 'Social inequalities in neighborhood visual walkability: Using street view imagery and deep learning technologies to facilitate healthy city planning', *Sustainable cities and society*, *50*, p.101605.

Research Paper

Inclusive Urban Design: Exploring the Relationship between Neighborhood Environments, Outdoor Activities, and Health in China from Children's Perception

Jiaxuan ZHAO, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Hong LENG, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Qing YUAN, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

The main purpose of this study is to explore the relationship between urban neighborhood environment, outdoor activities and health perceived by children living in different settlements in the same city. The subjects include children aged 10-12 years (n=113) from four primary schools in Handan City, Hebei Province, China, representing four residential types in one city (urban center, urban fringe, small town, and village). The study uses a variety of qualitative analysis methods, including cognitive maps and semi-structured interviews. The results show that there is a close connection between children's perceived neighborhood environment, outdoor activities, and physical and mental health. The allocation of activity resources is uneven among different settlements, but all have the opportunity to support outdoor activities that satisfy children.

Keywords

Neighborhood, Environmental Perception, Outdoor activities, Children, Cognitive map

1. Introduction

Participating in outdoor activities is an important way for children to understand and perceive the environment. Children who regularly engage in outdoor activities can obtain long-term health benefits. Under the influence of globalization and urbanization, China's urban environment and people's lifestyles have undergone significant changes. The rapid and high-density expansion of urban built-up areas (Han, Sternudd and Zhao, 2011), the deteriorating traffic environment and air pollution have resulted in increasingly limited places for children to engage in outdoor activities. The popularity of electronic products such as mobile phones and tablets has significantly shortened the duration of children's outdoor activities (Liu et al., 2020). The combined influence of these multiple factors has restricted the level of outdoor activities for Chinese children. Children's physical fitness has continued to decline over the past 20 years

(Wang and Cheng, 2009), and the prevalence of chronic diseases such as childhood obesity has continued to rise.

Compared with adults, children are more easily exposed to the environment. At the same time, children's physical and mental development is immature and they are highly dependent on the environment, making them more susceptible to environmental influences. However, China's current neighborhood environment is designed with adults in mind and cannot meet the growth needs of children (Wang and Han, 2012). Children, as a vulnerable group, carry the future of the country. Therefore, it is necessary to listen to children's voices and understand their views on the neighborhood environment.

Children have the ability to perceive the environment, express themselves, and solve problems (Manouchehri and Burns, 2023). Their perception of the environment is different from that of adults. Adults tend to focus on formal play spaces for children, while children focus on the overall living environment (Alarasi, Martinez and Amer, 2016). Children's perceptions are influenced by the environment and cultural characteristics in which they live (Kurt and Ozgun, 2023). For example, children's perceptions of sports venues vary due to the different stimuli presented in urban and rural areas (Guroglu and Onder, 2016). Parents' perception of the neighborhood environment has no direct relationship with the duration of their children's physical activities (Lin et al., 2023), which means that children have their own concepts about their environment (Spilsbury, Korbin and Coulton, 2009). Therefore, it is important to explore the relationship between the environment, activities, and health from the perspective of children, and to identify the elements of environmental perception that promote children's activities and health.

In summary, in terms of children's activities and health, the subjectively perceived neighborhood environment and the objective physical environment are equally important. However, existing research in China pays insufficient attention to the role of children's perception of the neighborhood environment. The research areas are mainly concentrated in specific communities in megacities such as Beijing and Shanghai, and there is a lack of perceptual comparisons of larger-scale neighborhood environments. This is because the assessment of children's environmental perception is challenging and requires the use of methods that are consistent with children's cognitive abilities (Pluhar et al., 2010). Compared with common methods such as direct observation, interviews and questionnaires in existing research, art-based methods such as drawing and writing techniques, cognitive maps and photography are more suitable for children (Han, Sternudd and Zhao, 2011; Zhu and Ye, 2022). Among them, cognitive maps refer to the method of recording spatial images on paper or in pictures through some tools. They are personalized psychological representations of people's perception and processing memory of the objective environment (Dai and Zhang, 2009). This method allows children to express their own views at their current cognitive level and has been widely used to explore children's environmental perception and behavioral decision-making mechanisms. It can serve as a valuable information resource for children's non-professional concepts (Onyango-Ouma, Aagaard-Hansen and Jensen, 2004).

Based on this, this study takes Handan City as a case to investigate the participation in outdoor activities of children in different settlements. Qualitative research methods such as cognitive maps and semi-structured interviews are used to explore children's perceptions of the relationship between neighborhood environment, outdoor activities, and health, to identify the neighborhood environmental perception elements and characteristics that affect children's outdoor activities and physical and mental health, and to assess the perception differences among children with different settlement types. This study will provide a basis for urban design that promotes children's outdoor activities and health levels.

2. Method

2.1. Areas

Handan City is located in the southern part of Hebei Province, which has strong economic strength and a high level of urbanization. As one of the top 100 cities in China, Handan faces many common problems of big cities, and also has the characteristics of diverse urban environment and socio-economic background of its population. As of the end of 2023, the percentage of children aged 0-15 years in Handan was 23.32%, much higher than the national level of 17.6% (Handan Municipal Bureau of Statistics, 2024). Meanwhile, the problem of childhood obesity is prominent in Handan, and the overweight and obesity rate of elementary school students is at a high level and increasing year by year (Wang et al., 2009; Zhao and Hou, 2020). In addition, with the development of economy and society, Handan residents pay more and more attention to children's activities and health. Thus, Handan provides an ideal sample for exploring the relationship between urban environments, activities and health as perceived by children.

Considering the influence of socio-economic and geographic location factors on children's perceptions and behaviors, this study further selects a typical school in each of the four types of settlements in Handan (urban center, urban fringe, small towns, and village) as the case site for the study. Based on the principle of nearby enrollment, the sample schools were screened according to the criterion that the neighborhood was representative of all types of residential environments in Handan. Finally, Zhonghuaqiao Primary School in Congtai District, Second Experimental School in Yongnian District, Guangping Primary School in Guangping County, and Second Primary School Branch in Linzhang County were selected as sample schools (subsequently referred to as School 1, 2, 3, and 4 respectively). The basic characteristics of each school are shown in Table 1.

Table 1. Sample school description. Source: Authors.

School	Region description	Surroundings description
Zhonghuaqiao Primary School (School 1)	Congtai district (urban center) regional economic and administrative center	mainly high-rise and multi-story residential buildings well-equipped with parks, medical and commercial facilities
Second Experimental School (School 2)	Yongnian district (urban fringe) county abolished and established as a district in 2018, good economic situation	mainly multi-story residential buildings, with a small number of high-rise residential buildings and urban villages relatively well-equipped with parks, medical and commercial facilities
Guangping Primary School (School 3)	Guangping town, Guangping county (small town) general economic status	mainly rural self-built houses, with a small number of high-rise and multi-storey houses relatively well-equipped with parks, medical and commercial facilities
Second Primary School Branch (School 4)	Dongjie village, Liuyuan township, Linzhang county (village) poor economic status	basically rural self-built houses Relatively poor supporting facilities

2.2. Participants

In this study, the participants were children in grades 4 to 6 (10-12 years old). With the permission of the school leaders, the children themselves and their parents, a sample of 30 children in each of the four elementary school was selected for the study through random sampling. After several visits in May 2024, a total of 120 children participated in this survey. However, due to the lack of personal information data of some children, the final valid data of this survey was 113. The sample sizes of the four schools were 28, 30, 27, and 28 respectively, and the overall male-female ratio was close to 1:1. The basic attributes of the

interviewed children, such as the family economic situation and the education level of their parents, were significantly different and evenly distributed, as shown in Table 2.

Table 2. Sample child description. Source: Authors.

Sample characteristics		Number	Percentage	Sample characteristics		Number	Percentage
gender	male	55	48.7%	household registration	urban	62	54.9%
	female	58	51.3%		rural	51	45.1%
age	10	38	33.6%	father's education	primary and lower	11	9.7%
	11	37	32.8%		Junior high and high school	68	60.2%
	12	38	33.6%		undergraduate and above	34	30.1%
monthly family income	less than RMB 10,000	35	31.0%	mother's education	primary and lower	5	4.4%
	RMB10,000-15,000	46	40.7%		Junior high and high school	69	61.1%
	more than RMB 15,000	32	28.3%		undergraduate and above	39	34.5%

2.3. Measures

The data were collected through demographic information forms, cognitive maps, and a semi-structured interview guide developed by the researchers. After the semi-structured interview questions were prepared, they were submitted for discussion by an expert panel consisting of three teachers from fourth to sixth grade. Based on the experts' feedback, necessary revisions were made to ensure that the children could fully understand the interview questions. To avoid disrupting regular classes, the researchers requested a free classroom from the school administration and prepared basic tools, such as A4 drawing paper and colored pencils. Children were invited one by one into the classroom to draw cognitive maps and answer interview questions, with each session lasting approximately 30 minutes. At the end of the session, the children were asked to complete a personal information questionnaire at home with their parents' assistance. This questionnaire included details such as the child's age and gender, household registration, residence location, family monthly income, and parents' education level. The following day, questionnaires were collected and handed over to the researchers by the class teachers. The specific questions the children were asked included:

Draw a picture of your ideal neighborhood environment in which every person of your age can be happy and healthy.
What do you think happens to people who stay indoors for long periods of time and lack outdoor exercise?
Draw a picture of the neighborhood where you regularly engage in outdoor activities in your leisure time, specifically, draw a simple map of places and things that are important to you around your home."
What types of outdoor activities do you engage in, and where do you usually do them?

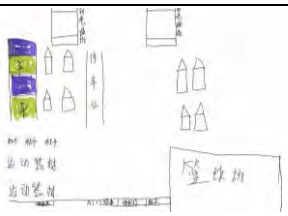
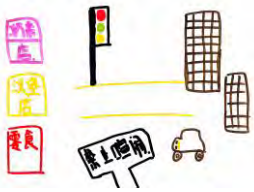
3. Results

3.1. Children's perceptions of ideal neighborhood environments

In the children's cognitive maps drawn for the question "Draw a picture of your ideal neighborhood environment in which every person of your age can be happy and healthy", 72.6% of them mentioned various types of outdoor activities, including football, basketball, badminton, and jump rope, as shown in

Table 3. This result indicates that the majority of children believe that a happy/healthy environment is closely related to frequent outdoor activities.

Table 3. Examples of cognitive maps of children's ideal neighborhood environments. Source: Authors.

School 1	School 2	School 3	School 4
			

There were both differences and commonalities in how children from different settlements perceived their ideal neighborhood. In terms of differences, children living in the urban center and fringe areas emphasized the importance of orderly parking, likely due to the complex urban environment where children face more traffic safety issues. On the other hand, children from small towns and rural areas were more concerned with the quietness of the community, expressing a desire for a comfortable and peaceful space for activities. In terms of commonalities, children from all settlements believed that natural elements are essential for achieving happiness/health. This suggests that the natural environment has a generally positive impact on children's psychological perception and emotional well-being.

3.2. Children's perceptions of long periods indoors and lack of outdoor activities

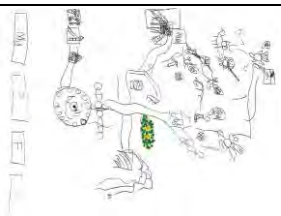
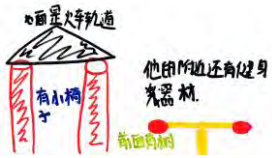
The second question asked participants to express their views on “What do you think happens to people who stay indoors for long periods of time and lack outdoor exercise?” The interview results showed that the majority of children (84.1%) believe that will be multiple impacts, affecting physical and mental health, as well as personality and behavior. The physical health impacts included reduced physical fitness, poor eyesight, illness, obesity, and excessive weight loss. Mental health impacts included loneliness, poor mood and lowered self-esteem. As for personality and behavior, children noted effects such as introversion, sloppiness in appearance, having no friends, avoiding communication, and being “different” from others. This indicates that children aged 10-12 are well aware of the negative effects of prolonged lack of outdoor activities on both behavior and health.

Children's perceptions on the physical health issues show regional differences. Those living in urban center and fringe areas identify decreased physical fitness, poor eyesight, and obesity as consequences of staying indoors for extended periods. In contrast, children from small towns and villages associate illness, obesity, and excessive thinness with this behavior. These responses indirectly reflect the prominent obesity, fitness, and eyesight problems faced by children in socio-economically advantaged areas of China, while children in socio-economically areas are still partially stunted and prone to illness. When categorized by gender, female children most frequently mention issues related to untidy appearance, introverted personality, and differences in physical appearance (such as obesity) that affect self-esteem and self-identity. Male children, on the other hand, are more concerned about resulting social issues, such as having no friends and lack of communication. There are gender differences in the perceptions of children in this age group. However, the acknowledgment and acceptance of peers are crucial for both genders.

3.3. Children's perceived characteristics and differences in neighborhood environments

Children's cognitive maps of their neighborhood illustrate environmental elements related to outdoor activities, as shown in Table 4. We coded the frequency of various elements found in these maps, identifying a total of 66 perceptual elements. Based on Kevin Lynch's five-element model from “The Image of the City (Lynch, 2001),” and considering the physical attributes of these elements along with children's cognitive development stages, we categorized the perceptual elements accordingly.

Table 4. Examples of cognitive maps of children's neighborhood environments. Source: Authors.

School 1	School 2	School 3	School 4
			

Environmental perception elements in the cognitive maps are categorized into six types: paths, edges, nodes, landmarks, natural elements and social elements, as shown in Table 5. Among them, “nodes” and “landmarks” are mentioned most frequently as the main places for children's outdoor activities; “paths” appeare less frequently as the links connecting children's activity places; “natural elements” and “social elements” are also often mentioned by children as environmental factors affecting children's outdoor activities; “edges” are least frequent because of their passive perceptual attributes.

Table 5. Classification and mentions of perceived elements of children's neighborhood environment. Source: Authors.

Type (number)	Elements of environmental perception (number of mentions)
Paths (170)	roads (91), paths/alleys (43), sidewalks (23), bike paths (13)
Edges (63)	roadside trees (29), walls (22), fences (7), rivers (3), railways (2)
Nodes (758)	Activity venues: squares (62), fitness venues (49), schools (42), table tennis courts (38), open spaces (26), open-air parking lots (21), parks (18), basketball courts (16), intersections (14), badminton courts (13), playgrounds (11), underground parking garages (8), botanical gardens (5), amusement parks (1) Entrance space: front door of home (101), front door of relative or friend’s home (38), shopping mall entrance (33) Service facilities: convenience store/supermarket (74), express delivery point (37), milk tea shop (26), canteen (24), cram school (19), vegetable market (13), bookstore (13), delicatessen (11), property building (8), laundry (7), garbage station (4), library (2), hospital (1) Transportation stations: bus station (23)
Landmarks (243)	Structures: pavilions (46), chairs (41), sculptures (19), fountains (16), bridges (11), community gates (9), signboards (6), rockery (6), fish ponds (4) Activity facilities: swings (33), slides (28), walking machines (13), seesaws (11)
Natural elements (142)	flowers/sunflowers/flower beds (32), grass (26), trees (21), streams (16), vegetable fields (13), pets (12), dirt piles/sand dunes (8), flying birds (8), insects (6)
Social elements (103)	friends (67), kids riding bikes/skateboards (16), people working out (11), homeless people (9)

There are differences in the composition and proportion of elements of neighborhood environment perception among children of different settlements, as shown in Figure 1. Overall, elements such as edges, nodes, and landmarks are more perceived by urban children, while natural elements are more likely to be perceived by rural children. Paths and social elements are equally important for children of different

settlements. These differences reflect the regional heterogeneity of resource allocation and environmental risks. Specifically, the activity venues, service facilities, transportation stations, structures, fitness and game equipment in urban areas are more abundant and complete, while the natural environment in rural areas is more superior. Different resource allocations provide opportunities for children's various outdoor activities and also cause differences in perception among children. Additionally, the relatively complex environment in urban areas and parents' concerns about safety have limited the scope of children's outdoor activities, and they are more concentrated in planned public spaces such as parks and squares. At the same time, they pay more attention to space management and safety facilities, while rural children may rely more on spontaneous natural cognition, such as understanding the terrain.

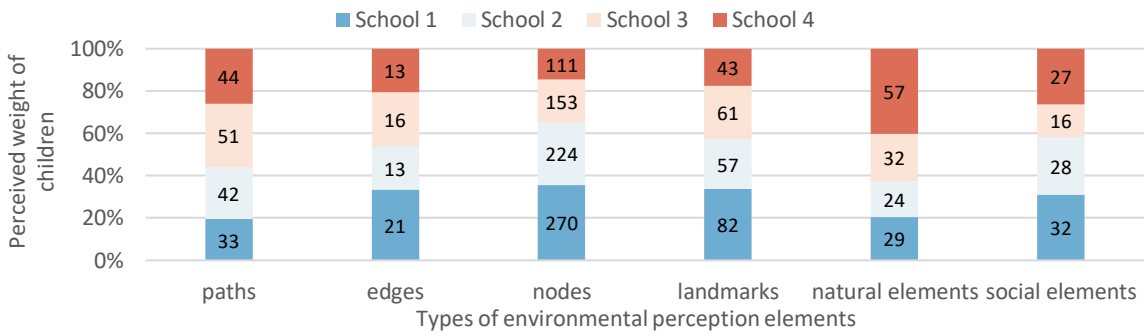


Figure 1. Composition of children's neighborhood environment perception elements in different settlements. Source: Authors.

3.4. Types and spatial distribution of children's actual outdoor activities

In response to the question, “What types of outdoor activities do you engage in?” the majority of children indicated that they frequently participate in at least two outdoor activities, with only two children explicitly stating that they rarely engage in outdoor activities. Based on Sara Smilansky's classification of children's play, and considering the physical and psychological characteristics of children aged 10 to 12, this study classifies the 23 outdoor activities mentioned by the children into leisure activities, rule activities, and physical activities, as shown in Table 6.

Table 6. Types of children's outdoor activities. Source: Authors.

Types	Characteristics	Items
leisure activities	with the main purpose of leisure and recreation, close to nature	walking, shopping, market, dog walking, water play, plant interaction
Rule activities	need to follow the rules of engagement	square dance, sandbag throwing, hide-and-seek, hopscotch, skipping, jumping rope
physical activities	somewhat confrontational or competitive	running, skateboarding, table tennis, soccer, basketball, badminton, volleyball, climbing, biking, fitness, rollerblading

Overall, physical activities are the most frequently participated outdoor activities among children aged 10 to 12, followed by rule activities, while leisure activities occur the least, as illustrated in Figure 2. The outdoor activities that children frequently engage in are mainly running, badminton, jump rope, and basketball. A common feature of these activities is that they have low demands on the availability of specific facilities or space. Conversely, football, an activity that requires more specific facilities and space, is mainly played by children from School 1 and School 4. This may be attributed to the higher socio-economic status of families in School 1, enabling them to support their children's participation in activities that require dedicated sports facilities. Meanwhile, many children from School 4 live in rural areas where

the lower population density provides open spaces for them to play football. Additionally, urban children show a preference for outdoor activities such as table tennis, dog walking, and shopping, while rural children more frequently engage in activities unique to their environment, such as visiting markets or climbing.

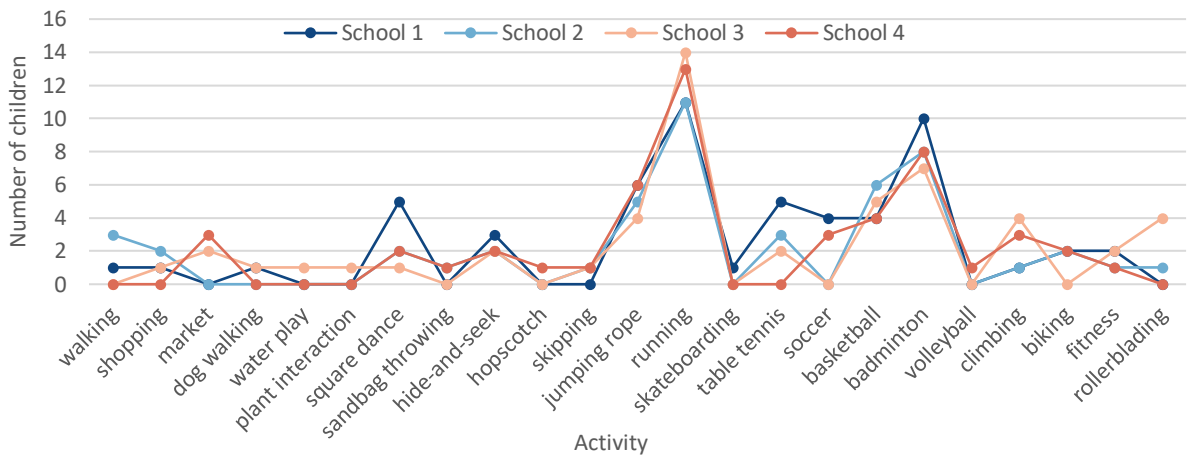


Figure 2. Use of the paragraphs. Source: Authors.

Participants' responses to the question "Where do you usually engage in outdoor activities?" ranked by frequency from highest to lowest include squares, parks, residential communities, streets, sports fields, primary schools, playgrounds, villages, nearby homes, yards, mall entrances, markets, open spaces, tourist attractions, riversides, sidewalks, botanical gardens, and supermarkets. The variety of locations for children's outdoor activities indicates that almost any space can serve as a venue for their play, which aligns with the randomness and unpredictability characteristic of children's activities. Children of all settlements consider squares and parks as their primary outdoor activity places. Rural children also often engage in outdoor activities in villages, yards, markets and open spaces. This reflects the limited types of activity spaces in rural areas and the relative lack of infrastructure but ample space for activities. It is noteworthy that streets, primary schools, mall entrances, sidewalks, and supermarkets—areas with high foot traffic and potential traffic safety risks—are also densely frequented by children for various activities

4. Discussion

This study employs cognitive maps and semi-structured interviews to explore the relationship between neighborhood environments, outdoor activities, and health from the perspective of 10-12 year old children living in different types of settlements. The findings suggest that (1) children of this age have the ability to understand the relationship between environment, activity, and health. Most children perceive a happy/healthy environment to be the same as an environment with frequent outdoor activities. Long periods of time spent indoors and a lack of outdoor activities may have a negative impact on children's physical and mental health, character, and behavior. (2) There is a strong link between children's perceived neighborhood environments and their outdoor activities and health. "Nodes" and "landmarks" are perceived as the main venues for outdoor activities, "paths" as the connections between these venues, while "natural elements" and "social elements" are environmental factors influencing outdoor activities. Together, these elements shape children's engagement in outdoor activities. (3) Children are involved in a wide range of outdoor activities. There are opportunities in different settlements to support outdoor activities that satisfy children. However, the types of activities actually carried out by children are often constrained by local environmental conditions. (4) A huge problem in the current neighborhood

environments is that children in different settlements face an imbalance in the allocation of resources. While urban children benefit from a wealth of activity resources, they also face safety challenges. In contrast, rural areas offer more favorable natural environments but are relatively lacking in activity resources. This imbalance may limit children's outdoor activities, and over time, may have adverse effects on their health.

Based on the above findings, the authors believe that more in-depth research is needed in the future in the following areas: (1) quantitative validation of the effect of environmental perceptions on children's outdoor activity and physical and mental health; (2) investigation of the dose-response relationship between environmental perception, outdoor activities, and children's physical and mental health; (3) construction of neighborhood environment evaluation system under the perspective of children's environment perception; and (4) examination of the mechanisms by which environmental perception affects children's physical and mental health, with outdoor activities serving as a mediating factor.

5. References

Alarasi, H., Martinez, J. and Amer, S. (2016) 'Children's perception of their city centre: a qualitative GIS methodological investigation in a Dutch city', *Children's Geographies*, 14(4), pp. 437–452. Available at: https://doi.org/10.1080/14733285.2015.1103836.

Dai, F. and Zhang, J.H. (2009) 'Survey methods in planning and design (5): The cognitive mapping method', *Chinese Landscape Architecture*, 25(3), pp. 98–102.

Guroglu, M. and Onder, D.E. (2016) 'Impacts of Different Physical Environments on Children's Playing Field Perception', in F. Uslu (ed.) 3RD INTERNATIONAL CONFERENCE ON EDUCATION AND SOCIAL SCIENCES (INTCESS 2016). *3rd International Conference on Education and Social Sciences (INTCESS)*, Istanbul: Int Organization Center Acad Research, pp. 413–421. Available at: https://webofscience.clarivate.cn/wos/woscc/full-record/WOS:000383785000052 (Accessed: 2 July 2024).

Han, X.L., Sternudd, C. and Zhao, W.Q. (2011) 'Progress in research on outdoor physical activities of urban children', *Human Geography*, 26(6), pp. 29–33. Available at: https://doi.org/10.13959/j.issn.1003-2398.2011.06.007.

Handan Municipal Bureau of Statistics (2024) *Statistical Bulletin on the National Economic and Social Development of Handan City in 2023*. Available at: https://www.hd.gov.cn/hdzfxxgk/gszbm/auto23694/202403/t20240322_2029056.html (Accessed: 28 September 2024).

Kurt, S.H. and Ozgun, O. (2023) 'Play Experiences and Perceptions of Young Children Living in Disadvantaged Socioeconomic and Cultural Contexts in Turkey', *Child Indicators Research*, 16(2), pp. 837–862. Available at: https://doi.org/10.1007/s12187-022-10000-2.

Lin, E.-Y. *et al*. (2023) 'The relationship between children's third-place play, parental neighbourhood perceptions, and children's physical activity and sedentary behaviour', *Children's Geographies*, 21(5), pp. 789–802. Available at: https://doi.org/10.1080/14733285.2022.2121913.

Liu, M.Y. *et al*. (2020) 'Survey and analysis of outdoor activity status among preschool children in Shanghai', *Chinese Journal of Child Health*, 28(6), pp. 609–612.

Lynch, K. (2001) *The Image of the City*. Beijing: Huaxia Publishing.

National Health Commission of the PRC (2020) 'Notice on the issuance of an implementation plan for the prevention and control of obesity in children and adolescents', [online]. Available at: http://www.nhc.gov.cn/cms-search/xxgk/getManuscriptXxgk.htm?id=9357ae09af9f4ba8850dacac5093e250 (Accessed: 28 September 2024).

Onyango-Ouma, W., Aagaard-Hansen, J. and Jensen, B.B. (2004) 'Changing concepts of health and illness among children of primary school age in Western Kenya', *Health Education Research*, 19(3), pp. 326–339. Available at: https://doi.org/10.1093/her/cyg034.

Piaget, J. and Inhelder, B. (1967) The child's conception of space. New York: WW Norton.

Pluhar, Z.F. *et al*. (2010) 'Representations of the relationship among physical activity, health and perceived living environment in Hungarian urban children's images', *Landscape and Urban Planning*, 95(4), pp. 151–160. Available at: https://doi.org/10.1016/j.landurbplan.2009.12.012.

Spilsbury, J.C., Korbin, J.E. and Coulton, C.J. (2009) 'Mapping Children's Neighborhood Perceptions: Implications for Child Indicators', *Child Indicators Research*, 2(2), pp. 111–131. Available at: https://doi.org/10.1007/s12187-009-9032-z.

Wang, D. and Han, X.L. (2012) 'Analysis of factors influencing the outdoor physical activity environment of children in urban villages in Beijing: A case study of Dayouzhuang and Saoziying neighborhoods', *Journal of Peking University (Natural Science)*, 48(5), pp. 841–847. Available at: https://doi.org/10.13209/j.0479-8023.2012.109.

Wang, G.Y. and Cheng, J. (2009) 'A comparative study of physical activity and health fitness among urban youth in China and Portugal: A case study of Shanghai and Braga', *Journal of Beijing Sport University*, 32(10), pp. 60–63. Available at: https://doi.org/10.19582/j.cnki.11-3785/g8.2009.10.018.

Wang, H.H. *et al*. (2009) 'A study on obesity among primary school students in Handan City', *Journal of Handan College*, 19(1), pp. 117–118.

Zhao, J.L. and Hou, J.F. (2020) 'Status of overweight and obesity among primary and secondary school students in She County, Handan City, and analysis of dietary behavior factors', *Practical Preventive Medicine*, 27(8), pp. 995–998.

Zhu, X.D. and Ye, C. (2022) '"An ideal home is just an ordinary home": An empirical analysis of place attachment among migrant children in Shanghai', *Human Geography*, 37(3), pp. 60–71, 109. Available at: https://doi.org/10.13959/j.issn.1003-2398.2022.03.007.

Research Paper

Artificial Intelligence (AI) in Urban and Territorial Development: Opportunities and Risks for decision-makers, planners and citizens

Ulrich GRAUTE, International Development and Governance Expert

Abstract

The paper documents recent research work and dialogues among ISOCARP members, academics and planners on the introduction, use and governance of artificial intelligence in urban and regional planning. In doing so it builds on Ulrich's production of a Policy briefing on AI in Urban Planning for the British Academy of Social Sciences (ACSS) and ISOCARP's #10 Cyber Agora on 19 June 2024 on the same subject which was curated by Tijana Tufek-Memisevic and Ulrich Graute. The paper also prepares the Urban Conversation on 'Ethical use of AI in Planning' on 11 October 2024 at ISOCARP's 60th World Planning Congress in Siena, Italy.

The central concept of modern AI is the intelligent and learning agent. AI experts are planning to make entities that are far more powerful than humans. Guiding question of the paper is: How do we ensure that they never have power over us? When talking about AI tech people use terms which immediately should draw the attention of social scientists: Artificial Intelligence, Large Language Models, Objectives, Reward Models, Change Perceptions, Decision-making, Uncertainty, Probability or Super Human Intelligence. Experts reflects also about the possibility that AI might be the end of humanity if not governed wisely. Some describe the ultimate goal of AI research as a system that needs no problem-specific engineering and can simply be asked to teach a molecular biology class or run a government.

It is of special interest to discuss AI in the context of urban planning as a highly complex, multi stakeholder dialogue and decision-making process. The paper looks eg at the 12 Guiding Principles of the International Guidelines on Urban and Territorial Planning IGUTP (adopted by the Governing Council of UN-Habitat in 2015) and puts the focus on those three of the principles most closely related to the planning process. Starting here the paper analyzes if AI will remain just technical tools, digital twins as assistants or will AI become a controlling factor in urban development limiting citizen rights? Research about the most effective use and the impacts of AI in planning is in an early stage and no final conclusions are available. Instead, the future of AI in planning can be described along the following three scenarios which will be presented and discussed:

1. Urban planning done by Artificial Intelligence and increasing control of life in cities

2. AI as technical tool and assistant of planners

3. AI as digital twin providing planners with a second eye

AI researchers are saying that AI will penetrate all spheres of life. Social scientists, politicians and the general public have to prepare for what that will mean for societies and political systems. Planners need to explore risks and opportunities of AI applications as technical tools, as co-pilots

that gradually gain more influence over our perceptions and actions or where it even may become a dominant tool for the control of cities. For citizens it will be even more important to get insights of the planning and decision-making process beginning with the way objectives and preferences are programmed into machines. The challenges in our world are so big and interrelated that we have to prevent a new cultural war with Luddites wrecking learning machines. Instead, we have to use wisely-governed AI to increase the much-needed problem-solving capacity of cities and beyond. This wise and ethical use will include government regulations but possibly also certifications for AI applications to ease the selection of qualified tools by Planners and City Administrations. Examples of governance like the AI Act of the European Commission will be discussed.

Keywords

Artificial Intelligence, urban planning, territorial development, risks and opportunities

1. The central concept of modern AI is the intelligent and learning agent

From ancient philosophical inquiries on human intellect to cutting-edge innovations, the quest to create intelligence has spanned the ages. The Term Artificial Intelligence was first used for a workshop held in Dartmouth (USA) in 1955. It began in a niche of the small number of AI researchers and it faced ups and downs. When talking today about Artificial Intelligence AI, tech people use terms which immediately should draw the attention also of social scientists: Artificial Intelligence, Large Language Models, reward models, change perceptions, decision-making or super human Intelligence.

Artificial Intelligence (AI) is rapidly becoming a pervasive aspect of the present and it is predicted by AI scientists like Stuart Russel of University of Berkeley, California to become the dominant technology of the future. Russel argues that *"We … are planning to make entities that are far more powerful than humans".* Unless these learning machines are governed wisely, the question is: "*How do we ensure that they never, ever have power over us?*".

Machines have long been shown to be beneficial insofar as their actions can be expected to achieve the objectives sought by human beings and not by machines with minds of their own. *"That's the ultimate goal of AI research: a system that needs no problem-specific engineering and can simply be asked to teach a molecular biology class or run a government."* The timeline and progress of this development is difficult to predict with certainty but we must plan for the possibility that machines will far exceed the human capacity for decision making in the real work. Gaining access to considerably greater intelligence would be the biggest event in human history. According to the AI scientist Stuart it is important to understand that *"It also might be the last event in human history and how to make sure that it is not."*

Russel remains *"fairly confident that we have some breathing space because there are several major breakthroughs needed between here and superintelligence, not just one. The problem of creating general-purpose, human-level AI is far from solved."* So, let's use the time to strike a careful balance between risk mitigation and harnessing AI's capabilities for public good and resilience.[1]

[1] Russel, St (2023) Human Compatible. AI and the Problem of Control. Dublin, Penguin Books.

2. The use of Artificial Intelligence in Urban Planning

The AI researcher and co-founder of two AI companies Mustafa Suleyman describes in his book 'The Coming Wave' AI and its expected power that will ultimately affect everyone alive and every generation that follows us.[2] He also discussed what he calls the Greatest human dilemma: '*that, sooner or later, a powerful generation of technology leads humanity towards either catastrophic or dystopian outcomes.*[3]'

In recent years, the use of Artificial Intelligence (AI) in Urban Planning became a subject of discussion and research by numerous planning experts and institutions.[4] In 2022, UN-Habitat analyzed the Risks, Applications and Governance of "AI and Cities"[5]. According to UN-Habitat *"The field of AI is growing at an unbridled pace. We are increasingly seeing AI systems leaving research settings to be deployed in almost all spheres of human activity. As a result, AI has the potential to profoundly transform the way our societies operate, including by supporting efforts on critical questions such as the climate crisis, public health, education and beyond. However, this ongoing societal transformation entails risks that must be addressed. There is an urgent need to develop responsible AI governance and practices across all scale levels of administrative and political organisations, in both the public and private sectors."*

The UN-Habitat report provides a first general framework on how to deploy AI responsibly in the context of cities and settlements. It is part of UN-Habitat's strategy for guiding local authorities in realizing a people-centered digital transformation process in their cities and settlements. But UN-Habitat has limited resources to study AI and therefore it is necessary to consider also other relevant literature which has been published since 2022.

For instance, Chris Chiancone, Chief Information Officer at the City of Carralton writes in his paper of 20 June 2023 'Revolutionizing Urban Planning with Generative AI: A new Era of Smart Cities'[6]: *"At its heart, Generative AI is a type of machine learning that crafts new data instances reflecting its training set. Picture a master artist who, rather than simply duplicating a scene, employs their creativity to produce unique, lifelike outputs from a given input. That's the magic of Generative AI, but in the realm of data. It's the digital world's virtuoso, wielding algorithms and computational power instead of brushes and pigments".*

Urban planning is a multifaceted field demanding the integration and scrutiny of a vast array of data. Traditionally, urban planners have had to manually sift through this data and make informed forecasts about future trends. This method is not only labor-intensive but also susceptible to human error and bias. Generative AI, with its prowess in analyzing large datasets and crafting realistic urban blueprints, provides a bridge to these hurdles. Furthermore, Generative AI can forecast urban expansion and optimize infrastructure planning.

The streets of InfiniCity, a model 3D city synthesis built using AI has as a goal to "automatically recreate lifelike real-world cities", generated entirely from the imagination of a synthetic mind.[7] According to Patrick

[2] Mustafa Suleyman with Michael Bhaskar (2023) The Coming Wave. London, The Bodley Head.
[3] Sukeyman, page 11.
[4] Pellegrin, J, Colnot, L & Delponte, L 2021, Research for REGI Committee – Artificial Intelligence and Urban Development, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels.
[5] https://unhabitat.org/ai-cities-risks-applications-and-governance.
[6] https://www.linkedin.com/pulse/revolutionizing-urban-planning-generative-ai-new-era-smart-chiancone/
[7] https://hubert0527.github.io/infinicity/

Sission the author of the Bloomberg paper "What it looks like When AI Designs a City" [8] it's sort of a 3D vision of a ChatGPT-authored term paper that descends into made-up quotations and awkward grammar. The organic logic of real-world cities can't quite be reduced to a SimCity-esque platform just yet. As mesmerizing as InitiniCity looks it is not very much appealing to live there. Several fictional examples created via programs like Midjourney can be found online. Meanwhile, city officials are beginning to wrestle with the relevance — and risk — of AI in urban governance. For a more specific analysis of the use of Generative AI in Urban Governance see Nelson, RJ. Naing, KM. Beroche, H. 2023. Generative AI for Urban Governance. Urban AI.[9]

In a nutshell, for Chiancone Generative AI brings a unique fusion of creativity and efficiency to urban planning. It's akin to having a supercharged assistant that can process numbers, analyze data, generate models, and make predictions at a pace and scale that humans simply can't compete with. All of this is done with the aim of creating more efficient, habitable, and sustainable cities.

The intersection of Generative AI and urban planning is a fascinating blend of technology and creativity. There are risks including ethical and data privacy considerations and there are technical limitations. Ensuring equitable outcomes, protecting individual privacy, and overcoming technical limitations are crucial tasks that require careful attention and thoughtful solutions. If well governed, it offers a potent tool for managing the complexity of urban environments, leading to smarter, more sustainable, and more equitable cities with a high quality of life. Cities that use digital technologies to enhance performance and wellbeing can pave their way for the creation of 'smart cities'.

AI as developed until now is useful to create impressionistic image and artwork to facility imagination but it doesn't generate blueprints. Patrick Sission describes that Zach Katz, who has deployed the technology to create more utopian versions of cities, is less concerned about the potential misuse of AI; to him, the explosion of AI-aided urban imagery reflects something healthier — an appetite for better places, and an avid desire to see cities remade with a little more intelligence.

Daniel Podrasa, Peter Zeile and Markus Nepp of the Karlsruhe Institute of Technology analyze in their paper "Machine learning for land Use Scenarios and Urban Design".[10] They discuss supervised and unsupervised machine learning algorithms and conclude that a supervised learning method, as they discussed it along the example of Artificial Neural Network for classification, can generate land-use scenarios and these can be used as a design basis for Generative urban design. However, the training of the Artificial Neural Network and the description for the land use for generating the training data is still a relatively time-consuming matter. And so it is not surprising that these authors too remain cautious: *"The proposed concept is not intended to replace the actual planning work in the sense of plan elaboration and plan realization; rather, we see it as a useful addition to be able to "explore" variants more quickly, better and more transparently and to be able to better grasp not only qualitative design work but also quantitative urban development designs. Used sensibly, it helps to be able to quickly examine variants at an early stage. Artificial intelligence is not intended to replace the planner's profession, but to better prepare the basis for decision-making."*

[8] https://www.bloomberg.com/news/features/2023-09-16/ai-invades-urban-planning-and-design-with-mixed-results
[9] https://urbanai.fr/wp-content/uploads/2023/10/Generative-AI-Report.pdf
[10] https://repository.corp.at/777/

3. Overview

Artificial Intelligence (AI) presents global societal challenges for researchers and policymakers. Given the highly complex, multi-stakeholder dialogue and decision-making processes involved, the application of AI in the context of urban planning is of particular interest for researchers from a wide range of hybrid disciplines spanning physical and human geography, political economy, public administration, socio-legal studies, social policy and anthropology,. Three of the twelve principles laid down in the International Guidelines on Urban and Territorial Planning IGUTP (IGUTP)adopted by the Governing Council of The United Nations Human Settlement Programme UN-Habitat in 2015, define the urban planning process in the following terms:

The Guidelines:
12 Key Planning Principles with 114 Recommendations

To orient and guide decision-makers in developing or reviewing urban and territorial policies, plans and designs through an integrated planning approach, the Guidelines are structured along 12 key planning principles and 114 recommendations in 5 main sections and addressed to the 4 stakeholder groups. An abridged version of the 12 guiding principles can be found below.

	URBAN POLICY AND GOVERNANCE
1	Urban and Territorial Planning is an integrative and participatory decision-making process that addresses competing interests and is linked to a shared vision, an overall development strategy and national, regional and local urban policies.
2	Urban and Territorial Planning promotes local democracy, participation and inclusion, transparency and accountability.
	URBAN AND TERRITORIAL PLANNING FOR SUSTAINABLE DEVELOPMENT
	Urban and Territorial Planning and Social Development
3	Urban and Territorial Planning primarily aims to realize adequate standards of living and working conditions for all through social inclusion and cohesion, recognizing the distinct needs of various groups.
4	Urban and Territorial Planning is a precondition for a better quality of life and successful globalization processes that respect cultural heritages and cultural diversity.
	Urban and Territorial Planning and Sustained Economic Growth
5	Urban and Territorial Planning provides an enabling framework for new economic opportunities, regulation of land and housing markets and timely provision of adequate infrastructure and basic services.
6	Urban and Territorial Planning provides a mechanism to ensure that sustained economic growth, social development and environmental sustainability go hand in hand to promote better connectivity at all territorial levels.
	Urban and Territorial Planning and the Environment
7	Urban and Territorial Planning provides a spatial framework to protect and manage the natural and built environment of cities and territories, including their biodiversity, land and natural resources.
8	Urban and Territorial Planning contributes to increased human security by strengthening environmental and socioeconomic resilience, enhancing mitigation of, and adaptation to, climate change.
	URBAN AND TERRITORIAL PLANNING COMPONENTS
9	Urban and Territorial Planning is a continuous and iterative process, grounded in enforceable regulations, that aims to promote more compact cities and synergies between territories.
10	Urban and Territorial Planning aims to facilitate and articulate political decisions based on different scenarios. It translates those decisions into actions that will transform the physical and social space and will support the development of integrated cities and territories.
	IMPLEMENTATION AND MONITORING URBAN AND TERRITORIAL PLANNING
11	Implementation of spatial policies and plans requires political leadership, appropriate legal and institutional frameworks, efficient urban management, and improved coordination, consensus-building approaches to respond coherently and effectively to current and future challenges.
12	Effective implementation and evaluation of Urban and Territorial planning requires continuous monitoring, periodic adjustments and sufficient capacities at all levels, as well as sustainable financial mechanisms and technologies.

Figure 1. Summary of the 12 principles of urban and territorial development as described in the IG-UTP

Principle 1 – Urban and Territorial Planning is an integrative and participatory decision-making process that addresses competing interests and is linked to a shared vision, an overall development strategy and national, regional and local urban policies.

Principle 9 – Urban and Territorial Planning is a continuous and iterative process, grounded in enforceable regulations, that aims to promote more compact cities and synergies between territories.

Principle 10 – Urban and Territorial Planning aims to facilitate and articulate political decisions based on different scenarios. It translates those decisions into actions that will transform the physical and social space and will support the development of integrated cities and territories.

3.1. How do we ensure that machine know and implement our objectives?

The many persons and institutions engaged in or affected by a plan often pursue in planning processes own interests, their priorities may shift, new issues and policies may emerge and new actors may join constellations and that again with their specific motivations, interests and capabilities. Nobody in the process is likely to have full information, and no single person is 100 per cent rational in his or her perceptions and actions. Very little knowledge is certain, especially regarding the future. These limitations make planning a complex enterprise. They explain why its processes often generate suboptimal results, why constant plan reviewing is necessary, and why the authors of the IGUTP understand urban and territorial planning ultimately as a continuous and iterative decision-making process. Inevitably, machines will be uncertain about our objectives – after all, we are uncertain about them ourselves.

In this context, urban planners ask: Should AI be seen just a technical tool, a digital twin or even a controlling factor in city planning? And how about the soft power of AI? In my own network, more and more colleagues use generative AI daily. They enter prompts in ChatGPT, the machine answers in seconds, they submit a new prompt, the machine answers again while it learns also from the first answer, and so on, giving the interplay a conversational character. Is this a purely technical use of a new tool or does the learning machine gradually gain more influence on users? Of course, if I ask them, they all claim to use it strictly as a technical tool and keep full control. Well, I tried it and asked ChatGPT about its luring power. This is, what the machine answered: *"The luring power of AI lies in its transformative potential across various domains. By offering significant economic, technological, and social benefits, AI attracts a wide range of stakeholders, driving investment, collaboration, and innovation on a global scale."* So, even ChatGPT admits its soft power. Certainly, more and more companies use generative AI to improve 'client satisfaction' and drive-up sales. To limit such risks the governance framework of AI can produce only part of the answer. What is needed in addition, is capacity building for all citizens. AI experts predict that AI will affect all spheres of life. Thus, everybody should learn how to draft prompts, read and cross-check the answers, and more generally speaking, interact with learning machines as new actors which are likely to try to influence our lives.

4. Key Evidence

Currently, no general-purpose AI urban planning programme exists that does everything. Instead, developers are building and experimenting with different types of agent programmes designed to address

different types of problems. Three scenarios can be identified to describe the positioning of AI in future urban planning:

1. **Urban planning by AI increases control over life in cities**

In the worst-case scenario, AI will be programmed ignoring the objectives and preferences of citizens. By targeting the lowest common denominator, it may instead lead to lower standards of quality of life and levels of urban sustainability, while surveillance and control might be added to the objectives of AI applications as major planning objectives, threatening to reduce or destroy freedoms of citizens.

2. **AI serves as a technical tool and assistant for planners**

This second configuration is often presented as the preferred scenario. Here, AI is strictly limited to functioning as a technical tool without power over humans. In this case, AI applications are used to fill data gaps and to write intelligent concept papers that generate problem trees and shorten the time needed to generate ideas. AI applications are given access to all applicable national and local visions, policies, laws, rules and regulations, including building codes, design guidelines, the United Nations' Sustainable Development Goals, the objectives of stakeholders and budgetary information, as well as best practice cases from other cities. Based on this cumulative body of knowledge, AI applications can, and increasingly often already do, generate design proposals, and textual descriptions of plans. They may even suggest how to reconcile competing interests, making it difficult to tell whether they are created by a human being or by AI. It remains to be seen if these technical tools do not develop the above-mentioned soft power if their recommendations become increasingly often trusted.

3. **AI serves as a digital twin providing planners with alternative options**

Machines may be far more capable than humans but are likely to remain far from perfect. AI as a digital twin can support planning departments to keep processes on track. However, if humans put the wrong objectives into a machine that is able to learn and is more intelligent than they are, it will achieve the objective regardless of any unwanted and unintended consequences. As planners get used to data and recommendations from AI, it can gradually gain influence over humans and become a co-pilot or at least a digital twin in planning rather than being treated simply as a tool.

5. Policy Contexts

In urban planning, the process takes years from the development of operational plans, through to their implementation and evaluation. We are only beginning to understand generative AI's capabilities and risks and the long-term impact on AI on the entire process remains to be seen. But the above three scenarios have already been adopted by urban planners in advanced societies: skeptics who are cautious and largely opposed to the development of new technologies; optimists who are convinced that AI will be beneficial, if used exclusively as technical tools, unable to gain control over humans; realists who are interested in the benefits of AI but who are also aware of the risks.

The success or otherwise of the introduction of new technologies is found to be dependent on a mix of contextual factors. Not every city has the best equipped planning department or the technical resources for sound planning. This situation often arises in fast-urbanising countries in the Global South, in cities with high numbers of foreign refugees or internally displaced persons. In addition, the degree of authority for urban planning delegated to cities varies a lot between countries and even where provision for AI exists, political decision-makers may use them as a political tool by including biases or discriminatory patterns in their outcomes.

Given the vast uncertainty about the nature, impact, and speed of developments in generative AI, IMF experts suggested in June 2024 that governments should take an agile approach that prepares them for both business as usual and highly disruptive scenarios.[11]

6. Recommendations by the Academy of Social Sciences (ACSS, UK)

AI researchers are predicting that AI will progressively penetrate all spheres of life. Research into the most effective use and the impacts of AI in the urban planning process remains at an early stage, and no final conclusions are available. To prepare for the challenges and risks associated with AI I made recommendations for a policy briefing of the British Academy of Social Sciences which I outline a bit more in detail in the following[12]:

- **Social scientists, technology developers, politicians, and the general public must be prepared to anticipate and adapt to the impact of AI on whole societies and political systems**; public financing cannot focus on AI development alone but needs to provide financial support also for the transition in affected sectors including employment and the need to train people for emerging new jobs. Generally speaking, politicians need to prepare for both, business as usual (in case that AI generates less change than currently expected) and major disruption which require interventions to rebalance economic, social, and political development. Current discussions about weather AI is mainly a hype or if it brings a real transformation is a typical part of the early phases in technological innovation waves. It's not clear yet if generative AI is an invention or rather a discovery. Electricity was discovered and only then began the invention of applications. The discovery of electricity didn't make money but the invention of the light bulb and thousands of other electricity-based tools did. In a similar way it may be that the ChatGPT -magically as it works- may not be the big profit generator. It remains to be seen which AI-based inventions generates profits investors hope for. And along these developments societal impacts need to be analyzed and the governance framework adapted.
- **Planners need to explore the risks and opportunities of AI applications as technical tools, and as co-pilots that are capable of gaining influence over perceptions and actions of humans, or of becoming a dominant tool for the control of cities and citizens' lives**; opportunities are mostly related to enhancing and fastening planning processes including scenario development and problem solving; in addition AI applications can support planning and development across policy levels eg in achieving global goals including the SDG of the 2030 Agenda and of the Paris Agreement on climate change; risks are related to individual tools and steps in the planning process but the biggest risk is that human creativity and participation is substituted by technology while societal, cultural and other impacts may be externalized from the planning process; this can be prevented by assuring transparency and participation in each step of the planning process.
- **To keep planning transparent, citizens need to be given insights into planning and decision-making processes beginning with the way objectives and preferences are programmed into machines**; the AI literacy of the public needs to be increased in general and planning is a good field to explore this; citizen can be included to the development of prompts and tools and then into the discussion of scenarios developed by AI; this may become even a crucial step to cross-check,

[11] https://www.imf.org/en/Publications/Staff-Discussion-Notes/Issues/2024/06/11/Broadening-the-Gains-from-Generative-AI-The-Role-of-Fiscal-Policies-549639
[12] https://acss.org.uk/publications/ai-in-urban-planning-risks-and-opportunities/

correct AI recommendation through citizen; especially in the local context it is likely that knowledge and experience of local people remains crucial for context specific planning. I personally doubt that all citizens want to be personally involved in all steps of planning processes. Instead, most are likely to be happy with a system they can trust and which is transparent enough to be monitored and controlled regularly and whenever needed. Of course, when people start trusting learning machines the risk arises that the machine becomes a (co-)pilot controlling and steering of our life. To prevent that the governance framework of AI has to include mechanisms that ensure that human don't lose control. **Therefore, it is important already now to include questions about the use and impact of AI implications into monitoring and evaluation mechanisms of all policies, programmes and projects. This way it will be possible to better track the impact AI applications gain as technical tools, co-pilot or even dominant factor in planning and development processes.**

- **Given the magnitude, complexity, and interrelatedness of the challenges facing society, researchers must prevent a new culture war with Luddites wrecking learning machines**; excluding the society from planning could generate major frustration and resistance against AI-generated plans and their implementation and this could hamper or even stop development; learning from disruption of past technological revolution should include accompanying measures to soften hardships due to negative impacts on employment, the provision of training and capacity building to provide workers in new and growing employment fields and, again, information of the public and an open dialogue help to generate understanding and support for the transformation.
- **Instead, scientists and policymakers across the world should learn how to use wisely governed AI to increase the much-needed problem-solving capacity of cities and beyond;** in a similar way as learning machines often apply a conversational approach should developers, planners, politicians, and civil society also launch and ongoing dialogue on AI in planning to assure that the risks of AI are minimized while the opportunities are exploited. Keeping control over learning machines and making their recommendations transparent will be essential to assure that no one is left behind by AI managed systems and that the entire society will benefit from the new technology.

7. Need for an intensified dialogue on AI and its governance

We are on the brink of a wave of technological revolution that could jumpstart innovation and productivity, boost global growth and raise incomes around the world. Yet it could also replace jobs and deepen inequality. The IMF is expecting tat 60 of jobs in advanced economies may be impacted by I. In emerging markets and low-income countries, AI exposure is expected to be 40 percent and 26 percent, respectively. What impact would that gain on the shape of our cities? There are many uncertainties but the International Monetary Fund (IMF) concludes "The AI era is upon us, and it is still within our power to ensure it brings prosperity for all." [13] As one of its related activities the IMF assessed the level of AI preparedness across 174 countries, based on a rich set of macro-structural indicators that cover the countries' digital infrastructure, human capital and labor market policies, innovation and economic integration, and regulation and ethics. The index includes several perception-based indicators and the IMF states that

[13] https://www.imf.org/en/Blogs/Articles/2024/01/14/ai-will-transform-the-global-economy-lets-make-sure-it-benefits-humanity https://www.imf.org/en/Blogs/Articles/2024/01/14/ai-will-transform-the-global-economy-lets-make-sure-it-benefits-humanity

measuring SI preparedness is challenging. However, the Index gives a clear indication that there is already a preparedness gap that might widen already existing inequalities across the world.

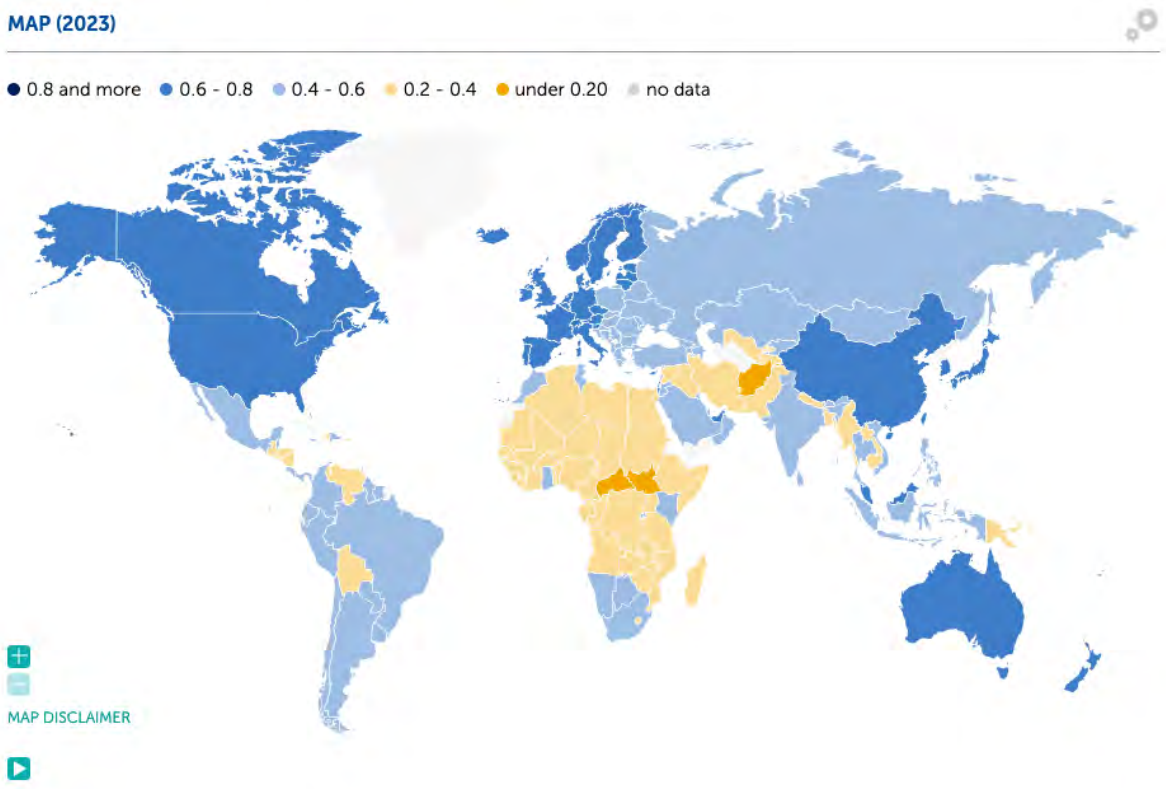


Figure 2. AI Preparedness Index of the IMF[14]

Considering the increasing urbanization in the world it will be important that urban and regional planners intensify their dialogue on AI in Planning and try to better understand what may be the footprint of AI in cities.

On 19 June ISOCARP organized its 10th Cyber Agora, an online workshop to discuss the use of AI in the context of urban and territorial planning and to do this from a planer's perspective. The primary learning objective of the Cyber Agora was to achieve a better understanding of opportunities and challenges related to the use of selected tools of AI. This was done through the presentation and discussion of examples of AI use. The successful session was addressed to a professional audience with an academic and/or practitioners background in urban and territorial planning. [15]

[14] https://www.imf.org/external/datamapper/AI_PI@AIPI/ADVEC/EME/LIC

[15] More information on the Cyber Agora and the video of the session are available on the ISOCARP website https://isocarp.org/news/74336/

Figure 3. Post of the #10 ISOCARP Cyber Agora on 19 June 2024

The fruitful dialogue will be continued at the 60th ISOCARP World Planning Congress in Siena, Italy on 11 October in form of a Special Session as Urban Conversation on 'Ethical use of Artificial Intelligence in Planning'.

Figure 4. Moderator and Speaker expected at the Urban Conversation on 11 October 2024 at the 60th ISOCARP World Planning Congress in Siena, Italy

Guiding questions will include

- AI in Urban Planning: Navigating the Intersection of Technology and Values – AI as a technical tool and/or as co-pilot in planning New Cities and inclusive economic development.
- Including AI in existing planning, monitoring and evaluation systems and processes and the requirement eg of a regulatory framework and capacity-building.
- What impact will AI gain on the shape of future cities?
- ISOCARP and the new wave of technological innovation.

Please join the discuss and related research in Siena and afterwards.

8. References

Academy of Social Sciences AcSS (2024) AI in urban planning: risks and opportunities. Policy Briefing.

https://acss.org.uk/publications/ai-in-urban-planning-risks-and-opportunities/ (accessed on 1 October 2024).

Federal Office for Information Security (2024) Generative AI Models. Opportunities and Risks for Industry and Authorities. Bonn, Federal Office for Information Security.

Georgieva, Kristalina (2024) AI Will Transform the Global Economy. Let's Make Sure It Benefits Humanity. IMF Blog, January 14, 2024. https://www.imf.org/en/Blogs/Articles/2024/01/14/ai-will-transform-the-global-economy-lets-make-sure-it-benefits-humanity (accessed on 1 October 2024).

IMF (2024) Broadening the Gains from Generative AI: The Role of Fiscal Policies. Staff Discussion Notes No. 2024/002 of June 17, 2024. Fernanda Brollo, Era Dabla-Norris, Ruud de Mooij, Daniel Garcia-Macia, Tibor Hanappi, Li Liu, Anh D. M. Nguyen. Washington, International Monetary Fund.

Nelson, RJ. Naing, KM. Beroche, H. 2023. Generative AI for Urban Governan. Paris, Urban AI.

OECD, UN-Habitat, UNOPS (2021), Global State of National Urban Policy 2021: Achieving Sustainable Development Goals and Delivering Climate Action, OECD Publishing, Paris, https://doi.org/10.1787/96eee083-en (accessed on 1 October 2024).

Podrasa, Daniel and Zeile, Peter and Neppl, Markus (2021) Machine Learning for Land Use Scenarios and Urban Design. CITIES 20.50 – Creating Habitats for the 3rd Millennium: Smart – Sustainable – Climate Neutral. Proceedings of REAL CORP 2021, 26th International Conference on Urban Development, Regional Planning and Information Society. pp. 489-498. ISSN 2521-3938.

Pellegrin, J, Colnot, L & Delponte, L (2021) Research for REGI Committee – Artificial Intelligence and Urban Development, European Parliament, Policy Department for Structural and Cohesion Policies, Brussels. European Commission.

Russel, St (2023) Human Compatible. AI and the Problem of Control. Dublin, Penguin Books.

Sanchez, Thomas, Brenman M and Xinyue Ye (2024) The Ethical Concerns of Artificial Intelligence in Urban Planning. Journal of the American Planning Association. 1-14, https://www.tandfonline.com/doi/full/10.1080/01944363.2024.2355305 (accessed on 1 October 2024).

Simon, Patrick (2023) What It Looks Like When AI Designs a City. Bloomberg. 16 September 2023 at 14:00 CEST. https://www.bloomberg.com/news/features/2023-09-16/ai-invades-urban-planning-and-design-with-mixed-results (accessed on 1 October 2024).

Suleyman, Mustafa with Michael Bhaskar (2023) The Coming Wave. London, The Bodley Head.

UNESCO (2022) Recommendation pf the Ethics of AI. Paris, United Nations Educational, Scientific and Cultural Organization.

UN-Habitat (2018) International Guidelines on Urban and territorial Planning. Handbook. Nairobi, United Nations Human Settlement Programme.

United Nations, AI Advisory Body (2024): Governing AI for Humanity. Final Report. New York United Nations.

UN-Habitat and Mila (2022) AI and Cities. Risks, Applications and Governance. Nairobi, United Nations Human Settlement Programme.

397Case Study Report

From Galleries to Screens: The Digitalization of Exhibition Spaces

Melis YILMAZ, Istanbul Technical University, Türkiye

Abstract

The significance of cyberspace has been amplified by the widespread use of technology. Digital 2023 Report demonstrates that the average internet user now spends approx. 6.5 hours per day using the internet in total equals nearly 48 hours (2 full days) per week online. This study explores strategies for digitizing art venues and creating virtual exhibition spaces, illustrating how these innovations revitalize urban environments, democratize art access, and foster public engagement through case studies. It investigates integrating digital tools into urban planning to create resilient, inclusive, and innovative cities. Within the scope of the research, the cases of ''Sanatorium'' which transfers its existing exhibition space into digital space, ''Akademililer'' which creates a virtual exhibition apart from its physical space, and ''Afterwork'' initiative which exhibits art via only virtual exhibition spaces were investigated via interviews conducted with the authorities of the initiatives. According to the interviews, despite their broad accessibility and lasting presence, virtual exhibitions are seen as supplementary rather than replacements, as key figures emphasize the irreplaceable sensory experience of physical art spaces.

Keywords

Public art, Virtual exhibition spaces, Accessibility of art, Digital transformation

1. Introduction

The fact that 67% of the world's population are internet users is a testimony to the role of the internet in today's society (Statista, 2023). Digital 2024 Report demonstrates that the average internet user now spends approx. The overall amount of time spent online across all devices is 6 hours 40 minutes each day, approx. 45 hours which equals to almost two full days in a week. The broad use of the internet has inevitably increased the importance of cyberspace. The concept of public space has been extensively researched through the years, and the nexus between Arendt (1958), Habermas (1989) and Sennett (2018) definitions is in the unifying capacity of public space, creating dialog and, thus, strengthening social relations. In addition, Sennett (2018) expands this concept by stating that the definition of public space should not be limited to physical spaces only, but should also include cyberspace. Public art, defined as art displayed in spaces accessible to all outside the conventional venues (Miles, 1997; Kwon, 2002; Cartiere & Willis, 2008; Knight, 2008), aligns with these contemporary understandings of public space. Based on these definitions, artworks displayed on virtual exhibitions, accessible to anyone with a technological device were considered as public art as well within the scope of this study. In addition; as in most industries, coronavirus and pandemic-related restrictions have also affected the view and accessibility of art. After the World

Health Organization (WHO) declared COVID-19 a pandemic on March 11, 2020 (Bao, Sun, Meng, Shi, Lu; 2020); and like many European countries, the Turkish government also imposed a curfew as of March 22, 2020. The authorized hours varied according to the regions and the contraction rates of the infection during the pandemic (Arpacıoğlu, Yalçın, Türkmenoğlu, Ünübol & Çelebi Çakıroğlu; 2021). The restriction of access to physical art spaces has led to the rise of digital exhibitions which allow people to continue to access art.

This study explores methods for digitizing art venues and creating virtual exhibitions, examining their impact on art accessibility, especially considering the widespread use of the internet. Within the scope of the study, two types of digitalization were identified: first, converting physical exhibition spaces into digital space, and second, directly creating virtual exhibition spaces without physical constraints. The first type involves the three-dimensional modeling of the exhibition space through programs. The Kuula platform used to create 3D, 360 virtual tours for various businesses can be given as an example tool for creating the digital twin of exhibition spaces. The platform was founded in 2016 in Los Angeles and used by over 300,000 professionals, artists, and companies. It was also used to transfer the Sanatorium, which will be examined within the scope of the study, to digital space.[1] NFT exhibitions, which started to be encountered frequently in web sources, especially in 2021 and 2022 can be given as an example of the second type. Apart from the Metaverse universe, virtual exhibition spaces can be created through some platforms on the internet such as Oarbt and ArtSteps. These platforms can be used individually without a fee. In Oarbt, 3D stores can be created besides exhibition spaces, and everything placed in a 3D store can be sold through Shopify.[2] Three essential processes are involved in creating a 3D virtual art exhibition: choosing or designing an exhibition venue, uploading and placing artworks and their details, and then sharing the finished display with the public. In addition; ''ArtSteps'' which can also be accessed via Google Play and App Store as well as the website, provides private web space, custom 3D design, curation, and 3D virtual event services. Under the custom 3D design service, they provide a virtual photorealistic replica of an existing space, exclusive 3D creation of an imagined space, and modification of a pre-designed gallery space on ArtSteps. To create a virtual version of an existing exhibition space, floorplans, section or elevation drawings, and pictures of the space should be submitted.[3]

Within the scope of the study; 3 case studies from Istanbul, Türkiye were analyzed: ''Akademililer'', representing the creation of a virtual exhibition apart from their physical exhibition space; ''Sanatorium'', representing the digitalization of existing exhibition space; "Afterwork", representing the creation of a virtual exhibition without a physical exhibition space. Interviews with officials from these institutions provided insights into their experiences and views on the digitalization process. Interviews held with the officials of 3 initiatives via e-mail were about the institutions' view of the digitization of the exhibition spaces and process of the digitalization (see Appendix A).

[1] https://kuula.co/about
[2] https://www.oarbt.com
[3] https://www.artsteps.com

2. The Case of ''Akademililer'', ''Sanatorium'' and ''Afterworks''

Akademililer Art Center located in Beyoğlu, Istanbul was founded by Neslihan and Resul Aytemür in 1998 to bring together the leading names of Turkish Painting Art and it includes a gallery space, workshops, and workspaces. While the art center was closed due to the Coronavirus epidemic, an exhibition on a virtual environment was created with 49 paintings of various artists. The first virtual exhibition of the art center ''Sanata Devam'' (Continue to Art) was opened to access in April 2020 and could be visited until May 18, 2020. The exhibition consisted of artworks produced by the painters who continued to produce in the quarantine period in their homes, away from their workshops. It is stated on the website that the process of the pandemic has left unforgettable effects on people and art can be considered as ''a savior'', ''a way of continuing life'', ''a form of monumental recording'' during important historical process.[4]

Figure 1. The street view of Akademililer, Beyoğlu. Source: Goggle Maps.

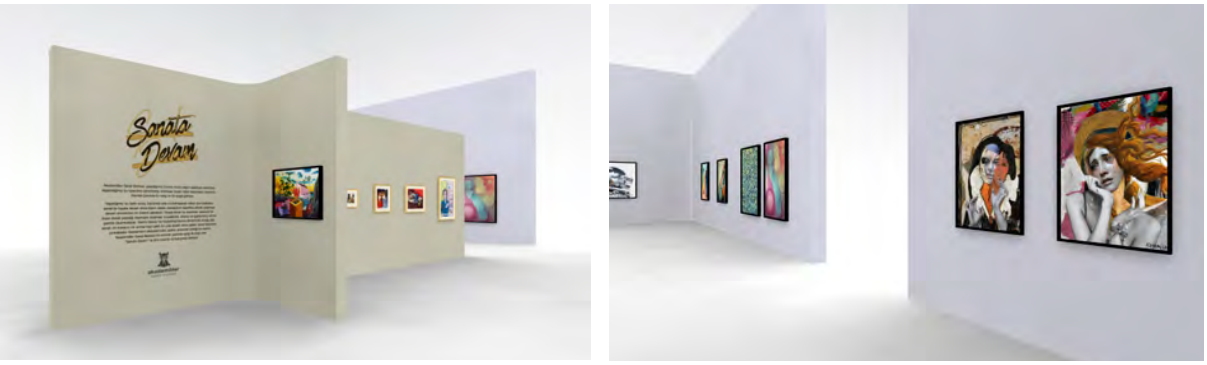


Figure 2. Sanata Devam (Continue to Art) Virtual Exhibition. Source: https://www.sanatorium.com.tr/en/about.

[4] http://akademililer.com/

Sanatorium located in Karaköy, Istanbul was founded by eight artists as an initiative whose foundations were dated back to 2009. Later on, it evolved into a gallery and opened in September 2011 as a gallery space with the continuation of the initiative spirit. has carried out many exhibitions both at the national and international level.[5]

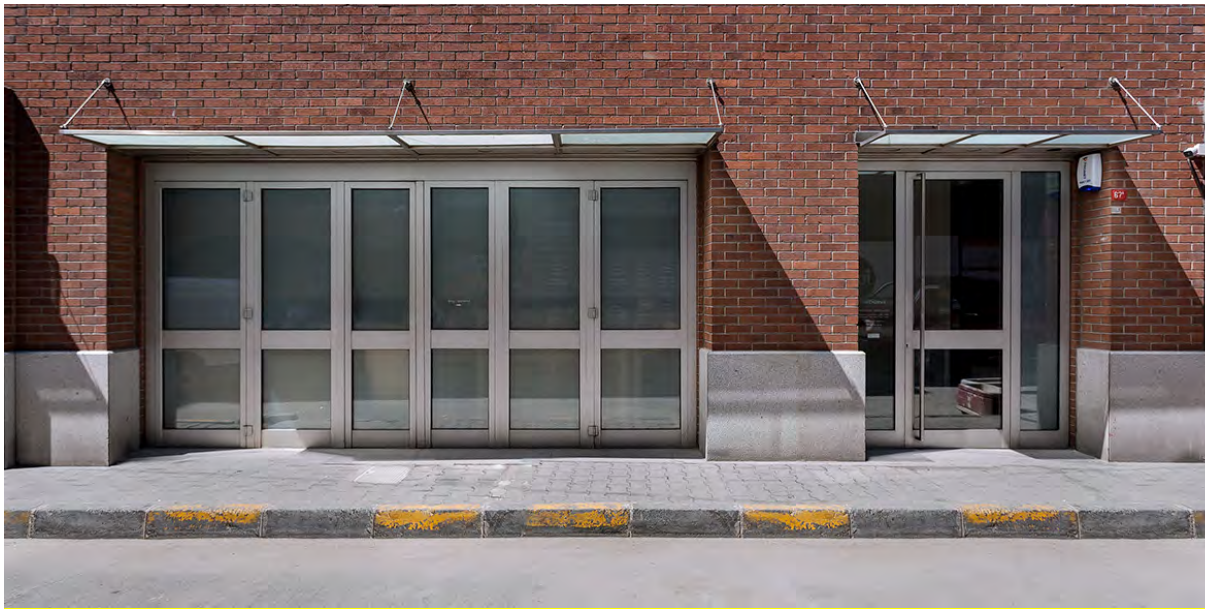


Figure 3. The view of Sanatorium, Karaköy. Source: https://www.sanatorium.com.tr/en/about

Sanatorium has 8 exhibitions transferred to digital space in a platform called Kuula which enables any business to create 3D 360 virtual tours. Among these 8 exhibitions, the exhibition of Berkay Tuncay titled "Human, how strange, how vulgar, such a masterpiece and yet so primitive", which was published 4 years ago in the platform, reached the most viewer (5,097 views). The last exhibition published on the platform was Christiane Peschhek's Oasis, which received only 99 views in 2 years.

Figure 4. ''Human, how strange, how vulgar, such a masterpiece and yet so primitive'' Virtual Exhibition, Berkay Tuncay. Source: https://kuula.co/post/7F4Wg

[5] https://www.sanatorium.com.tr/en

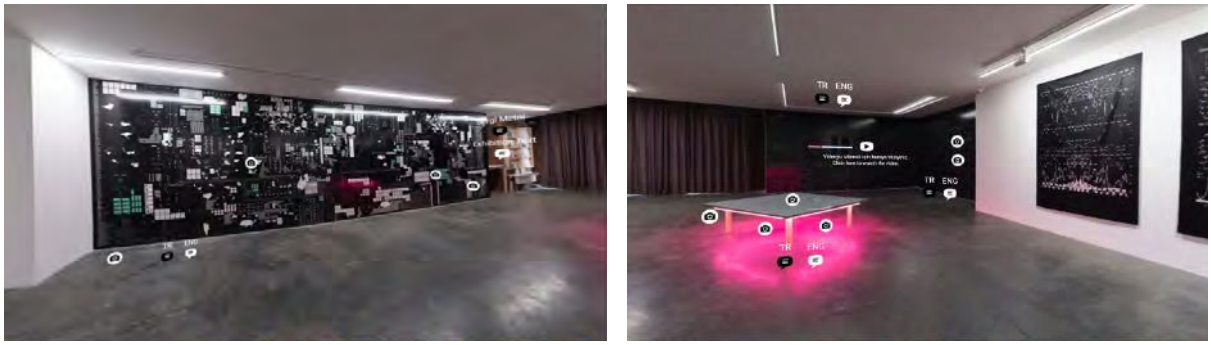


Figure 5. ''The Gaming Room'' Virtual Exhibiton, Ludovic Bernhardt. Source: (https://kuula.co/post/Nfk3F

Afterwork is an initiative which brings together arts, digital design, video, photography projects, and creative ideas and it continues to create through collaborations and volunteer projects.[6] In 2020, Afterwork created two online exhibitions called "Temas"(Contact) and "New Normal" in 3D, graphics and illustrations. While the first exhibition ''Temas'' includes works of 7 artists and initiatives, ''New Normal'' which is a more comprehensive project includes work of 20 artists. Both exhibition is still available on their site.

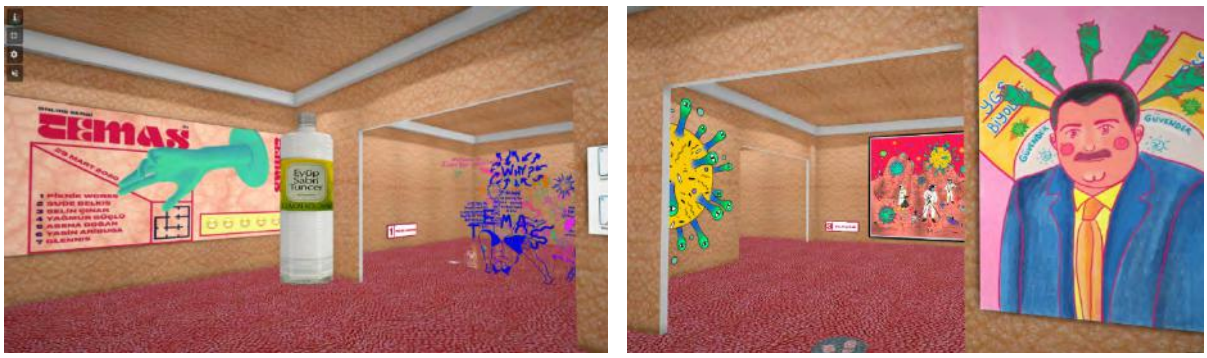


Figure 6. ''Temas'' Virtual Exhibiton, Afterwork. Source: https://afterwork.house/sergi/

Figure 7. ''New Normal'' Vitual Exhibition, Afterwork. Source: https://afterwork.house/newnormal/

[6] https://afterwork.house/about-us/

3. Interview Results

Within the scope of this study, interviews were held with the Coordinator of Akademililer, Emre Aytemur; the Exhibitions and Communications Specialist of Sanatorium, Melih Aydemir, and the Creative Directors of Afterwork, Yasin Arıbuğa & Sude Belkıs.

The Coordinator of Akademililer, Aytemur stated that he had not come across with the virtual exhibition in Turkey earlier; upon a German friend telling him that there are virtual exhibitions in Germany, created a virtual exhibition via the Kunstmatrix platform. On the other hand; Aydemir was familiar with the Kuula platform because he had held virtual exhibitions before. While Afterwork prepared their first virtual exhibition ''Temas'' on Artsteps which has a very accessible and simple interface; in their second exhibition ''New Normal'', they preferred the Unity platform to take their exhibition to the next level. They indicated their will to be able to enter the exhibition page with as few clicks as possible. The fact that the exhibition could be visited via a browser and was suitable for gamification was a factor in preferring this platform. About the difficulties or limiting factors they experienced in the digitization process, Akademililer officials stated that they had problems with the internet speed and the program was running sluggishly over the phone. The sanatorium official said that they didn't encounter any problems, Afterwork officials said that the issue that limited them the most was compatibility and therefore they gave up on some of the things they thought about because it should be easily accessible from every desktop device.

The shift to virtual exhibitions arose from a need to maintain public access to art during pandemic restrictions. Akademililer aimed to keep contemporary art available despite the closure process due to the pandemic, while Sanatorium quickly adapted Berkay Tuncay's scheduled solo exhibition into a 360-degree virtual format, responding to anticipated shutdowns. Similarly, Afterwork's creative directors, impacted by quarantine measures, developed a virtual exhibition model to overcome the quarantine barrier, aiming to set an example in this process. In addition, the Coordinator of Akademililer indicated that their curiosity about opening a virtual exhibition outside of the physical environment affected the digitalizatioın process. In terms of accessibility, while praising virtual exhibitions for providing access to audiences outside of Istanbul, Aytemur from Akademililer highlighted the special experiential importance of physical spaces. The Communications Specialist of the Sanatorium focused on the virtual exhibition's contribution to accessibility at the time of the pandemic. However; because the Sanatorium's physical space is open to visitors free of charge and is located at an easy point, Aytemur thinks their exhibitions are accessible enough. Creative Directors of Afterwork defined the digital space as a more accessible area naturally. They indicated that people don't have to leave the house to experience artwork and nowadays, it is possible to follow the artist's productions on Instagram daily even with mobile phones. They also emphasized that user-friendly interfaces are crucial to maximizing the accessibility of virtual exhibitions.

On the differences between the viewing numbers of the exhibitions on the Kuula platform; Aydemir from Sanatorium noted that being among the first of its sort in Turkey, their first 360-degree virtual exhibition (Berkay Tuncay's exhibition) generated a lot of interest. As physical access was restored, successive virtual exhibitions operated more as documentation. Akademililer noticed a significant difference in virtual and physical attendance, with the "Continue to Art" exhibition during the first 2 days drawing 20-25,000 virtual visitors per day and 1000-2000 per day later, compared to typical physical attendance of 200-250 for openings and around 20-25 on regular days, reflecting their gallery's limited space. About the comparison of the virtual exhibition space and the physical exhibition space, Aytemur argued that the virtual exhibition has the capacity to reach a large number of people. However, it does not have the same effect as a physical exhibition because the buyer wants to see, get closer, and touch. Concordantly, Aydemir expressed that

even though the virtual exhibitions made art accessible during the isolation period, the physical space offers a better environment to fully experience the exhibits. On the other hand, Belkıs and Arıbuğa indicated that the situation changes depending on the content of the exhibition because of their distinctive features. To connect the user to the virtual exhibition, it is necessary to prepare the exhibition as a game. In the physical exhibitions, it is enjoyable for the participants to communicate with each other; but physical location and transportation factors may prevent many people. In addition, while there is a wider even endless use of digital space, it can be difficult for users to adapt to it.

3. Discussion

In the study; the ways of the digitalization of exhibition spaces are explained, examples of tools that can be used for the transition are given. Through interviews conducted with the officials of case studies selected from Turkey for three categories, namely the creation of virtual exhibition apart from the physical exhibition space, the digitalization of existing exhibition space and the creation of a virtual exhibition without a physical exhibition space; investigations related to the virtual exhibitions were carried out.

As explained in the study, many online digitization tools are easily accessible over the internet and these platforms can be easily used for free, and in this way, every artwork can be shared with the whole world without the need for the person sharing to have any proficiency in the art. In addition, the fact that all of the exhibition spaces and initiatives selected as case studies used a different platform for moving the exhibitions to the digital environment shows that there are many different platform options. On the other hand; interviews with key figures from selected art spaces and initiatives shed light on the transition to virtual exhibitions, revealing challenges such as internet speed and platform compatibility. As can be understood from the interviews; the pandemic, which has affected more or less all sectors globally, has been quite effective on virtual exhibitions too. Although virtual exhibitions increased accessibility during the pandemic; officials from Akademililer and Sanatorium emphasized the irreplaceable sensory experience of physical spaces, echoing artist Berkay Tuncay's views on artwork perception.

It can be seen that considering the rapid development of technology, global pandemic conditions, and accessibility problems related to the pandemic, the rapid development of Metaverse, and an increasing number of exhibitions taking place in that universe; it can be said that dematerialization and digitalization of art and culture events accelerated. The Sanatorium noted that its 360-degree virtual exhibition garnered significant attention, serving as a documentation method once physical access was restored. In contrast, Akademililer's virtual exhibition saw a dramatic viewership spike, highlighting the vast reach of virtual spaces. Despite these nuances, virtual exhibitions have democratized art access beyond geographic confines, supported by easily accessible online digitization tools. Virtual exhibitions offer indefinite lifespans for artworks, unrestricted by time or place, as Tuncay expresses for his works. In a world where people access various e-services, virtual art and culture events can significantly enhance urban services. These findings suggest that digitalization can play a crucial role in modernizing urban systems, enhancing cultural services, and ensuring that art remains accessible even during crises. The research advocates for the integration of digital tools in urban planning to create resilient, inclusive, and innovative cities that can adapt to future challenges. This study calls for further exploration of the impacts of virtual and physical exhibitions on people's experience of artworks, encouraging a balanced approach to integrating these innovations into urban planning and policy-making.

4. References

Arendt, H. (1958) *The Human Condition*. Chicago, London: The University of Chicago Press.

Arpacıoğlu, S., Yalçın, M., Türkmenoğlu, F., Ünübol, B., and Çelebi Çakıroğlu, O. (2021) 'Mental health and factors related to life satisfaction in Nursing Home and community-dwelling older adults during COVID-19 pandemic in Turkey', *Psychogeriatrics*, 21(6), p881–891. https://doi.org/10.1111/psyg.12762

Bao, Y., Sun, Y., Meng, S., Shi, J., and Lu, L. (2020) '2019-nCoV epidemic: Address mental health care to empower society', *The Lancet*, 395, p37–38. https://doi.org/10.1016/S0140-6736(20)30309-3

Banister, D. (2008) 'The sustainable mobility paradigm', *Transport Policy*, 15(2), p73–80.

Bibri, S. E. and Krogstie, J. (2017) 'Smart sustainable cities of the future: An extensive interdisciplinary literature review', *Sustainable Cities and Society*, 31, p183–212.

Cartiere, C. and Willis, S. (eds.) (2008) *The Practice of Public Art.* New York: Routledge.

Habermas, J. (1989) *The Structural Transformation of the Public Sphere: An Inquiry into a Category of Bourgeois Society*. (T. Burger & F. Lawrence, Trans.). Massachusetts: MIT Press.

Heinberg, R. (2010) What is sustainability? In Heinberg, R., & Lerch, D. (Eds.), *The Post Carbon Reader: Managing the 21st Century's Sustainability Crises* (pp. 37–52). Watershed Media, Plymouth.

Miles, M. (1997) *Art, Space and the City: Public art and urban futures*. London: Routledge.

Knight, C. K. (2008) *Public Art: theory, practice and populism*. Oxford: Blackwell Publishing.

Kwon, M. (2002) *One Place After Another: Site-Specific Art and Locational Identity*. Cambridge, London: The MIT Press.

Rees, W., & Wackernagel, M. (2008). Urban ecological footprints: Why cities cannot be sustainable—and why they are a key to sustainability. In J. M. Marzluff (Ed.), *Urban Ecology* (pp. 537–555). Springer, Boston, MA.

Sennett, R. (2018) The Public Realm. In S. Hall & R. Burdett (Eds.), *The SAGE Handbook of the 21st Century* (pp. 203–215). London: SAGE Publications.

We Are Social. *Digital 2024 Report*. Available at: https://wearesocial.com/uk/blog/2024/01/digital-2024/ (Accessed: 10 April 2024)

Afterwork House. *Sergi*. Available at: https://afterwork.house/sergi/ (Accessed: 10 April 2024)

Akademililer Sanat Merkezi. *Sanata Devam*. Available at: http://akademililer.com/sanata-devam/ (Accessed: 10 April 2024)

Statista. (2024) Digital population worldwide. Available at: https://www.statista.com/statistics/617136/digital-population-worldwide/ (Accessed: 10 April 2024)

Statista. (2024) Number of internet users worldwide. Available at: https://www.statista.com/statistics/273018/number-of-internet-users-worldwide/ (Accessed: 10 April 2024)

Sanatorium Art Center. *About*. Available at: https://www.sanatorium.com.tr/en/about (Accessed: 6 May 2024)

Kuula. *About*. Available at: https://kuula.co/about (Accessed: 6 May 2024)

OARbt. *Homepage*. Available at: https://www.oarbt.com (Accessed 6 May 2024)

Artsteps. *Homepage*. Available at: https://www.artsteps.com (Accessed: 6 May 2024)

Akademililer Sanat Merkezi. *Homepage*. Available at: http://akademililer.com (Accessed 6 May 2024)

APPENDIX A.

Interview Questions

Name & Surname:

Job Description:

1. How long was the exhibition space (if exists) closed during the pandemic?

2. How did you think about moving the exhibitions from physical space (if exists) to the virtual platform? What are the reasons behind this idea?

3. How do you choose the platform when moving the exhibition space to the virtual space?

4. Can you explain the process of digitization?

5. Were there any difficulties or limiting factors you experienced in the digitization process?

6. Can you compare the virtual exhibition space and the physical exhibition space?

What do you think are the advantages and disadvantages?

7. Are there great differences between viewers between the digital platform and the physical exhibition space (if exists)? What do you think are the reasons for this?

8. Do you think there is a relationship between the pandemic and the digitalization process of the exhibitions? Why?

9. Do you think digital spaces have the potential to increase the accessibility of art? Why? If you think it does, to what extent and under what conditions does it increase accessibility?

10. Do you consider the works exhibited in digital exhibition venues as public art? Why?

11. What are your thoughts on the future of virtual exhibitions?

Case Study Report

Heritage as a leverage for urban innovation.
Case study of using AI as a co-designer

Will GARNER, WGXYZ, The United Kingdom
Naomi HÉBERT, Tekuma Frenchman, The Netherlands
Wenchi YANG, Tekuma Frenchman, The Netherlands
Piotr ŻELAZNOWSKI, Tekuma Frenchman, Poland

Abstract

Heritage cities often face a 'past vs. future' challenge due to the complex layers of cultural, architectural, spatial, and social developments accumulated over centuries. These intricate urban elements, which contribute to a city's unique genius loci, are difficult to translate into the language of modern urban development. This study examines a workflow developed at Tekuma while working on the regeneration masterplans in the Middle East, where AI tools, including Large Language Models (LLMs) and image generation software, were integrated into the design workflow to address these challenges creatively and democratically without compromising on time.

The general objective of the research is to explore the multi-layer opportunities that lie in the use of generative AI tools, as well as to examine the potential threats that one needs to be careful about, while deploying those tools. The following study provides a framework for integrating AI into heritage and urban development strategies. In detail, the study takes the methodology developed by Tekuma team, and explains the way designers can include the generative AI tools in their workflow in order to provide more democratic, context-respectful and informed planning and design process, with special focus on heritage sites and cities. The study approaches to answer the question of how the new tools with their complex algorithms, and computing power can change the designers workflow and help deliver compelling masterplans and strategies.

The research carried out by the team included testing a number of available AI software recommended by an AI design integration specialist. The selection of the software was based mainly on the team's image generation possibilities, controlling opportunities, and confidentiality standards. The input material collection was based on both online impression image research, taking photos during site visits and hand-sketching during design process.

Key findings of the research include both opportunities and threats. The large potential of the computing power can not only speed up the design process in a very significant way, but also provide more variants and scenarios to choose from without losing on production time. The ability to make the process more collective and democratic is an important opportunity as well. However, the users should be aware of the threats of using generative AI tools, including hallucinations of the LLMs (leading to faking the original heritage), the need for human-in-the-loop (to ensure ethical and intended use of the tools and to filter the outcomes). Definitely, a discovery worth pointing out is the emerging new role of the designer as a curator or creative director, not a draftsman.

Keywords

Heritage, artificial intelligence, regeneration, urbanism, architecture, masterplanning,

1. Introduction

Cities are one of the most complex organisms (or structures) developed by human species. They are so advanced that they themselves have the power to shape us. The amount of factors including social, technological and environmental (or human and non-human) factors that need to be taken into consideration in the responsible process of city making is constantly growing. The recent development of Generative Artificial Intelligence (GenAI) and Large Language Models (LLMs) opens new opportunities for urbanists (planners, urban designers, architects) to deal with these complex processes more efficiently. Thanks to AI's ability to process large quantities of information in a short amount of time, urbanists have the opportunity to train the AI models as design assistants, helping them to analyse, synthesise and communicate relevant information during the planning and design process both in the existing and new urban conditions. GenAi can be particularly useful during regeneration processes of the heritage sites, where the identity of these cities was shaped by hundreds or thousands of years of developing. Complexity of cultural layers, architectural languages, and other tangible and intangible nuances, create a rational environment and conditions to explore the potential of GenAI.

2. Heritage

According to Cambridge Dictionary 'heritage' can be defined as: 'features belonging to the culture of a particular society, such as traditions, languages, or buildings, that were created in the past and still have historical importance' or 'relating to buildings, places, works of art, etc. that are considered to have historical importance for a particular area or for all people'.

Heritage in urban planning encompasses both the tangible and intangible—encompassing architectural styles, urban textures, and cultural practices that define a city's unique spirit or "genius loci". When working with GenAI in this context, it is essential to translate these nuanced heritage elements into inputs that AI can understand and replicate. In order to ensure that the generated outputs respect and reflect these critical elements, the AI system needs to be fed with carefully selected data about local architectural styles, historical periods, and socio-cultural subtleties. In the regions where these details are not well documented

or described, AI can be used to help preserve those subtle regional characteristics. Therefore this methodology can prevent losing them in the underrepresented areas. Following the described methodology, those cultural attributes and architectural forms are inputted to AI tools, allowing LLMs to produce the outputs more relevant to the actual heritage.

3. GenAI landscape (brief overview of the selected tools):

The use of Generative AI tools becomes more common among architects and urbanists working in diverse environments and conditions. Platforms like UrbanistAI advocate for using generative tools to enhance the participatory process among stakeholders. AI-generated images play a role in 'enhancing the quality of decision-making process through collaborative ideation'. The goal is to improve the dialogue between residents and policymakers. The company has already carried a number of participatory workshops around the world and is collaborating across public, educational and private sectors. This proves that Generative AI tools are being successfully deployed across the planning and design sector and can significantly enhance inclusivity and democratisation in the planning processes.

Other generative tools that are being explored are the ones that are already designed to help architects and urbanists with designing cities and buildings. Software like Giraffe Build® or Digital Blue Foam®, kolega.space®, or software provided by OutlineAI help designers test their ideas and generate 3D forms based on the real life regulatory constraints (insolation, building heights, FAR, setbacks, open space coefficients, etc). The software enables designers to generate forms while monitoring the outcome numbers such as floor area, programme ratio and sun exposure in real time. These tools significantly speed up the ideation process, enabling designers to iterate through hundreds of viable forms and options, thereby enhancing creativity while adhering to urban design regulations. The generative tools such as kolega.space® proved to be more efficient than human designers, providing hundreds of viable options within a very short amount of time.

Currently there are at least tens of Generative AI tools to create text and images. Each of them gives different opportunities, from amateur to more professional use. The most common image generation tools and interfaces that were used and explored by the Tekuma team were Midjourney®, Dall-E®, Disco Diffusion®, Stable Diffusion®, ComfyUI®, Visual Electric®, LookX® and Adobe Firefly®. The tool used for image enhancing was Magnific® and for video generation the team used Runway®. For text generation the most common tool was ChatGPT®.

The tools for the methodology were being selected over a period of time. The selection was made based on a number of factors such as: accessibility, control and editing options, ease of use, possibility to use and train bespoke models, quality of produced images, but also pricing, development perspectives and data privacy (detrimental while working with confidential projects). At the moment of writing this paper and developing the methodology, the team has not found a single tool that would satisfy all the needs for all the project stages at the desired quality level. Therefore they employ a variety of tools based on the stage of the project and the expected outcome. The tools are used in various combinations depending on the project needs.

4. Hypothesis: GenAI as a Co-Designer

AI has the ability to process and synthesise large amounts of information very fast. This creates an opportunity to train dedicated AI models capable of analysing and synthesising relevant images of heritage buildings, urban fabrics and landscapes. Such models need to be thoroughly and meticulously curated. This

can be done by applying the possible creativity factors (ranges), which allow the models to deviate on its own from the raw information that it was fed with. This method can lead to unexpected outcomes that are unattainable with the use of bare human skills in such a short amount of time.

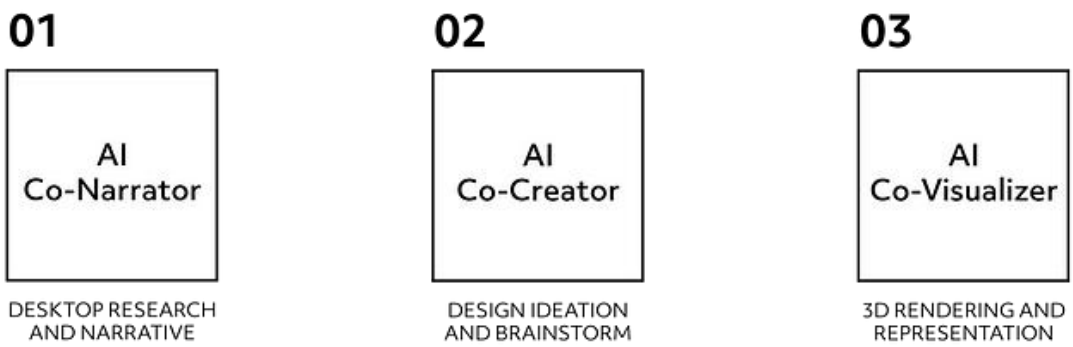


Figure 1. Three applications of AI at Tekuma. Source: Tekuma Frenchman.

4.1. Three roles of AI

In order to maximise the potential of Generative AI tools Tekuma established a series of workflows. The flexible nature of selected tools allows for mixing them across the methods. The proposed algorithms cover almost the full spectrum of the design process: from early analysis and ideation, to building compelling and immersive narratives, to brainstorming over more advanced ideas, to visualising the final outcomes in high quality imagery and motion pictures.

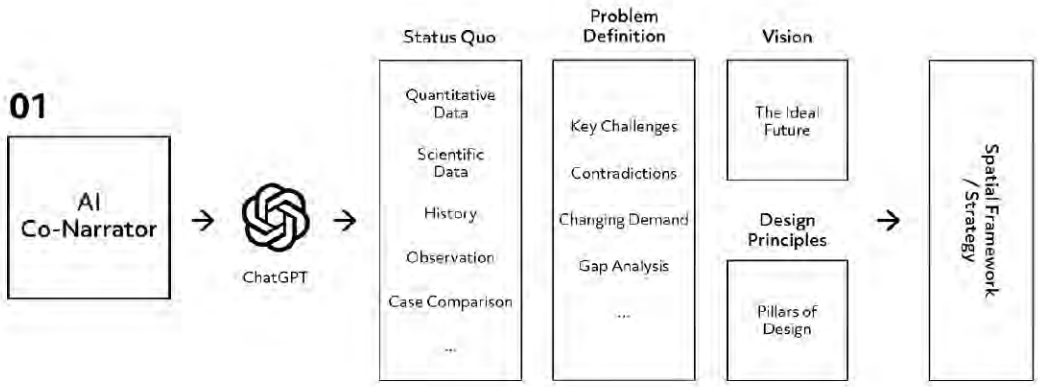


Figure 2. AI as a Co-Narrator workflow. Source: Tekuma Frenchman.

4.2. AI as a Co-Narrator

AI can be prompted to perform desktop research, organise and synthesise information into a coherent narrative. Rather than expecting AI to generate powerful writing from the start, it is an iterative process, as if communicating and sharing drafts, combining ideas, with a peer that has limited knowledge in the

topic. It helps structure statements, define problems, analyse data, find case studies, extract scientific research to support our own thinking, and challenge our ideas.

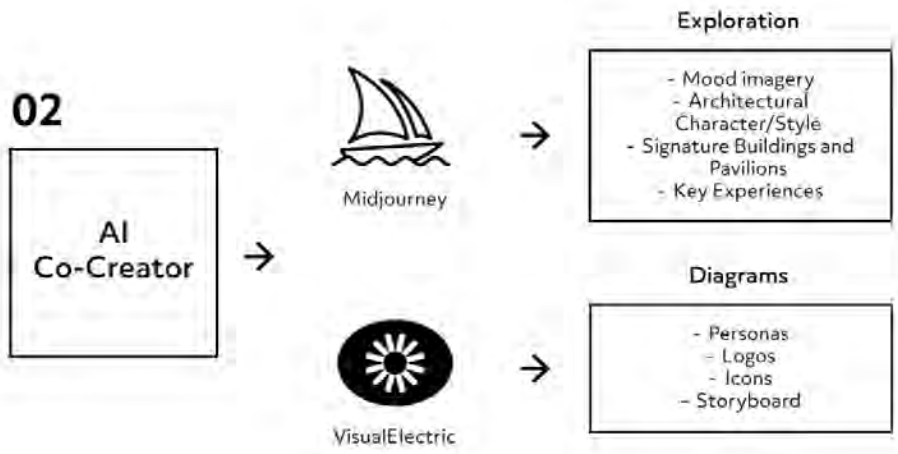


Figure 3. AI as a Co-Creator workflow. Source: Tekuma Frenchman.

4.3. AI as a Co-Creator

The notion of creativity in architecture has traditionally been seen as a uniquely human attribute. While conventional software enables the designers to free their creative minds, AI-aided tools open-up even greater possibilities. GenAI tools can not only accelerate the creative process of coming-up with solutions but also unveil unique alternatives (i.e.. *Midjourney, Dall-E*) that might not have been immediately apparent to human designers, enhancing the ideation and brainstorming process.

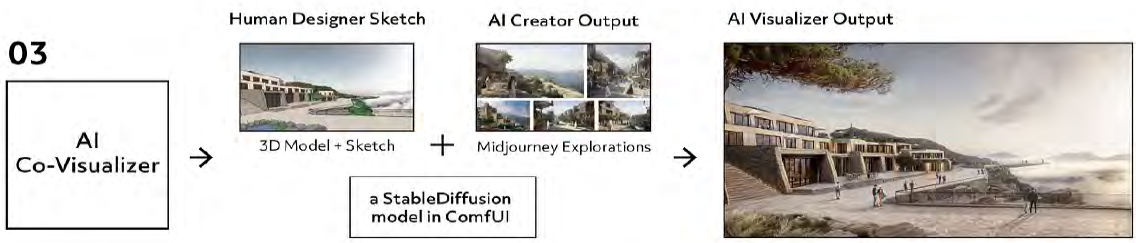


Fig. 4: AI as a Co-Visualiser workflow. Source: Tekuma Frenchman.

4.4. AI as a Co-Visualiser

It often comes as a challenge to translate abstract design concepts into understandable and compelling images. AI's visualizing capabilities seem to be indispensable in the work of a designer, where one needs to communicate often very complex design ideas to various stakeholders, e.g. real estate developers, investors, residents, or other planners. Thanks to the tools like ComfyUI and Midjourney that help generate the images based on the uses input, it becomes far easier and quicker to generate and then convey these urban and architectural concepts, with respect to the identity and the vision of the project.

5. Methodology & application

There are four basic AI tools used in the methodology: (1) ChatGPT (generative AI chatbot), (2) Midjourney (generative AI program), (3) ComfyUI (Graphic User Interface for Stable Diffusion – a deep learning AI model), and (4) Magnific (AI based image upscaler and enhancer). Each of the software played a different role at the consecutive stages of design development.

ChatGPT is a language model that allows for writing immersive texts depending on the requested style, it also helps synthetize large quanta of text information into coherent paragraphs. The purpose of ChatGPT is to formulate compelling and comprehensive narratives out of the complex data inputted by the curator (designer). The data may include designer's observations, case comparisons, historical facts, problem definition (e.g. key challenges, market demands, opportunities and constraints), and lastly – project vision and design principles. This is a text-to-text stage of AI use.

Following the narrative, the stage of exploration is then introduced. This is where Midjourney was deployed – to create mood imagery, potential architectural styles and characters, explore the look of signature buildings or the feeling of key experiences that will fall into the strategies later on. The images created in this tool are not directly set in the real context – their purpose is to turn the narratives into initial visual character of the future design proposals. This is a text-to-image stage of AI use.

The third step is to connect the generated mood boards and narratives with the actual design solutions. This is the stage where ComfyUI is being used. The selected views of the 3D models prepared by the designers are uploaded to the AI image generation tool. Then, using the models trained on the mood boards created earlier, the curator visualizes the actual design proposals. The views from the models can also be used for hand-sketching in order to further refine the mood and the details that one wants to achieve. This is an image-to-image stage of AI use, supported by additional text prompts to further guide the AI model.

The output images that come from the generative software often come in low quality and resolution. The final stage of the methodology is image enhancing, where the team uses Magnific software. This tool uses AI to add the missing details, increase the visual quality and resolution of the uploaded images. The software can be steered in a way that allows for more creativity or that forces the AI engine to stick as much as possible with the source image. This is where the curator also needs to carefully watch for the "hallucinations" or fake details that are added by the enhancing AI tool. This is also an image-to-image stage of AI use.

An additional step can be applied if necessary. This is a stage where the still images can be animated into motion pictures. Runway software provides the opportunity to add motion to the images in the selected areas. The team often used this to create more immersive visual materials for the projects. This is an image-to-video stage of AI use.

The use of GenAI tools has three main areas: (1) generation of new architectural expressions, rooted in the traditional architecture, (2) ideation of the concepts relevant to the context and inspired by the land and nature, and (3) visualisation and aiding the traditional tools. In order to employ the GenAI tools, a dedicated method was developed. It is based on splitting the input into thematic components that describe the architectural language, elements, as well as urban space. They are the ingredients that are then fed into the LoRa model. These elements consist of: traditional, contemporary, details, materiality, environment and program. Each of these elements is represented by relevant images. The selection of images depends on the designers and curators. In other cases the source images can be collected by other stakeholders, such as investors or city residents, during participatory workshops.

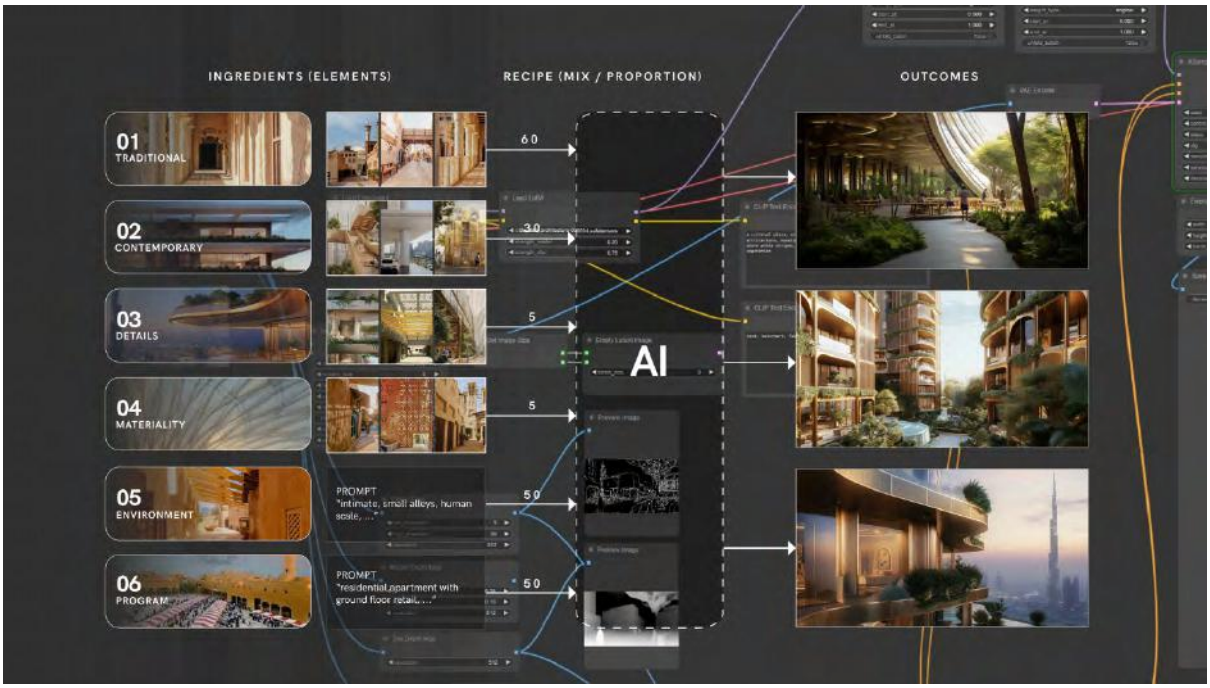


Figure 5: A simplified architectural design workflow using AI for a project in the UAE. Source: Tekuma Frenchman.

The ingredients are then introduced to the LoRa model in different proportions. This allows for controlling the focus of the model on specific elements or character and driving the model towards desired outcomes. For example, the proportion of each of the ingredients makes it possible to achieve architectural expressions that have the right balance between contemporary or traditional, and thus making it possible to explore and create different characters of architectural expressions and the look and feel of the urban space.

An example application process was applied to the 4-step methodology used by one of the clients: (1) defining the design drivers (e.g. understanding the site, climate and natural conditions), (2) architectural features (desktop research on existing architecture characters), (3) new identity interpretation (modern interpretation and artificial intelligence testing), (4) design application (designing the modern experience authentic to the place and aligned with the vision). The first two act as ingredients (elements), and the following ones as recipe and the outcome, where AI is being integrated into the design process.

6. Case studies

6.1. Case study of a masterplanning project in Al Ain, UAE

The confidential project site was allocated by local municipal and housing authorities. It is located north of the city of Al Ain in the natural dune landscape. The main part of the brief assumed thousands of villas along with the community facilities and retail program. The project is an answer to the question: how can the Emirati culture be preserved and innovated?

Figure 6: Scheme illustrating the inputs and outcomes of GenAI use within the workflow used for the project in Al Ain. Source: Tekuma Frenchman.

The city's name Al Ain is derived from the word for "source". Originally it used to be a green oasis on the UAE-Oman caravan route. Today, Al Ain is known for being the emirate's garden city. It also holds the position of being one of the world's oldest continuously inhabited settlements and a UNESCO World Heritage Site.

Taking the key landscape features that define Al Ain: the grand Oasis and the dunes, they became the design drivers and inspiration for the masterplan. Further, these elements along with the relevant photographs of local architectural language were fed into the LoRa model and initial images were generated. The target was to explore how the urban space can look and feel, and how the traditional architectural language can be translated into more contemporary forms without losing its vernacular character. The images generated at this stage play an indicative role (mood board), rather than specific design answers. Based on the created atmosphere, more precise images were produced in the following stages of the design process, reflecting the actual locations in the project.

This case study shows how AI image generation tools can be used to take the natural features of the site and based on that, create the look and feel of the future urban spaces. It also shows how the designers can explore the new uses of local architectural language creating new local identity. These images can later support the development of more detailed design guidelines.

6.2. Case study of a masterplanning project in Al Ahsa, KSA

The project site in Al Ahsa was a lifestyle and residential development led by a prominent government developer. Three vacant plots totaling roughly 50 ha were identified within the city, which had grown past its historical heart, rendering these fringe lots strategically located. The larger fabric of Al Ahsa is distinctive: it is a rich weave of orchards and urban settlement, where a canal system fed by fresh water springs once

irrigated the land. Al Ahsa is indeed a UNESCO site for its cultural landscape, featuring a unique relationship between agricultural land, water, and remarkable geological land formation such as Jabal Al-Qarah.

In the following case study the AI tools were used for concept ideation relevant to the context and inspired by nature. The team used the client's 4-step methodology: (1) design drivers, (2) architectural identity, (3) interpretation, (4) application. The AI integration was applied during step 3, where AI tools were used to aid the exploration process.

One of the challenges during the large scale masterplanning projects is to create new identity for proposed neighbourhoods or character zones. In the Al Ahsa project, the natural site features were used as a point of inspiration to create three distinct characters: the Canyon, the Groves, and the Gardens – each with different programme and landscape driving features. The Canyon features retail and commercial programme and acts as a heart of the west urban expansion area. Its design form was inspired by a distinctive geological formation which overlooked the site. The resulting synthetic form was intended to dialogue with the natural mountain. The Groves are proposed as a community surrounded by the orchards and palm tree oasis and featured a hospitality program. The design of the hotel, its small villas, and apartments were inspired by traditional farm houses. Lastly, the Gardens was inspired by the lavish gardens and agricultural plots locals maintained, and proposed a vocational school focused on the agriculture sector, and a residential community integrating urban farming.

In this project, AI tools were used to ideate on different architectural forms inspired by natural elements. Following that initial exercise, a selection of the results were used as a palette to guide the 3D modelling and sketching on the site. Then further AI-aided visualization software were used to dress the hand and computer perspectives into striking imagery. It was understood by the client, that while AI generated imagery is seductive, an architect's hand with deep understanding of local techniques and available material would be engaged following this process as these tools do not have a sophisticated comprehension of how buildings behave.

Figure 7: Three different characters and the corresponding AI imagery. Source: Tekuma Frenchman.

It is important to highlight that the role of urban designers is not to be overly prescriptive, but to guide and inspire using different media and means of communication. The explorations shown in figure 6 show how the AI-generated images help to convey the distinct look and feel of each neighbourhood. The explorations and iterations are the most important part, where the generative tools help urban designers work with the context and innovate.

Apart from design explorations, AI was also deployed to aid traditional visualisation tools. This approach combined digital modelling, human sketching skills and AI imaging software.

Figures 8-10: The stages of image development. From digital models, to human sketches, to AI-generated images. Source: Tekuma Frenchman.

In this particular case, still images were not the final outcome, as generative AI tools allow for creating animated pictures. Figures 10-11 show a hand sketch and an AI-generated image based on it. Further, using the Runway® software the team developed a more lively, animated picture.

Figures 11-12: From hand sketch to AI generated image. Source: Tekuma Frenchman.

7. Challenges, threats and opportunities of GenAI use

The reasoning and value drivers that AI should consider need to be defined by humans. It is also the human designer that knows how to judge and curate the AI's outcomes. Only humans can set purpose and give meaning or value to the outcome, therefore there is an imposed responsibility on the designers to make sure the AI is well informed by clear, curated and fair input, and the biases are reduced to a minimum. That translates into safeguarding the integrity and ethical use of AI.

One key challenge in using AI for heritage design is the risk of "hallucinations". While the AI-generated details and architectural features can look credible, they can miss the historical accuracy or actual reasoning. In other words AI is prone to misinterpret the cultural features and architectural elements that are part of the heritage. This comes as a risk especially while working in the historical sites, where extra professional care and overview is highly recommended. The ways to do counteract or mitigate these hallucinations effects, it is crucial to involve qualified heritage specialists, conduct a thorough data validation, provide high-quality graphical input materials etc. Any AI-generated output, which is the (re)interpretation of the traditional architectural styles and its features, should be reviewed against actual historical records. Careful curation of those inputs and outputs is key to avoid faking the historical features, and ensuring the authenticity of the architectural expressions with its cultural and historical layers.

Along with the evolving AI tools, the role of designers changes. It seems that while advancing GenAI tools can take over the majority of creating and visualizing workload, the human role can gradually turn into taking more supervising role. As curators, the designers can steer the AI to emphasize the importance of the project goals and make sure the general vision is coherent, comprehensible, and true to the historical and spatial context. One of the important tasks of the curators is to give purpose and meaning to the outputs in order to ensure the authenticity of the design solutions – at the same time "teaching" the AI human approaches and reasoning.

It is important to highlight the human oversight in the context of ethical use and actions of AI tools. An approach called "human-in-the-loop" ensures consistency and reduces biases in the AI-generated outputs. Models trained with this approach will be more reliable and able to understand the complex nature of architectural and cultural features, details, and deeper references which only humans can properly understand and then convey to the LLMs. This process of iterative feedback and correcting the AI models allows them to improve over time. Ultimately, those models will function and be treated as collaborative partners instead of just tools.

8. References

Lafond, D.K., Yang, W., Hébert N., Garner, W., (2024) 'How AI and Humans are Co-Creating Future Cities', Medium, 22 May [online]. Available at: https://medium.com/@urbanmemo/how-ai-and-humans-are-co-creating-future-cities-fe728c124ee9 (Accessed: 5 Nov 2024)

https://dictionary.cambridge.org/dictionary/english/heritage (28.10.2024)

Software used in the methodology:

ChatGPT, https://chatgpt.com/ (21.01.2025)

ComfyUI, https://github.com/comfyanonymous/ComfyUI (21.01.2025)

Magnific, https://magnific.ai/ (21.01.2025)

Midjourney, https://www.midjourney.com/home (21.01.2025)

Runway, https://runwayml.com/research/gen-2 (21.01.2025)

Research Paper

Evaluation and strategy of community belonging based on Multi-agent LLM:

A case study of the long-term rental apartments in Beijing

Xuanmin Dong, Tsinghua University, China

Yu Du, Tsinghua University, China

Abstract

In the new period of urban development in China, the policy of 'Houses are for Living, Not for Speculation' remains in effect. Concurrently, Long-Term Rental Apartments have been integrated into the affordable housing system. Meanwhile, the rental housing market is troubled by misalignments in both space and policies. Lack of community belonging among residents, presents a challenge for current urban community governance. The subjects of the study are two projects of 'Vanke Boyu', the top-ranked housing rental company in China, located in Xizhimen and Caoqiao in Beijing. The study mainly responds to: 1) The community belonging level of residents in long-term rental apartments; 2) The influencing mechanism of community belonging; 3) Planning strategies and decision-making system to enhance community belonging. Apart from that, introducing Multi-agent LLM as technological method, the study tries to establish an intelligent urban community governance system. Overall, the study not only expands the scale of urban community research in the New Era, but offers an intelligent community governance method as well.

Keywords

Community Belonging, Multi-agent LLM, Long-term Rental Apartment, Community Governance

1. Introduction

In the current phase of urban development in China, the policy of 'Houses are for Living, Not for Speculation (房住不炒)' continues to be enforced. Looking ahead, to more effectively accelerate the transformation and upgrade traditional industries and cultivate the growth of strategic emerging industries, it is crucial to establish and enhance the housing supply and support system. This is particularly important for accommodating new urban residents, as it will optimize human resource allocation and promote the sustained and healthy development of new, high-quality productive forces.

In recent years, China has made significant progress in developing a housing supply and support system, which mainly includes public rental housing, government-subsidized rental housing, and shared ownership housing (see Fig. 1). On June 24, 2021, the General Office of the State Council issued a document entitled 'Opinions on Accelerating the Development of Subsidized Rental Housing,' which provides a comprehensive overview of the relevant policies for government-subsidized rental housing and highlights the government's commitment to addressing housing needs, particularly for low- and middle-income groups. This new stage of development offers a unique growth opportunity for the long-term rental apartment

sector, which has seen the continual emergence and expansion of long-term rental apartment brands, especially in the context of government-subsidized rental housing (保障性租赁住房).

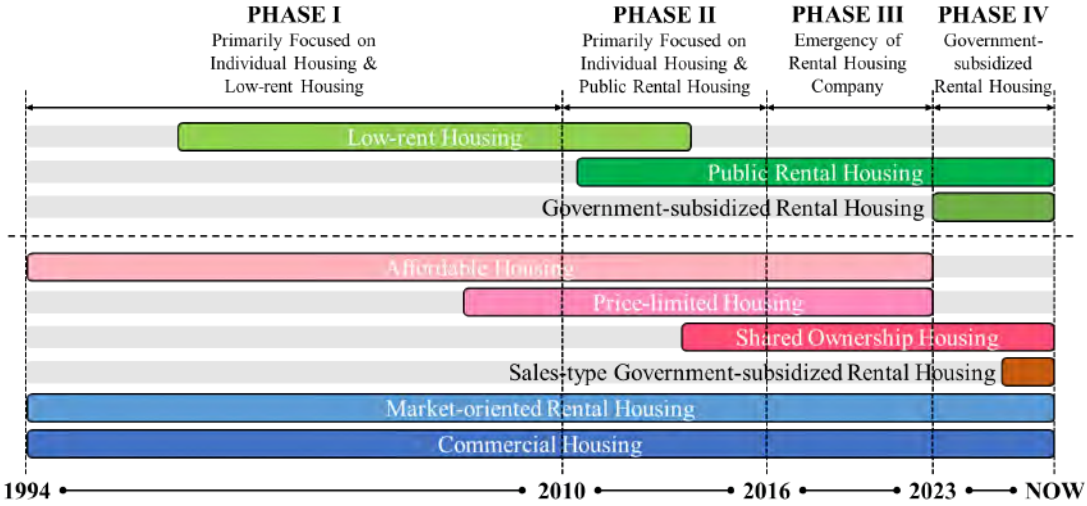


Figure 1. The Evolution of China's Affordable/Market Housing Supply System (1994 - Now).

Source: 2024 China Housing Rental Enterprise Research Report.

"Community Belonging (社区归属感)" describes the sense of emotional connection and identification that residents have with their community. It's a feeling of attachment and fondness for the community's people, as well as its physical space. This concept has its origins in urban community studies conducted by the Chicago School in the 1920s and 1930s. Theories such as "community interests" by R.E. Park and "community consciousness" by E.W. Burgess partially reflect this psychological understanding of community.

The assessment of "Community Belonging" has become a concentrated area of scholarly inquiry. Since the 1980s, researchers have revised the measurement indicators for community belonging multiple times. Notably, in 2008, Chavis and colleagues developed a 24-item Likert scale known as the "Sense of Community Index," which has been utilized in research involving various demographic groups.

In terms of the dynamics influencing "Community Belonging," existing studies indicate that stronger feelings of community belonging correlate with a greater desire to integrate within the community. Demographic factors such as gender, marital status, education level, and homeownership have been found to influence these feelings significantly. Moreover, in their exploration of the determinants of community belonging, international researchers have proposed both linear and systemic models (see Fig. 2). Empirical evidence suggests that overall community satisfaction and intermediary variables such as community interaction play significant roles in fostering community belonging.

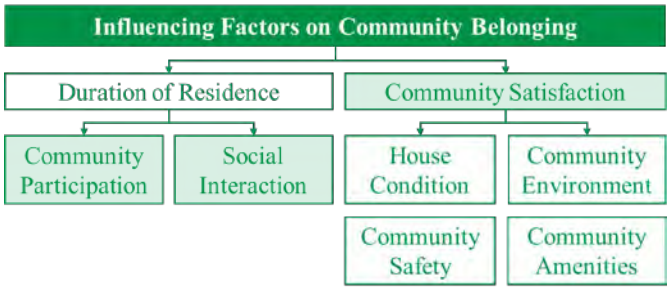


Figure 2. Systemic Model of Influencing Factors on Community Belonging. Source: Wu X. and Tan X., 2020.

The evolving urban dynamics necessitate urgent exploration of new research areas by academics. The first area of focus is the expansion of research paradigms to include emerging community types, such as long-term rental apartments. The second area involves innovating technical methodologies in urban community research through the use of big data and artificial intelligence technologies.

Consequently, this study addresses four critical aspects (see Fig. 3):

1) Evaluating the level of community belonging among residents of long-term rental apartments;

2) Investigating the mechanisms that influence community belonging;

3) Developing planning strategies and decision-making systems to enhance community belonging;

4) Implementing an intelligent urban community governance system using Multi-agent Large Language Models.

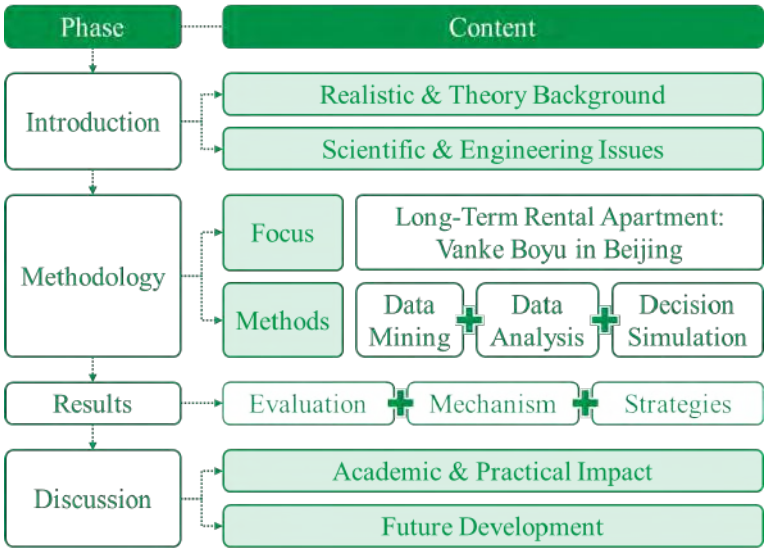


Figure 3. Research Framework. Source: Author.

2. Methodology

2.1. Research Subjects

According to the "2024 China Housing Rental Enterprise Research Report," Vanke Boyu is ranked first in the comprehensive strength index among housing rental enterprises. Over recent years, Vanke Boyu has been actively involved in the construction and management of government-subsidized rental housing, partnering with state-owned enterprises and asset management institutions. It offers extensive integrated services that enhance living and lifestyle quality, fostering a robust community culture.

Currently, Vanke Boyu manages services for 83,000 government-subsidized rental units across 19 cities, making it the leading market-operated organization in terms of volume within government-subsidized programs. Statistics indicate that more than half of the units in Vanke Boyu's operational projects are government-subsidized. By 2022, Vanke Boyu had initiated over ten projects in Beijing alone. This study focuses on two Vanke Boyu projects located in Xizhimen and Caoqiao in Beijing as research subjects (see Fig. 4).

Figure 4. Layout of two Research subject. Source: Internet.

According to the survey, "Vanke Boyu Xizhimen" primarily caters to residents in the Zhongguancun area and the Financial Street Business District. This demographic chiefly consists of recent university graduates and office workers from Financial Street and major corporations, characterized by relatively brief work experience and higher educational levels. The predominant living arrangements are solo living (76%) or cohabitation with a partner (16%), with a majority favoring short-term leases of three months or less (48%) and leases lasting between six months to one year.

In contrast, "Vanke Boyu Caoqiao" serves primarily the residential groups surrounding the Lize and Financial Street business districts. This group also mainly includes recent university graduates and employees, similarly noted for short work experience and high educational attainment. The living arrangements here predominantly consist of solo living (64%) or cohabitation with a partner (28%), with the majority engaging in rental agreements lasting 1-2 years (72%), and a smaller segment opting for shorter rental periods of 3-6 months (28%).

2.2. Research Methods

In terms of specific research methods, this study goes through three stages.

In the initial stage, comprehensive data collection is conducted. This involves deploying structured questionnaires and conducting detailed interviews with both operators and community residents to gather quantitative and qualitative insights. Additionally, extensive data pertaining to community characteristics and relevant policies is amassed through advanced online research and big data analytics techniques. This multifaceted data collection approach ensures a robust foundation for subsequent analyses.

Moving into the second stage, the study utilizes a suite of sophisticated statistical tools to analyse the data. First, we use correlation analysis to explore and measure the strength of relationships between key variables. Next, we apply structural equation modeling (SEM), which helps us understand the complex causal links in the data, offering deeper insights into the underlying factors that drive these relationships. Additionally, we use the analytic hierarchy process (AHP) to systematically prioritize and make decisions, especially when dealing with the multifaceted nature of urban planning and policy effectiveness.

In the final stage, the research innovatively incorporates a multi-agent Large Language Model (LLM) during the planning and decision-making processes. This advanced AI-driven tool facilitates the simulation of various stakeholder perspectives, enhancing the depth and breadth of scenario planning. The LLM's capacity to process and generate human-like text enables it to propose and evaluate a range of outcomes

based on the extensive data and analyses previously conducted. This integration of AI technology is instrumental in refining strategies and ensuring that decision-making is both data-driven and aligned with diverse stakeholder interests.

3. Results

3.1. Evaluation of Community Belonging

According to the Community Belonging Index, community belonging encompasses four dimensions: Reinforcement of Needs (RN), Membership (ME), Influence (IN), and Shared Emotional Connection (EC).

For this study, we adapted the scale from the Sense of Community Index II (SCI-II), which was developed by Chavis in 2008. Each item on the scale is rated on a 4-point scale, and the total score across all items forms the Community Belonging Index, which can range from 0 to 60. A total of 100 valid questionnaires were collected, comprising 10 items assessing the current state of the community and 20 items from the community belonging scale. All items were subjected to Cronbach's alpha reliability test, demonstrating high reliability with a coefficient of 0.905 (see Table I).

Table I Level of Community Belonging in Long-term Rental Apartment*. Source: Author.

Community Belonging Index (Adapted from SCI-II, Chavis, 2008)			Level of Community Belonging	
Dimensions	**Items**		**Xizhimen**	**Caoqiao**
Reinforcement of Needs	RN-1	I get needs of mine met because I am part of this community.	1.4	1.6
	RN-2	The community successfully meets the needs of its residents.	1.58	1.86
	RN-3	I and other community members value similar things.	1.24	1.62
	RN-4	Residents have similar needs, priorities, and goals.	1.18	1.64
	RN-5	When I encounter problems, I can discuss with residents.	0.72	0.94
	SUM (RN)		**6.12**	**7.66**
Membership	ME-1	Being a part of this community is an aspect of my identity.	0.8	1.16
	ME-2	I can trust the residents of this community.	1.08	1.38
	ME-3	I can recognize most of the community members.	0.38	0.36
	ME-4	Most residents of the community know me.	0.36	0.36
	ME-5	This community has identifiable symbols and signs.	0.46	0.52
	SUM (ME)		**3.08**	**3.78**
Influence	IN-1	Being integrated into this community is important to me.	0.72	0.7
	IN-2	I care about how other community members view me.	0.44	0.52
	IN-3	I contribute to the building of the community.	0.34	0.54
	IN-4	Residents can resolve internal disputes on their own.	1.24	1.22
	IN-5	There are good leaders within the community.	0.9	1
	SUM (IN)		**3.64**	**3.98**
Shared Emotional Connection	EC-1	I enjoy being with other residents frequently.	0.74	0.9
	EC-2	I hope to live in this community for a long time.	0.92	1.64
	EC-3	Community members share important festivals and activities.	0.72	1.34
	EC-4	I am hopeful about the future of this community.	1.1	1.64
	EC-5	Members of the community care about each other.	0.9	1.02
	SUM (EC)		**4.38**	**6.54**
SUM (RN+ME+IN+EC)			**17.22**	**21.96**

** E.g. XQ1 = "I get important needs of mine met because I am part of this community."*
Not at All = 0, Somewhat = 1, Mostly = 2, Completely = 3

The data indicates that the overall level of community belonging is relatively low. Although the practical needs of residents are adequately met, there is a weak sense of membership among them.

Additionally, Boyu in Xizhimen involves the renovation of an old building dating back to the 1980s, whereas Boyu in Caoqiao comprises a new construction project on rural collective land. From a spatial perspective, residents in larger, more cohesive long-term rental environments report higher levels of belonging; these settings benefit from active involvement by operators and government agencies. From the demographic perspective, more educated and longer-term residents tend to experience a stronger sense of community belonging.

3.2. Mechanism of Influence on Community Belonging

Based on the Systemic Model showed in Figure 2, the factors influencing the sense of community belonging can be summarized into four aspects: Participation, Interaction, and Perception of Objective Conditions.

Table II Correlation Analysis between Influencing Factors and Community Belonging. Source: Author.

	RN	ME	IN	EC	Community Belonging
Willingness of Participation	0.305	0.310	0.281	0.346	0.371
Frequency of Participation	0.260	0.312	0.403	0.338	0.391
Community Participation	**0.403**	**0.407**	**0.367**	**0.331**	**0.450**
Interaction with Neighbours	0.337	0.430	0.412	0.460	0.489
Interaction with Common Grounds	0.171	0.175	0.144	0.154	0.191
Interaction with Parents	-0.144	-0.175	-0.116	-0.079	-0.151
Interaction with Mates	0.118	0.145	0.263	0.159	0.203
Social Interaction	**0.136**	**0.161**	**0.214**	**0.204**	**0.214**
Satisfaction of House	0.400	0.292	0.349	0.459	0.451
Satisfaction of Environment	0.375	0.227	0.183	0.342	0.339
Satisfaction of Safety	0.338	0.200	0.275	0.405	0.368
Satisfaction of Amenities	0.515	0.213	0.245	0.416	0.419
Perception of Objective Conditions	**0.528**	**0.298**	**0.338**	**0.522**	**0.508**

As demonstrated in Table II, a correlation analysis was conducted to explore the relationships between various factors and community belonging. The correlation coefficients are color-coded in the table, with darker shades indicating stronger correlations. It was observed that the Perception of Objective Conditions exhibits a stronger correlation with community belonging. Moreover, while community participation significantly impacts belonging, social interaction has a more direct influence on it (see Fig. 5).

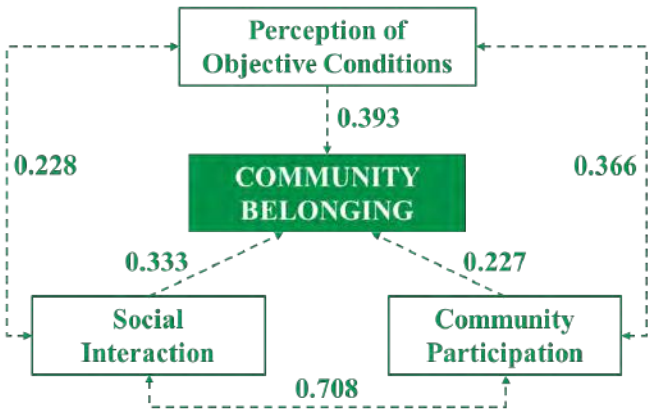


Figure 5. Covariance Coefficients Results of Factors Influencing Community Belonging from the Structural Equation Model. Source: Author.

3.3. Strategies for Enhancing Community Belonging

According to the Analytic Hierarchy Process (AHP) Judgment Matrix concerning the priorities for enhancing community belonging, there is a strong demand among residents for the improvement of objective conditions, emphasizing the importance of housing and safety, as well as enhanced amenities. Additionally, community participation, which encompasses more than mere social interactions, is highly prioritized by residents, as shown in Table III.

Table III the AHP Judgment Matrix of the Priority of Enhancing Community Belonging. Source: Author.

Average	Item	Interaction	Environment	Participation	House	Amenities	Safety
2.17	Interaction	1	0.577	0.939	0.492	0.485	0.559
3.76	Environment	1.733	1	1.628	0.853	0.841	0.969
2.31	Participation	1.065	0.614	1	0.524	0.517	0.595
4.41	House	2.032	1.173	1.909	1	0.987	1.137
4.47	Amenities	2.06	1.189	1.935	1.014	1	1.152
3.88	Safety	1.788	1.032	1.68	0.88	0.868	1

The strategies for enhancing community belonging can be clearly delineated along two principal axes.

1) **Upgrade of Service-Oriented Conditions.** Analysis indicates that the most critical area for improvement is service facilities, which constitute 21.29% of the priorities, highlighting an urgent demand from residents for well-equipped community services. Despite the relatively complete commercial offerings in Caoqiao, the low recognition of these shops does not satisfy the residents' evolving lifestyle needs. Conversely, Xizhimen faces a more acute shortage of service facilities due to limited spatial resources.

2) **Incentive for Gradual Participation.** The correlation analysis previously mentioned suggests a potential sequential relationship between social interactions and participation, indicating that closer neighborhood relationships correlate with higher levels of community involvement. In long-term rental apartments, interactions often consist of "necessary social interactions," such as daily greetings and inquiries. However, from a strategic perspective, there is a shift towards fostering more proactive and positive social interactions. Whether through festival activities or interest groups, such engagement can significantly enhance the added value of community participation, transcending basic social exchanges.

However, given the increasing complexity of urban environments, questions arise about the effectiveness of such top-down and elite-style planning decisions. Do they adequately consider the needs of multiple stakeholders? How can Planning Strategies and Decision-making Systems be made more comprehensive and scientifically robust?

3.4. LLM-based Strategy Optimization for Enhancing Community Belonging

Based on Large Language Models (LLMs), configured agents are capable of addressing specialized issues effectively, while multi-agent systems can function as role-playing simulation tools, collaboratively tackling complex tasks. The development and management of long-term rental apartments involve a diverse array of stakeholders, including governments, operators, and residents, making coordination among these groups essential. Community belonging is intrinsically linked to the welfare of all residents, highlighting the importance of public participation in developing strategies to enhance this belonging. Multi-agent systems offer a robust technological framework to facilitate such collaborative efforts (see Fig. 6).

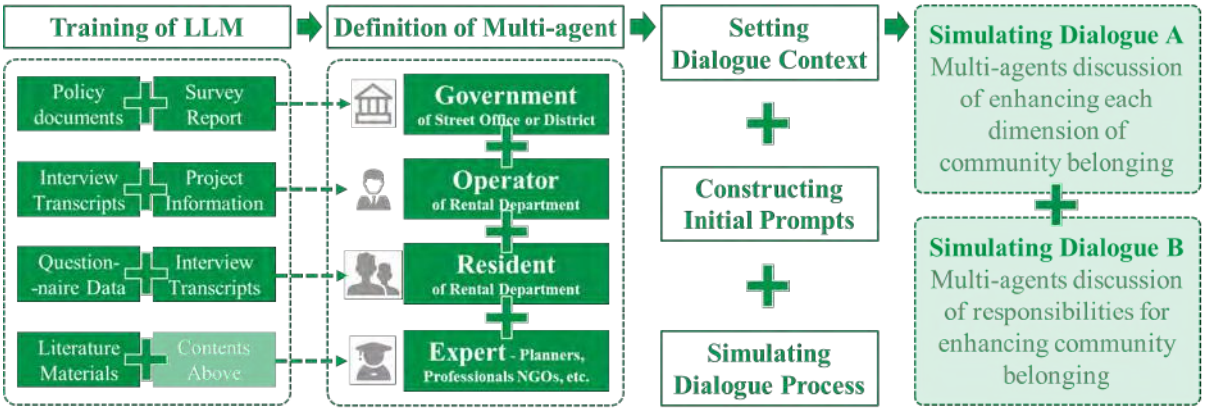


Figure 6. LLM-based Multi-agent Decision-making Simulation. Source: Author.

Initially, the study leverages existing textual data as a corpus to train four principal agents—government, operators, residents, and experts—each with distinct purposes and preferences. Additionally, various resources are compiled to serve as supplementary knowledge bases for training the agents, ensuring alignment with their respective roles and the characteristics of the simulation scenarios.

Subsequently, a string variable "community_status" is defined to encapsulate pertinent information about the long-term rental apartment community. Moreover, details concerning the agents and their objectives are integrated into a dialogue prompt to facilitate separate dialogues. The study also introduces a "simulate_dialogue" function, which utilizes OpenAI's API to execute multiple dialogue rounds in a loop, appending each round to the dialogue prompt.

Through the steps outlined above, the study effectively simulates the public participation planning decision process. Upon reviewing the simulation results, it was determined that planning decisions informed by Multi-agent LLM offer two primary benefits: they refine various dimensions of community belonging and delineate the responsibilities of different stakeholders more clearly (see Fig. 7).

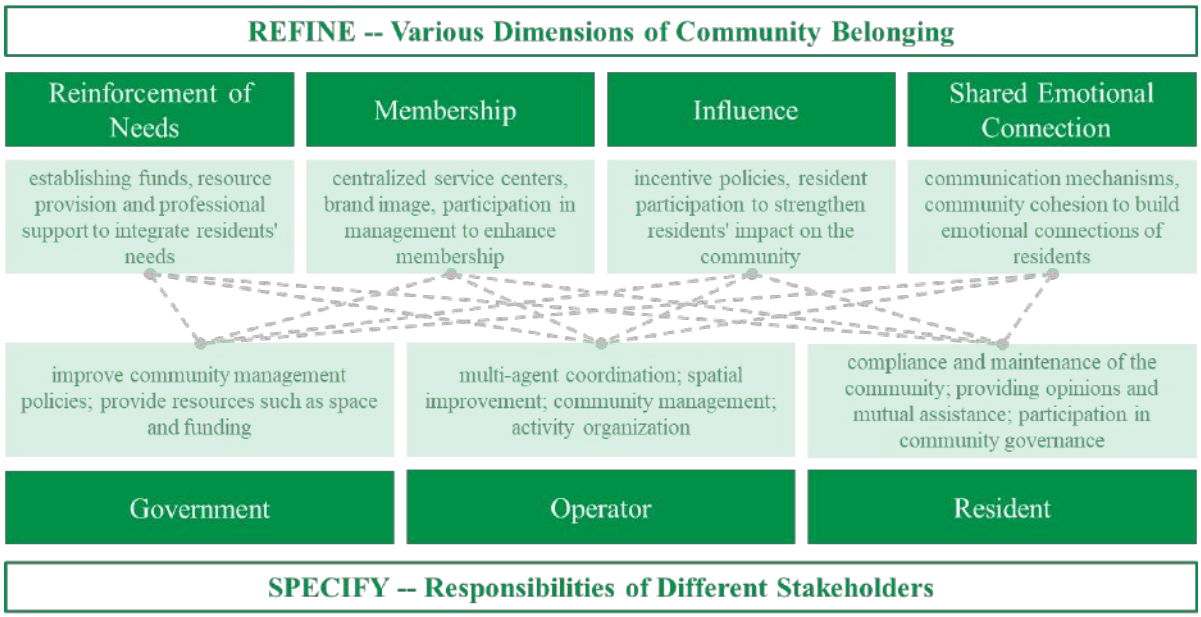


Figure 7. LLM-based Strategy Optimization for Enhancing Community Belonging. Source: Author.

4. Discussion

The study primarily investigates the level and influencing mechanisms of community belonging among residents in long-term rental apartments. By integrating Multi-agent Large Language Models (LLMs) as a technological method, it aims to establish an intelligent urban community governance system, thereby optimizing strategies to enhance community belonging.

The study has broader impacts:

1) **Expansion of Urban Community Research in the New Era.** Building on prior research, this study probes into new community spaces—long-term rental apartments—and harnesses innovative technologies such as big data and AI.

2) **Multi-Agent Community Governance Method Based on LLMs.** Employing large language models, the multi-agent decision-making system is envisaged to become a scientific, comprehensive, and intelligent approach to community governance. Although challenges remain, it seeks to merge participatory planning with elite-oriented planning, forming a dynamic planning process and enhancing the efficiency of planners during their tenure.

In conclusion, the study is set to broaden its scope and deepen its technological application in the future. On one hand, research will focus on more macroscopic subjects and complex issues, such as affordable rental housing from an urban and regional perspective, and a universal study of multi-stakeholder community governance. On the other hand, an intelligent urban community governance system will be progressively established as the research advances. By developing Information Port, Decision Making Port, and Application Port, an advanced urban community governance system for future cities will be realized.

5. References

Baral, C., Gelfond, G., Pontelli, E. and Tran, C.S. (2022) 'An action language for multi-agent domains', *Artificial Intelligence*, 302, p. 103601.

Elhenawy, M., Abutahoun, A., Alhadidi, T.I., Jaber, A., Ashqar, H.I., Jaradat, S., Abdelhay, A., Glaser, S. and Rakotonirainy, A. (2024) 'Visual Reasoning and Multi-Agent Approach in Multimodal Large Language Models (MLLMs): Solving TSP and mTSP Combinatorial Challenges', *Machine Learning and Knowledge Extraction*, 6(3), pp. 1894–1920.

Jiang, F., Peng, Y., Dong, L., Wang, K., Yang, K., Pan, C., Niyato, D. and Dobre, O.A. (2024) 'Large Language Model Enhanced Multi-Agent Systems for 6G Communications', *IEEE Wireless Communications*.

Li, R. and Ta, N. (2024) 'The Impact of Urban Space Utilization on the Urban Sense of Belonging Among Migrant Populations: A Case Study of Shanghai', *Human Geography (Chinese)*, 39(1), pp. 93-100+172.

Liang, H., Zhang, J., Li, Y., Wang, B. and Huang, J. (2024) 'Automatic Estimation for Visual Quality Changes of Street Space via Street-View Images and Multimodal Large Language Models', *IEEE Access*, 12, pp. 87713–87727.

Liu, J. (2016) 'Reflections on the Spatial Location Selection of Large-Scale Subsidized Housing Areas', *Modern Urban Research (Chinese)*, (12), pp. 98-104+132.

Liu, Y., Liu, Y. and Li, Z. (2017) 'Analysis of the Mechanisms of Residents' Sense of Belonging, Neighbourhood Interactions, and Community Participation: A Case Study of Urban Village Transformation in Guangzhou', *Urban Planning (Chinese)*, 41(9), pp. 38-47.

Manzoor, U. and Zafar, B. (2014) 'Multi-Agent Modelling Toolkit - MAMT', *Simulation Modelling Practice and Theory*, 49, pp. 215–227.

Mi, Q. (2004) 'Exploration of Urban Sense of Belonging Among Migrant Workers in Cities', *Youth Research (Chinese)*, (3), pp. 25-32.

Ning, Y. and Liu, H. (2024) 'UrbanKGent: A Unified Large Language Model Agent Framework for Urban Knowledge Graph Construction', [online]. Available at: http://arxiv.org/abs/2402.06861 (Accessed: 10 May 2024).

OpenAI (2024) 'ChatGPT: Large Language Model for Academic Research', [online]. Available at: https://platform.openai.com/docs/guides/chat (Accessed: 10 May 2024).

Park, J.S., O'Brien, J.C., Cai, C.J., Morris, M.R., Liang, P. and Bernstein, M.S. (2023) 'Generative Agents: Interactive Simulacra of Human Behaviour', *UIST '23: Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology*, (2), pp. 1-22.

Qiu, H. (1989) 'Community Belonging: A Comparative Case Study of Hong Kong and Guangzhou', *Journal of Zhongshan University (Chinese)*, (2), pp. 59-63.

Tian, L. and Xia, J. (2022) 'International Comparison of Rental Housing Supply and Development Models and Their Implications for China', *Architectural Journal (Chinese)*, (6), pp. 11–17.

Wang, D., Jin, X., Wang, J. and Zhou, Y. (2012) 'Research on the Site Selection and Evaluation Methods for Subsidized Housing Land: A Case Study of the Urban Area of Nanjing', *Urban Planning (Chinese)*, 36(3), pp. 85–89.

Wu, X. and Tan, X. (2020) 'Solving the Dilemma of "Stranger Communities": An Assessment of Community Belonging Research', *Administrative Forum (Chinese)*, 27(2), pp. 118-124.

Yan, H., Li, Q., Zhang, Y. and Wu, F. (2022) 'Empirical Analysis of the Willingness to Participate in Community Co-Governance Among Subsidized Housing Residents Based on Logistic Regression: A Perspective of Residential Satisfaction', *Modern Urban Research (Chinese)*, (6), pp. 74–81.

Ye, Y. (2023) 'Public Rental Housing, Group Rental Housing, and Private Rental Housing: A New Pattern in Urban Rental Housing', *Exploration and Contention (Chinese)*, (4), pp. 24-27.

Ye, Y., Zhang, L., Sun, Y. and Wang, J. (2020) 'Research on the Linked Mechanism to Solve the "Twin Problems" of Urban Village Renewal and New Citizens' Housing: A Case Study of Guangzhou', *Journal of Renmin University of China (Chinese)*, 34(2), pp. 14-28.

Zhang, H. (2021) 'The Impact of Subsidized Rental Housing Policy on Young New Citizens', *People Forum (Chinese)*, (26), pp. 83-86.

Zhou, Z., Lin, Y., Jin, D. and Li, Y. (2024) 'Large Language Model for Participatory Urban Planning', [online]. Available at: https://doi.org/10.48550/arXiv.2402.17161 (Accessed: 10 May 2024).

Acknowledgement

The primary focus of this research has been the urban planning decision-making system, supported by multi-agent LLMs. Over the past six months, the research has progressed through various phases, undergoing continuous iterations and optimizations. During this period, I encountered unprecedented challenges but also experienced profoundly impactful moments.

The completion of this article was significantly facilitated by the collaborative efforts of several individuals. I am deeply grateful to my co-author, Yu Du, and her colleague, Jiaqi Li, for their invaluable cooperation. I also wish to extend my sincere thanks to Professor Li Tian and senior researcher Xin Yang for their dedicated guidance. My gratitude also goes to Professor Yan Tang and senior researcher Lanqing Li for providing valuable investigative opportunities. Furthermore, I appreciate the support and trust from all other faculty, peers, and friends involved. Without their contributions, this research would not have been possible.

Looking forward, I am excited to further develop this research, as outlined in the concluding sections of the paper. Best wishes to all who have been a part of this journey!

Research Paper

Adressing the Impact of Urban Form on Liveability
A Critical Review

Neha JAISWAL, Indian Institute of Technology Kharagpur, India
Abraham GEORGE, Indian Institute of Technology Kharagpur, India

Abstract

The large-scale complexity of urban agglomerations and human-centered urbanity in the current context of increasing urbanization is a scientific, planning, and policy issue that necessitates suitable analytical techniques and efficient policymaking. Expectations of sustainability, ethical production and sense of well-being contributing to the overall livability are on the rise in cities. Further, mobility, age-friendliness, access to facilities and services gathering higher importance as globalisation influences rapid urbanisation. The term "liveability" refers to the general standard of urban environments with respect to the physical, social, psychological, and emotional needs, demands, and expectations of their inhabitants. Since it is comprehended as the quality of the human–environment relationship, urban form is a key element in the conceptual structure of liveability. Further, spatial arrangement of urban components; blocks, streets, buildings, etc. affect the quality of urban spaces, accounting for livability. This paper is a critical literature review of existing liveability approaches in the context to urban studies specifically to India. It provides a perspective to urban livability approaches and indicators focusing on urban form, at various levels. Current trends, key concepts and frameworks, and evidences from global case studies are also compared to establish the existing gap and limitations, and the need for policies and alternative methodologies for indexing spatial patterns for liveability. Conclusive results from this study will benefit future urban planning for better liveability.

Keywords

Urban Enviornment, Liveability, indexing, urban forms, wellbeing

1. Introduction

The problem of human-scale urbanity and large-scale urban agglomerations is a critical scientific and policy concern in the burgeoning "urban century," necessitating innovative analytical methods and successful policy measures (Jan Gehl, 2010; Kourtit, Osth and Nijkamp, 2020; Glaesar, Kourtit and Nijkamp, 2021). Ethnic division, land-use segregation, separation of employment and residence, neighbourhood deterioration, frequent traffic jams, social and economic irregularities, and unequal access to resources and opportunities are just a few of the issues that most large cities deal with. It may impact the health and safety of residents, non-acceptable living conditions and compromised social values (Kuddus, Tynan and McBryde, 2020). Sustainable development has drawn a lot of attention in recent decades. as a collective urban interest, accelerated from the inception of the UN Sustainable Development Goals (SDGs) (United Nations, 2016). With regard to a higher standard of living, community cohesion, less urban isolation, and easier access to facilities and services, expectations for sustainability, ethical production, and a sense of wellbeing are rising in Indian cities, particularly in metropolitan areas. The "Global Youth Letter Report,"

which polled over 8,000 individuals between the ages of 18 and 35 from 23 nations, found that younger generations are reflecting this. (Bhatiani *et al.*, 2022).

Since modern dense spatial settlements have the capacity to improve place quality and create an inclusive and sustainable future for everyone, cities and urban agglomerations are acknowledged as major players in addressing sustainability concerns. With the diverse fabric of Indian cities having unpredictability, there is a need to transform urban environments into sustainable, resilient, and equity ensured for all (SDG, 2016; Paul and Sen, 2018). Numerous strategies have been put out to address the aforementioned problems, including livability, sustainability, and quality of life (Ellis and Roberts, 2016; Ali and Akbari, 2017). Quality of life and livability have assumed a prominent place on the human well-being ladder. Urban livability is the ability of urban spaces to fulfil the expectations of its users and inhabitants for wellbeing and better quality of life (Martino, Girling and Lu, 2021). Therefore, identification of factors that determines the livability of cities is a major concern of the contemporary world (Kourtit *et al.*, 2022).

The totality of safe, appealing, socially cohesive, and inclusive neighborhoods is known as urban livability. Additionally, they are ecologically sustainable, offering reasonably priced and varied housing that is easily accessible by public transportation, bicycles, and pedestrians to places of work, education, public parks, local stores, health care, and other community services, as well as recreational and cultural activities (Higgs *et al.*, 2019). Contemporary Asian cities are witnessing high-rise and compact urban development, which requires better understanding of the physical living environment; *both built and unbuilt,* and urban quality is necessary to deal with multifaceted issues of urbanism (Lai *et al.*, 2018). Accessibility, travel distance, time, energy, social fairness, land-use efficiency, economic benefits, CO2 emission reduction, and liveliness are all impacted by urban form, either positively or negatively (Johnson, 2007). Thus, it is high time to study the dynamics of urban livability, and model relationship among urban form and other factors that contribute to better livability of a city (Williams, Burton and Jenks, 2000). This paper deals with current urban trends, key concepts, frameworks, and comparison of evidences from global case studies to establish the existing gap and limitations, alternative methodologies for indexing spatial patterns for liveability and appropriate policies from reports and journal papers.

2. Research Background

One of the main tenets of urban planning and governance is livability, whose definition and assessment have emerged as key areas of study (Liang, Liu and Qiu, 2020). Therefore, there is growing interest in measuring policy outcomes related in creating more liveable cities, with reduced inequalities. Since the elements of livability are subjective, the measures and approaches vary at individual, social, built environment and policy levels (Cox, Arnold and Tomás, 2010). In 1980s to 1990s, "livability" acquired popularity, demanding sociologists and planners to study the "shift in urban development patterns; from urban centres to rapidly growing suburbans. The definition of livability entails multiple ranges of aspects, mostly corresponding to human settlements, social, economic, environmental, and health-related features along with social inclusivity rather than the mere considerations of the "utilitarian view that reduces livability to primary considerations of public amenities and health" (Liang, Liu and Qiu, 2020; Çalışkan, 2022). However, a robust humanistic perspective achieving the interaction between city dwellers and the urban environment is desired. Livability cannot be better understood without studying the relationship among the behaviour, perception, and interactions of people and space (Pacione, 1990). Newman stated that livability is the "human requirement for social amenity, health, and wellbeing" which includes both "individual and community wellbeing" (Newman, 1999). In addition, livability consists of other two elements; *the city's environment and the population that demands goods and services.* In general, these definitions emphasize the interaction between people and the environment (Ruth & Franklin, 2014).

2.1 Livability Measurement Tools

Livability index is a table that ranks cities, regions, or nations based on a combination of their quantitative and qualitative properties. These indices are often developed and produced for commercial and governmental interests. A wide range of constructs, indices and measurement tools constructed over a period of time are discussed and compared below.

Global Livability Index (EIU)

The Economist Intelligence Union (EIU)'s "Global Livability Ranking" is the most comprehensive and far-reaching of all livability ranking systems as on today. The ranking system assesses 170 cities for over 30 qualitative and quantitative factors that are grouped under five weighted categories namely "stability, healthcare, education, infrastructure, culture and environment" (EIU, 2021).

Mercer's Quality of Living Survey

The Mercer Quality of Living Survey measures quality of living in over 460 cities worldwide with the aim to help companies and expatriate professionals assess appropriate allowances and incentives for relocation. Quality of living is measured considering 39 descriptors that are grouped in 10 categories namely, "socio - political environment, economics, socio-cultural environment, health and environment, education, transportation, housing, and natural environment"(Mercer, 2020).

American Association of Retired Persons (AARP)

American Association of Retired Persons (AARP) Public Policy Institute supports the livable urban environment by developing 'AARP livability Index', an online instrument to quantify community livability on a scale of 0 to 100, under seven categories namely "affordable and accessible housing, accessible neighbourhood, work and play, safe and convenient transportation, environment with clean air and water, health, community engagement with civic, economic, social involvement, and inclusive and potential opportunities" (AARP, 2015).

OECD Better Life Index

OECD Better Life Index (BLI) is a tool that allows users to "compare the well-being of countries". It is a multi-dimensional framework covering 11 dimensions, that include "income and wealth, work and job quality, housing, health, knowledge and skills, environmental quality, work-life balance, social connections, civic engagement, safety and subjective well-being" (OECD, 2011).

Human Development Index

Human Development Index (HDI) is a "United Nations (UN) measurement system that evaluates a country's average human development in three areas; *health, knowledge and standard of living"*(UNDP, 2024) .

Ease of Living Index

Ease of Living Index (EoI) is a tool used by the Ministry of Housing and Urban Affairs (MoHUA), Govt. of India to "assess the quality of life and the impact of urban development initiatives". The index is based on four pillars; *Quality of life, Economic ability, Sustainability, and Citizens Perception Survey"*. These pillars are further divided into 14 categories and 49 indicators (MoHUA, 2020).

Overall Livability Index by IFC

Overall Livability Index by IFC-India is built upon eight core pillars namely "demographic, education, health and medical standards, socio-cultural, natural, environment, economic environment, safety, housing, and

planned environment". These pillars are sub-divided into 20 sub-pillars, which consist of indicators that map the factors quantitatively (CII, 2010).

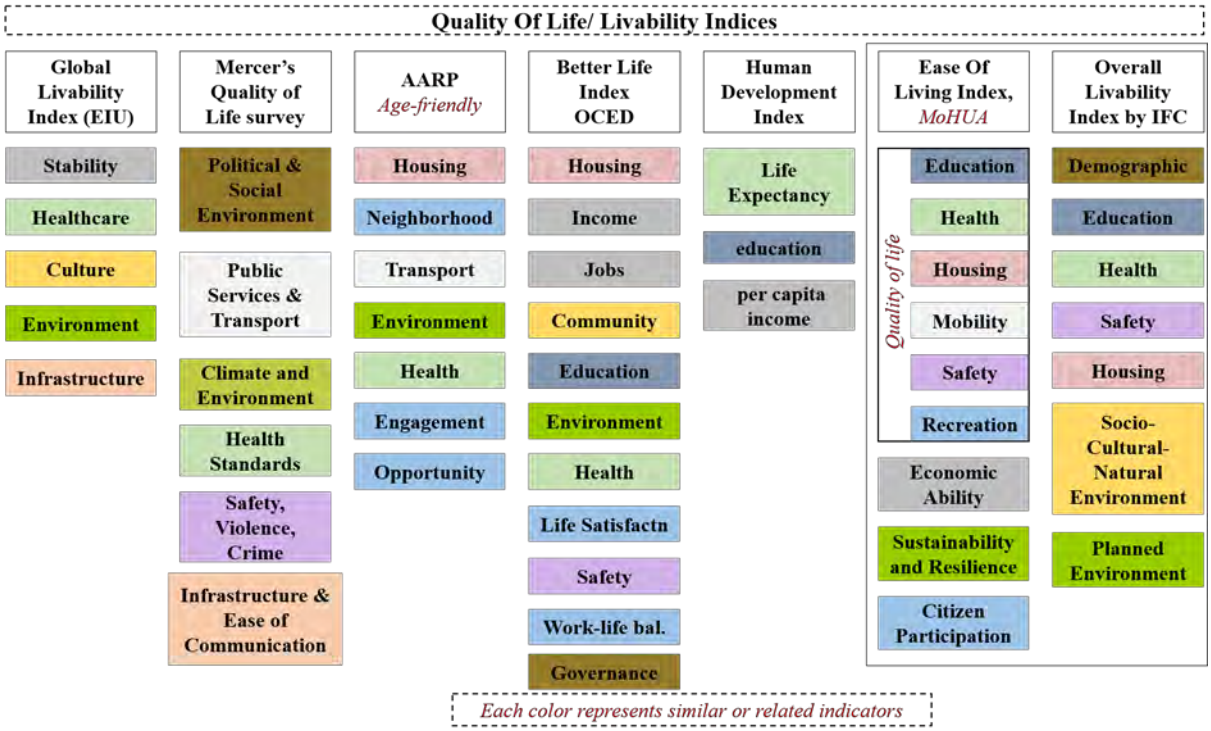


Figure 1: Livability dimensions used in various indices. Source: Authors

It has been observed that the methods and systems utilized to assess liveability only take into account a limited number of urban planning indicators related to businesses that provide a wide range of services to the general public, as shown in Table 1. These tools/indices measure the cities at different scales from neighbourhoods, districts and cities/regions. Our objective is to identity the most relevant aspects which relate to urban planning and analyse their evaluation methodologies in detail.

Table 1 Research Matrix for urban livability systems

Indications to Measure	Global	Mercer's QoL	AARP	Better Life	Human	EASE OF	Overall
Crime / Safety		✓		✓		✓	✓
Governance		✓		✓			✓
Economic Ability	✓		✓	✓	✓	✓	
Education		✓		✓	✓	✓	✓
Healthcare	✓	✓	✓	✓	✓	✓	✓
Environment	✓		✓	✓			✓
Infrastructure	✓	✓					
Culture	✓						✓
Public Participation						✓	
Community			✓	✓			✓
Universal Inclusivity			✓				
Ease of Communication	✓						
Housing			✓	✓		✓	✓
Recreation						✓	
Public Services/Transport		✓	✓			✓	
Life Satisfaction				✓			

2.2 Historical background and Global Initiatives

The 15-minute city

The "*15-minute city* is an urban planning tool, aimed at improving the quality of life for city-dwellers. It is an innovative idea, aimed at establishing hyper-proximity infrastructure, which is not new on the urbanism contours, specifically in the Indian context". Since public transportation in Paris occupies 66% of its public space, need for individual cars for mobility is preferred by 17% of the nation's population, Singapore's outstanding infrastructure and quality amenities makes accessibility easier and the city pedestrian-friendly. Making Indian cities more resilient requires incorporating walkability and accessibility into micro-level planning at the ward and neighbourhood levels. For example, the historic walled city of Jaipur, which was built 294 years ago, is a "15-minute city" because its essential services, recreational amenities, and workplaces are all within 15 minutes of housing. (Hastak, 2022).

Form Based Code

Form Based Code (FBC) is developed as an alternative to conventional zoning and building regulations with a focus on comprehensive development and economic, social and environmental sustainability with community participation. Relationships between buildings and streets, people and cars, public and private areas, and the size and kind of roadways and blocks in the urban area are emphasised. (Russell and Stanton, 2014)(NIUA, 2023). Redwood City, California which has a downtown that's more vibrant than it used to be in past decades, Cincinnati, Ohio, where the entire city is revamped and Nashville, Tennessee, where taxable value in the districts increased by 75 percent, are some of the examples of FBC which reduces crime rates considerably by extending activity throughout the day.

3. Livability and Urban Form

Ideal city models, from "Plato's *early utopia* to Garden city of Ebenezer Howard (Howard, 1902) and Pual and Percival Goodman (Percival and Paul, 1960)", embed an intrinsic search for livability in environment and community". The concept of urban form covers "location, shape, geometry, and relationships among the spatial elements like streets and roads, plots and buildings, public spaces, and green areas, within the built environment; at a variety of scales, from the building block to the urbanized region" (Hack, 2012). Urban elements' spatial relationships like *buildings, streets, and blocks* constantly interact with users and affect the perceived quality of urban spaces for better livability. Built environment's physical characteristics have a major impact on a place's long-term performance, it is pertinent to address liveability in relation to urban form (Southworth, 2013). It influences how people plan their lives, delineates or offers chances for the distribution of resources and facilities that promote human mobility and enhance social interaction, education, and pleasure (Hack, 2012). The study of urban form leads to objectively quantifying such relations and understand their dynamics.

3.1 Density

Healthy and thriving cities aren't just dense metropolises but they are vibrant ecosystems that welcome, support, and serve everyone. Further, the length and width of blocks and sidewalks respectively are designed for closer proximity to transit, healthcare, education, food, and open spaces that are critical to making it liveable. One important aspect of how cities operate is urban density. According to research, maintaining urban density as the only important indicator for assessing densification is crucial. On the other hand, adding spatial variety and network centrality metrics may promote more livable density (Martino, Girling and Lu, 2021). Many measures of density describe important urban phenomena. However, a mission-oriented public policy that measures its success with a single measure for the city at large is easier

to formulate, garner support, and implementation (Angel, Lamson-Hall and Blanco, 2021). Density can be measured and expressed in a variety of ways, each of which is useful in a distinct context. There is no consensus on how to quantify density and, thus, how to utilise density criteria in plans and policies. (Churchman, 1999; Banai and DePriest, 2014). In all circumstances, density is expressed as a ratio, with the numerator representing a quantity of human activity, people, jobs, or constructed form and the denominator representing a certain land base. Typically, density is stated as a single unit of land area, housing units per hectare, or population per square kilometre. Lack of proper regulations and required institutional framework for fulfilling the high demand for "compact and high density built areas" can lead to overcrowding, environmental degradation, lack of privacy, isolation and breakdown of identity (Kotharkar, Bahadure and Sarda, 2014; Ali and George, 2022). This makes urban form a key aspect of what can be considered a vibrant, safe and healthy neighbourhood.

3.2 Diversity

Diversity or the degree of diversity is an essential factor for livability, economic growth, and attractiveness of cities that finds its prominence in relation to physical form (Jacobs, 1961; Smith, Nelischer and Perkins, 1997; Sayyar, 2011). Social diversity is regarded as something that makes the world more liveable and attractive (Young, 1994; Ezati, 2023). Urban public spaces are crucial in maintaining the social life of a city, since they are intended to be enjoyable to use, and to create a lively city expressing their culture and traditions and welcomes social diversity. From the consideration of morphology to ideals of sustainable urbanism, diversity plays a major role in not only enhancing mixed-use development but also creating opportunity to attract industries, diverse backgrounds, and healthier communities (Sadeghi and Li, 2019) (Cheshmehzangi and Li, 2020). Land use diversity, in terms of mix of uses, can be used to assess the potential of livability of urban landscapes (Jacobs, 1961; Koster and Rouwendal, 2012) Mixed and multifunctional land uses are able to promote urban vibrancy and yield socio-economic benefits. However, fine-grained mixing of diverse uses creates vibrant and successful neighbourhoods (Jacobs, 1961). *Shannon entropy* is the most widely used for diversity measurement when examining mixed use, although it has been found to be inadequate in capturing the multidimensional aspects of mixed use. (Manaugh and Kreider, 2013; Yue *et al.*, 2016). Entropy generally quantifies homogeneity of land use in a given area (Bordoloia *et al.*, 2013). Diversity is composed of three dynamic attributes: *intensity, variability, and consistency,* (Batty, 2013) and examination of cities at appropriate scales and gain a better understanding of the city is required.

3.3 Accessibility

Through its "New Urban Agenda," the UN has called on cities to improve accessibility in order to meet the Sustainable Development Goals (SDGs). Well-connected infrastructure would allow people to come to public spaces, improve walkability, and create sustainable cities (United Nations, 2015). The study of accessibility can be viewed from two perspectives; *first one referring to distribution of public amenities, the second to the spatial configuration of the streets.* Although, measures of accessibility can be related to different aspects of transport infrastructure, its indicators can be used to measure pedestrians and cyclists as well as public and private transport. Proximity to the accessible places and locations, from an identified point in the study area is a key factor in organizational concept of a city system. Attractive and accessible locations are the ones with lowest distance and travel costs, with availability of frequent transport to other places (Batty, 2009). Although, accessibility studies focus mostly on one element "proximity" it should be expanded to affordability and equity, to understand the efficiency of transport infrastucture (Heerden *et al.*, 2022). "Transit-oriented development (TOD)" facilitates the development of dense urban forms (Lang *et al.*, 2020). However, "*development-oriented transit*" could be found in Indian context, which lowers the

livability, social integration; *both vertically and horizontally as in the case of metro rails.* Considering the multi-dimensional nature of the concept, three interacting input variables are used to calculate spatial accessibility; *supply, demand, and mobility* (Park and Goldberg, 2021). Accessibility, thus, is considered very influential in decision-making and policy formulations.

3.4 Affordability

Affordability is a central criterion of built environment in urban livability and vitality, apart from "density, land use mix, block size, building age, accessibility, and lack of border vacuums" (Singer, 2021; Tang *et al.*, 2022). Vitality in streets is a prerequisite to create liveable urban environments. Although economic vitality of community is not a new concept, lack of economic vitality would result in declining property values and quality of life. Affordability makes housing and other facilities financially affordable for the majority, and it is a significant issue in most big cities across the world (Martino, Girling and Lu, 2021; Singer, 2021). Urban form affects housing affordability stress through both productivity and living amenities (Jiuwen *et al.*, 2024). Researchers have found a significant correlation between the configuration of spatial networks and land price (Chiaradia *et al.*, 2013). Location affordability refers to the combined housing and transportation costs that has to be borne from a share of their income (Haas *et al.*, 2006). Studies have been using multiple spatial variables and machine learning models to predict housing prices based on transportation infrastructure and neighbourhood amenities (Yoo, Im and E.J., 2012; Chen *et al.*, 2017). The availability of high-frequency datasets facilitate the accurate assessment of housing costs and affordability (Boeing and Waddell, 2017). Decisions on affordability can be made "real-time" if sufficient real-time data is available, with the assistance of geographic information systems and upcoming artificial intelligence.

4. Comparative Critical Perspective

A definition and framework for the study of urban liveability are provided by earlier research (Mahmoudi et al., 2015). These studies do, however, still have certain shortcomings. "Overemphasis on the effects of economic expansion on the urban environment (Romao et al., 2018; Xiao et al., 2021) and lack of focus on physical pillar of liveability" (Paul, 2020). There is a need for a holistic concept of human-environment relationships, to integrate city form and social processes (Romice *et al.*, 2016; Dorado, 2023). There are studies on comprehensive evaluation of urban livability from multiple dimensions, and scanty related studies from the perspective of geographic space (Liang, Liu and Qiu, 2020; Fu and Zhang, 2023).
Indicators used in the current researches do not apply a "community-driven approach" but centered on 'top-down' approaches. It is a critical gap since the core of urban livability is people's interaction with urban environment, not just the availability of social spaces or merely score or rank by any system of assessment (Christy, Raissa and Sandhy, 2021). Although, factors of urban form such as density and diversity are considered crucial components of liveable cities, they are only the visible part of a much larger ecosystem. Thus, there is a need to research on micro level planning approaches (ORF, 2020), role of urban form and spatial structure on accessibility. Athough, researchers have identified the relevance of livability at the intersection of the urban environment and community, affordability and economics imply the overarching notion of quality of life in cities (Kamp et al., 2003; Loeiz et al., 2012It is clear that most research is focused on the evaluation of experience in rich countries, and there is a dearth of scientific analysis about urban liveability in developing or impoverished countries (Okulicz-Kozaryn, 2013).
In India, data availability is from limited source and sparse. Frequency of data updation is also a big question. Data collection is mostly done using statistical data and questionnaire surveys. However, studies in China, Hong Kong and other parts of the world shows the use of spatial big data (Leipnik, Ye and Gong, 2011; Zhu *et al.*, 2020; Yu and Fang, 2023). It is suggested that data acquired from web sources such as open street maps (OSM), point of interests (POI) and publicly accessible data on housing price, employment etc. will help in reflecting the spatial differences related to urban liveability better.

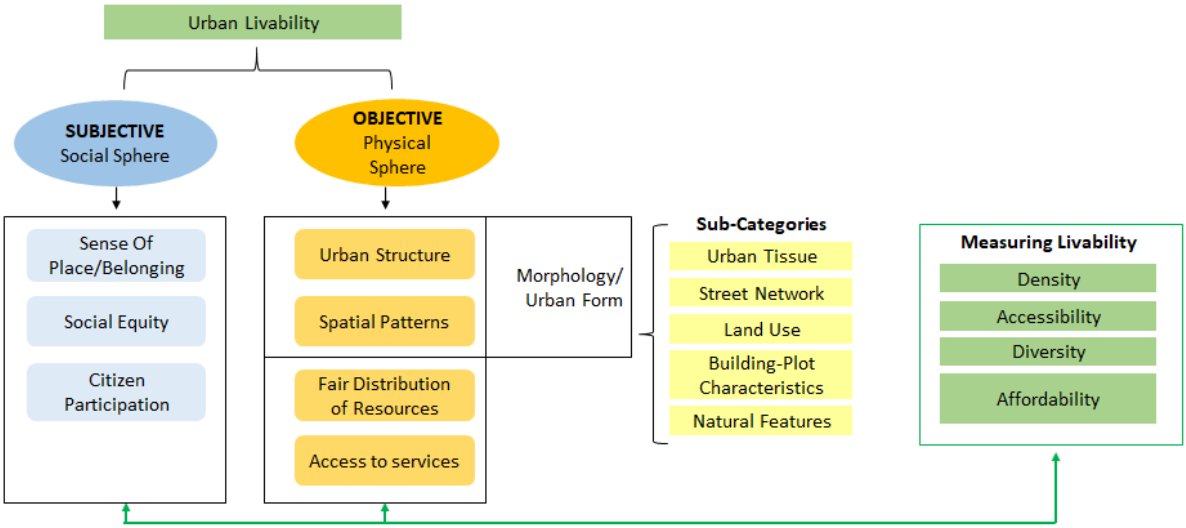


Figure 2 Urban form-based livability conceptual diagram. Source: Authors

5. Conclusion

Cities over the centuries have to deal with numerous problems, and resolving each requires specific strategies and techniques which are elucidated through this study. It is established that the connection between livability and urban form is complex in Indian context, which is influenced by rapid urbanization, population density, economic disparities, and diverse cultural landscapes. Addressing the well-being and quality of life of residents has become increasingly important as a result of the growth of industrial parks and special economic zones (SEZs), which draw commercial and industrial investments. The relationship between quality of living and urban form is multidimensional, with appropriate urban design playing a essential function in influencing the livability and sustainability. The paper reiterates the importance of quantification of relationship among density, accessibility, diversity, and affordability which provide a significant benefit to planners and decision makers. It is established that urban livability needs to consider the urban form; *shape and organisation*, to achieve an acceptable humane urban quality of life. Other pertinent stakeholders, including urban planning departments, may benefit from the study's findings.

6. References

AARP (2015) *American Association of Retired Persons*. Available at: https://www.aarp.org/content/dam/aarp/about_aarp/annual_reports/aarp-2023-annual-report.pdf.

Ali and Akbari (2017) 'Interpretive-Structural Modeling of the Factors that Affect the Viability of Tehran Metropolis', *Spatial Planning (Modares Human Sciences)*, 21(1), pp. 1–31. Available at: http://hsmsp.modares.ac.ir/article-21-3785-en.html.

Ali, S. and George, A. (2022) 'Redressing urban isolation: A multi-city case study in India', *Journal of Urban Management*, 11(3), pp. 338–352. Available at: https://doi.org/https://doi.org/10.1016/j.jum.2022.04.006.

Angel, S., Lamson-Hall, P. and Blanco, Z.G. (2021) 'Anatomy of density: measurable factors that constitute urban density', *Building and Cities*, 2(1), pp. 264–282.

Banai, R. and DePriest, T. (2014) 'Urban sprawl: Definitions, data, methods of measurement, and environmental consequences', *Journal of Sustainability Education*, 7. Available at: http://www.jsedimensions.org/wordpress/wp-content/uploads/2014/12/Banai-DePriest-JSE-Vol-7-Dec-2014.pdf.

Batty, M. (2009) 'Cities as Complex Systems: Scaling, Interaction, Networks, Dynamics and Urban Morphologies', in *Encyclopedia of Complexity and Systems Science. Springer, New York, NY.* New York, NY: Springer New York, pp. 1041–1071. Available at: https://doi.org/10.1007/978-0-387-30440-3_69.

Batty, M. (2013) 'Big data, smart cities and city planning', *Dialogues in Human Geography*, 3(3). Available at: https://doi.org/https://doi.org/10.1177/2043820613513390.

Bhatiani, G. *et al.* (2022) *Sustainable Urban Networks for Dynamic and Resillient (Sundar) India*. Delhi. Available at: https://doi.org/10.13140/RG.2.2.24783.76964.

Boeing, G. and Waddell, P. (2017) 'New insights into rental housing markets across the United States: Web scraping and analyzing craigslist rental listings', *Journal of Planning Education and Research*, 37(4), pp. 457–476. Available at: https://doi.org/https://doi.org/10.1177/0739456X16664789.

Bordoloia, R. *et al.* (2013) 'Quantification of Land Use diversity in the context of mixed land use', in *Social and Behavioral Sciences*, pp. 563 – 572.

Çalışkan, O. (2022) 'Urban Form and Liveability: Towards a Socio-Morphological Perspective', *Built Environment*, 48(3).

Chen, J.-H. *et al.* (2017) 'Forecasting spatial dynamics of the housing market using support vector machine', *International Journal of Strategic Property Management*, 21(3), pp. 273–283. Available at: https://doi.org/https://doi.org/10.3846/1648715X.2016.1259190.

Cheshmehzangi, A. and Li, H.M.A. (2020) 'Innovation through Urban Diversity and Achieving Comprehensive Sustainable Urbanism from a Community-Oriented Approach', *Current Urban Studies*, 8(2). Available at: https://doi.org/https://doi.org/10.4236/cus.2020.82012.

Chiaradia, A. *et al.* (2013) 'Compositional and urban form effects on residential property value patterns in Greater London', *roceedings of the Institution of Civil Engineers—Urban Design and Planning*, 166(3), pp. 176–199. Available at: https://doi.org/https://doi.org/10.1680/udap.10.00030.

Christy, F., Raissa, G. and Sandhy, S. (2021) 'Critical Analysis of Urban Livability Measures Based on the Perspective of Placemaking', in *IOP Conference Series Earth and Environmental Science*.

Churchman, A. (1999) 'Disentangling the Concept of Density', *Journal of Planning Literature*, 13(4), pp. 389–411. Available at: https://doi.org/http://dx.doi.org/10.1177/08854129922092478.

CII (2010) *Livability Index 2010*.

Cox, M., Arnold, G. and Tomás, S.V. (2010) 'A Review of Design Principles for Community-based Natural Resource Management', *Ecology and Society*, 15(4), p. 19. Available at: https://www.jstor.org/stable/26268233.

Dorado, M.I.A. (2023) 'Theoretical conceptions for a holistic, transdisciplinary approach to contemporary landscape', *City, Territory and Architecture*, 10(32). Available at: https://doi.org/https://doi.org/10.1186/s40410-023-00220-6.

EIU (2021) *The Global Livability Index*.

Ellis, P. and Roberts, M. (2016) *Leveraging Urbanization in South Asia: Managing Spatial Transformation for Prosperity and Livability*, *The World Bank*.

Ezati, B.A. (2023) 'Social Diversity, Gender, Equity and Public Policy', *Public Policy and Research in Africa* [Preprint]. Available at: https://doi.org/https://doi.org/10.1007/978-3-030-99724-3_8.

Fu, C. and Zhang, H. (2023) 'Evaluation of Urban Ecological Livability from a Synergistic Perspective: A Case Study of Beijing City, China', *Sustainability*, 15(13). Available at: https://doi.org/https://doi.org/10.3390/su151310476.

Glaesar, E., Kourtit, K. and Nijkamp, P. (2021) *Urban Empires*. Taylor & Francis.

Haas, P.M. *et al.* (2006) 'Housing & transportation cost trade-offs and burdens of working households in 28 metros', *Center for Neighborhood Technology*, p. 197.

Hastak, S. (2022) 'Analyzing the 15-Minute City Concept and Its Applicability in India', in *International Journal of*

Engineering Research & Technology.

Heerden, Q. van *et al.* (2022) 'Accessibility, affordability, and equity in long-term spatial planning: Perspectives from a developing country', *Transport Policy*, 120, pp. 104–119. Available at: https://doi.org/https://doi.org/10.1016/j.tranpol.2022.03.007.

Higgs, C. *et al.* (2019) 'The Urban Liveability Index: Developing a policy-relevant urban liveability composite measure and evaluating associations with transport mode choice', *International Journal of Health Geographics*, 18(1), pp. 1–25. Available at: https://doi.org/10.1186/s12942-019-0178-8.

Howard, E. (1902) *Garden Cities of To-Morrow*.

Jacobs, J. (1961) *The death and life of great americal cities*, *Vintage Books a Division of Random House, Inc. New York*.

Jan Gehl (2010) 'Cities For People', *Jan Gehl*, pp. 1–269.

Jiuwen, S. *et al.* (2024) 'Impact of urban form on housing affordability stress in Chinese cities: Does public service efficiency matter?', *Cities*, 145. Available at: https://doi.org/https://doi.org/10.1016/j.cities.2023.104682.

Johnson, A. (2007) 'Monitoring Settlement Sustainability-A Review of Practice', in *Conference on Politics of Planning, New Zealand Planning Institute Conference*.

Koster, H.R.A. and Rouwendal, J. (2012) 'The impact of land use on residential property values', *Journal of Regional Science*, 52(5), pp. 733–761. Available at: https://doi.org/https://doi.org/10.1111/j.1467-9787.2012.00776.x.

Kotharkar, R., Bahadure, P. and Sarda, N. (2014) 'Measuring Compact Urban Form: A Case of Nagpur City, India', *Sustainability*, 6(7). Available at: https://doi.org/https://doi.org/10.3390/su6074246.

Kourtit, K. *et al.* (2022) 'City love and place quality assessment of liveable and loveable neighbourhoods in Rotterdam', *Land Use Policy*, 119.

Kourtit, K., Osth, J. and Nijkamp, P. (2020) 'My home is my castle – assessment of city love in Sweden', *Int. J. Inf. Manag.* [Preprint].

Kuddus, M.A., Tynan, E. and McBryde, E. (2020) 'Urbanization: A problem for the rich and the poor?', *Public Health Reviews*, 41(1), pp. 1–4. Available at: https://doi.org/10.1186/s40985-019-0116-0.

Lai, P.-C. *et al.* (2018) 'Neighborhood Variation of Sustainable Urban Morphological Characteristics', *Int J Environ Res Public Health.*, 7(15). Available at: https://doi.org/10.3390/ijerph15030465.

Lang, W. *et al.* (2020) 'Understanding livable dense urban form for social activities in transit-oriented development through human-scale measurements', *Habitat International*, 104(July 2019), p. 102238. Available at: https://doi.org/10.1016/j.habitatint.2020.102238.

Leipnik, M.R., Ye, X. and Gong, G. (2011) 'Geo-spatial technologies and policy issues in China: status and prospects', *Regional Science Policy & Practice*, 3(4).

Liang, X., Liu, Y. and Qiu, T. (2020) 'Livability Assessment of Urban Communities considering the Preferences of Different Age Groups', *Complexity*, 2020. Available at: https://doi.org/10.1155/2020/8269274.

Manaugh, K. and Kreider, T. (2013) 'What is mixed use? Presenting an interaction method for measuring land use mix.', *Journal of Transport and Land Use*, 6(1), pp. 63–72.

Martino, N., Girling, C. and Lu, Y. (2021) 'Urban form and livability: socioeconomic and built environment indicators', *Buildings and Cities*, 2(1), pp. 220–243. Available at: https://doi.org/10.5334/bc.82.

Mercer (2020) *Quality of Living 2020*. Available at: https://mobilityexchange.mercer.com/Portals/0/Content/PDF/qol-2020-evaluating-assignment-locations.pdf.

MoHUA (2020) 'Ease of Living Index 2020', *Government of India*, pp. 1–76. Available at: https://smartnet.niua.org/eol19/pdf/EOL-2019-Completed-Version.pdf.

NIUA (2023) *Guidebook for adoption of Form Based Codes*.

OECD (2011) *Better life index*. Available at: http://www.oecdbetterlifeindex.org/.

Okulicz-Kozaryn, A. (2013) 'City Life: Rankings (Livability) Versus Perceptions (Satisfaction)', *Social Indicators Research*, 110(2), pp. 433–451. Available at: https://doi.org/10.1007/s11205-011-9939-x.

Park, J. and Goldberg, D.W. (2021) 'A review of recent spatial accessibility studies that benefitted from advanced geospatial information: multimodal transportation and spatiotemporal disaggregation', *International Journal of Geographical Information Science*, 10(8). Available at: https://doi.org/https://doi.org/10.3390/ijgi10080532.

Paul, A. (2020) 'Developing a methodology for assessing livability potential: An evidence from a metropolitan urban agglomeration (MUA) in Kolkata, India', *Habitat International*, 105(September), p. 102263. Available at: https://doi.org/10.1016/j.habitatint.2020.102263.

Paul, A. and Sen, J. (2018) 'Livability assessment within a metropolis based on the impact of integrated urban geographic factors (IUGFs) on clustering urban centers of Kolkata', *Cities*, 74(June 2017), pp. 142–150. Available at: https://doi.org/10.1016/j.cities.2017.11.015.

Percival and Paul (1960) *Communitas: Means of Livelihood and Ways of Life*.

Romice, O. *et al.* (2016) 'Urban Design and Quality of Life', in *Handbook of Environmental Psychology*. Available at: https://doi.org/https://doi.org/10.1007/978-3-319-31416-7_14.

Russell, J. and Stanton, M. (2014) *Livability in Action*, *AARP Livable Communities*. Available at: https://www.aarp.org/content/dam/aarp/livable-communities/livable-documents/documents-2014/Livability Fact Sheets/Form-Based-Code-Fact-Sheet.pdf.

Sadeghi, G. and Li, B. (2019) 'Urban Morphology: Comparative Study of Different Schools of Thought', *Current Urban Studies*, 7, pp. 562–572.

Sayyar, S.S. (2011) 'Urban diversity and how to measure it – an operational definition of classes and scales', in *18th International Seminar on Urban Form: ISUF 2011*.

SDG (2016) *Goal 11: Make cities inclusive, safe, resilient and sustainable*, *United Nations*.

Singer, M.E. (2021) 'How affordable are accessible locations? Neighborhood affordability in U.S. urban areas with intra-urban rail service', *Cities*, 116. Available at: https://doi.org/https://doi.org/10.1016/j.cities.2021.103295.

Smith, T., Nelischer, M. and Perkins, N. (1997) 'Quality of an urban community: a framework for understanding the relationship between quality and physical form', *Landscape and Urban Planning*, 39(2–3), pp. 229–241. Available at: https://doi.org/https://doi.org/10.1016/S0169-2046(97)00055-8.

Tang, J. *et al.* (2022) 'The Effect of Built Environment on Physical Health and Mental Health of Adults: A Nationwide Cross-Sectional Study in China', *Int J Environ Res Public Health.*, 19(11), pp. 64–92. Available at: https://doi.org/https://doi.org/10.3390%2Fijerph19116492.

UNDP (2024) *Human Development Report*. Available at: United Nations%0ADevelopment Programme.

United Nations (2015) *Transforming Our World: the 2030 Agenda for Sustainable Development*.

United Nations, U. (2016) *The new urban agenda*. Available at: https://doi.org/10.18356/4665f6fb-en.

Williams, K.., Burton, E.. and Jenks, M. (2000) *Achieving Sustainable Urban Form*.

Yoo, S., Im, J. and E.J., W. (2012) 'Variable selection for hedonic model using machine learning approaches: A case study in Onondaga County, NY.', *Landscape and Urban Planning*, 107(3), pp. 293–306. Available at: https://doi.org/https://doi.org/10.1016/j.landurbplan.2012.06.009.

Young, I. (1994) 'Gender as Seriality: Thinking about Women as a Social Collective', *signs*, 19(3), pp. 713–738.

Yu, D. and Fang, C. (2023) 'Urban Remote Sensing with Spatial Big Data: A Review and Renewed Perspective of Urban Studies in Recent Decades', *Remote Sensing*, 15(5).

Yue, Y. *et al.* (2016) 'Measurements of POI-based mixed use and their relationships with neighbourhood vibrancy', *International Journal of Geographical Information Science*, 31(4), pp. 658–675.

Zhu, L. *et al.* (2020) 'Assessing Community-Level Livability Using Combined Remote Sensing and Internet-Based Big Geospatial Data', *Remote Sensing*, 12(24). Available at: https://doi.org/https://doi.org/10.3390/rs12244026.

Research Paper

From Aesthetics to Functionality:

Planning for Public Art in Shaping Helsinki's Inclusive Public Spaces – A Case Study of the Pasila Neighborhood

Najmeh Motalaei, PhD Researcher, Aalto University, Finland

Anssi Joutsiniemi, Adjunct Professor at Aalto University, Associate Professor at University of Oulu, Finland

Klas Fontel, Helsinki Art Museum(HAM), Finland

Jarno Peltonen, Former Museum Director at TOP Talents, Finland

Abstract

Public art is a key issue in urban planning and design as impacts on quality of everyday life. These impacts include enhancing aesthetics, fostering social cohesion, reflecting cultural identity, and offering functional and educational benefits.

This study analyses the multi-dimensional impact of public art on public spaces through a case study of Helsinki's Pasila neighbourhood. Pasila's diverse cultural background, strong institutional support and its record as an art make it the most important case study to consider public art impacts on public spaces.

The research employs a mixed-methods approach, including field observations, interviews with urban planners, analysis of public art contents and public space usage by people. In a deep observation, we have study whole urban sculptures and murals in Pasila which integrates art into pedestrian routes and enrich urban landscape.

The results demonstrates that these elements enhance wayfinding, promote cultural engagement, and encourage physical activity, making public spaces visually appealing.

Despite these benefits, some critics highlight a lack of community representation in Pasila's public art. It seems that residents' voices are insufficiently reflected in both the creation and content of artworks. In addition, there are concerns about an institutional gap between the Helsinki Art Museum (HAM), Urban Art Association and the City of Helsinki in planning for public art.

In summary, this study emphasizes on the role of public art in enhancing Pasila's aesthetic appeal while highlighting its limitations in fostering social inclusivity. The findings show a gap in community engagement, where local voices, especially from diverse cultural backgrounds, are underrepresented in public art projects through the process of artwork's creation and in their content. To address Pasila's multicultural identity, future public art development should focus on participatory and inclusive practices. This approach would enable public art to serve not only as visual enrichment but also as a meaningful tool for community cohesion and cultural representation.

Keywords

Public Art, Multicultural Neighbourhoods, Public Space Quality, Community engagement, Pasila neighborhood

1. Introduction

Regarding ongoing urban challenges worldwide, public art planning has been integrated into cultural policies to address these issues and enhance the quality of urban public spaces. A critical point in this process is how we perceive public art. This perception can result in either a purely visual impact of public art on public spaces or, in a broader view, can foster social interaction and community engagement, promoting greater social cohesion. This paper focuses on the broader perspective, considering public art within social dynamics.

From this point of view, public art, as defined by Luo et al. (2022), serves as a shared civic element that adapts over time to address social challenges. It prioritizes public engagement and the common good, creating spaces where people feel a sense of belonging and see reflections of themselves, fostering inclusion and community identity (Aharon-Gutman, 2017; Sharp et al., 2005). Kwon (2002) supports integrating public art with urban development to align with its social and spatial context, creating accessible and collective spaces for interaction. Public art's participatory nature often brings diverse voices into the creative process, giving marginalized communities a platform within urban spaces (Minty, 2005). Caris and Cowell (2016) view it as "situation art," emphasizing democratic engagement, while Phillips (1989) stresses that its "publicness" arises from its interaction with social issues, cultural patterns, and community life.

Promoting social cohesion and cultural vibrancy (Sharp et al., 2005), enhancing aesthetics, fostering cultural engagement and social cohesion. (Luo et al., 2022; Zhe & Uyttenhove, 2018) are among those impacts that public art might have on urban spaces. By welcoming cultural diversity and community identity, public art can create inclusive public spaces. (Hall & Robertson, 2001; Cartiere, 2016). Regarding Public art's interdisciplinary nature, Zebracki et al. (2017) has noted that public art has the potential to reflect socio-economic shifts and foster collective identities within public spaces. Public art can act as a dynamic platform that engages communities, challenges dominant narratives, and fosters dialogue (Guazon, 2013; Bengtsen, 2013; Szőke & Parizeau, 2019). It can influence the socio-economic and cultural dynamics of urban spaces, transforming them into livable cultural landscapes. (Mark & Pederick, 2010; Pérez et al., 2022).

Recent academic discourse concentrates on not well-discovered aspects of public art, particularly around publicness, civic participation, and the balance between community benefit and privatization (Ehrenfeucht, 2014). Collective experiences in public spaces would be assumed because of public art's integration into cities (Michels & Steyaert, 2016). Both curated and spontaneous public art can change public spaces through engaging communities in dialogue, enhancing cohesion and fostering identity (Raposo, 2022; Pollock & Paddison, 2014; Gagliardi, 2020). The impact of public art on social dynamics and urban regeneration has been pursued by some scholars emphasizing its potential as a tool for community innovation and cultural expression (Strom, 2020).

A review of current literature shows that public art is widely studied in terms of aesthetic, social, and economic benefits. There is a significant gap in the current literature, however, concerning respective vitality and full-course integrations into urban planning and design. Moreover, there are not enough empirical studies to prove that public art can affect the functional inclusiveness of public spaces. Questions remain about its effectiveness in creating accessible and welcoming spaces for people of diverse backgrounds. Another critique is related to the absence of community involvement in the process of planning and placement of public art. A disconnect between the artworks and the communities using public spaces could be assumed as a result of this absence. This lack of local engagement and neglecting the potential for art to shape a shared sense of place can result in spaces that feel imposed rather than inclusive. Regarding the gaps mentioned above,

this study aims to share a critical perspective of public art's influence in Helsinki's Pasila neighborhood. This kind of critic focuses on the essential need for community engagement in the process and procedure of planning for public art to resonate with and benefit the local people.

2. Literature review

Although the effects of public art on public spaces have been at the center of current literature, but a holistic view of these effects has not presented well. The role of public art in the aesthetic dimensions of public spaces, social interaction, placemaking, and urban renewal has been emphasized in many studies of current knowledge. On the contrary, its role in community engagement, inclusivity, and social commentary has not been fully explored.

Public art plays a vital role in affecting the public spaces to better serve their function, transforming them into inviting, engaging environments that contribute to community health and cultural identity. Environmentally integrated public arts further enhance the aesthetic appeal of places by fitting in with their natural surroundings. These works are meant to have long-term artistic value and to meet the requirements of environmental design (Zhe & Uyttenhove, 2018; Kwon, 2002). Public art is critical in defining unique spatial identities and producing places of experience (Evans, 2005; Ernwein & Matthey, 2019). The performative public art discussed by Massey and Rose (2003) and Zebracki (2015) provides visitors with an opportunity to touch it, and thus cultivation of their physical attributes in various ways induces unique emotional responses. This helps give rise to community engagement.

Public art, especially sculptures and other prominent installations, plays a major role in promoting social interaction within public space by providing focal points for conversation and engagement. Such works improve the social life of public spaces by making areas such as plazas more attractive and usable, establishing lively social environments where people congregate for leisure activities. (Abdulkarim & Nasar, 2014) At the same time, as larger groups of individuals are encouraged actively to use these public spaces, organizing themselves into loose yet effective organizational formations, the meaning that they attach to them can thus be nurtured in one way or another.

Public art also creates diverse spaces—whether material, virtual, or imagined—where individuals can ponder communal life and the usage of public places fostering sense of belonging. In this infinitely important and fundamentally necessary message to the world at large, some scholars have been especially outspoken (Aharon-Gutman, 2017; Sharp et al., 2005).

Public art contributes to place-making by transforming urban spaces and reshaping perceptions. It often takes place in areas associated with criminality and turning them into cultural and artistic hubs that improve public space inclusivity (Campos, 2020). By integrating site-specific elements, public art strengthens social and physical environments, aligning with trends in creative placemaking where various sectors collaborate to build neighborhood identities around arts and cultural activities, fostering local business viability and safety (Kwon, 2002; Markusen & Gadwa, 2010). The concept of creative placemaking places a special emphasis on how public art can help create neighborhood character, support local markets and materials businesses, and ensure safety (Markusen & Gadwa, 2010).

Public art is an essential factor in urban renewal. By redefining public spaces and developing them into local public spheres, it benefits communications between people and contributes to urban regeneration by creating culture and sense of place. To cite Aharon-Gutman (2017): public art can renovate urban environments but is also likely to involve conflicts, and in politically charged

contexts may bring these to the very fore. This sentiment points to the roots of tension existing in art and response by the public. Legalizing street art can also make cities more vigorous and change the direction of public space usage in a positive way (Chang, 2018). Mathews (2010) suggests that as public art is supportive of community building and economic development, it can further reinforce capital control by providing authorities with an opportunity to serve their own interests as well. Because of this dual potential within urban environments, public art requires credence as well as caution.

Public art provides a powerful vehicle for social and political criticism. The areas it creates are inclusive spaces in which memory, cultural background, and public opinion come together. Consequently, public art can both deal with societal divides and rejection, as a form of resistance, social norms and urban control (Aharon-Gutman, 2017; Villa, 1992; Kane, 2009). It is during the course of reflecting on issues such as in/exclusion that public art enters into a dialogue with the city, thereby giving space for marginalized individuals to participate in "everyday politics" and assert their identity in the public sphere (Kearns et al., 2020; Guazon, 2013; Youkhana, 2014).

Public art not only sustains public dialogue but also democratizes urban space by involving inhabitants in artistic processes, thus creating a sphere that is both participatory and inclusive (Radice, 2018; Wright, 2018; Hall, 2007). By depicting the identity and dreams of a community, public art keeps public spaces alive, fostering pride and a sense of ownership among residents (Evans, 2005; Lees & Melhuish, 2015).

On top of promoting engagement, public art can also enhance social inclusivity by providing a living platform where people in the community come together and perform activities together. Thus, at the same time as promoting social cohesion through shared experience and common memory banks can be established where people coexist in peace. (Fransberg et al., 2023; Hedegaard, 2014) Participatory art forms like graffiti and street art involve the public in creating and asserting their own identities. Other examples are the urban knitting project, which creates links among neighbors and breeds (Farinosi & Fortunati, 2018); and installations that help consolidate cross-community relationships and reconcile antagonistic groups (Downey & Sherry, 2022). Public art also generates "micropublics," which can serve as the bearers of meaningful dialogues bringing societal issues to the fore and promoting inclusion through interaction (Zebracki & Bekker, 2018; Malachowski, 2022). Public art thus becomes a form of emotionally compelling media through these various forms of engagement, a way where people in the city express, commemorate, and stand together by turns the common values. (Nguyen, 2019).

As a final note on the potential impacts of public art we can say it has close links to the quality of the public sphere; through creativity and artistic expression, it is able to foster inclusion, democratic citizenship, and communal involvement combined. When public art involves whole communities in the creative process, it reflects society even better and becomes invigorated with the site, causing it to impact the urban fabric all of a sudden (Caris & Cowell, 2016; Chang, 2008). It also enables citizens to assert their "right to the city" and address social problems (Pinder, 2005; Gartus et al., 2015). The co-productive nature of public art can creates both ownership and belonging, not only endowing individuals with a sense of identity but also developing new types of urban citizenship whose development can be seen in street art (Lee, 2013; Palmer, 2018).

Therefore, public art's all-embracing nature not only contributes to the aesthetic enhancement of urban spaces but also benefits them socially by promoting interaction, dialogue, and an ebullient communal life. Despite references in the current literature to the role of public art in community engagement and inclusiveness in urban public spaces, few studies present this potential based on evidence-based research.

3. Methodology

3.1. Study area

Pasila occupies a unique position in the Helsinki region, linking residential areas, commercial zones, and new urban districts as a transitional area. Its excellent location, linked to a major rail station, has elevated it into a daily waypoint for those on business or social visits in town, as well as those coming and going. Over the previous 25 years, improved accessibility and its modernist architectural style have made it an ideal site for urban art. As a result, Pasila's East has become a synonym of the coming art district. (Fig 1, 2 & 3)

Pasila is renowned as a unique blend of different peoples, languages, and lifestyles that has produced its incredibly multicultural atmosphere. With its vast walls of mid-century concrete, Pasila has developed into a leisurely downtown collection of murals and artistic installations. It emphasizes grand-scale effects that serve as architectural signatures for viewers to enjoy from pedestrian bridges on either side for a long distance. The neighborhood has been under renewal, with new mixed-use projects such as Mall of Tripla complex. Art in public places like Pasila has played a strategic role in creating the flavor of the district, moving it from being just a place people change trains to one where they live and work.

Now Pasila is at last becoming a dynamic and living cultural center both for the people who live there every day as well as those who come into it from other areas. There are such organizations as Helsinki Urban Art and Helsinki Art Museum (HAM), which carry out projects to bring art out of traditional galleries and place it directly in everyday places. This will provide the people with an experiential and accessible cultural opportunity that is interactive, personal, and enjoyable. The variety of artworks found in Pasila—everything from outdoor murals to statues and delicate lighting installations—means that it stands as a space encompassing numerous artistic voices.

East-Pasila's transformation into an art district also introduces Helsinki's cultural vision to integrate art into public spaces. It is also would be a sign of a forward-looking approach to urban design. This district represents the city's commitment to creativity within urban contexts and introducing Helsinki's reputation as an innovative cultural capital.

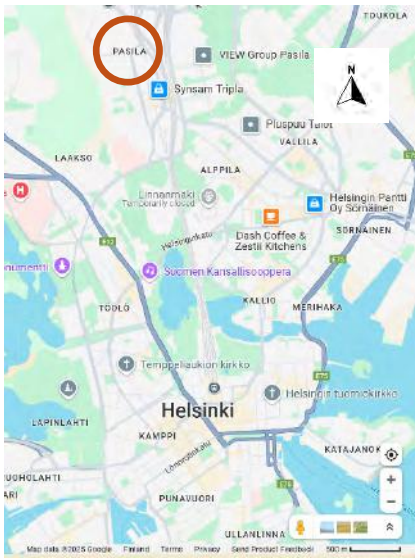


Figure 1: Psaila's location in Helsinki, Google Map, 2025

Figure 2: location of artswork in East-Pasila (Helsinki Urban Art Association, 2024)

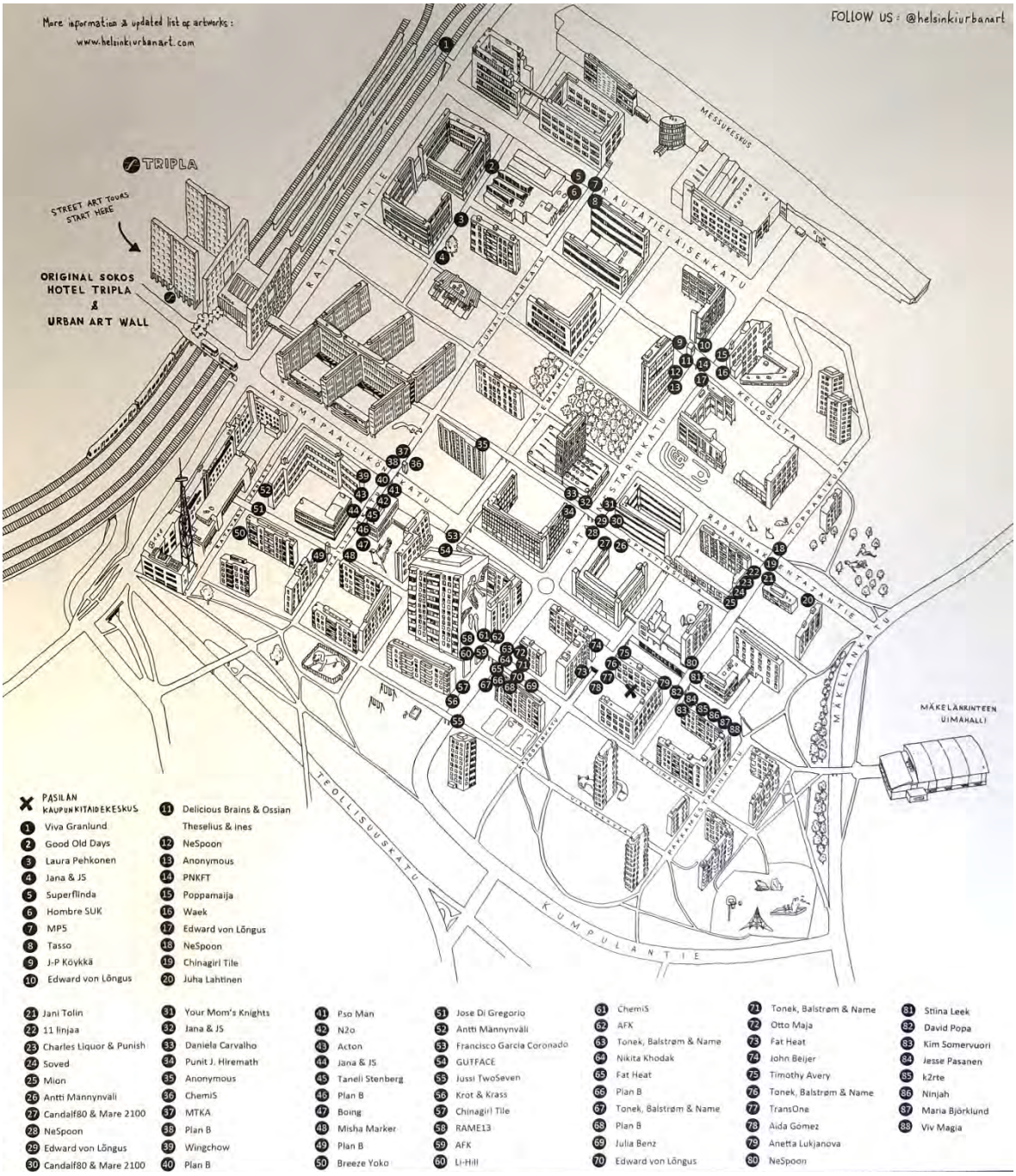


Figure 3 : spatial distribution of artworks (Helsinki Urban Art Association, 2024)

3.2. Methods

To carry out this study, we have combined field observations and structured interviews to analyze the role of public art in shaping inclusive public spaces within the Pasila neighborhood. We conducted systematic observations in Pasila to photograph its public art installations and content-analyze them for spatial interaction with the environment. The focus of the research lay on where artworks were sited in relation to the environment, how they melded with that physical environment, and what architecture they contained/deferred to, as well as content that reflects the diversities of culture in the neighborhood itself.

We paid particular attention to people's interactions with such public art—whether they looked at it quietly, came together socially to discuss it, or even played around nearby installations themselves. In doing so, we were able to capture changing patterns of engagement over time and how much time a person spent near the various installations. This observation data shows the subtle as well as more manifest ways that public art can help create an inclusive space where everyone feels like they belong. It also shows how residency is transformed and touches on issues of human interaction in cities.

Interviews were conducted with a diverse range of urban professionals and artists. In the interviews, they were asked to voice their views on public art's impact on urban inclusiveness, as well as its aesthetic and social functions.

The specific questions asked are:

1. 1. How do you evaluate the impact of public art in Pasila on the overall aesthetic and everyday life of the neighborhood?
2. Does it primarily enhance visual qualities, or does it have a broader impact on social interaction, community engagement, and urban tourism?
3. Do you think that Pasila's public art reflects the cultural diversity which is present within the neighborhood?
4. How do you judge Pasila's public art in terms of inclusive content and process of producing? Is the voice mainly or entirely those of minorities or local inhabitants contained in murals and installations? Please give reasons for your answer.
5. What kinds of obstacles do you see now, and how would you suggest future public art plans in Pasila to be more inclusive and better meet community needs?

4. Result and Discussion

The impact of public art in East Pasila demonstrates both its potential and limitations in fostering inclusiveness within urban spaces. This study's findings, supported by field observations and expert interviews, indicate that while public art contributes to East Pasila's visual landscape, its role in cultivating a socially inclusive public realm remains constrained.

Field observations reveal that East Pasila's public art, primarily mural and graffiti-based works, is positioned in areas initially perceived as neglected or less welcoming. These artworks, placed along key pedestrian paths and transitional gateways, succeed in enlivening these spaces, providing a raw and organic aesthetic that resonates with East Pasila's diverse, urban character. This visually compelling environment invites exploration and engagement, contributing meaningfully to social interaction. However, despite these benefits, the inclusiveness of public spaces remains limited, as the artworks often lack direct input from the local community in their conceptualization. Consequently, these installations do not fully capture the voices and identities of East Pasila's residents.

Expert interviews further underscored the limitations in cultural representation within East Pasila's public art. While the artworks occasionally reference multicultural themes, their expression remains conventional and predictable, lacking spontaneity and local character typical of authentic street art. Experts observed that many of the artworks are generic commissions with limited site-specific engagement, reducing their impact and potential to serve as meaningful expressions of East Pasila's cultural diversity. The absence of raw, interactive elements in these works diminishes

their potential for inclusivity, as they fail to embody the unique, layered cultural narratives of the neighborhood.

The inclusiveness of the creation process was also questioned. Interview insights suggest that many artworks were commissioned by external experts, with minimal engagement from local residents or minority voices. This top-down approach to public art curation has resulted in installations that, although visually appealing, lack resonance with the community's unique social fabric. Without mechanisms for community involvement in art selection and creation, these artworks fail to reflect the lived experiences of East Pasila's diverse population. This disconnect reflects a broader challenge in making public art more inclusive: the need for participatory approaches that center local perspectives and encourage representation from marginalized groups.

Figure 4: reflection of inclusiveness, artist: Superflinda (Finland)

The study also identified institutional and policy challenges in promoting inclusivity through public art in East Pasila. The existing framework tends to prioritize political correctness and aesthetic safety, often at the expense of artistic authenticity or social critique. Based on experts' viewpoints that East Pasila's public art tends toward beautification rather than embracing dialogical qualities necessary for better community engagement. Also, improving institutional coordination, particularly between the Helsinki Art Museum (HAM) and the City of Helsinki, is needed for future public art development.

5.Conclusion

To sum up, this study shows the importance of public art in creating inclusive public spaces in East Pasila, Helsinki, as well as the complexity of its role.Though public art has been instrumental in beautifying the aesthetic landscape of the neighborhood and is helping get its image as an art district, it has limited benefits at the social level.It shows how the practices of public art in East

Pasila have not reached the level of impact since the initiatives lack the common will of the community, which reduces the installations to merely aesthetic value and does not reflect the cultural diversity and the voices of the citizens.Prioritizing local perspectives, especially those of marginalized and minority groups, is the gist of participatory approaches in public art planning; therefore, filling this gap.

Future programs might put more emphasis on collaborative initiatives among artists, policymakers, and the community to bolster the message that public art can not only beautify but strengthen community ties and reflect the multicultural identity of the region. Such inclusive practices enable public art to do its work as a transformative social force while bringing a sense of belonging and ownership into East Pasila's urban landscape.

6. References

Abdulkarim & Nasar. (2014) 'Evaluating public spaces for social interaction'. Journal of Environmental Psychology, 40, pp. 134-142.

Aharon-Gutman. (2017) 'Public art as a social agent: Integrating multicultural expressions. Journal of Urban Design', 22(2), pp. 245-260.

Bengtsen. (2013) 'Street art as an urban phenomenon'. Public Art Studies, 10(4), pp. 298-312.

Campos. (2020) 'Revitalizing public spaces through public art: Case study from São Paulo'. Community Art Research, 27(1), pp. 43-56.

Caris & Cowell. (2016) 'Situation art in contemporary urban landscapes'. Urban Culture Review, 20(4), pp. 305-319.

Cartiere. (2016) 'Regenerating urban spaces: Public art and its impact'. Creative Cities Journal, 12(1), pp. 67-85.

Chang. (2018) 'Regulated street art in Singapore and its role in urban aesthetics'. Southeast Asian Art Perspectives, 6(3), pp. 123-139.

Ehrenfeucht. (2014) 'Public space and inclusion: Perspectives on contemporary urbanism'. Urban Theory and Practice, 18(2), pp. 158-173.

Ernwein & Matthey. (2019) 'The role of art in urban regeneration: space, place, and policy'. Urban Studies, 56(5), pp. 1034-1050.

Evans. (2005) 'Measure for measure: Evaluating the evidence of culture's contribution to regeneration'. Urban Studies, 42(5-6), pp. 959-983.

Gagliardi. (2020) 'Public art and social justice in conflict zones'. International Art & Conflict Journal, 7(2), pp. 202-219.

Guazon. (2013) 'Marginalized voices in public art: A study of community impact'. Art & Society Review, 21(2), pp. 85-103.

Hall. (2007) 'Public Art and the City'. Geography Compass, 1(5), pp. 1018-1035.

Hall & Robertson. (2001) 'The social role of public art in urban renewal'. Cultural Cities Quarterly, 9(4), pp. 287-302.

Kane. (2009) 'Graffiti as resistance: youth and urban space in Brazil'. Journal of Latin American Studies, 41(3), pp. 457-481.

Kee, et al. (2020). 'Everyday politics in public art: Voices from the margins'. International Journal of Urban Studies, 18(2), pp. 158-174.

Kwon. (2002) 'One place after another: Site-specific art and locational identity'. Cambridge, MA: MIT Press.

Lees & Melhuish. (2015) 'Urban renaissance and the art of public space'. Urban Studies, 52(10), pp. 1904-1918.

Luo, et al. (2022) 'Public art as civic engagement: An evolving discourse'. Contemporary Public Art Journal, 30(1), pp. 55-76.

Mark & Pederick. (2010) 'Community murals and urban identity'. Street Art Journal, 15(3), pp. 142-157.

Markusen & Gadwa. (2010) 'Creative placemaking: Transforming communities through art'. Urban Studies Quarterly, 22(1), pp. 35-50.

Massey & Rose. (2003) 'Urban art and spatial politics'. Cultural Geographies, 10(2), pp. 142-160.

Mathews. (2010) 'The dual role of public art in urban Spaces: Beautification vs. social commentary'. Urban Culture Studies, 22(4), pp. 310-325.

Michels & Steyaert. (2016) 'Public art and civic participation in urban landscapes'. Civic Engagement Review, 19(1), pp. 102-119.

Minty. (2005) 'Public art and multiculturalism in post-apartheid Cape Town'. Cultural Studies of Africa, 11(2), pp. 219-234.

Oakes & Warnaby. (2011) 'Festivals and urban renewal: Insights from Manchester'. Cultural Economy Journal, 8(4), pp. 311-325.

Pérez, et al. (2022) 'The social impact of murals in urban settings'. Public Space and Art Journal, 28(2), pp. 157-176.

Phillips. (1989) 'Public art and the public sphere: The place of art in society'. Art & Urbanism Quarterly, 3(2), pp. 120-135.

Pollock & Paddison. (2014) 'Public art and the inclusive city'. Urban Arts Studies, 16(3), pp. 234-250.

Radice. (2018) 'Public art as community bridge in multicultural neighborhoods'. International Journal of Urban Culture, 25(2), pp. 89-104.

Raposo. (2022) 'Interactive public art and urban dynamics'. Art & Space Quarterly, 24(1), pp. 75-98.

Sharp & Paddison. (2005) 'Just art for a just city: Public art and social inclusion in urban regeneration'. Urban Studies, 42(5), pp. 929-939.

Strom. (2020) 'Public art and urban regeneration: Insights from European cities'. European Cultural Affairs Journal, 29(1), pp. 65-84.

Szőke & Parizeau. (2019) 'Graffiti as a form of social commentary in urban spaces'. Art and Urban Culture Review, 18(3), pp. 194-210.

Toukan. (2020) 'Performance art and social dynamics in Beirut'. Middle Eastern Art & Politics, 15(2), pp. 111-130.

Villa. (1992) 'The politics of art in divided cities: A Jerusalem case study'. International Journal of Conflict Art, 4(3), pp. 201-215.

Wright. (2018) 'Public art as inclusive practice: Socially engaged art in the city'. International Journal of Cultural Policy, 24(2), pp. 241-257.

Youkhana. (2014) 'Everyday politics of identity: Migrant voices in public art'. Social and Cultural Geography, 15(4), pp. 441-459.

Zebracki. (2015) 'Public art and interaction in urban space'. Urban Studies, 52(13), pp. 2488-2504.

Zebracki, et al. (2017) 'The role of public art in building community identities'. Journal of Urban Art and Society, 23(4), pp. 411-427.

Zhe & Uyttenhove. (2018) 'Environmental art in urban landscapes: A perspective from Asia'. Eco-Art Journal, 14(2), pp. 98-115.

Spatial Analysis of Urban Growth Patterns and Land Use Dynamics in Industrial Cities along the DMIC Corridor: A Remote Sensing and GIS Approach

Purba Biswas, Research Scholar, Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur, India

Priyanka Dey, Professor, Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur, India

Abstract

Urban expansion due to increasing population and rapid industrial growth is one of the key drivers for Land use and Land cover (LULC) transformations in developing nations. It is essential to monitor LULC in rapidly urbanising cities in India for effective and long-term urban land management. The aim of this research is to analyse and understand the spatial characteristics of three industrial cities along the DMIC corridor based on LULC metrics. LULC statistics and built-up growth data have been used to analyse and compare the urban growth patterns and urban planning approaches in the Indian cities of Delhi NCR, Surat and Ahmedabad. Remote Sensing (RS) data and Geographic Information System (GIS) methods were employed to analyse LULC dynamics over the past two decades (2000, 2010 and 2020). The statistical values and spatial mapping indicate rapid socioeconomic growth in both industrial cities, complex urban development patterns, and multiple development nodes along major transportation routes. The built-up density, which is a crucial metric for assessing urban spatial expansion, has significantly enhanced the understanding of spatial behaviors. This study's findings depict a decline in barren land and vegetation and substantial growth in urban built-up and high built-up densities in and around industrial areas, major growth nodes, and along the DMIC corridor.

Keywords

Built-up, GIS, Land use Land Cover (LULC), Remote Sensing (RS), Urban Expansion

1. Introduction

Currently, 54% of the global population lives in urban areas and by 2050, this number is projected to increase to 66% (Nations, 2015). India is expected to be one of the most significant contributors to this urban growth, with an estimated increase of 404 million urban residents by 2050 (Nation, 2014). Rapid population and economic growth are the most significant contributors to urban land expansion (Indrawati *et al.*, 2020). Land is the most important natural resource accessible to society and is used in various ways depending on prevailing conditions and human requirements. Thus, any changes over land because of new industrial and economic activities affect the overall Land Use and Land Cover (LULC) pattern of cities and regions (Nelson *et al.*, 2010). Population changes also directly affect built-up growth and overall urban LULC transformation (Kyule and Wang, 2024).

Land use refers to the aplication of Earth's terrestrial resources for diverse human endeavours, whereas land cover signifies the physical material covering over Earth's surface. i.e., built-up areas, vegetation or agricultural lands, water bodies etc (Herold *et al.*, 2006 ; Mishra and Rai, 2016). Changes in LULC collectively refer to modifications to the terrestrial surface driven by both natural processes and human actions

(Chaturvedi *et al.*, 2022). Urban LULC alterations are fundamental indicators of urban transformations (Banzhaf *et al.*, 2017). Changes in few land use impact the functions of various other land use categories differently, resulting in diverse consequences even within the same urban region or city (Rashed and Jurgens, 2010). Identyfying and assessing various types and forms of urban spatial growth and their transformation is essential for explaining urban land-use interactions and transformations (Yılmaz and Terzi, 2021; Aithal and Ramachandra, 2016).

1.1. Industrialisation and Urban Expansion

Urbanisation is always associated with industrialisation, as it directly relates to socio-economic conditions (Christy RD, 2000). Industrialisation is a critical driver of socio-economic growth in both developed and developing nations (Kyule and Wang, 2024), serving as a transformative process that reshapes societies both socially and economically and leads to rapid LULC changes (Biswas and Dey, 2023). Urbanisation is always associated with industrialisation as it directly relates to socio-economic conditions (Li and Yeh, 2004). The rate of urban expansion and LULC transformations are influenced by many regional and local factors like industrial development, types of economy, population growth, transportation network, investment and land-use policies (Karen C. Seto, 2011). Among all these factors, economic development through industrial growth, transport or investment corridors plays the most significant role in built-up expansion (Ratner and Goetz, 2013; Omwamba, 2015) as shown in Figure 1.

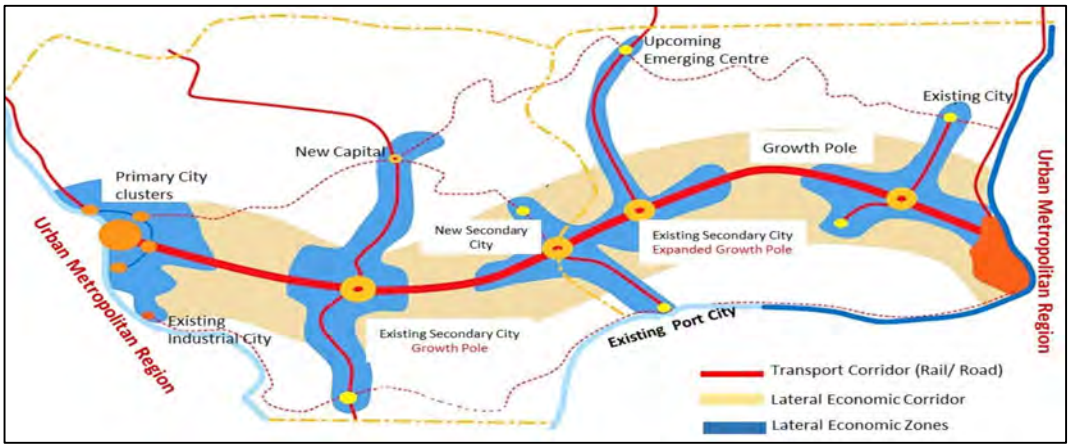


Figure 1: Economic Corridor and Urban Expasion; Souce: Generated by Authors

Assessing Land Cover changes using RS data and GIS tools is very significant as it delivers precise, timely, and consistent data on spatial transformations (Manesha, Jayasinghe and Kalpana, 2021; Martellozzo and Clarke, 2011). RS data has been extensively applied in urban expansion studies due to its high spatial resolution and required temporal frequency, making it ideal for analysing urban growth and LULC changes (Bhatta, 2009, Maher Milad Aburas *et al.*, 2017). RS data provides multi-temporal and multi-spectral data important for comprehensive land cover mapping (Kabisch *et al.*, 2019; Trujillo-Jiménez *et al.*, 2022). By integrating RS data with GIS, researchers and urban planners can effectively analyse LULC changes and their impacts through land cover mapping and spatio- temporal change detection (Atay Kaya and Kut Görgün, 2020; Bao Pham *et al.*, 2024).

This research paper analysed the LULC transformation pattern of three different economic cities and investigated the relationship between urban expansion and industrial growth. Objectives of this study are (i) to study the spatio–temporal relations between industrial growth and urban LULC transformation, which

led to change in urban extent, and (ii) to assess the pattern of built-up changes in the three distinct tiers of industrial cities.

2. Study Area

Currently in India, five distinct planned transport or transit or economic corridors are proposed to facilitate regional economic growth and overall national development. These corridors are- 'Chennai- Bangalore Industrial Corridor (CBIC), 'Delhi-Mumbai Industrial Corridor (DMIC), 'Bengaluru- Mumbai Economic Corridor (BMEC), 'Amritsar- Kolkata Industrial Corridor (AKIC) and 'Visakhapatnam- Chennai Industrial' Corridor (VCIC) as shown in Figure 2(a). DMIC serves as one of India's most significant mega-regions and agglomeration economies, witnessing, significant growth over recent decades. DMIC is situated in the western part of India, spanning 1500 km from Delhi to Mumbai (Toppo and Nimbekar, 2015). The total influence area of DMIC is 436,485 sqkm, accounting for 13.8% of India's total geographical area (DIPP, 2013). The DMIC was developed along the existing National Highway 8, covering parts of the states and union territories of Madhya Pradesh, Uttar Pradesh, Maharashtra, Rajasthan, Haryana, Gujarat and Delhi. Many cities and new urban centers situated along the DMIC and within the influence area witnessed tremendous economic and industrial growth, leading to rapid LULC transformations and built-up expansion. We have done a comparative LULC analysis of three cities along the DMIC to trace their transformation dynamics. i.e. Delhi National Capital Territory (NCT), Surat Urban Development Authority (SUDA) and Ahmedabad Municipal Corporation (AMC) as shown in Figure 2(b).

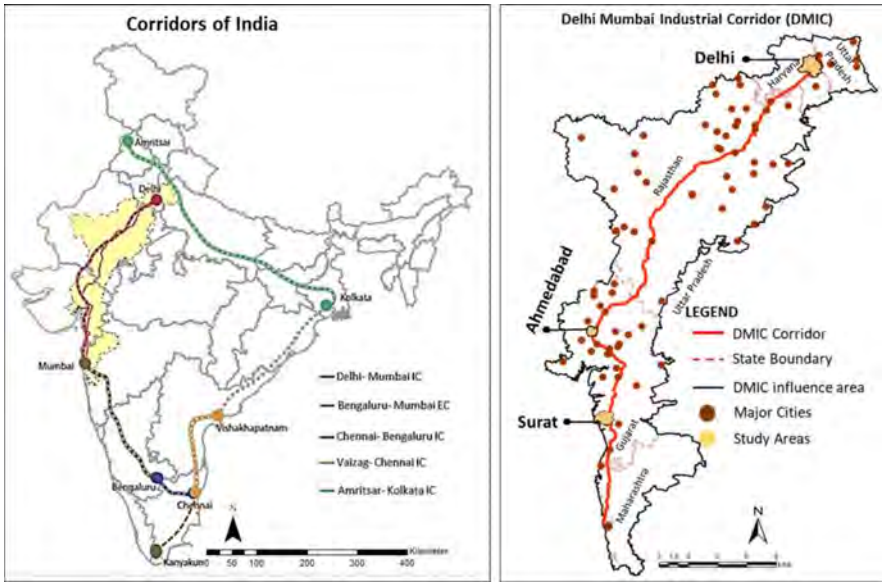


Figure 2: Corridors of India (a), Delhi Mumbai Industrial Corridoor (b), Year 2024
Souce: Generated by Authors

Delhi NCT

Delhi is India's largest metropolitan region, with an area of 1500 sqkm as shown in Figure 3(a). NCT extends from 28°24'30"N to 28°53'4"N and from 76°49'58"E to 77°20'15"E. Over the decades, the total population increased from 9.42 million in 1991 to 16.7 million 2011. i.e., an increase in 78% population from 1991 to 2011. Delhi is one of the world's most widely dispersed suburbs due to its high population and built-up concentration, including residential, commercial, and industrial land uses. For ages, industries have been

the backbone of Delhi's economic growth; the DMIC project also induced more industrial growth and infrastructure development in NCT.

SUDA

Surat is a tier-II coastal city situated in the western region of the Indian state of Gujarat. Surat is extended between 21°10'12"N to 21°17'02"N and 72°49'51"E to 72°83'10"E. The Tapi River passes the northern part of the city and meets with the Arabian Sea to the west. It is the second-largest city in Gujarat and the eighth-most populous city in India (Corporation, 2023). Surat is among the rapidly developing cities in India for economic development and globally ranks as the fourth fastest-growing city.

SUDA consists of one municipality (SMC) and 95 villages shown in Figure 3(b). It has a population of 5 million and an area of 1,027 square km. The Surat district demonstrates the highest population growth rate of all districts in Gujarat, exceeding both the state and national average growth rates. Industries are the primary drivers of Surat's economy.

AMC

Ahmedabad is located in the western Indian state of Gujarat, adjacent to the Sabarmati River as shown in Figure 3(b). Ahmedabad municipality is extended between 23°02'2"N and 72°57'1" E. Since the 1950s, the city's population has increased gradually, surpassing 8,059,441 in 2020 at an annual growth rate of 2.54%, making it the seventh most densely populated city in India. Ahmedabad is an urban, densely populated, industrialised, largest city in the central part of India. The municipality area comes under the authority of the Ahmedabad Municipal Corporation (AMC), including an area of 466 sqkm. The total area of Ahmeda bad district is 7,170 sqkm.

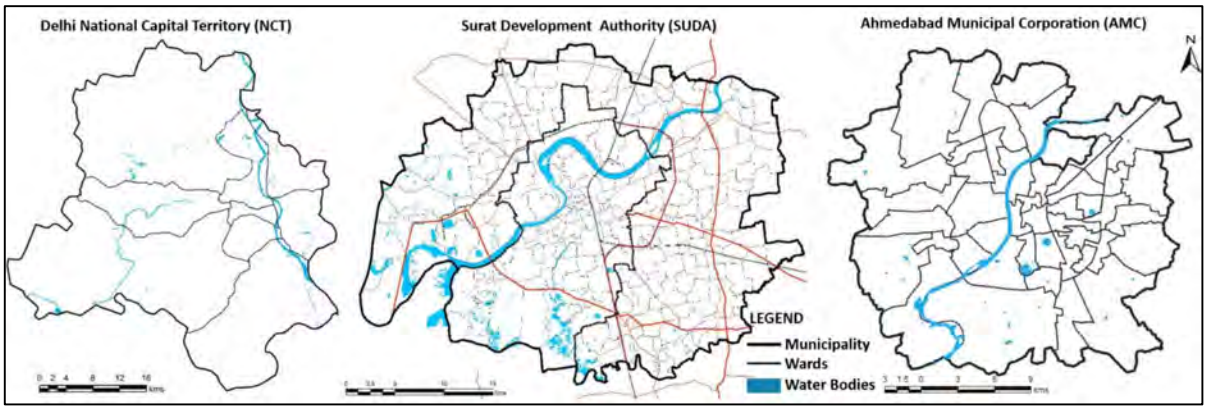


Figure 3: Study Area (a) Delhi National Capital Territory, (b) Surat Development Authority, (c) Ahmedabad Yera 2024 ; Souce: Generated by Authors

3. Methodology

This study analysed LULC dynamics and urban expansion patterns using spatio-temporal RS data and GIS techniques. The LULC for all three study areas are broadly grouped into four classes: Water Bodies include river, lakes, streams, channels and ponds; Built-up includes all built-up types of rural and urban areas; Vegetation includes forests, cropland, agricultural fields and shrubs; Range or Barren land including bare ground, grazing land and flooded land. The detailed LULC classifications for 2000, 2010, and 2020 were done using USGS's multi-temporal satellite images based on India's NRSC classification. The process encompassed satellite database preparation, imagine categorisation, on-screen visual interpretation,

ground truth checking, validation, map finalisation, quality assessment of final maps, and accuracy assessment. The detail methodology is shown in Figure 4.

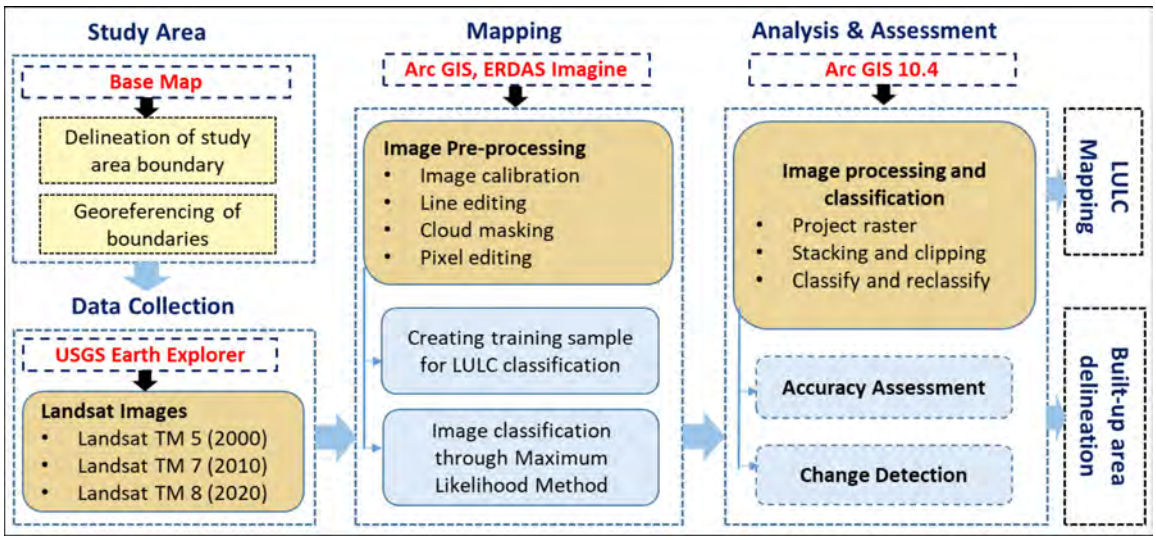


Figure 4: Detail Methodology; Souce: Generated by Authors

3.1. Steps of Data Analysis

Firstly, Landsat images for the years 2000, 2010 and 2020 were obtained from the United States Geological Survey portal (USGS). The multi-temporal images of NCT, SUDA and AMC were downloaded for LULC classification. Secondly, image processing was done using Arc GIS and ERDAS IMAGINE. Thirdly, for each study area, LULC classification and preparation of LULC maps were done by following the Maximum Likelihood Method in Arc GIS 10.4. Fourthly, the NDBI analysis for all three study areas was done to highlight the built-up expansion pattern from 2000 to 2020.

Cloud Free (cloud less than 10%) and without precipitation data was considered while downloading data from USGS for accurate LULC classification (USGS, 2024). Landsat 7TM images were used for 2000, Landsat 5TM images for 2010, and Landsat 8TM images for 2020 shown in Table 1.

Table 1: Detail of Satellite Images acquired from USGS

Data Types	Acquired Date (SUDA)	Acquired Date (AMC)	Acquired Date (NCT)	Source	Spatial Resolution
Landsat 7 (WRS -2)	20/03/2000	17/02/2000	19/2/2000	USGS	30 m
Landsat 5 (WRS -2)	17/04/2010	19/02/2010	14/2/2010	USGS	30 m
Landsat 8 (WRS -2)	15/04/2020	21/02/2020	28/2/2020	USGS	30 m

Source: USGS, 2024

3.2. Data Used and Data Classification

The latest administrative boundaries for each study area were taken from the respective administrative authority and subsequently georeferenced and rectifies using Google Earth Pro. Multi-spectral satellite data for years 2000, 2010 and 2020 were acquired from Landsat (TM/ETM+/OLI-TIRS) utilising Path (125) and Row (52) as the geocoding method. We have chosen a cloud coverage range of 0 to 10% to obtain cloud-free, high-resolution satellite images for LULC classification. Geometrically corrected photos in

GeoTIFF format, projected to a standardised Universal Transverse Mercator (WGS 1984 UTM) zone, were used for final map preparation.

The temporal population data was collected from the Census of India (Census, 2011), and other statistical data was collected from the respective municipalities, development authorities and District Census Handbook.

4. Results and Discussion

Statistical data and preparation of maps provide a comprehensive and unique landscape scenario for three different cities. The graphical representation of LULC classes offers a general interpretation of changing land use dynamics in the last two decades.

4.1. NCT

In the last two decades, NCT has witnessed moderate changes in all the LULC categories, but maximum changes have been witnessed in Built-up. The built-up area has expanded from 846.74 sqkm in 2000 to 880.93 sqkm in 2010 and 904.36 in 2020 as shown in Figure 5. Built-up areas have mostly encroached on vegetation, water bodies, and barren land, from 56.40 % in 2000 to 58.68 % in 2010 and 60.12 % in 2020. During the study period, built-up growth was maximum during 2000- 2010 because of the proposed industrial (DMIC) and freight corridors. Majorly built-up growth has been seen outside the central part and immediate vicinity, besides major cities like Rohtak, Merrut, Sonipat, Ghaziabad, Muzaffarnagar, etc.

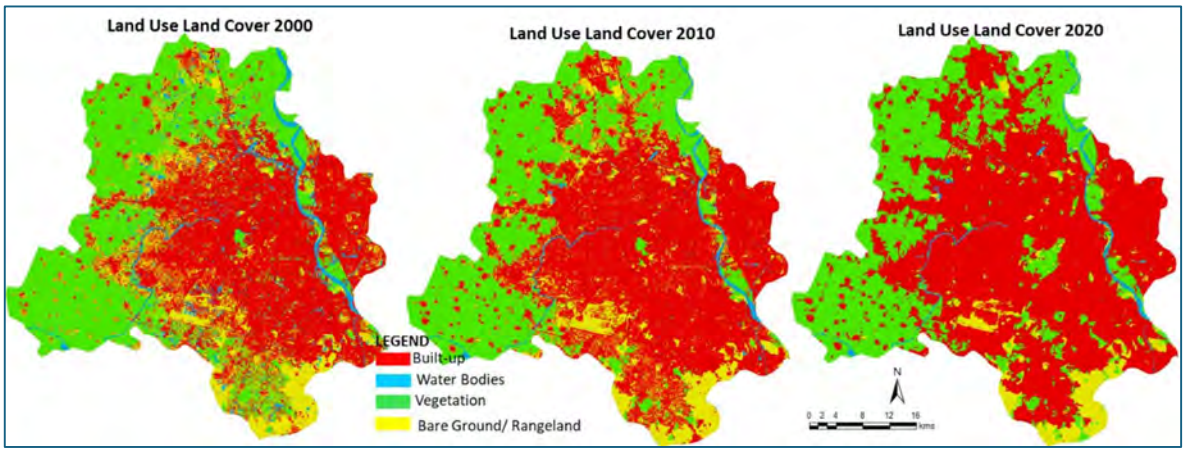


Figure 5: LULC maps of Delhi National Capital Territory (a) 2000, (b)2010, (c) 2020;
Souce: Generated by Authors

Vegetation land has witnessed a decrease of 2.05 % during the study period, 2000-2020. Vegetation land coverage was 517.58 sqkm (34.48 %) in 2000, 501.21 sqkm (33.39 %) in 2010 and 492.58 sqkm (32.74 %) in 2020. The decline in green coverage is majorly at the expanse of built-up growth for commercial, industrial and residential land uses. Vegetation land decreases tremendously in the western part of the NCT because of new and upcoming industries, expressways and rapid growth of adjoining small and urban centers.

Rangeland, or bare ground available mostly along the periphery area, has also witnessed a decrease of 1.67 % from 2000 to 2020. Bare ground was 114.32 sqkm (7.61 %) in 2000, 99.21 sqkm (6.61 %) in 2010, and 89.45 sqkm (5.95%) in 2020 shown in Figure 6. Majorly, bare ground has been converted into new built-up growth, as Delhi is still witnessing tremendous industrial growth on the outskirts of the city.

From 2000 to 2020, the total area of the water body decreases by 0.32 %. The area of the water body was 22.68 sqkm in 2000, 20.05 sqkm in 2010 and 18.01 sqkm in 2020. The area near major water bodies is encroached, and people are filling small water bodies with new built-up, which is harmful to the environment. In recent periods, Delhi has been facing water scarcity issues for daily use and hazardous conditions in the river Yamuna.

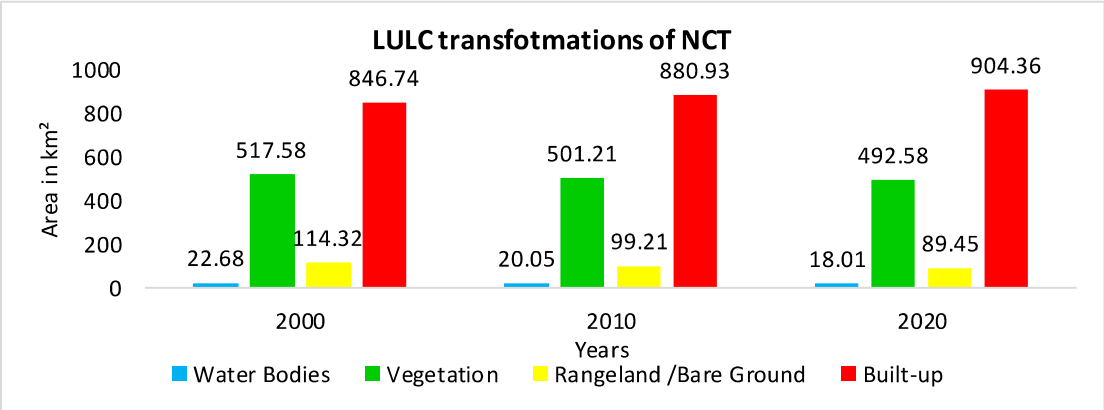


Figure 6: LULC transformations of Delhi NCT (2000- 2020); Souce: Generated by Authors

4.2. SUDA

Over the last two decades, SUDA has experienced continuous LULC transformation. The city is experiencing significant urban expansion due to a rapid increase in built-up growth and a decline in vegetation as shown in Figure 7. In the last two decades, the built-up area has expanded by 19.39 % (199.2 sqkm) from 2000 to 2020. The built-up area expanded from 120.50 sqkm (11.74 %) in 2000 to 170.37 sqkm (16.59 %) in 2010 and 319.70 sqkm (31.13 %) in 2020. During the study period, built-up growth was maximum during 2010-2020 due to numerous industrial growth and other commercial developments in the periphery area, along the port and highways.

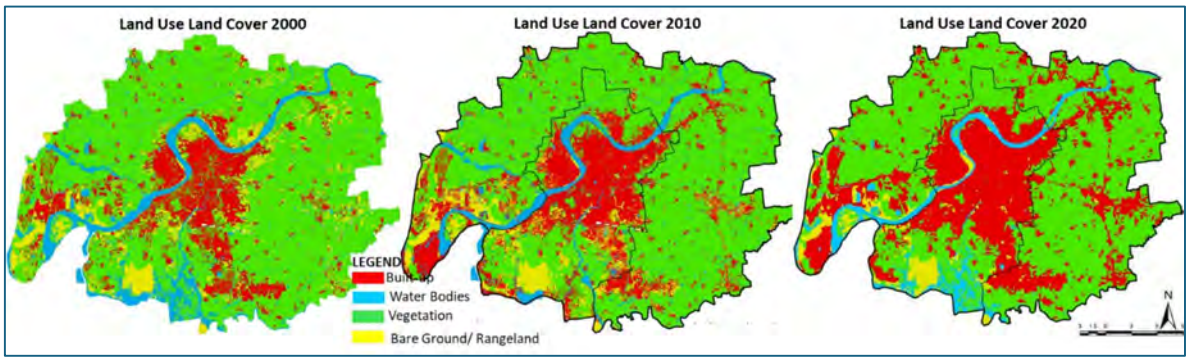


Figure 7: LULC maps of Surat Urban Development Authority (a) 2000, (b)2010, (c) 2020
Souce: Generated by Authors

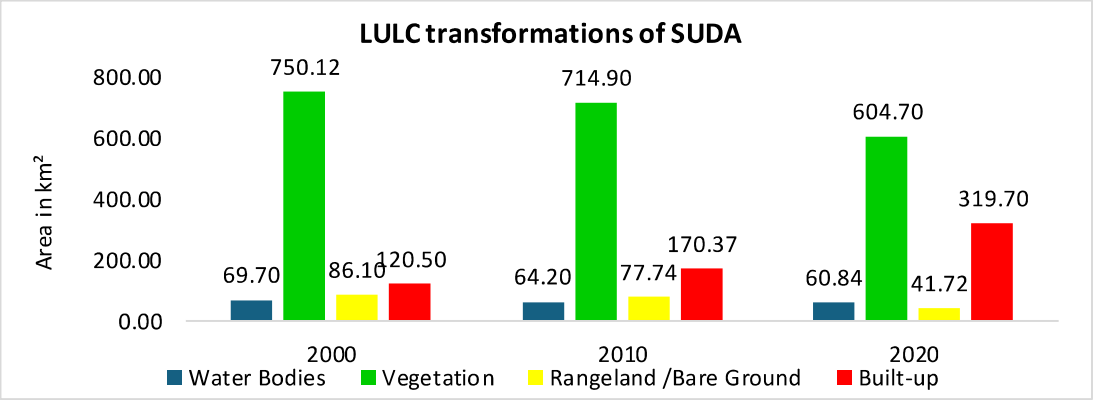


Figure 8: LULC transformation of SUDA (2000- 2020) ; Souce: Generated by Authors

Outside the Surat municipality, vegetation cover has witnessed major setback because of rapid transformation of vegetation land to built-up area. Vegetation land share decreases from 750.12 sqkm (73.08 %) to 714.90 sqkm (69.60 %) in 2010 to 604.70 sqkm (58.87 %) in 2020. In last 20 years vegetation cover has been diminished by 14.21 % (145.42 sqkm) at an average rate of 7.27 sqkm.

Rangeland or bare ground also witnessed a decrease of 4.33 % (44.38 sqkm) from 2000 to 2020. The statistical value displayed a rapid decreasing trend from 86.10 sqkm (8.39 %) in 2000 to 77.74 sqkm (7.57%) in 2010 and 41.72 sqkm (4.06 %) in 2020 shown in Figure 8. Bare ground and barren land surrounding highways, corridors, and near the port are mostly transformed into new constructions for industrial, commercial, or residential purposes.

The coverage of water bodies is dealing with issues such as the filling of ponds, streams, and lakes, land acquisition challenges, and violations of construction regulations in eco-sensitive areas, resulting in a significant reduction of water bodies. Water bodies witnessed a decrease of 8.86 sqkm (0.78 %) from 2000 to 2020. The total water body coverage was 69.70 sqkm (6.80 %) in 2000, which decreased to 64.20 sqkm (6.25 %) in 2010 and then 60.84 sqkm (5.92 %) in 2020.

4.3. AMC

Ahmedabad city's overall built-up area has increased extensively in terms of both extent and density. In the last two decades, the built-up area has expanded by 58.29 sqkm (13.24 %) from 2000 to 2020 as shown in Figure 9. The highest built-up percentage increase is seen during 2010 – 2020. Urban growth increased from 269.56 sqkm (61.21 %) in 2000 to 297.04 sqkm (67.45 %) in 2010 and 327.85 sqkm (74.45 %) in 2020. This city witnessed rapid urban transformation at the expense of vegetation, barren land or bare ground and water bodies.

Vegetation land evidently experienced major setbacks because of new built-up growth in industrial and residential sectors. Vegetation land share decreases by 8.91 % (39.26 sqkm) from 2000 to 2020. Percentage share of vegetation cover decreased from 138.61 sqkm (31.48 %) in 2000 to 119.53 sqkm (27.14 %) in 2010 and 99.35 sqkm (22.57 %) in 2020.

Rangeland or bare ground also witnesses a decreasing trend of 2.6 % (11.44 sqkm) from 2000 to 2020. The total range land cover was 14.70 sqkm (3.34 %) in 2000, which decreased to 8.10 sqkm (1.84%) in 2010 and 3.26 sqkm (0.74 %) in 2020.

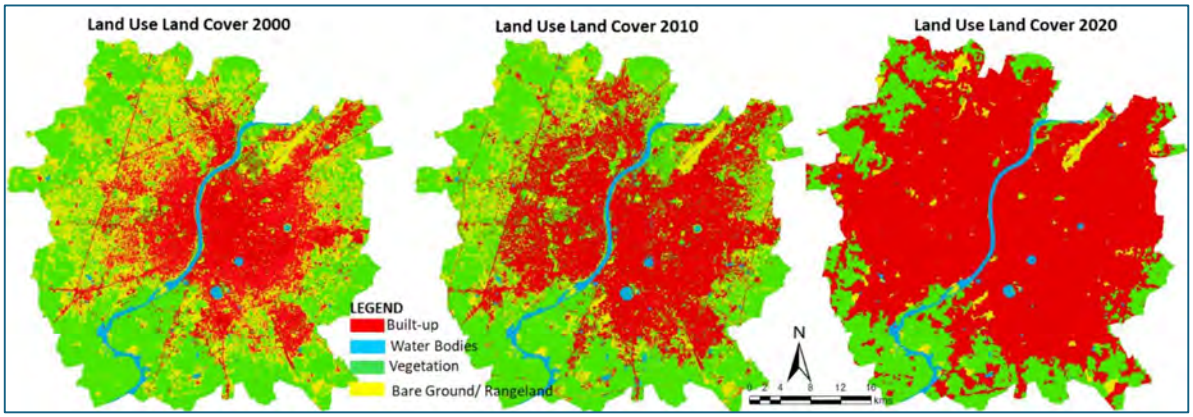


Figure 9: LULC maps of Ahemedabad Municipal Corporation (a) 2000, (b)2010, (c) 2020
Souce: Generated by Authors

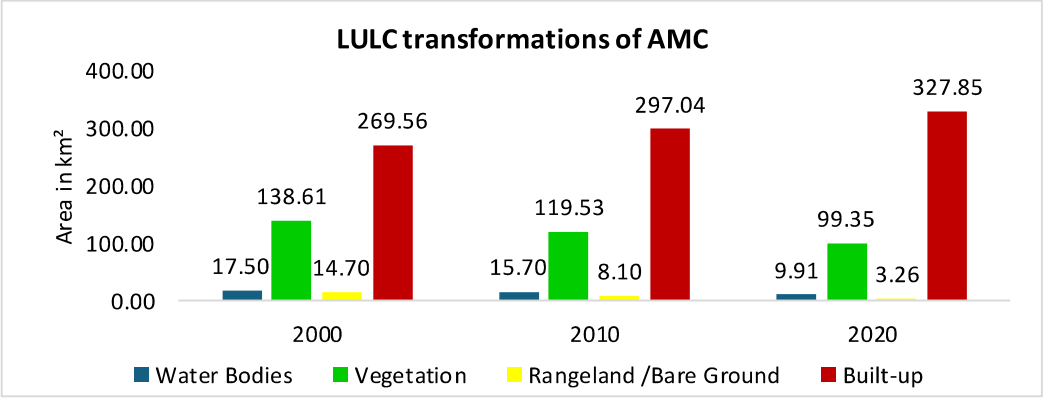


Figure 10: LULC transformations of AMC (2000- 2020) ; Souce: Generated by Authors

During 2000 to 2020, total land coverage of water bodies also witnessed negative trends, decreased by 1.73% (7.59 sqkm). The expansion in built-up areas impacts water bodies, causing encroachments, filling water bodies and water pollution. The land coverage of water bodies was 17.50 sqkm (3.98 %) in 2000, 15.70 sqkm (3.56 %) in 2010 and 9.91 sqkm (2.25 %) in 2020 as shown in Figure 10.

4.4. Built-up Expansion

Over the last two decades, urban expansion has taken place at an unprecedented rate, particularly following the DMIC proposal. The statistical data and Figure 11(a) shows that the built-up pattern of Delhi NCT has changed significantly. Maximum built-up change is witnessed in northwest, south and eastern directions, especially in the urban areas adjoining cities like Gurgaon, Noida, Meerut, etc. The maximum expansion of the built-up area is observed towards the direction of the Gautam Buddha Nagar district. Because of economic/ industrial development and population growth, both the cities of Delhi and Noida are experiencing rapid urban transformations.

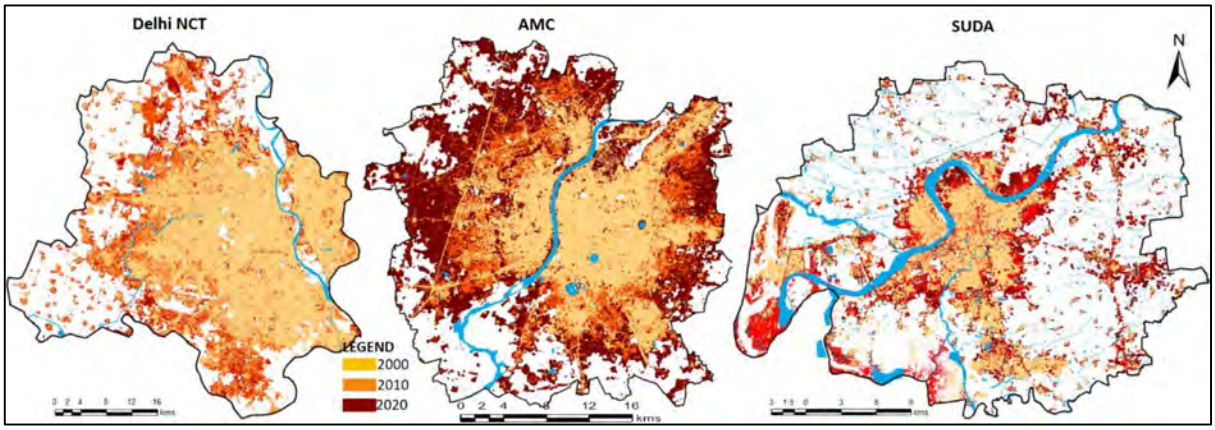


Figure 11: Spatio- temporal built-up expansion from 2000- 2020 (a) Delhi NCT, (b) AMC, (c) SUDA
Souce: Generated by Authors

Over the period, Ahmedabad has also been expanding rapidly; major urban expansion occurred between 2010 and 2020 as shown in Figure 11(b). Accelerated industrial expansion and employment opportunities attracts migrants from various regions of the district, state and nation. Extensive urban development, encompassing both residential and commercial sectors, occurred in Chandkheda and Ranip to the north and in Thaltej, Sarkhej, Changodar, and Bopal to the south. The establishment of new industries, good transportation networks and better infrastructure facilities attracted individuals to inhabit in outer semi-urban and suburban regions, thereby promoting further urban expansion. This city is also facing problems of informal settlements and urban sprawl along the municipal boundary and near some industrial zones. The rapid infilling surrounding developed areas augmented urban density in the city's older parts, resulting in accelerated city expansion.

Due to widespread industrial growth outside the SMC and in peri-urban areas, the SUDA's urban expansion exhibits a sharp rise in built-up areas as shown in Figure 11(c). Over time, Surat has transformed into a prominent economic and industrial hub, with its diverse economic sectors and strategic industrial development serving as major contributors to the state's overall economic advancement. Throughout the study period from 2000 to 2020, SUDA's municipal wards and surrounding villages displayed variable rates of built-up area expansion across different intervals. The western zone, particularly in areas like Khajod, Abhana, Sarsana, and Bhatpore, has experienced substantial settlement growth, accompanied by new industries emerging in and around these villages. This industrial surge has accelerated the transformation of vegetation and bare land into urbanised landscapes. In the eastern zone, strategic locations along DMIC, national and state highways, major urban nodes, Special Economic Zones (SEZs), and areas dedicated to light and heavy industries, warehouses, and real estate development play critical roles in fostering economic growth and driving the city's expansion.

5. Conclusion

This comparative study examines the spatio-temporal pattern of LULC changes in three industrial or economic towns situated along the DMIC, which have experienced rapid economic development and urban transformations in the last two decades. LULC transformation mapping and delineation of built-up expansions was done using RS data and GIS methods. Multi-temporal RS data and GIS tools facilitate the detection and comparison of LULC patterns and spatial built-up expansion of the study area. The integration of RS and GIS has become a significant tool for data collection and interpretation, enabling comprehensive analysis of urban transformation.

The spatio-temporal LULC maps were generated from satellite imagery. i.e., Landsat 5, Landsat 7 and Landsat 8. The statistical data and maps demonstrate that the LULC patterns of all three study areas (Delhi NCT, SUDA and AMC) underwent significant shifts over the study period (2000- 2020). The spatio-temporal findings indicate that vegetation cover and bare ground or range lands are primary contributors to the growth of built-up areas, as expansion predominantly occurs over these land use classes. Additionally, water bodies also play a significant role in built-up expansion. The maximum built-up changes are noticed in SUDA.

6. References

Aithal, B. H. and Ramachandra, T. V. (2016) 'Visualization of Urban Growth Pattern in Chennai Using Geoinformatics and Spatial Metrics', *Journal of the Indian Society of Remote Sensing*, 44(4), pp. 617–633. doi: 10.1007/s12524-015-0482-0.

Atay Kaya, İ. and Kut Görgün, E. (2020) 'Land use and land cover change monitoring in Bandırma (Turkey) using remote sensing and geographic information systems', *Environmental Monitoring and Assessment*, 192(7). doi: 10.1007/s10661-020-08411-1.

Banzhaf, E. *et al.* (2017) 'Integrated research on land-use changes in the face of urban transformations – An analytic framework for further studies', *Land Use Policy*, 60, pp. 403–407. doi: 10.1016/j.landusepol.2016.11.012.

Bao Pham, Q. *et al.* (2024) 'Multi-spectral remote sensing and GIS-based analysis for decadal land use land cover changes and future prediction using random forest tree and artificial neural network', *Advances in Space Research*, 74(1), pp. 17–47. doi: 10.1016/j.asr.2024.03.027.

Bhatta, B. (2009) 'Analysis of urban growth pattern using remote sensing and GIS : a case study of Kolkata , India', 1161. doi: 10.1080/01431160802651967.

Biswas, P. and Dey, P. (2023) 'Spatio - temporal impact of industrial corridor development on built - up growth : a case of Delhi – Mumbai industrial corridor , India', *GeoJournal*, (0123456789). doi: 10.1007/s10708-023-10827-4.

Census, 2011. Census of India. [Online] Available at: https://censusindia.gov.in/census.website/data/census-tables

Chaturvedi, S. *et al.* (2022) 'A spatio-temporal assessment and prediction of Ahmedabad's urban growth between 1990–2030', *Journal of Geographical Sciences*, 32(9), pp. 1791–1812. doi: 10.1007/s11442-022-2023-4.

Christy RD, W. M. D. W., 2000. A Microenterprise-Centered Economic Development Strategy for the Rural South: Sustaining Growth with Economic Opportunity. Journal of Agricultural and Applied Economics, pp. 331-344.

Corporation, S. M., 2023. www.suratmunicipal.gov.in/TheCity/Contribution. [Online] Available at: https://www.suratmunicipal.gov.in/TheCity/Contribution

DIPP (2013) 'Department of Industrial policy & promotion Ministry of commerce & Industry government of India. ', *Dipp*, (August). Available at: www.nic.in.

Herold, M. *et al.* (2006) 'Evolving standards in land cover characterization', *Journal of Land Use Science*, 1(2–4), pp. 157–168. doi: 10.1080/17474230601079316.

Indrawati, L. *et al.* (2020) 'Urban expansion analysis through Remote Sensing and GIS in Semarang-Indonesia', *IOP Conference Series: Earth and Environmental Science*, 485(1). doi: 10.1088/1755-1315/485/1/012113.

Kabisch, N. *et al.* (2019) 'A multi-sensor and multi-temporal remote sensing approach to detect land cover change dynamics in heterogeneous urban landscapes', *Ecological Indicators*, 99(December 2018), pp. 273–282. doi: 10.1016/j.ecolind.2018.12.033.

Karen C. Seto, M. F. B. G. M. K. R., 2011. A Meta-Analysis of Global Urban Land Expansion. PLoS One 6 (8).

Kyule, B. M. and Wang, X. (2024) 'Quantifying the link between industrialization, urbanization, and economic growth over Kenya', *Frontiers of Architectural Research*, 13(4), pp. 799–808. doi: 10.1016/j.foar.2024.03.009.

Li, X. and Yeh, A. G. O. (2004) 'Analyzing spatial restructuring of land use patterns in a fast growing region using remote sensing and GIS', *Landscape and Urban Planning*, 69(4), pp. 335–354. doi: 10.1016/j.landurbplan.2003.10.033.

Maher Milad Aburas *et al.* (2017) 'Measuring and Mapping Urban Growth Patterns Using Remote Sensing and GIS Techniques', *Pertanika Journal of Scholarly Research Reviews*, (January).

Manesha, E. P. P., Jayasinghe, A. and Kalpana, H. N. (2021) 'Measuring urban sprawl of small and medium towns using GIS and remote sensing techniques: A case study of Sri Lanka', *Egyptian Journal of Remote Sensing and Space Science*, 24(3P2), pp. 1051–1060. doi: 10.1016/j.ejrs.2021.11.001.

Martellozzo, F. and Clarke, K. C. (2011) 'Measuring urban sprawl, coalescence, and dispersal: A case study of Pordenone, Italy', *Environment and Planning B: Planning and Design*, 38(6), pp. 1085–1104. doi: 10.1068/b36090.

Mishra, V. N. and Rai, P. K. (2016) 'A remote sensing aided multi-layer perceptron-Markov chain analysis for land use and land cover change prediction in Patna district (Bihar), India', *Arabian Journal of Geosciences*, 9(4). doi: 10.1007/s12517-015-2138-3.

Nations, U., 2015. International Migration Report, s.l.: Department of Economic and Social Affairs, population division..

Nation, U., 2014. World Urbanization Prospects: The 2014 Revision , New York: United Nations, Department of Economic and Social Affairs, Population Division.

Nelson, E. *et al.* (2010) 'Projecting global land-use change and its effect on ecosystem service provision and biodiversity with simple models', *PLoS ONE*, 5(12). doi: 10.1371/journal.pone.0014327.

Omwamba, J. (2015) 'The Role of Transport and Transit Corridors in Fostering International Cooperation for Sustainable Development : Issues and Recommendations'.

Punia, J. P. H. .. M., 2019. Urban dynamics assessment of Ghaziabad as a suburb of National Capital Region. Geo Journal.

Rashed, T. and Jurgens, C. (2010) *Remote sensing of urban environmental conditions*, *Remote Sensing and Digital Image Processing*. doi: 10.1007/978-1-4020-4385-7_14.

Ratner, K. A. and Goetz, A. R. (2013) 'The reshaping of land use and urban form in Denver through transit-oriented development', *Cities*, 30(1), pp. 31–46. doi: 10.1016/j.cities.2012.08.007.

Toppo, P. and Nimbekar, A. (2015) *Gujarat's Shining Jewels: The Infrastructure Impetus*. Available at: KnightFrank.com/Research.

Trujillo-Jiménez, M. A. *et al.* (2022) 'SatRed: New classification land use/land cover model based on multi-spectral satellite images and neural networks applied to a semiarid valley of Patagonia', *Remote Sensing Applications: Society and Environment*, 26(February). doi: 10.1016/j.rsase.2022.100703.

USGS, 2024. USGS: Science for a Changing World (.gov). [Online] Available at: https://www.usgs.gov/landsat-missions/landsat-8

Yılmaz, M. and Terzi, F. (2021) 'Measuring the patterns of urban spatial growth of coastal cities in developing countries by geospatial metrics', *Land Use Policy*, 107(April), p. 105487. doi: 10.1016/j.landusepol.2021.105487.

Case Study Report

‘Rethinking’ digital twins and building alternatives for smart city planning in Dublin

Mani DHINGRA, University College Dublin, Ireland
Aphra KERR, University College Dublin, Ireland
Jack R. LEHANE, University College Dublin, Ireland

Abstract

Digital tools, including 3D spatial media, have existed for almost three decades. but they are gaining popularity with the emerging yet vague concept of Urban Digital Twin (UDT), believed to contribute to smart cities and resilient urban futures. While UDTs can visualise a multitude of datasets in an integrated, interactive, and comprehensive 'realistic looking' way, there are emerging structural and cultural challenges in their adoption within public sector planning. This case study explores these challenges within the context of Smart Dublin – an initiative involving the four Dublin Local Authorities, through an embedded research framework within an industry collaborative project between ADAPT Research Centre and Dublin City Council. The project aims at the ethical development and deployment of UDTs for territorial planning while understanding the barriers, opportunities and limitations for the largest Dublin Local Authority and evaluating alternative approaches to support participatory governance, informed decision-making, and awareness among urban planners working in a ‘virtual’ environment. It also introduces a transnational European project ‘Twin4Resilience’ with Dublin as one of the pilot actions aiming for a wider uptake of UDTs for data-driven urban decision-making. The lessons learnt will be incorporated into the broader digital twin strategy of the council.

Keywords

Urban Digital Twins, Territorial Planning, Smart Cities, Decision-making, Active Travel, Community Engagement

1. Introduction

In the past, since the 1980s, to support a spatially augmented approach to planning, digital tools including computer-aided design, 3D modelling, and GIS, have existed (Kitchin et al., 2021). However, today, global attention is shifting to an intelligent geospatial tool – *the Urban Digital Twin (UDT).* This study is from an embedded research collaboration between ADAPT Research Ireland Centre (a government-funded multi-institutional, multidisciplinary research centre) and Dublin City Council (DCC) (Dhingra and Kerr, 2024). The outcomes of our project contribute to the discussion on challenges and opportunities for implementing UDTs by Dublin local authorities for city planning, operations and management. This is backed up by the need for democratic governance processes and a ‘human-in-the-loop’ data-driven ethical decision-making approach.

UDTs are defined as virtual replica models of physical places, assets and processes developed through the integration of large datasets in a single platform. Most of this data, if near-real-time, enables data processing and analysis through cloud computing and live feeds. A digital twin can enable a seamless way of working with multiple urban themes at once, which enables multistakeholder engagement to resolve the multidimensional challenges of our urban environment (Ziehl et al., 2023). However, there is a risk that, just like the 'smart city' concept, UDT can be reduced to a mere technology solution and not a long-term approach to innovative public sector planning (Nochta et al., 2021). This paper assesses structural, institutional and cultural challenges within an Irish public sector environment and proposes a conceptual approach to ethically implement UDTs.

Our approach is positioned within the current policy landscape of the European Union (EU) as the concept is significant in terms of digital twin initiatives such as the flagship Destination Earth[1] project for building a digital twin of Earth, the (Urban) Local Digital Twin (LDT) Toolbox[2] , project DUET (Digital Urban European Twins[3]) and the EDIC (European Digital Infrastructure Consortium[4]) initiative. Our research team seeks to unlock the potential of UDTs for urban planning, stakeholder collaboration and engagement by closely linking with challenges faced during implementation of use-cases with the key thematic areas at DCC smart city unit. We intend to address some of the urban challenges and improve public service delivery as well as support participatory governance, data-informed decision-making, and awareness-raising among city planners.

2. State of the art

2.1. Urban Digital Twin (UDT)

The literature review of 'digital twin' concept shows exponential growth, but mostly in areas of product lifecycle management, manufacturing and aerospace industries and operational and engineering solutions (Crespi et al., 2023; Syed Abdul Rahman et al., 2024). Cities on the contrary are complex ecosystems of built environment, people, their political, institutional, socio-economic and cultural contexts. Most of the time, private companies are hired for UDT services, but it is the public sector organizations who are responsible for day-to-day city operations (Deren et al., 2021; Ferré-Bigorra et al., 2022).

UDT research is still nascent and evolving and therefore needs an innovative approach tailored to a given city's needs, challenges and opportunities (Ziehl et al., 2023). There are a few already existing examples of UDTs as the ones highlighted by Bermúdez González et al. (2023), Dembski et al. (2020), Liu et al. (2023) and Park et al. (2023), however when distinguishing between digital 3D model or City Information Model from digital twins, an intermediary stage known as 'digital shadow' signifies information transfer from the physical to the virtual world through live data feed (Botín-Sanabria et al., 2022). A UDT, on the contrary, pivots towards 'platform urbanism' (Barns, 2019; Sadowski, 2020) serving as a unified platform for historical and real-time urban data to support advanced urban analytics, predictive simulation, near real-time visualisation and manifest back from virtual to physical dimension as shown in Figure 1**Error! Reference source not found.** (Fernandez et al., 2024). This interaction allows a UDT to serve as a 'living replica' throughout the project lifecycle, leverage real-time data insights, and simulate future scenarios, while also acting as 'virtual public spaces' for the public to interact with their cities (Cureton and Hartley, 2023; Truu et al., 2021; Ye et al., 2023).

[1] About Destination Earth - Destination Earth
[2] Procurement for the development of the Local Digital Twins toolbox | Shaping Europe's digital future
[3] Home | digital urban european twins
[4] European Digital Infrastructure Consortium (EDIC) | Shaping Europe's digital future

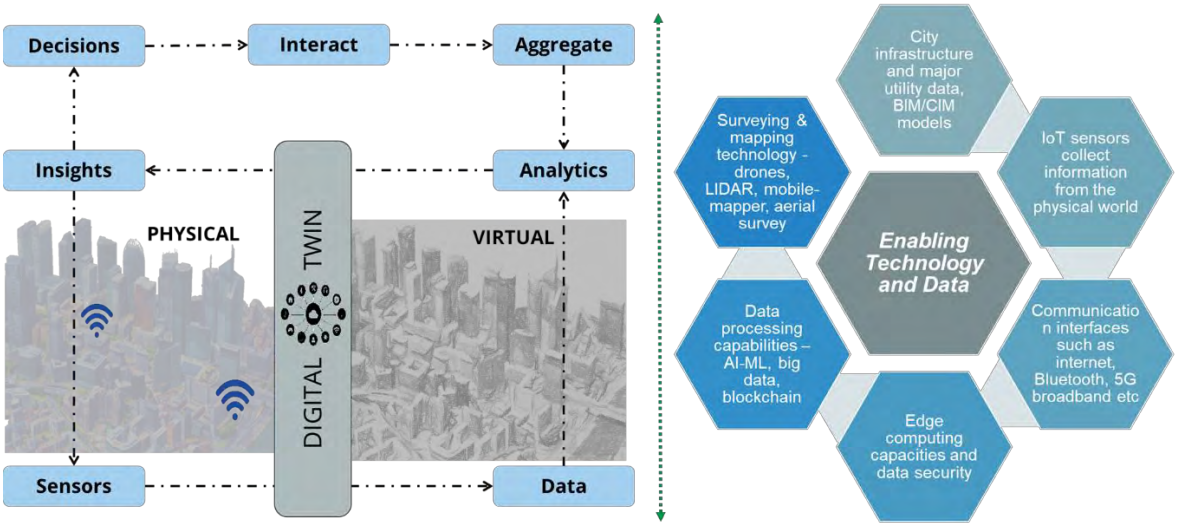


Figure 1: Bidirectional UDT and Underlying Technology. Source: Authors.

2.2. UDT examples

The novelty of the digital twin concept is such that it can transform physical assets into programmable entities with clear analytics of major features in a targeted environment and conditions (Crespi et al., 2023). Other suggested advantages of UDTs delivery, include risk-aversive workflow optimization, support public sector planning and decision-making (Botín-Sanabria et al., 2022). To demonstrate UDTs in action, we present some examples in this section.

The first example (Figure 2) focuses on a climate-resilient housing project funded by the Public Sector Innovation Fund, with IES Pvt Ltd and DCC. A digital twin model was created for social housing stock at Dominic Street in Dublin, originally built in 1960. The model aimed to support reduction of carbon emissions and housing delivery targets of DCC. It calculates whole-life carbon impact in terms of building energy usage and renovating costs considering building lifecycle (Integrated Environmental Solutions Ltd., 2022).

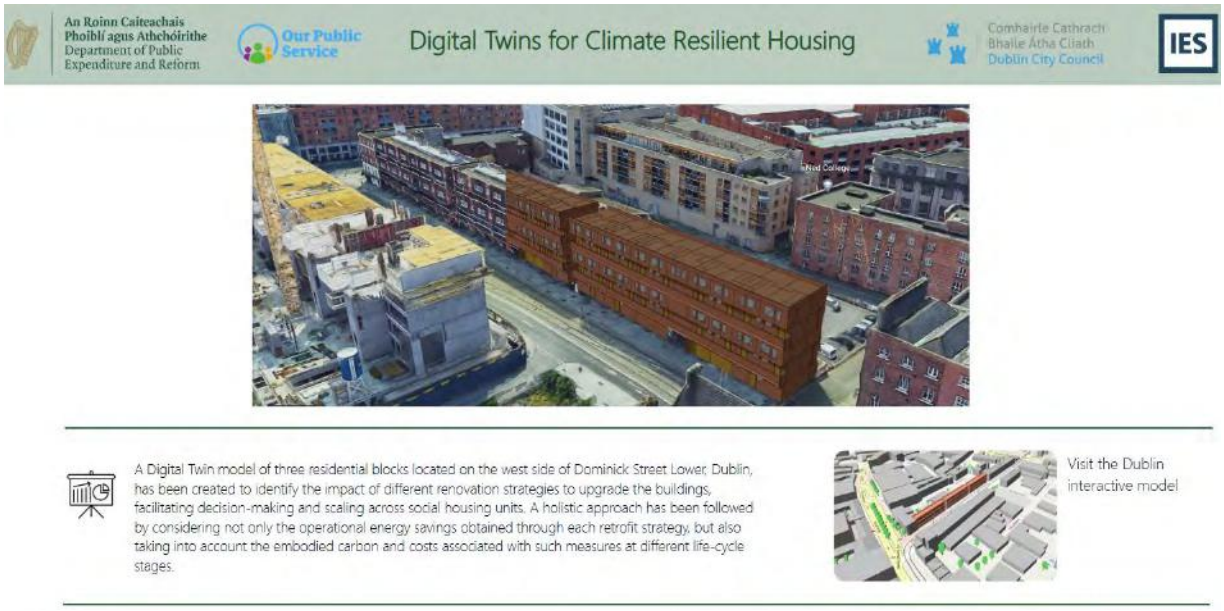


Figure 2: UDT example 1 - Climate Resilient Housing. Source: IES Ltd.

The second example (Figure 3) shows a community-design intervention to address socio-spatial issues of a Dutch neighbourhood in Eindhoven using workshops and virtual reality tools (Najafi et al., 2023). The approach was rated as highly satisfactory by local residents, indicating an immersive UDT interface is effective for urban co-design exercise.

Figure 3: UDT example 2 - Community Design. Source: (Najafi et al., 2023).

The third example (Figure 4) proposed a co-creative planning layer in UDT technical architecture through an interactive gaming environment for urban design (Kavouras et al., 2023). Such creative engagement processes using UDTs show possibility for more dynamic, inclusive and responsive solutions to community needs. These examples also illustrate how UDTs can be employed for different levels and forms of community engagement – more small scale and active at the beginning of projects and in the design phase, while more passive and larger scale during the deployment of projects and monitoring phase – but all implemented within an ethical and rights driven approach.

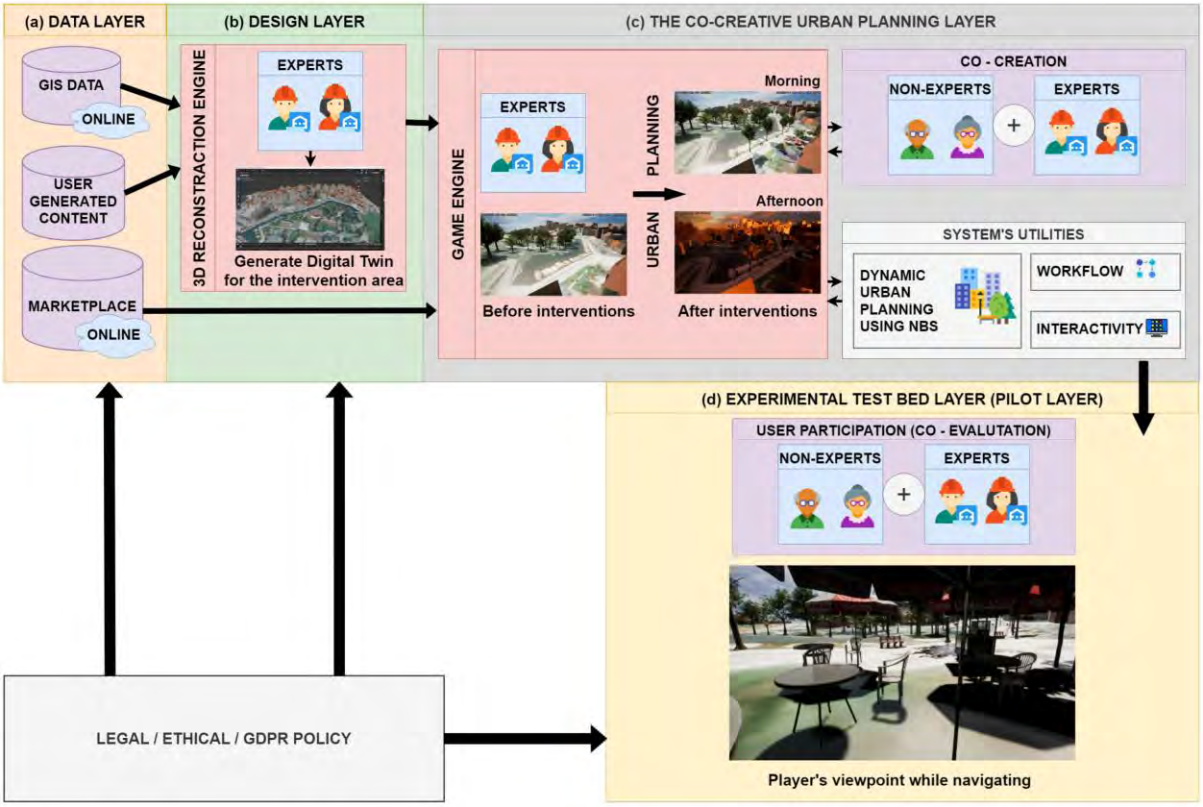


Figure 4: UDT example 3 - Co-creation. Source: (Kavouras et al., 2023).

3. Smart Dublin case study

UDTs face many challenges with public sector lacking computational and technical resources (Ferré-Bigorra et al., 2022; Kitchin et al., 2021). Other aspects which need investigation while implementing a UDT project are related to defining the scale and scope of such interventions, ownership issues and operation manuals for envisaged functionalities, developing data governance guidelines, using FAIR and high-quality open datasets, and building a secure system (Barcik et al., 2023; Quek et al., 2023; Ye et al., 2023).

This case study is based within the Smart City unit of DCC, which uses smart districts as testbeds for developing and deploying emerging technology in a strategic manner, aligning with the local urban challenges and national policy framework (Dhingra and Kerr, 2024). Recent policies, such as the EU AI Act, Interoperable Europe Act, and Data Governance Act, highlight the importance of developing and deploying UDTs multi-thematic and multi-stakeholder approach to preserve democratic values and mitigate high risks (Figure 5).

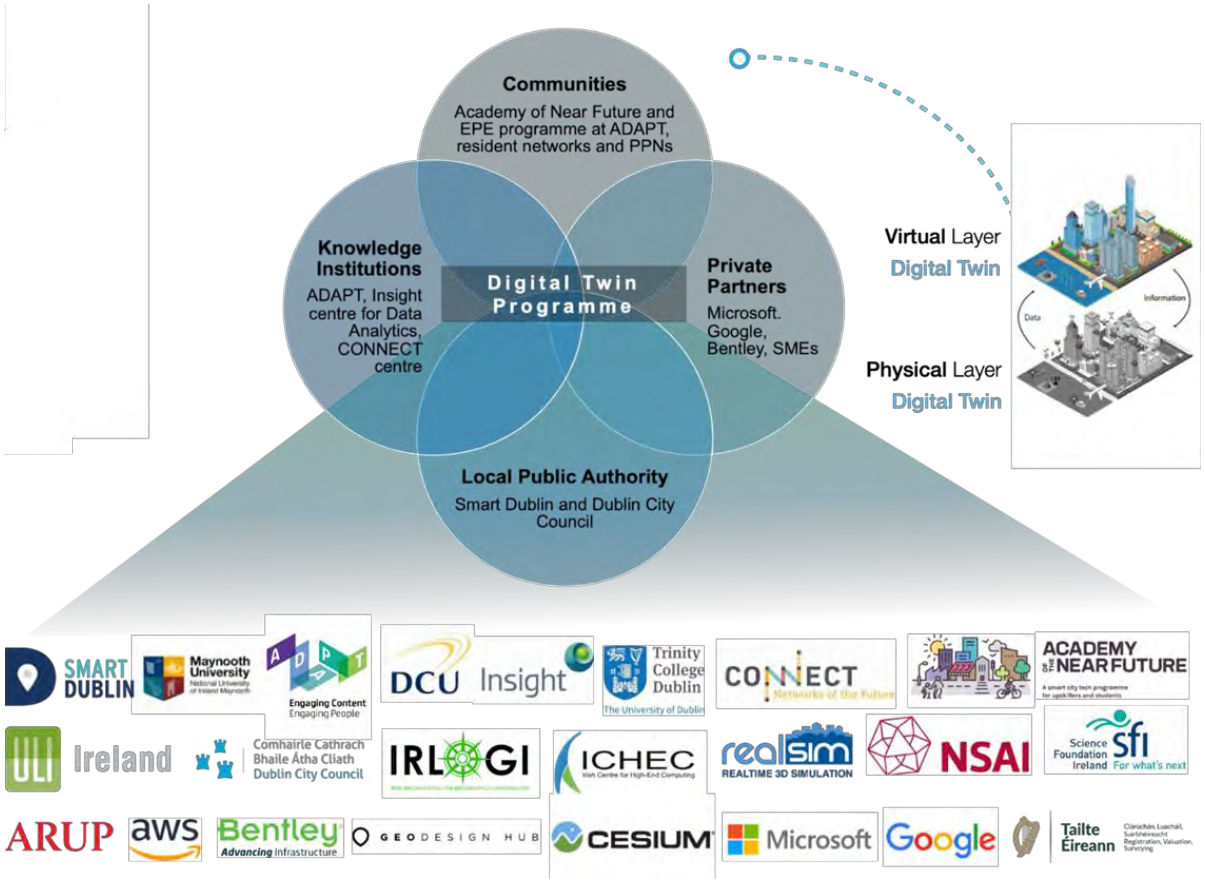


Figure 5: UDT Programme - DCC. Source: Authors.

4. Rethinking 'Urban Digital Twins'

At DCC, existing UDT projects are 3D Docklands model, a university-based Smart DCU digital twin, and other bespoke approaches for emergency response, tourism etc. (Dhingra and Kerr, 2024; Fernandez et al., 2024). This industry-academia project intentionally moves away from a technocentric to an integrated, user-centric, and ethical process-oriented mindset. It is also based on prior work that found that a realistic-looking visual interface is critical for engagement via UDTs (Ferré-Bigorra et al., 2022).

Besides UDT enabling technology such as urban sensors, 5G network, and cloud computation, non-technical enablers include awareness to adopt interoperable standards, a compliant institutional data governance framework, and regular capacity building of local authority staff. Our conceptual approach shown in Figure 6, highlights data, platform and people at the core of any UDT project while constant alignment with ethics, governance, engagement and impact assessment. This conceptual approach intends to include humans, organisations and their abilities to implement and sustain a digital twin programme while safeguarding society's critical interests, optimal resource management and compliance with EU law and policies.

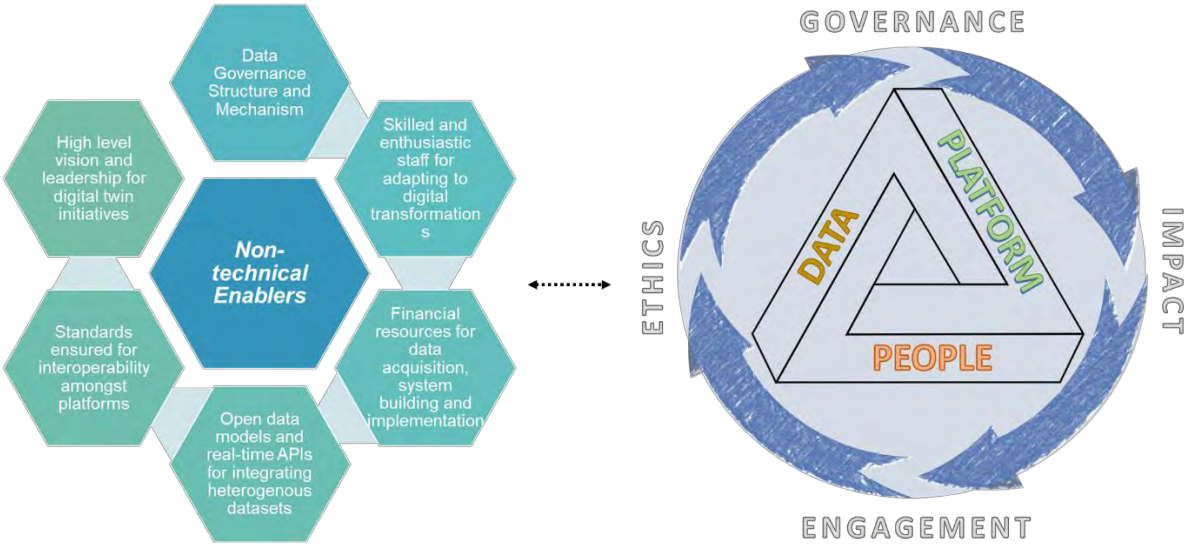


Figure 6: Proposed approach for UDTs. Source: Authors

5. Project 'Twin4Resilience' (T4R)

Twin4Resilience[5] (T4R) is a European project from 2024 to 2027 and aims to enhance adoption of UDTs by public bodies for resilient territorial planning through four co-created frameworks as shown in Figure 7– technical design, governance, ethics-inclusion-democratisation and training. DCC's proposed pilot action focuses on two use cases – (i) territorial planning: visualize future urban projects in a virtual city-like environment and, (ii) active travel: assess the impact of new cycling and walking infrastructure. The first use case is achieved through publicly procured 3D-modelling services and the second use case leverages partnerships with nationally funded research centres.

Figure 7: Joint T4R strategy for pilot actions. Source: Authors.

Active travel, similar to digital twins, is multidimensional cutting across domains of urban mobility, climate and environment, community development, etc. Since 2020, there's been over USD 1 billion[6] invested in active travel projects across Ireland with DCC alone targeting a city-wide network of 314 kilometres of cycle paths by 2031. Two pilot routes viz. Clontarf to City Centre[7] and Kilmainham to Thomas Street[8] offer a

[5] https://t4r.nweurope.eu
[6] Dublin is not just counting bicycles | Partnership for Healthy Cities
[7] Clontarf to City Centre Project | Dublin City Council
[8] Project Overview and Design Information | Dublin City Council

thematic template to assess the impact of these schemes and their contribution to environmental, and public health goals in Dublin. A series of dedicated stakeholder meetings and surveys were carried out to identify and subsequently prioritise key performance indicators and outcomes. This approach departed from the previous technology-led approach and emphasised a clear understanding of challenges and public needs (Cardullo and Kitchin, 2018). A regional Smart Dublin dashboard to show active travel routes is shown in Figure 8 and will be iterated as a digital twin engagement tool.

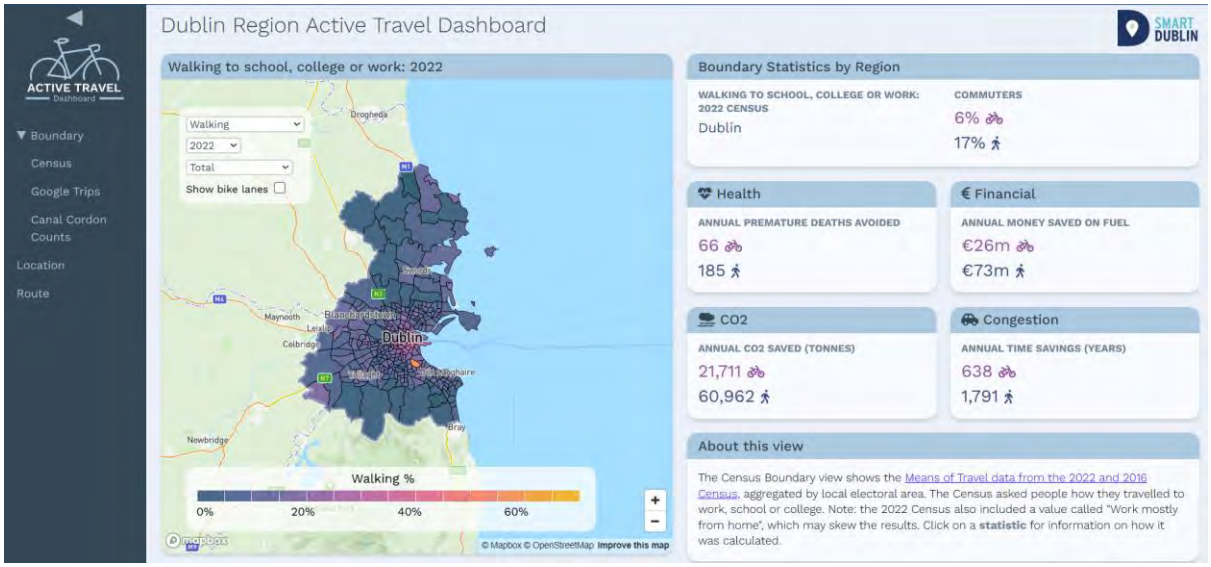


Figure 8: Active Travel Regional Dashboard. Source: Smart Dublin (2024).

6. Way Forward

This study gives an overview of Dublin's ongoing projects researching and implementing UDTs and throws insights into the practical barriers, issues and best practices for fostering participatory governance of urban planning in a digitally transformed environment. While many public sector applications of UDTs are still uncharted, emerging regulatory and multilateral governance frameworks are increasingly prioritising human-centredness, public values and fundamental rights (Muench et al., 2022; Ye et al., 2023). Although legislated responsibility may rest within different levels of local government, all actors (both institutional and non-institutional) must sufficiently enable the democratisation of urban digital twins.

Our research recognises that UDTs may serve as a vehicle to explore the engagement practices which collectively, could significantly enable and scale, impacts for interconnected climate and sustainable urban development determinants. Such data-driven approaches can potentially augment spatial representation and contribute substantially to people-centred planning systems, resilient urban futures, and better decision-making. There is a need to address potential barriers (e.g. proprietary software, lack of technical skillset amongst local authority staff and digital literacy of the general public, traditional mindset, cost of technologies etc.) by adopting a multistakeholder approach that is led by transparent governance, open standards, fundamental human rights and local social and context.

7. Acknowledgements

This research was conducted with the financial support of Research Ireland under Grant Agreements Nos. 13/RC/2106_P2 and 20/SP/8955 at the ADAPT Research Centre at University College Dublin and Dublin City Council.

8. References

Barcik, P., Coufalikova, A., Frantis, P., Vavra, J., 2023. The Future Possibilities and Security Challenges of City Digitalization. Smart Cities 6, 137–155. https://doi.org/10.3390/smartcities6010008

Barns, S., 2019. Negotiating the platform pivot: From participatory digital ecosystems to infrastructures of everyday life. Geogr Compass 13. https://doi.org/10.1111/gec3.12464

Bermúdez González, J.L., Castaño Perea, E., Fernández Tapia, E.J., 2023. The time variable in the Territorial Digital Twin: The case of Guadalajara (Spain). Vitruvio 8, 38–51. https://doi.org/10.4995/vitruvio-ijats.2023.20828

Botín-Sanabria, D.M., Mihaita, S., Peimbert-García, R.E., Ramírez-Moreno, M.A., Ramírez-Mendoza, R.A., Lozoya-Santos, J. de J., 2022. Digital Twin Technology Challenges and Applications: A Comprehensive Review. Remote Sens (Basel). https://doi.org/10.3390/rs14061335

Cardullo, P., Kitchin, R., 2018. Smart urbanism and smart citizenship: The neoliberal logic of 'citizen-focused' smart cities in Europe. Environment and Planning C: Politics and Space 37, 813–830. https://doi.org/10.1177/0263774X18806508

Crespi, N., Drobot, A.T., Minerva, R., 2023. The Digital Twin, The Digital Twin. Springer International Publishing. https://doi.org/10.1007/978-3-031-21343-4

Cureton, P., Hartley, E., 2023. City Information Models (CIMs) as precursors for Urban Digital Twins (UDTs): A case study of Lancaster. Front Built Environ 9. https://doi.org/10.3389/fbuil.2023.1048510

Dembski, F., Wössner, U., Letzgus, M., Ruddat, M., Yamu, C., 2020. Urban digital twins for smart cities and citizens: The case study of herrenberg, germany. Sustainability (Switzerland) 12. https://doi.org/10.3390/su12062307

Deren, L., Wenbo, Y., Zhenfeng, S., 2021. Smart city based on digital twins. Computational Urban Science 1. https://doi.org/10.1007/s43762-021-00005-y

Dhingra, M., Kerr, A., 2024. The role of digital twins for building resilient communities: case of Dublin, in: Junussova, M., Carrillo, J., Belpaire, E., Litvinaite, M. (Eds.), Proceedings of the 5th Urban Economy Forum + 59th ISOCARP World Planning Congress. ISOCARP, Toronto, Canada.

Fernandez, J.B., Dhingra, M., Mandal, S., O'connor, N.E., Kerr, A., Mc|Guinness, K., Intizar, A., Cudden, J., Mahon, K., 2024. Smart DCU Digital Twin: Towards Smarter Universities, in: 2023 IEEE Smart World Congress (SWC). IEEE, Portsmouth. United Kingdom. https://doi.org/10.1109/SWC57546.2023.10448967

Ferré-Bigorra, J., Casals, M., Gangolells, M., 2022. The adoption of urban digital twins. Cities 131. https://doi.org/10.1016/j.cities.2022.103905

Integrated Environmental Solutions Ltd., 2022. Digital Twin Modelling for Climate Resilient Housing. Dublin.

Kavouras, I., Sardis, E., Protopapadakis, E., Rallis, I., Doulamis, A., Doulamis, N., 2023. A Low-Cost Gamified Urban Planning Methodology Enhanced with Co-Creation and Participatory Approaches. Sustainability (Switzerland) 15. https://doi.org/10.3390/su15032297

Kitchin, R., Young, G.W., Dawkins, O., 2021. Planning and 3D Spatial Media: Progress, Prospects, and the Knowledge and Experiences of Local Government Planners in Ireland. Planning Theory and Practice 22, 349–367. https://doi.org/10.1080/14649357.2021.1921832

Liu, P., Zhao, T., Luo, J., Lei, B., Frei, M., Miller, C., Biljecki, F., 2023. Towards Human-centric Digital Twins: Leveraging Computer Vision and Graph Models to Predict Outdoor Comfort. Sustain Cities Soc 93. https://doi.org/10.1016/j.scs.2023.104480

Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salvi, M., Scapolo, F., 2022. Towards a green & digital future. Publications Office of the European Union, Luxembourg (Luxembourg). https://doi.org/10.2760/977331 (online),10.2760/54 (print)

Najafi, P., Mohammadi, M., van Wesemael, P., Le Blanc, P.M., 2023. A user-centred virtual city information model for inclusive community design: State-of-art. Cities 134. https://doi.org/10.1016/j.cities.2023.104203

Nochta, T., Wan, L., Schooling, J.M., Parlikad, A.K., 2021. A Socio-Technical Perspective on Urban Analytics: The Case of City-Scale Digital Twins. Journal of Urban Technology 28, 263–287. https://doi.org/10.1080/10630732.2020.1798177

Park, J.H., Choi, W.G., Jeong, T.Y., Seo, J.J., 2023. Digital twins and land management in South Korea. Land use policy 124. https://doi.org/10.1016/j.landusepol.2022.106442

Quek, H.Y., Sielker, F., Akroyd, J., Bhave, A.N., Von Richthofen, A., Herthogs, P., Yamu, C.V.D.L., Wan, L., Nochta, T., Burgess, G., Lim, M.Q., Mosbach, S., Kraft, M., 2023. The conundrum in smart city governance: Interoperability and compatibility in an ever-growing ecosystem of digital twins. Data Policy 5. https://doi.org/10.1017/dap.2023.1

Sadowski, J., 2020. Cyberspace and cityscapes: on the emergence of platform urbanism. Urban Geogr 41, 448–452. https://doi.org/10.1080/02723638.2020.1721055

Singh, M., Srivastava, R., Fuenmayor, E., Kuts, V., Qiao, Y., Murray, N., Devine, D., 2022. Applications of Digital Twin across Industries: A Review. Applied Sciences (Switzerland). https://doi.org/10.3390/app12115727

Syed Abdul Rahman, S.A.F., Abdul Maulud, K.N., Ujang, U., Wan Mohd Jaafar, W.S., Shaharuddin, S., Ab Rahman, A.A., 2024. The Digital Landscape of Smart Cities and Digital Twins: A Systematic Literature Review of Digital Terrain and 3D City Models in Enhancing Decision-Making. Sage Open 14. https://doi.org/10.1177/21582440231220768

Thelen, A., Zhang, X., Fink, O., Lu, Y., Ghosh, S., Youn, B.D., Todd, M.D., Mahadevan, S., Hu, C., Hu, Z., 2022. A Comprehensive Review of Digital Twin -- Part 1: Modeling and Twinning Enabling Technologies.

Truu, M., Annus, I., Roosimägi, J., Kändler, N., Vassiljev, A., Kaur, K., 2021. Integrated decision support system for pluvial flood-resilient spatial planning in urban areas. Water (Switzerland) 13. https://doi.org/10.3390/w13233340

Weil, C., Bibri, S.E., Longchamp, R., Golay, F., Alahi, A., 2023. Urban Digital Twin Challenges: A Systematic Review and Perspectives for Sustainable Smart Cities. Sustain Cities Soc 99. https://doi.org/10.1016/j.scs.2023.104862

Ye, X., Du, J., Han, Y., Newman, G., Retchless, D., Zou, L., Ham, Y., Cai, Z., 2023. Developing Human-Centered Urban Digital Twins for Community Infrastructure Resilience: A Research Agenda. J Plan Lit 38, 187–199. https://doi.org/10.1177/08854122221137861

Young, L., Denize, S., 2008. Competing interests: the challenge to collaboration in the public sector. International Journal of Sociology and Social Policy 28, 46–58. https://doi.org/10.1108/01443330810852891

Ziehl, M., Herzog, R., Degkwitz, T., Niggemann, M.H., Ziemer, G., Thoneick, R., 2023. Transformative Research in Digital Twins for Integrated Urban Development: Two Real-World Experiments on Unpaid Care Workers Mobility. International Journal of E-Planning Research 12. https://doi.org/10.4018/IJEPR.333851

Research Paper

Identifying the Determinants of the Innovation Districts: An Empirical Study across US Neighbourhoods

Eleni OIKONOMAKI, Aristotle University of Thessaloniki, Greece
https://orcid.org/0000-0001-6534-7695

Abstract

Location matters for innovation, as specific neighbourhood characteristics can significantly influence the production of innovative activities at the local level and explain the variations in technological innovation levels among different neighbourhoods across a city. This study sparks a discussion on the primary neighbourhood elements that can constitute innovation determinants aiming to bridge the gap between national, regional and local innovation policy and support place-based transformations. Through an analysis of patent data and innovation spaces, it identifies patterns of innovative activity. It uses big and geospatial data analytics to illustrate significant variables associated with high innovative activity and provides an empirical exploration of the innovation determinants across the neighbourhoods of two of the US leading innovative states. The dataset combines traditional data from governmental agencies with publicly available data retrieved through open APIs to obtain a more granular and broader understanding of determinants. When assessing innovation spaces as the dependent variable and a proxy of innovative capacity, we observe that specific observable characteristics in a neighbourhood have a stronger effect in the level of the innovation outcomes in neighbourhoods ten years later. The findings indicate that city policymakers should carefully consider key determinants and distinctive characteristics of individual neighbourhoods when formulating and implementing innovation policies.

Keywords

Innovation Districts, Innovation Determinants; Urban Informatics; Geospatial – Big Data – Urban Analytics; Innovation Geography

1.Introduction: Location and Geographic Context Matter for Innovation

Intuitively, location and neighbourhood context contribute to innovation, as knowledge spillovers from narrow distances, typically through face-to-face interaction (Davis and Dingel 2019; Allen 1977) and information disseminates within local spheres (Kerr and Kominers 2015; Arzaghi and Henderson 2008; Catalini 2018). There are interdependencies among elements of the microeconomic environment and the actual rate of technological innovation and economic growth (Richard R Nelson and Nathan Rosenberg 1993). Location and geographic context are considered key factors in explaining the determinants of innovation and technological change (Audretsch David B and Feldman 2004), since firms, and even larger idea-based economies, tend to cluster or agglomerate geographically. Examples of economic and tech clusters often come down to the neighbourhoods, such as Kendall Square in Cambridge, MA, and the critical role they play in accelerating their regions.

The influence of firms' immediate environments (as represented by neighbourhoods) on innovative activity has garnered growing attention in recent empirical research (Richard Shearmur 2012a; Jang, Kim, and von Zedtwitz 2017a; Rammer, Kinne, and Blind 2019; Roche 2020; Matsiuk, Doloreux, and Shearmur 2024). Wallsten underscored the clustering theory for innovative firms in the U.S. and found that if these firms are located within a 0.25-mile radius of each other, their innovation productivity increases (Wallsten 2001a). Kerr and Kominers 2015) and Arzaghi and Henderson (2008) also document how knowledge spillovers quickly dissipate if travel is larger than about 15 minutes. However, the relationship between neighbourhood characteristics and its innovation outcomes as well as its innovative capacity have been largely overlooked in the economic geography literature, which if assessed, could provide useful insights to low-income, low-growth neighbourhoods.

1.1 Problem statement

Until today most of the innovation analyses are done at either large geographic region such as metro areas and nationwide systems (Porter 1990; Nelson1993; Furman, Porter, and Stern 2002), or within firm geographies and individual university buildings (Catalini 2018; Roche et al. 2022; T. J. Allen 1977, Wallsten 2001b). This approach helps in achieving a sufficient sample size, as illustrated by Acs, Anselin, and Varga (2002), Delgado, Porter, and Stern (2010), Glaeser et al. (2009), and G. Carlino and Kerr (2015). While informative, these are inconsistent with the importance of distance for innovation which predicts that it would mostly occur within narrower geographies.

Also, previous studies have theoretically discussed the relationships between some of the variables examined in this paper (Boschma 2005; Cooke 2001; Furman, Porter, and Stern 2002), while there is limited empirical evidence on the mechanisms of these variables at the neighbourhood level. In part, this is because studying neighbourhood innovation has proved difficult. Observable neighbourhood measures that can be used to understand the determinants of neighbourhood innovation have typically not been available systematically across neighbourhoods, while a small number of indicators measured at the national and regional levels, can be reliably measured at this lower level.

For this, new indicators of innovative activity need to be created at a lower level of spatial analysis, which could assess a variety of aspects ranging from economic and social effects to environmental context. These new indicators can offer another perspective on the effects of the neighbourhood elements on the innovative activity. In support of this need, the current study identifies socioeconomic and neighbourhood characteristics that can be set as indicators capturing diverse dimensions of the innovative activity.

2. Research aim and questions

The comparison of innovative activities across diverse neighbourhoods of two US states is used to illustrate the geographical context and the underlying factors that fuel innovation processes. The goal of the study to identify how past factors, earlier neighbourhood conditions or behaviours, might relate to future outcomes of innovation, provide insights for urban and innovation policymakers to orchestrate the next generation's innovation districts.

The empirical study starts by considering first what it means (as an outcome) for a neighbourhood to be innovative. To respond to this, the analysis follows previous such empirical examples, using the number of granted patent data as the most evident expression of innovation for the neighbourhoods across NY and MA states. Monitoring the number of patents granted by individuals and companies within the city is crucial for assessing the innovation landscape, as it provides valuable insights into the neighbourhoods' technological advancement.

The study continues by considering what it means for a neighbourhood to have high innovative capacity. Innovation space data has been selected and then analysed to assess that. Big data analytics related to socio-economic, infrastructure and urban morphological characteristics within both Massachusetts and New York's neighbourhoods were also collected.

Specifically, the study aims to respond a) how does the geography of innovation differ when examining concentration of patent records versus alternative enablers of innovative activity, such as the innovation spaces and b) whether specific independent variables could consistently predict innovation outcomes across neighborhoods of diverse regions (e.g. neighborhoods of two different US states – New York and Massachusetts).

3. Methods and data

To respond to the research questions, both traditional big data and publicly, open-source data, retrieved through modern APIs, are collected. Collected data were aggregated at the zip code level, a geographic area commonly used to designate a district in the U.S. Most countries use postal codes as a practical proxy for neighbourhood analysis, as zip code data are widely available and commonly used by government agencies, and dataset providers, making it easier to access and integrate across different sources. For this study, patent data were drawn from USPTO, while a new measure of innovation spaces has been constructed, in a way to assess the factors contributing to variations among neighbourhoods in shaping innovative capacity (e.g., presence of startups, local innovation centres, hubs and incubators, accelerators etc.).

First, to illustrate the potential of the collected data for an analysis at the local level, an examination of the geospatial context of neighbourhoods across the two US states (Massachusetts and New York) is undertaken. Additionally, patent change has also been estimated during the decade 2012-2022 for the total of the zip codes across both states to capture changes in innovation patterns. Then, the association of patents and innovation spaces with socioeconomic, morphological and infrastructure characteristics of the neighbourhoods is examined to respond to our research questions. The analysis is applied to a group of neighbourhoods' characteristics, from the commuting patterns to the presence of a high number of formal and informal places of interaction (institutions and cafes), which could be considered innovation determinants.

4. Early Findings and Analysis

4.1 Assessing innovation patterns across the two states

To address the first research question, the study examines the distribution of the granted patents and innovation spaces across the neighbourhoods of the two US states (Massachusetts and New York). The aerial views of the top four zip codes show that for 2022 granted patents are concentrated in central areas of the cities but also extend into the suburban such as the Hopkinton, Mansfield, Waltham in Massachusetts, as well as Armonk and Schenectady in New York State. Five out of eight top zip codes identified with the highest number of granted patents have suburban context (figures 1, 2). This spatial distribution suggests that while innovation systems are centralized, the resulting patent activity extends beyond these urban cores, reaching into suburban areas where industries, institutions are part of the innovation ecosystem.

The records of the granted patents for the New York state show a decrease in patent activity over the decade 2012-2022. This possibly indicates changes in patenting behaviour during these years. There was a stability from 2012 to 2014 with the peak in 2014, the highest number of patents granted. After 2014, we

observe a downward trend in the number of patents granted each year. The lowest point in the decade examined was in 2022, possibly due to the disruption caused by the pandemic (figure 3).

When assessing innovation in Massachusetts state, we see a similar decrease in the number of granted patents over the observed decade. There was a period during which the number remained relatively stable (between 2012 and 2015). This period was the peak of patent activity in Massachusetts. However, since then there has been a decrease with few exceptions in the number of granted patents each year. 2022 was the year with the lowest number in the observed period, similar to the trend for New York zip codes, though the overall scale was smaller (4).

Patent Records (Granted) in New York State

Figure 1. Aerial views of the top 4 zip codes with highest number of granted patent records in 2022 for New York State. Own elaboration, 2024

Patent Records (Granted) in Massachusetts State

Figure 2. Aerial views of the top 4 zip codes with highest number of granted patentrecords in 2022 for Massachusetts State. Own elaboration, 2024

Patent Decade Change in New York State

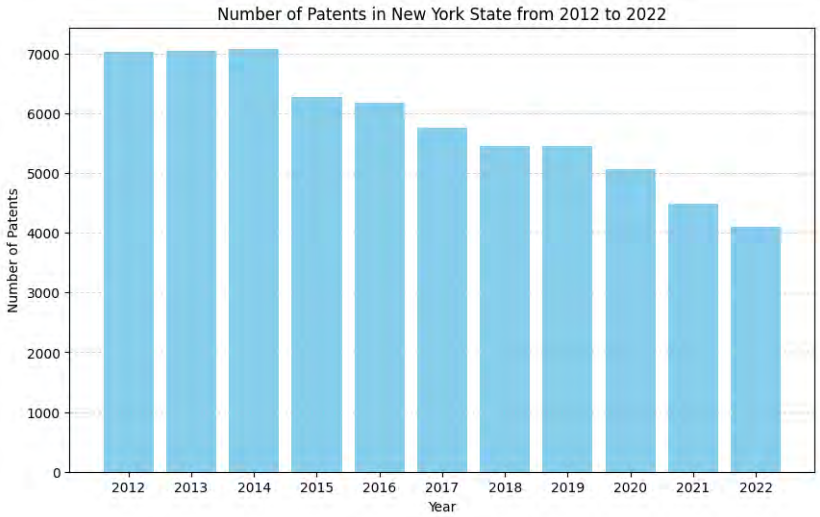


Figure 3. Patent Record Change in New York State from 2012 to 2022. Own elaboration, 2024

Patent Decade Change in Massachusetts State

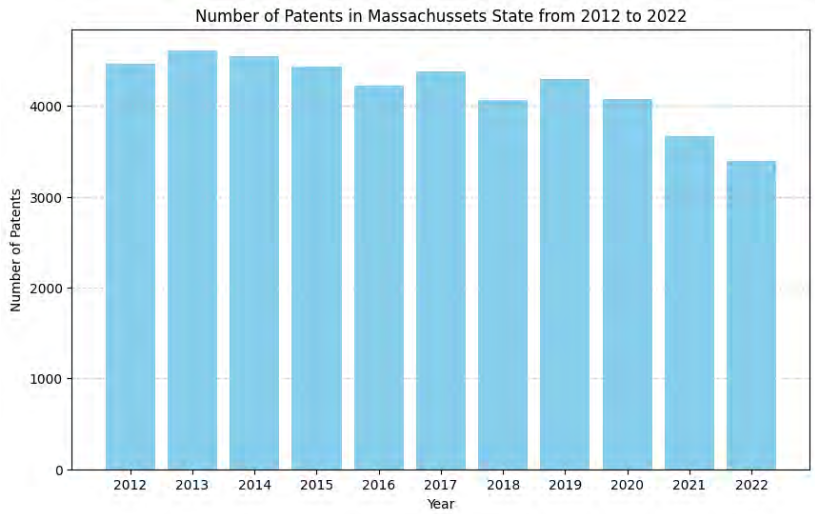


Figure 4. Patent Record Change in Massachusetts State from 2012 to 2022. Own elaboration, 2024

Note: This figure presents a histogram illustrating the annual count of new patents granted within Massachusetts State (b) from 2012 to 2022. The Y-axis represents the number of patents, while the X-axis indicates the year.

4.2 Understanding dependencies of neighbourhood elements with innovative outcomes

The study uses a random forest algorithm as part of the process to identify the most important of the independent variables for predicting the records of granted patents. This algorithm helps with handling complex datasets, reducing overfitting, and determining which of the factors have the most significant effect on the dependent variable. This way, the model will focus only on the key drivers that predict the concentration of innovative activity quantified in granted patents. From all the selected variables, we see that a smaller number of social, economic, infrastructure and urban morphological characteristics allows to predict innovation outcomes (figure 5).

More specifically, feature importances attribute is used to estimate the importance of each feature. When examining the number of granted patents for a given zip code as the dependent variable of the model, we see that the number of H1B applications, the median income, the percentage of people getting to work by walking or riding a bike, the percentage of people acquiring a bachelor's degree have the most significant impact on this dependent variable.

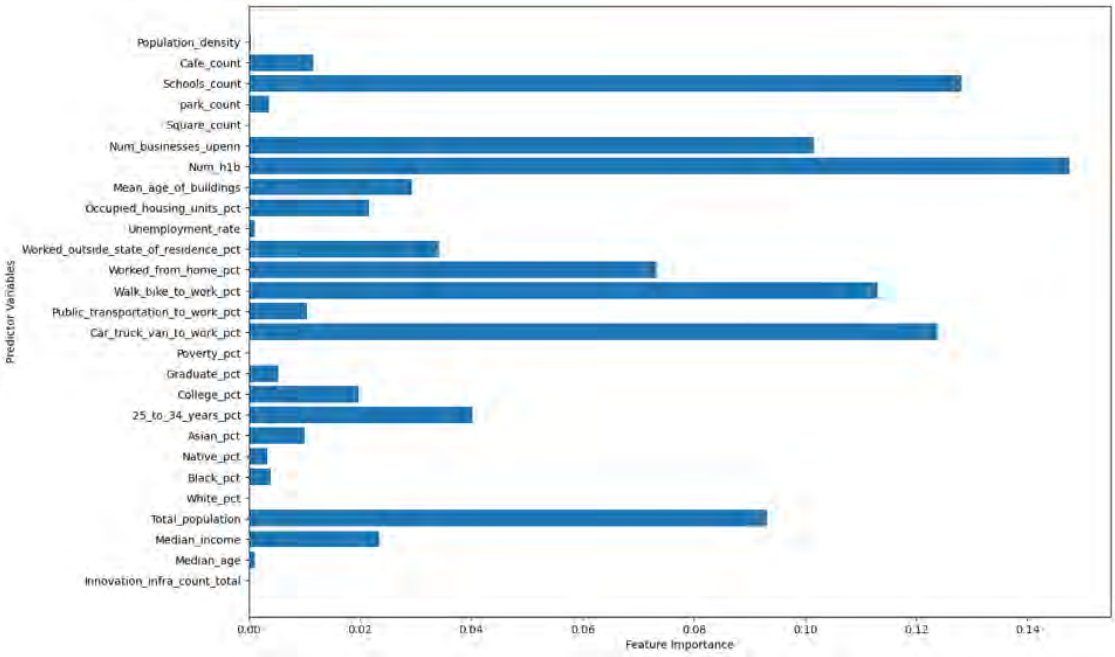


Figure 5. Random forest algorithm for assessing feature importance in innovation outcomes (patent data).

Own elaboration, 2024

As another step of the analysis, correlation matrices (figures 6,7) were examined to help understand the association between neighbourhood elements and granted patent records across the two US states. Two groups of transformed variables were created, the one with standardized variables and a second with log transformed. Looking at the second set of variables, we see that in both US states, there is a strong correlation of 0.7 between the number of H1B applications filed in 2012 and the number of granted patents in that zip code ten years later (2022). More specifically, in New York state, we observe a correlation of 0.6 between the number of cafes that existed in 2012 and the granted patents in 2022 within the same ZIP code, indicating that these two variables might have an association.

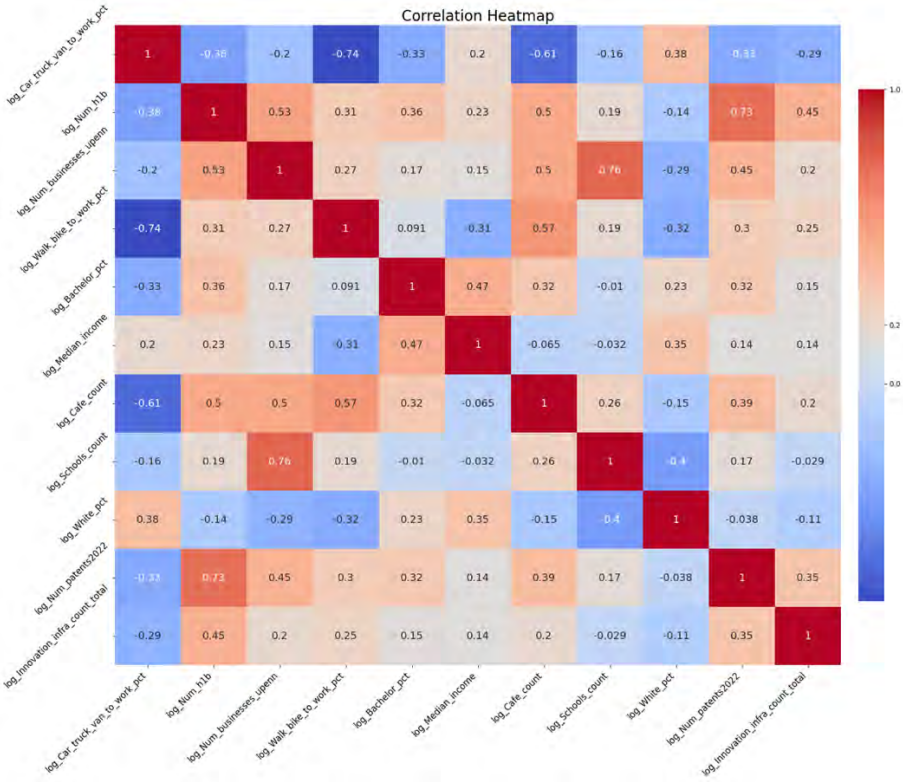


Figure 6. Pearson's Correlation Matrix for the most significant log-transformed variables for Massachusetts State. Own elaboration, 2024

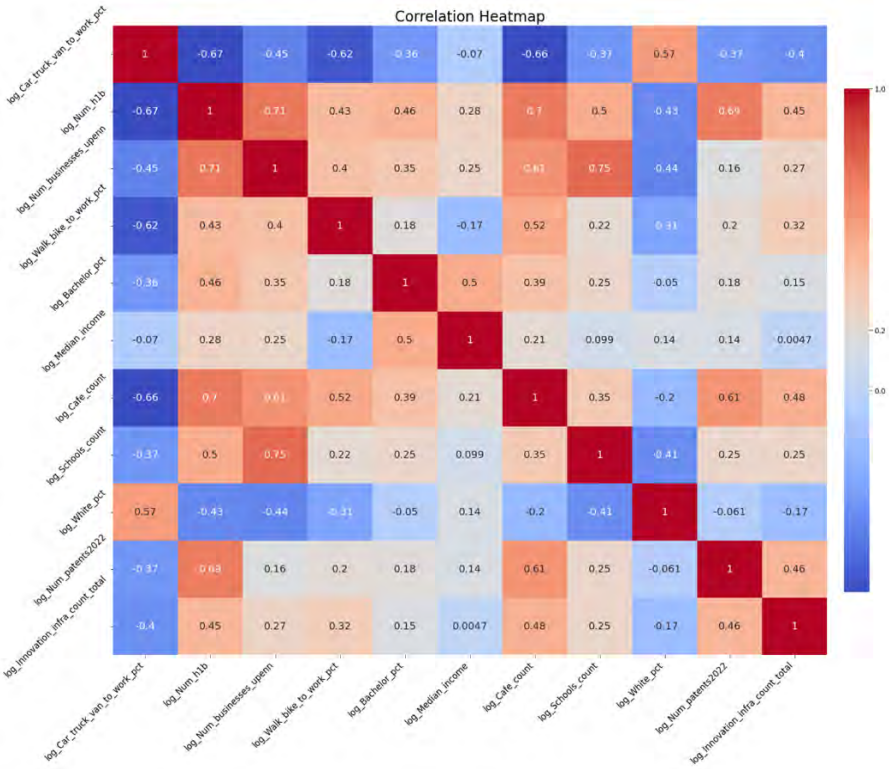


Figure 7. Pearson's Correlation Matrix for the most significant log-transformed variables for New York state. Own elaboration, 2024

4.3 Predicting innovative capacity using infrastructure across diverse neighbourhoods

To respond to the second research question, Machine and Deep Learning models were trained with New York's records and tested in an out-of-sample of the two states (NY, MA), to examine whether they can accurately predict innovative outcomes quantified by granted patent records. By using predictive modelling, the study examines the neighbourhood characteristics that have a significant effect on the innovation outcomes quantified by the granted patents. When examining neighbourhood innovation outcomes for zip codes of New York state as the dependent variable of the model, we find that the number of H1B visa applications, the percentage of population with bachelor's degree, the median income, the percentage of people walking or riding a bike to work, have the most significant impact on this dependent variable. More specifically, when the model trained with records from NYNJ Metropolitan division and tested for Boston's neighbourhoods, we see that these observable characteristics predict with high accuracy the variation in the level of capacity ten years later (Figures 8,9). The predictions of the innovation outcomes are stable across New York and Boston -- that is, when assessing this dependent variable in both locations, we see it is explained well by the same independent variables.

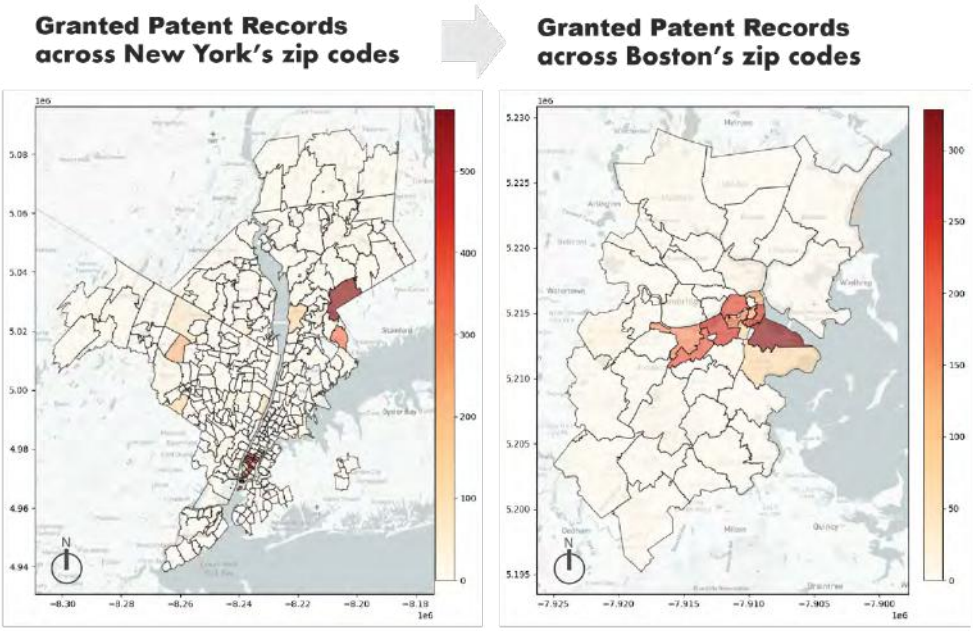


Figure 8. Maps of the granted patents, the dependent variable for the model. Own elaboration, 2024

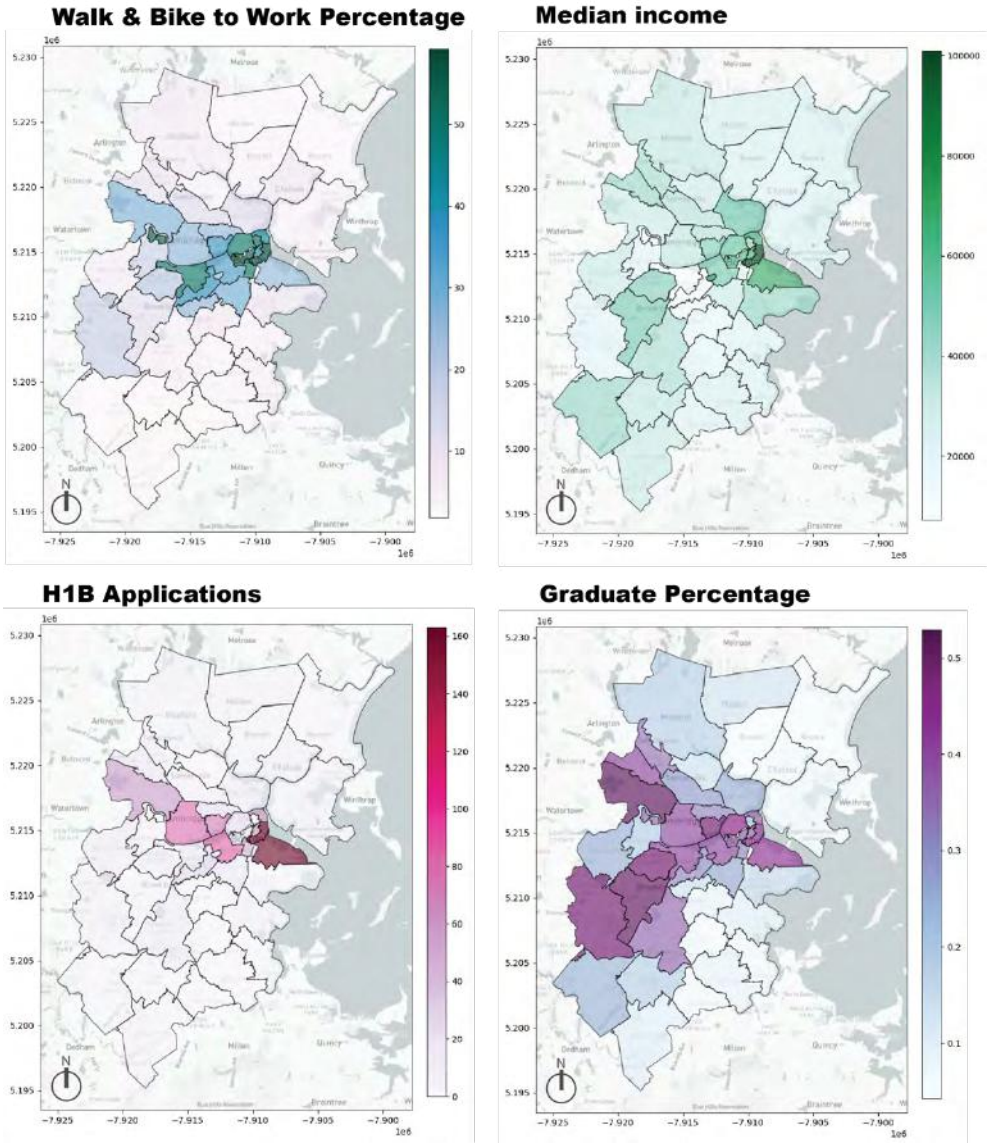


Figure 9. Maps of the most significant variables for the model. Own elaboration, 2024

5. Conclusions and future outlook

For this study, a unique dataset is created by merging data across different aspects of a neighbourhood, the socioeconomic characteristics, the urban morphology and its infrastructure to predict its innovative outcomes quantified by granted patents, a decade later. First, correlation matrices and the RF algorithm's capacity are used to understand the effect of neighbourhood variables on the innovative outcomes.

This analysis emphasized the role of real time, big data analytics in enabling better decision-making within urban ecosystems. By real-time tracking the growth of specific variables, without having to wait for innovative activity such as innovation outcomes to take place, policymakers and innovation researchers will be given the option to understand the advancement of the specific neighbourhood's activity in real time in order to inform innovation policy at the local level.

A future study should aim at geographically expanding and including other indicators and time-periods, to understand if the same variables have a great effect on innovative outcomes across US neighbourhoods

with diverse socioeconomic contexts. By applying the methodology to several real cases in the US, its validation in environments with district neighbourhood characteristics can be achieved.

References

1. Acs, Z.J., Anselin, L. & Varga, A., 2002. Patents and Innovation Counts as Measures of Production of New Knowledge. Research Policy, 31.

2. Allen, T. J. 1977. "Managing the Flow of Technology." M.I.T. Press, Cambridge, Mass.

3. Audretsch, D.B. & Feldman, M.P., 2004. Chapter 61 - Knowledge Spillovers and the Geography of Innovation. In J.V. Henderson & J.-F. Thisse, eds. Handbook of Regional and Urban Economics. Vol. 4. Elsevier, pp. 2713–2739. https://doi.org/10.1016/S1574-0080(04)80018-X.

4. Arzaghi, M. & Henderson, J.V., 2008. Networking off Madison Avenue. The Review of Economic Studies, 75(4), pp.1011–1038. https://doi.org/10.1111/j.1467-937X.2008.00499.x.

5. Boschma, R., 2005. Proximity and Innovation: A Critical Assessment. Regional Studies, 39(1), pp.61–74. https://doi.org/10.1080/0034340052000320887.

6. Carlino, G. & Kerr, W., 2015. Agglomeration and Innovation. In Handbook of Regional and Urban Economics. Vol. 5. Elsevier, pp. 349–404. https://EconPapers.repec.org/RePEc:eee:regchp:5-349.

7. Catalini, C., 2018. Microgeography and the Direction of Inventive Activity. Management Science, 64(9), pp.4348–4364. https://doi.org/10.1287/mnsc.2017.2798.

8. Cooke, P., 2001. Regional Innovation Systems, Clusters, and the Knowledge Economy. Industrial and Corporate Change, 10(4), pp.945–974. https://doi.org/10.1093/icc/10.4.945.

9. Davis, D.R. & Dingel, J.I., 2019. A Spatial Knowledge Economy. American Economic Review, 109(1), pp.153–170. https://doi.org/10.1257/aer.20130249.

10. Delgado, M., Porter, M.E. & Stern, S., 2010. Clusters and Entrepreneurship. Journal of Economic Geography, 10(4), pp.495–518. https://doi.org/10.1093/jeg/lbq010.

11. Furman, J.L., Porter, M.E. & Stern, S., 2002. The Determinants of National Innovative Capacity. Research Policy, 31.

12. Glaeser, E.L., Kerr, W.R., Ponzetto, G.A.M. & Rock Center, 2009. NBER Working Paper Series Clusters of Entrepreneurship. Available at: http://www.nber.org/papers/w15377.

13. Jang, Seongsoo, Jinwon Kim, and Max von Zedtwitz. 2017a. "The Importance of Spatial Agglomeration in Product Innovation: A Microgeography Perspective." Journal of Business Research 78:143–54. https://doi.org/https://doi.org/10.1016/j.jbusres.2017.05.017.

14. Kerr, W.R. & Kominers, S.D., 2015. Agglomerative Forces and Cluster Shapes. The Review of Economics and Statistics, 97(4), pp.877–899. https://doi.org/10.1162/REST_a_00471.

15. Matsiuk, Nadiia, David Doloreux, and Richard Shearmur. 2024. "Beyond 'Buzz': Knowledge Interactions, Innovation, and Neighborhood Characteristics." Journal of Economic Geography, August, lbae026. https://doi.org/10.1093/jeg/lbae026.

16. Nelson, R.R., 1993. National Innovation Systems: A Comparative Analysis. Oxford: Oxford University Press.

17. Nelson, R. & Rosenberg, N., 1993. Technical Innovation and National Systems. Vol. 1. Oxford: Oxford University Press.

18. Rammer, Christian, Jan Kinne, and Knut Blind. 2019. "Knowledge Proximity and Firm Innovation: A Microgeographic Analysis for Berlin." Urban Studies 57 (5): 996–1014. https://doi.org/10.1177/0042098018820241.

19. Roche, Maria P, Alexander Oettl, Christian Catalini, and Morgan Hall. 2022. "(Co-)Working in Close Proximity: Knowledge Spillovers and Social Interactions."

20. Roche, Maria P. 2020. "Taking Innovation to the Streets: Microgeography, Physical Structure, and Innovation." The Review of Economics and Statistics 102 (5): 912–28.

21. Shearmur, Richard. 2012a. "The Geography of Intrametropolitan KIBS Innovation: Distinguishing Agglomeration Economies from Innovation Dynamics." Urban Studies 49 (11): 2331–56. https://doi.org/10.1177/0042098011431281.

22. Wallsten, Scott J. 2001a. "An Empirical Test of Geographic Knowledge Spillovers Using Geographic Information Systems and Firm-Level Data." *Regional Science and Urban Economics* 31 (5): 571–99. https://EconPapers.repec.org/RePEc:eee:regeco:v:31:y:2001:i:5:p:571-599.

Acknowledgement: The work presented in the conference proceedings represents an initial exploration, with ongoing research to expand on these findings. The author is completely responsible for any deficiencies, errors and omissions that may remain in the article. I extend my sincere gratitude to Professor Guzman for the guidance and insights provided during the coneptualization and data curation. I sincerely thank Professor Kakderi and Komninos at Aristotle University of Thessaloniki as well as Dr. Dimitris Belivanis for their invaluable insights.

Research Paper

Modeling the effect of amenity determinants on urban innovation spaces using geographical random forest model

A Beijing case study

Tianheng SHU, Tsinghua University, China

Xia LIAO, Chongqing University, China

Shuo YANG, Tsinghua University, China

Taofang YU, Tsinghua University, China

Contact: Tianheng SHU, sthcqu@163.com

Abstract

Urban areas have different amenities that shape their innovation spaces. Previous research has examined urban amenities' effects at broader scales but rarely analyzes each factor's relative contribution and geographic variations. This study examines how different amenity factors affect urban innovation spaces in Beijing by using multiple global and local machine learning models at a 0.5 km² hexagonal grid scale. The analysis uses geographical random forests (GRF), a new nonlinear machine learning regression method, to examine how each amenity factor varies spatially and contributes to innovation spaces distribution. We then compare how GRF performs against geographically weighted regression (local model), random forest (global model), and ordinary least squares (global model). Our analysis shows that GRF works better than other models, and amenity factors vary in importance across different areas. The results show that education and research factor most strongly affect urban innovation spaces, followed by bus stations, healthcare amenity, and natural greenspace while recreation and entertainment amenity are relatively less significant. The influence of these factors also varies spatially; natural amenities and transportation accessibility exert a stronger influence in the outer areas, while commercial and cultural amenities are more pivotal in inner areas. Education and research facilities matter both in core areas and some outer regions. These patterns suggest that urban planning should develop specific strategies for different parts of the city to support innovation.

Keywords

Urban innovation spaces, Amenity determinants, Geographical random forest, Spatial analysis, Beijing

1. Introduction

Innovation is a key force in urban development, enhancing economic growth, advancing technology, and increasing a city's ability to compete globally and regionally (Johnson, 2008). In today's knowledge economy, innovation-focused cities not only modernize industries, but also attract talented individuals and

investment, transforming them into centers of creative activity and adaptability (Li and Du, 2022). This makes supporting innovation a major priority for urban policy and planning. Urban innovation spaces are the physical environments in which innovation occurs. These spaces include technology parks, incubators, and makerspaces that create opportunities for people to share ideas and resources and build networks that stimulate creativity. Through these spaces, people collaborate to create new products and services (Yigitcanlar, Adu-McVie and Erol, 2020). Beyond their physical presence, these spaces act as an ecosystem that connects people, businesses, and organizations, forming the foundation of the city's innovative capacity. Their growth depends on several factors, including market needs, policy support, and local amenities. Among these factors, urban amenities strongly influence the attractiveness and functionality of innovation spaces. Amenity determinants such as educational institutions, transportation, healthcare, and green spaces help create an environment where innovation can thrive (Arauzo-Carod, 2021). These amenities support innovation both directly and indirectly by enabling access to resources, reducing travel time, and improving the lives of those who work there.

In China, the study of urban innovation spaces is particularly important because cities such as Beijing, Shanghai, and Shenzhen are emerging as global innovation leaders (JLL, 2022). These cities illustrate China's move toward an innovation economy. To create effective policies for sustainable urban growth, we need to understand how innovation spaces work in these cities. It is important to investigate how different amenity determinants affect the development of innovation spaces in Chinese cities. This type of analysis can guide urban planning decisions by indicating the specific amenities that help innovation grow and concentrate in a particular area. By seeing how the effects of amenities vary geographically, planners can develop strategies that meet the needs of each inner urban space.

Previous research on urban innovation space has largely focused on the spatial clustering of innovation actors, especially the distribution of innovation districts and high-tech firms. Innovation districts and tech firms tend to be spatially concentrated, and these areas become centers for driving local economic development and attracting professionals (Bevilacqua, Parisi and Biancuzzo, 2019; Arauzo-Carod, 2021; Taecharungroj and Millington, 2022). Creative spaces also play an important role in urban innovation ecosystems by supporting cultural and artistic activities that enrich the overall innovation environment (He and Gebhardt, 2014). Analysis of these spaces often centers on their formation mechanisms and spatial distribution characteristics, which help us understand the processes and factors that influence the development of urban innovation spaces (Yigitcanlar, Adu-McVie and Erol, 2020; Yuan *et al.*, 2021; Tan, Qian and Chen, 2023).

While much attention has been given to the structural aspects of innovation spaces, relatively few studies look at the effects of amenity determinants on these spaces. Studies about urban amenity often use qualitative methods like case studies to examine how amenity factors attract and support innovation spaces (Esmaeilpoorarabi *et al.*, 2018; Adu-McVie *et al.*, 2021). Quantitative research typically uses traditional linear econometric models - including correlation analysis (Taecharungroj and Millington, 2022), count data models (Arauzo-Carod, 2021), and geographically weighted regression (GWR) (Zhou and Yang, 2024) - to study the connections between amenity determinants and innovation spaces. However, linear models may oversimplify the complex non-linear relationships and spatial variations between these elements, making it harder to understand deeply how different amenity determinants shape innovation spaces.

Recent advancements in modeling techniques, such as the geographical random forest (GRF) model, represent new approaches that addresses these modeling challenges. Developed by Georganos et al. (2021), GRF combines the benefits of machine learning with GWR, effectively capturing local variations and

non-linear effects within spatial data. This model is increasingly used in urban studies to address spatial heterogeneity and shows promise in revealing complex patterns and local interactions that may be missed by traditional linear models (Grekousis *et al.*, 2022; Lotfata and Georganos, 2023; Lotfata, Grekousis and Wang, 2023; Wang *et al.*, 2024).

To conclude, while extant studies have made progress in identifying the general factors that contribute to urban innovation spaces, research that systematically examines the interaction between various amenity determinants on the spatial distribution of these spaces remains limited. Given the potentially complex and nonlinear relationships, traditional linear models may not fully capture these dynamics. This study addresses these gaps by employing GRF to provide a more detailed analysis of how amenity determinants influence the location and density of innovation spaces within a city, offering new insights into the spatial heterogeneity of these effects.

Given these considerations, this study aims to answer the following questions: How do various amenity determinants contribute to the distribution of innovation spaces within a city? and is there local heterogeneity in how these determinants impact innovation spaces?

2. Method and data

Figure 1 shows our research framework, which has three main parts. First, we analyze data and variables. Second, we build and compare different models. Third, we examine the key results. We use the GRF model to study how amenity determinants affect where urban innovation spaces are located. This model helps us understand these relationships across different areas and how they interact with each other.

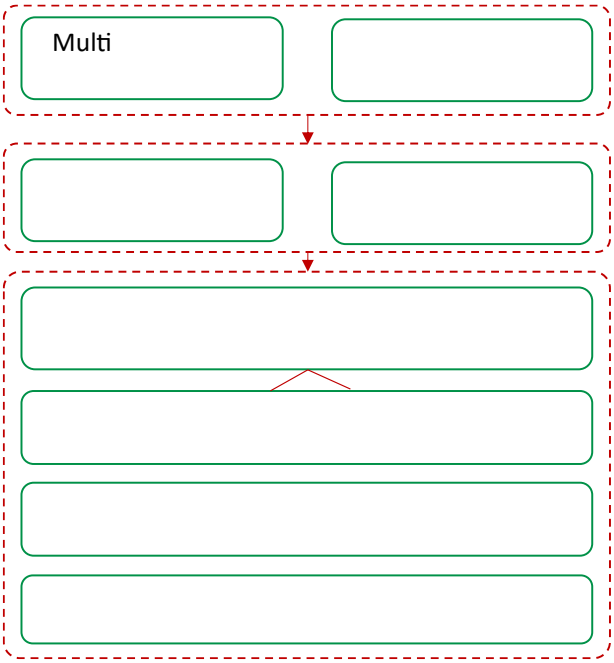


Figure 1. Workflow of this study. Source: Drawn by the authors

2.1. Variable description and data sources

This study aims to explore the impact of various amenity determinants on urban innovation spaces. To achieve this, we first need to measure innovation spaces within the city. Innovation space represents the physical area where innovation-dominant entities are clustered in urban microspatial units. In this study, we focus on key innovative enterprises, such as high-tech enterprises and innovative small and medium-sized enterprises (SMEs) that have a tendency to form spatial clusters. The choice of spatial location for these firms is influenced by amenity factors; for instance, enterprises often prefer locations with convenient transportation.

To quantify innovation spaces, we measure the density of these innovative enterprises within each study unit to understand both the clustering and spread of innovation activities. This variable is denoted as $kd_innovation$, and is calculated by kernel density estimation of the innovative enterprises within each spatial unit. Data on these innovative enterprises are provided by Qichacha, a Chinese enterprise information query platform. We further extracted enterprise addresses and used the Amap API for geocoding (Amap, 2024), enabling spatial positioning within the city.

Following existing literature on urban amenities (Ullman, 1954; Glaeser, 1999; Florida, 2014; Taecharungroj and Millington, 2022), we selected five categories of amenity determinants: natural factors, transportation accessibility, cultural factor, commercial factors, and education & research factor. Each category contains one or more indicators as shown in Table 1. Most of the amenity determinants data come from Amap's Points of Interest (POI) dataset. Additionally, greenspace data is sourced from high-resolution (1m) green space data published by Shi *et al.* (2023).

Table 1 Variable description. Source: Compiled by the authors

Amenity Type	Variable	Description	Unit
Natural factors	$greenspace$	Green space area	km^2
	$distance_to_park$	Distance to nearest park	m
Transportation accessibility	$distance_to_subway$	Distance to subway station	m
	$distance_to_highspeed$	Distance to highspeed rail station	points/km^2
	$kd_bus_station$	Kernel density for bus station	points/km^2
Cultural factor	$kd_culture$	Kernel density for cultural facility POI	points/km^2
Commercial factors	$kd_shopping$	Kernel density for shopping POI	points/km^2
	kd_daily_life	Kernel density for daily life POI	points/km^2
	$kd_recreat_enter$	Kernel density for recreation and entertainment POI	points/km^2
	$kd_healthcare$	Kernel density for healthcare POI	points/km^2
	kd_food_drink	Kernel density for food and drink POI	points/km^2
	$kd_finance_insurance$	Kernel density for finance and insurance POI	points/km^2
Education and research factor	$kd_edu_research$	Kernel density for education and research POI	points/km^2

As shown in Figure 2, when we map these factors, we can see clear differences across different areas. Each type of amenity has its own unique spatial pattern. Some areas have better access to resources, while others have limited availability.

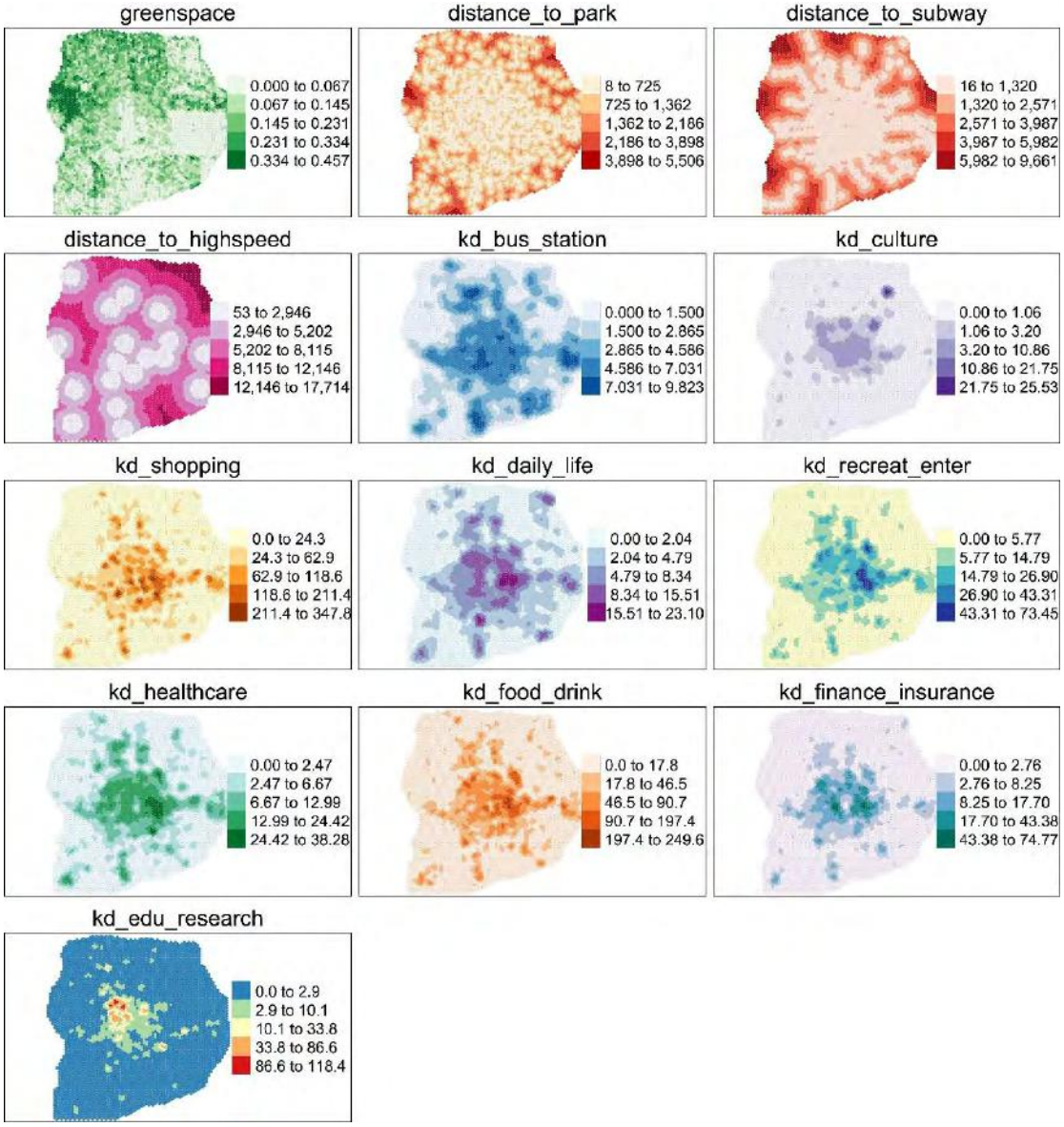


Figure 2. Spatial variation of amenity determinants. Source: Drawn by the authors

2.2. Development of GRF Model

GRF model is an extension of the traditional Random Forest (RF) model, designed to incorporate spatial heterogeneity into predictions, making it particularly useful in urban studies where spatial effects are significant (Georganos *et al.*, 2021). Unlike traditional RF, which assumes a single global model for all data points, GRF applies multiple local models to account for spatial variability, similar to the approach used in GWR.

The core idea behind GRF is to leverage local variations by calibrating a separate RF model for each spatial location, rather than relying on a single model across the entire study area (Georganos *et al.*, 2021; Georganos and Kalogirou, 2022). This approach allows GRF to capture the localized relationships between independent variables and the dependent variable, improving model accuracy in scenarios where spatial heterogeneity plays a crucial role. In GRF, each local model is calibrated using a spatial weights matrix and a subset of observations that are spatially proximate to the location being analyzed. For each spatial unit i, a separate RF model is trained using only nearby data points within a specified spatial window, defined by a distance or neighborhood threshold. This approach ensures that predictions reflect local conditions, allowing the model to adapt to variations in the spatial distribution of independent variables.

To better understand GRF, we first outline the standard RF model. In a traditional RF model, the dependent variable y_i at location i is predicted based on a nonlinear function of the independent variables ax_i, with an error term ε:

$$y_i = ax_i + \varepsilon \tag{1}$$

The GRF model extends the RF framework by introducing local calibrations, allowing predictions to account for spatial heterogeneity. The GRF prediction equation at each location i can be represented as follows:

$$y_i = a(u_i, v_i)x_i + \varepsilon \tag{2}$$

where $a(u_i, v_i)$ represents the RF model calibrated specifically for location i, with (u_i, v_i) denoting the spatial coordinates of the centroid of the spatial unit i. This location-specific calibration uses only a subset of the original dataset, defined by a spatial window around each point. To determine the subset of observations used in each local model, GRF applies a spatial weighting function, typically based on a kernel density approach. A common choice is the adaptive kernel, where the size of the kernel adjusts to include a fixed number of nearest neighbors around each observation. This method is similar to the approach used in GWR and allows for flexibility in areas with varying data densities.

2.3. Study area and units

We chose Beijing as the research area for several reasons. As China's political, cultural and technological center, Beijing has a high concentration of innovative enterprises, making it an ideal setting for analyzing the spatial distribution of innovation spaces. Furthermore, Beijing's status as a major innovation center ensures a rich dataset of various amenity determinants and innovation activity, providing an opportunity to explore the complex relationships between them. We limited our research to the area inside Beijing's Sixth Ring Road, where most economic activities happen (Figure 3a). The city's main business operations take place in this central area. In contrast, areas outside the Sixth Ring Road have few innovative enterprises, and in some places, none at all. If we included these outer areas in our study, it would make our model predictions less accurate because innovation spaces there are scattered and hard to define.

For a fine-grained spatial analysis, we divided the area into hexagonal cells. Each cell is 0.5 km² (Figure 3b), about the same size as a typical block in Beijing's core districts (People's Government of Beijing Municipality, 2018). Hexagons provide consistent measurement units across the study area, avoiding size and shape variability issues associated with administrative boundaries. This structure reduces edge effects, enhances spatial comparability, and minimizes boundary biases in analyzing the distribution of innovation spaces and amenities (Zhang, Xiong and Wei, 2022; Liu, Meng and Shi, 2023).

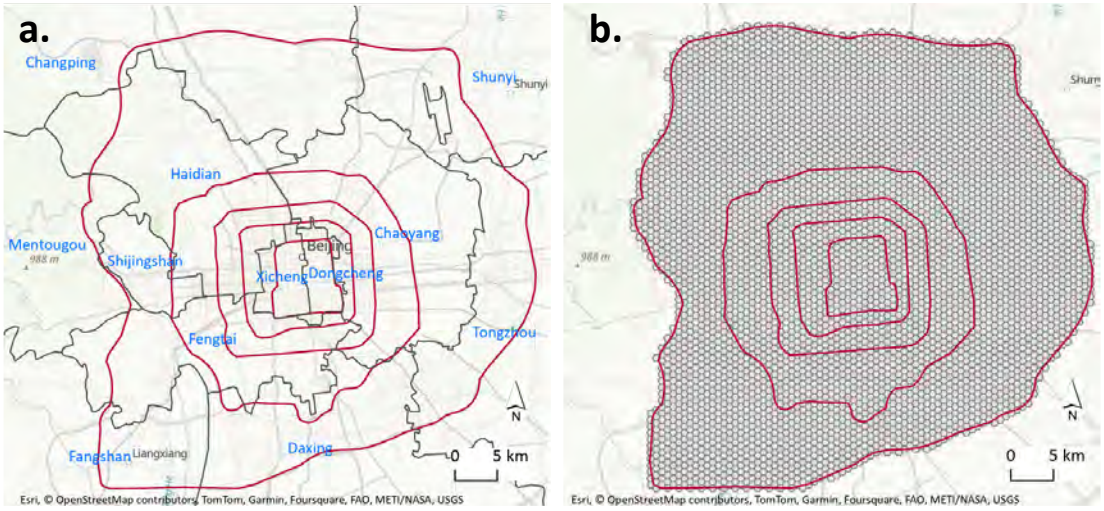


Figure 3. Study area (a) and spatial units (b). Source: Drawn by the authors

2.4. Model performance metrics and model preparation

To assess the performance of our model, we use three common evaluation metrics: R-square (model fitness), mean square error (MSE), and mean absolute error (MAE). These metrics enable to verify how well the model captures the relationships within the data and its predictive accuracy. The formulas for each metric are as follows:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2} \tag{3}$$

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2 \tag{4}$$

$$MSE = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}_i| \tag{5}$$

where where y_i represents the observed values, $\hat{y}_i$ represents the predicted values, and $\bar{y}$ is the mean of the observed values.

Before implementing the GRF model, several preparatory steps were taken to ensure the reliability and robustness of the results. First, a co-linearity check was performed to investigate potential multicollinearity among the amenity determinants. By calculating the variance inflation factor (VIF) for each variable, we ensured that all VIF values were less than 5, indicating that collinearity would not harmfully impact the del's performance or interpretation.

With the amenity determinants confirmed for inclusion, hyperparameter tuning was conducted to optimize the model's performance. The process involved a random grid search using the "caret" package in R. Various configurations of the parameters of the random forest were tested. A 10-fold cross-validation approach was applied and parameter combinations were iterated to identify optimal settings. The results

showed that the best performance was achieved with 500 trees (ntree=500) and 8 randomly selected variables in each split (mtry=8).

Finally, bandwidth selection was necessary to define the local neighborhood size of the GRF model. The Golden Section Search method was applied to minimize the corrected Akaike information criterion (AICc) and to identify the optimal bandwidth. This method determines a bandwidth of 68, which allows the model to balance local sensitivity with spatial smoothness and effectively capture spatial heterogeneity without over-fitting.

3. Results and analysis

3.1. Spatial pattern of innovation spaces in Beijing

We first marked all innovative enterprises on a map. Then we used different methods to analyze how these enterprises spread across Beijing. Our analysis methods included kernel density estimation, grid aggregation, and LISA clustering analysis (Figure 4). The results showed that these enterprises tend to form clusters in certain areas, showing a polycentric distribution across the city.

The major clusters identified include Zhongguancun, Shangdi, CBD (Central Business District), Wangjing, and Yizhuang. These clusters demonstrate that Beijing's innovation spaces are not randomly dispersed, but strategically concentrated in specific areas known for high economic activity, robust infrastructure, and a wealth of amenities that support innovation. This polycentric distribution reflects a deliberate spatial organization in which multiple centers of innovation emerge throughout the city, perhaps influenced by a variety of amenity determinants and urban policies tailored to each region.

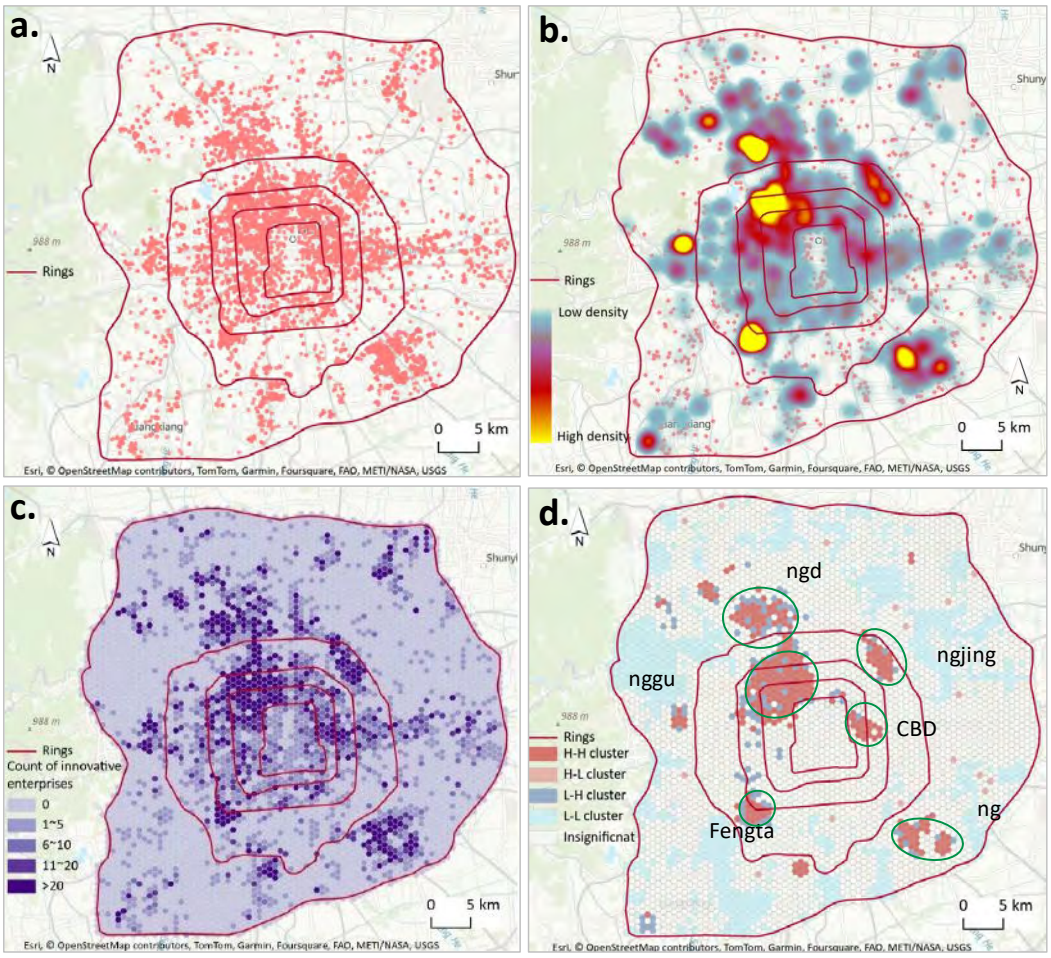


Figure 4. Spatial distribution of urban innovation spaces in Beijing. a, Location of innovative enterprises. b, Kernel density distribution of innovative enterprises. c, Count of innovative enterprises. d, Anselin Local Moran's I clusters (see method in Anselin, 1995). Source: Drawn by the authors

3.2. Model performance comparison

We tested four different models in this study: the GRF model, the global ordinary least squares (OLS) model, the traditional RF model, and the local GWR model. To see which model worked best, we looked at their R^2, MSE, and MAE values, as we mentioned earlier. The GRF model got better results than all other models. It had the highest R^2 at 0.909, and the lowest MSE (76.40) and MAE (3.19) values (see Table 2). The GRF model's high accuracy comes from its ability to capture both nonlinear relationships and spatial heterogeneity in the data. These two features make the model effective for studying how innovation spaces spread across different parts of a city.

Table 2. Metric performance of different models. Source: Compiled by the authors

Model	R^2	MSE	MAE
OLS	0.290	595.25	11.02
RF	0.682[a]	266.8	6.92
GWR	0.853	122.94	5.52
GRF	0.909[a]	76.40	3.19

[a] Metrics are computed from Out-of-Bag samples

3.3. Importance of amenity determinants' effect on innovation spaces

Using the "ranger" package in R, we ran a global RF model to determine the relative importance of various amenity determinants in predicting the distribution of $kd_innovation$. The importance of each factor was evaluated based on the increase in Mean Squared Error (IncMSE) when each amenity determinant was randomly permuted (Breiman, 2001), meaning that a higher IncMSE indicates a more important factor for the model's predictive power.

As shown in Figure 5, education and research amenity is the most important factor influencing the spatial distribution of Beijing's urban innovation space. This suggests that proximity to universities, research centers, and other educational facilities strongly attracts innovative enterprises, possibly because of the availability of skilled human resources and research partnerships in these areas (Oh *et al.*, 2016). Following education and research amenity, bus station density ranks as the second most important factor, highlighting the role of transportation accessibility in supporting innovation spaces. Healthcare amenity and natural greenspaces are also important elements, which suggests innovative enterprises prefer areas with good health facilities and natural environments. In contrast, determinants related to recreation and entertainment and proximity to parks show relatively lower importance. While these determinants can

make urban life better overall, they don't seem to strongly influence where innovative enterprises choose to locate in Beijing.

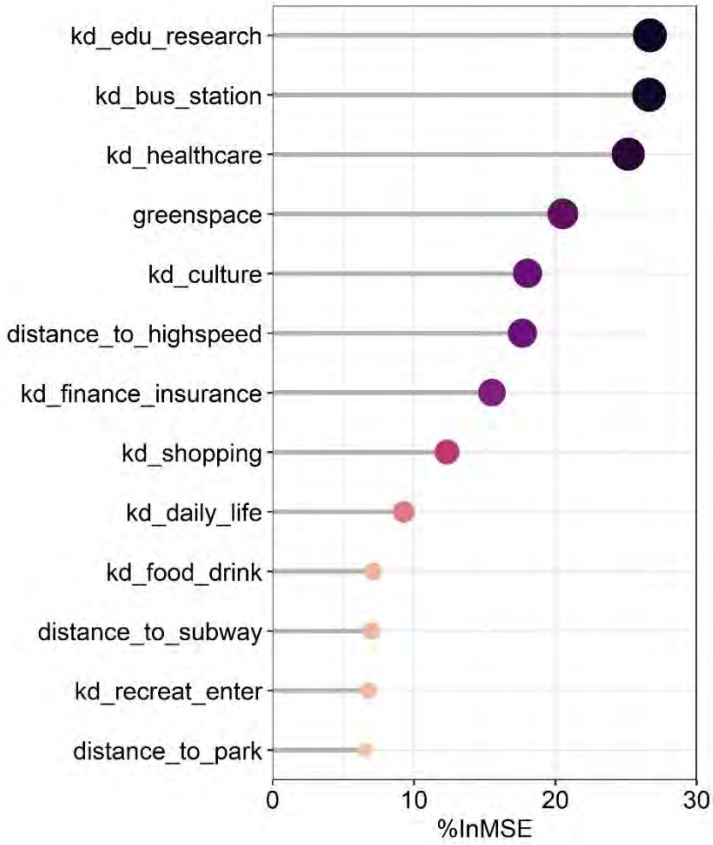


Figure 5. Global importance of amenity determinants. Source: Drawn by the authors

Furthermore, using the "SpatialML" package in R, we ap
variability in the importance of different amenity determinants across Beijing's urban zones. The
reveal distinct patterns: in the outer areas, natural factors like greenspace and transportation accessibility (proximity to subway and high-speed rail) are highly influential. This makes sense because companies in these areas need both a pleasant working environment and quick ways to reach the city center. In contrast, central areas depend more on cultural, commercial, and transit-related amenities. Cultural facilities and daily life services add vibrancy and convenience, appealing to talent in dense urban environments, while bus station density enhances connectivity within these areas. Healthcare, shopping, and food amenities are also important, as they help workers' daily lives and make business operations smoother for innovative enterprises.

A unique factor, education and research factor, holds substantial influence in both core and specific peripheral regions. In the central city, they provide direct access to talent and research resources, while in outer zones, they help create new clusters of innovative companies, showing how important educational and research facilities are for innovation across the whole city.

In summary, the spatial patterns reveal that outer zones emphasize natural factors and transportation accessibility, while central areas rely more on cultural, commercial, and transit-related dterminants. Education and research factor hold unique significance across both core and certain peripheral regions, acting as foundational elements for innovation. Based on these findings, city planners should develop

different strategies for different areas when placing public facilities. This way, they can create better conditions for innovation spaces across the entire city.

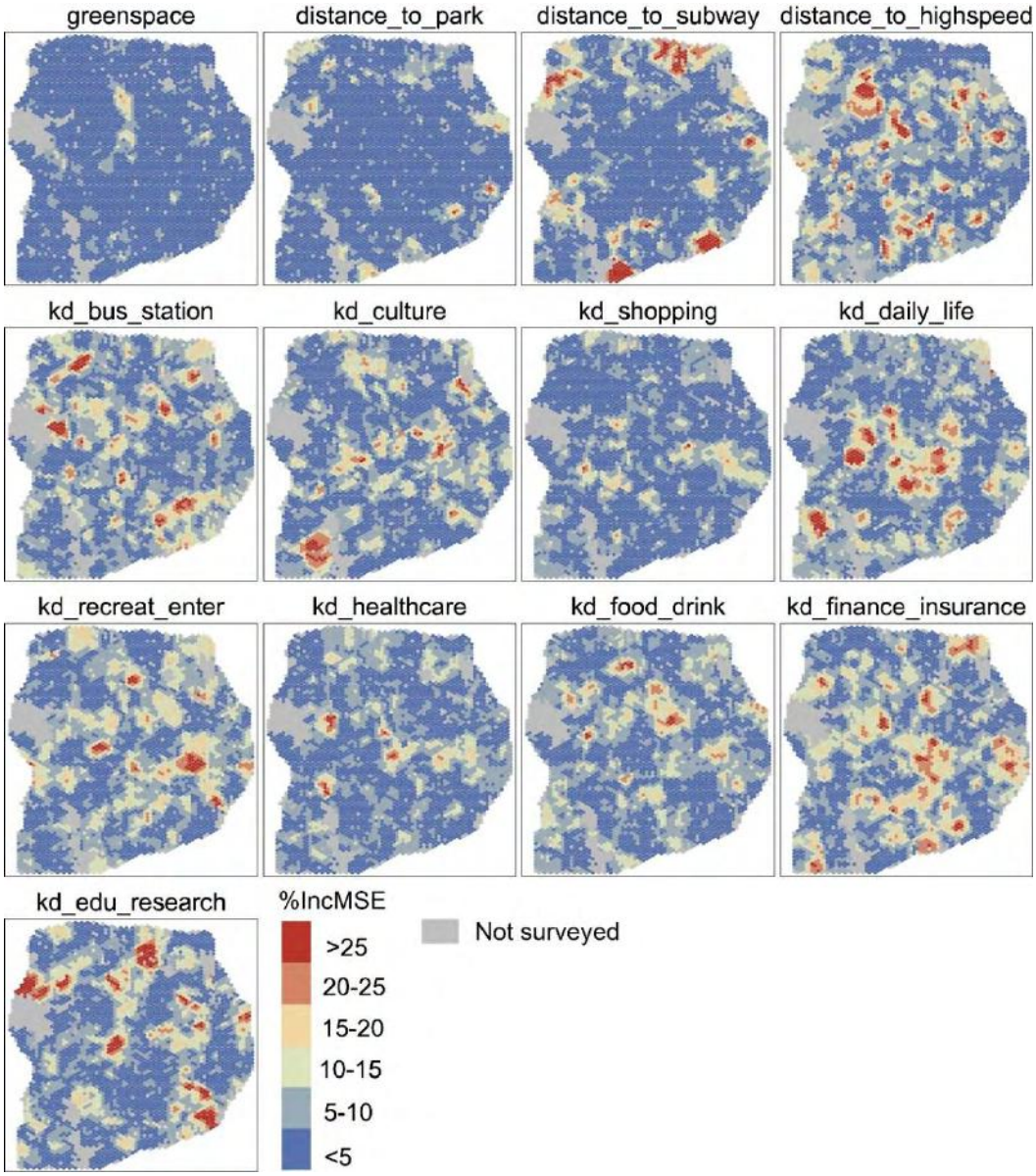


Figure 6. Local importance of amenity determinants. Source: Drawn by the authors

3.4. Nonlinear response of amenity determinants to innovation spaces

To explore the nonlinear effects of amenity determinants on innovation spaces, we analyzed the response curves of selected amenity determinants on $kd_innovation$ using the "spatialRF" package in R. These response curves illustrate each predictor's effect on $kd_innovation$ while holding other predictors constant at their median values. The RF model was repeated 30 times, with the red lines representing the median one (Figure 7).

The response curves show that many predictors exhibit nonlinear threshold effects and that after a certain point, their impact on kdd _innovation stabilizes. Below are some key examples of each facility type. Here are some key examples for each amenity type:

Green space ($greenspace$): when the green space area reaches about 0.3 km^2, the impact on $kd_innovation$ increases rapidly and then levels off. This indicates that green space enhances the surrounding innovation space, but the impact of additional green space above this threshold is limited.

Distance to highspeed rail station ($distance_to_highspeed$): A U-shaped response shows that $kd_innovation$ increases as distance to high-speed rail stations decreases, reaching an optimal point around 5,000 meters. However, locations too close to stations might have less innovation, probably because of noise and traffic near these stations.

Cultural amenity ($kd_culture$): kd_innovation increases with cultural facilities up to 10 nearby locations, then stops growing. This means a diversified cultural environment encourages innovation, but more facilities add little value.

Healthcare amenity ($kd_healthcare$): $kd_innovation$ grows with the increase of healthcare facilities in the neighborhood, peaking around 12. This suggests that moderate access to healthcare supports innovation spaces without oversaturation.

Education and Research ($kd_edu_research$): $kd_innovation$ benefits from educational and research institutions up to around 15, then levels off, suggesting a moderate clustering of these resources is optimal.

These nonlinear response patterns indicate a threshold effect, indicating that while conveniences such as education, culture, and health care intensify $kd_innovation$, their impact stabilizes after a certain level. For this reason, balanced comfort measures are more effective than oversaturation.

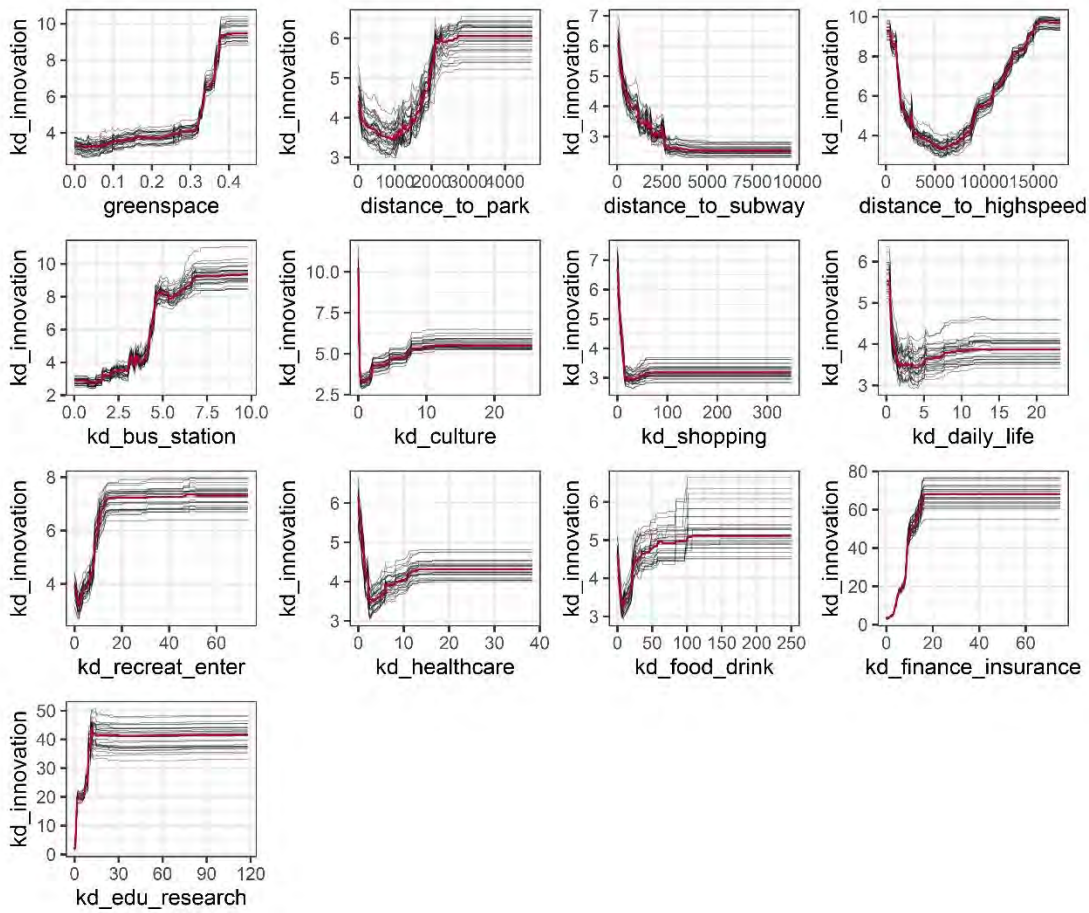


Figure 7. Response curves of amenity determinants. Source: Drawn by the authors

4. Conclusion and implications

This study employed the GRF model to assess the complex, spatially heterogeneous effects of various amenity determinants on the distribution of urban innovation spaces in Beijing. By leveraging the GRF model, we were able to account for both the nonlinear relationships and spatial heterogeneity inherent in the influence of amenity determinants on innovation spaces. Our findings reveal that education and research factor are the most influential determinant, demonstrating their importance in promoting innovation by offering access to skilled talent and knowledge resources. Additionally, the impact of different amenity determinants differs between core and peripheral areas, underlining the importance the importance of spatial context in understanding amenity effects. The nonlinear response patterns observed—particularly threshold effects and saturation points—suggest that urban amenities can support innovation spaces up to an optimal level, beyond which additional amenities contribute less significantly.

Theoretically, this research advances our understanding of the spatial dynamics of urban innovation spaces by integrating the effects of multiple amenity determinants through a localized, nonlinear analytical approach. Our findings demonstrate that the spatial distribution of innovation spaces is determined by both the type and concentration of surrounding amenities, adding new insights to urban studies literature.

For urban planning practice, our research has direct implications. Urban planners must consider both spatial heterogeneity and nonlinear effects when developing amenity provision strategies. Recognizing the

varying requirements of innovation spaces across different city zones, planners can tailor the distribution and intensity of key amenities—such as education facilities in both core and strategic outer areas, and healthcare and cultural services in the central zones—to optimize their effectiveness in attracting innovative enterprises. This targeted approach can enhance the urban environment's appeal to innovative entities, supporting a more balanced and innovation-friendly city structure.

This research has several limitations that point to directions for future study. First, we only looked at innovation spaces at one point in time. A long-term analysis would show how these spaces change over time, helping us understand their development patterns. Additionally, future studies could explore the interactive effects of different amenity determinants on innovation spaces to refine amenity provision strategies further. Finally, our study treated all innovation spaces the same way. Investigating how amenity determinants affect different types of innovation spaces - like those in service industries versus manufacturing - would help planners better meet the specific needs of each sector.

5. Acknowledgements

This work was supported by National Key Research and Development Program of China with grant number 2022YFC3800101. The authors acknowledge the use of ChatGPT-4 (OpenAI, 2023) for language improvement in this paper.

6. References

Adu-McVie, R. *et al.* (2021) 'Classifying s: amework', *Land Use Policy*, 111, p. 105779. Available at: https://doi.org/10.1016/j.landusepol.2021.105779.

Amap (2024) *Geododing-Amap API*. Available at: https://lbs.amap.com/api/webservice/guide/api/georegeo (Accessed: 18 September 2024).

Ans n, L. (1995) 'Local Indicators of Spatial As n—LISA', *Geographical Analysis*, 27(2), pp. 93–115. Available at: https://doi.org/10.1111/j.1538-4632.1995.tb00338.x.

Arauzo-Carod, J.-M. (2021) 'Lo high-tech firms: an intra-u h', *Industry and Innovation*, 28(10), pp. 1225–1248. Available at: https://doi.org/10.1080/13662716.2021.1929868.

Bevilacqua, C., Parisi, L. and Bia o, L. (2019) 'Mu -stage Strategic Approach in Spatial Innovation: How In er?', F. brò, L. na, C. Bev acqua (eds) *New Metropolitan Perspectives*. Cham: Springer International Publishing, pp. 85–94. Available at: https://doi.org/10.1007/978-3-319-92099-3_11.

Br an, L. (2001) 'Ra s', *Machine Learning*, 45(1), pp. 5–32. Available at: https://doi.org/10.1023/A:1010933404324.

Esmaeilpoorarabi, N. *et al.* (2018) 'Do e qu ion districts? Determining the om Brisbane's knowledge pre s', *Land Use Policy*, 79, pp. 734–747. Available at: https://doi.org/10.1016/j.landusepol.2018.09.016.

a, R. (2014) 'The Creative Class and Eco ent', *Economic Development Quarterly*, 28(3), pp. 196–205. Available at: https://doi.org/10.1177/0891242414541693.

Georganos, S. *et al.* (2021) 'Geographical random forests: a spatial ext algorithm to address spatial heterogeneity in remote sensing ng', *Geocarto International*, 36(2), pp. 121–136. Available at: https://doi.org/10.1080/10106049.2019.1595177.

Georganos, S. and Kalogirou, S. (2022) 'A Forest of Forests: A Spatially Weighted and Computationally Efficient Formulation of Geographical Random Forests', *ISPRS International Journal of Geo-Information*, 11(9), p. 471. Available at: https://doi.org/10.3390/ijgi11090471.

Glaeser, E.L. (1999) 'Learning in Cities', *Journal of Urban Economics*, 46(2), pp. 254–277. Available at: https://doi.org/10.1006/juec.1998.2121.

Grekousis, G. *et al.* (2022) 'Ranking the importance of demographic, socioeconomic, and underlying health factors on US COVID-19 deaths: A geographical random forest approach', *Health & Place*, 74, p. 102744. Available at: https://doi.org/10.1016/j.healthplace.2022.102744.

He, J.-L. and Gebhardt, H. (2014) 'Space of Creative Industries: A Case Study of Spatial Characteristics of Creative Clusters in Shanghai', *European Planning Studies*, 22(11), pp. 2351–2368. Available at: https://doi.org/10.1080/09654313.2013.837430.

JLL (2022) *Beijing, Shanghai, and Shenzhen listed in Global Top 15 Innovative Markets*. Available at: https://www.joneslanglasalle.com.cn/en/newsroom/beijing-shanghai-and-shenzhen-listed-in-global-top-15-innovative-markets (Accessed: 1 November 2024).

Johnson, B. (2008) 'Cities, systems of innovation and economic development', *Innovation*, 10(2–3), pp. 146–155. Available at: https://doi.org/10.5172/impp.453.10.2-3.146.

Li, Y. and Du, R. (2022) 'Polycentric urban structure and innovation: evidence from a panel of Chinese cities', *Regional Studies*, 56(1), pp. 113–127. Available at: https://doi.org/10.1080/00343404.2021.1886274.

Liu, J., Meng, B. and Shi, C. (2023) 'A multi-activity view of intra-urban travel networks: A case study of Beijing', *Cities*, 143, p. 104634. Available at: https://doi.org/10.1016/j.cities.2023.104634.

Lotfata, A. and Georganos, S. (2023) 'Spatial machine learning for predicting physical inactivity prevalence from socioecological determinants in Chicago, Illinois, USA', *Journal of Geographical Systems* [Preprint]. Available at: https://doi.org/10.1007/s10109-023-00415-y.

Lotfata, A., Grekousis, G. and Wang, R. (2023) 'Using geographical random forest models to explore spatial patterns in the neighborhood determinants of hypertension prevalence across chicago, illinois, USA', *Environment and Planning B Urban Analytics and City Science* [Preprint]. Available at: https://doi.org/10.1177/23998083231153401.

Oh, D.-S. *et al.* (2016) 'Innovation ecosystems: A critical examination', *Technovation*, 54, pp. 1–6. Available at: https://doi.org/10.1016/j.technovation.2016.02.004.

OpenAI (2023) 'ChatGPT-4'. Available at: https://chat.openai.com.

People's Government of Beijing Municipality (2018) *Beijing's Xicheng District implements a block division plan to reshape the ecology of the old city*. Available at: https://www.beijing.gov.cn/renwen//jrbj/csjz/201808/t20180822_1874277.html (Accessed: 20 September 2024).

Shi, Q. *et al.* (2023) 'UGS-1m: fine-grained urban green space mapping of 31 major cities in China based on the deep learning framework', *Earth System Science Data*, 15(2), pp. 555–577. Available at: https://doi.org/10.5194/essd-15-555-2023.

Taecharungroj, V. and Millington, S. (2022) 'Amenity mix of innovation districts', *Journal of Place Management and Development*, 16(1), pp. 125–143. Available at: https://doi.org/10.1108/JPMD-05-2022-0042.

Tan, Y., Qian, Q. and Chen, X. (2023) 'Innovation District Space and Element Identification Framework: Empirical Research from Shenzhen, China', *Journal of Urban Planning and Development*, 149(1), p. 05022041. Available at: https://doi.org/10.1061/(ASCE)UP.1943-5444.0000884.

Ullman, E.L. (1954) 'Amenities as a Factor in Regional Growth', *Geographical Review*, 44(1), p. 119. Available at: https://doi.org/10.2307/211789.

Wang, S. *et al.* (2024) 'Geographically weigh ng for modeling spatial heterogenei frequ US', *Accident Analysis & Prevention*, 199, p. 107528. Available at: https://doi.org/10.1016/j.aap.2024.107528.

Yigitcanlar, T., Adu-McVie, R. d Erol, I. (2020) 'How can contemporary innovation districts be classified? A view e', *Land Use Policy*, 95, p. 104595. Available at: https://doi.org/10.1016/j.landusepol.2020.104595.

Yuan, X. *et al.* (2021) 'Innovation Districts in Beijing: Evolution, Distribution, an s', in L. Bian, Y. Tang, and Z. Shen (eds) *Chinese Urban Planning and Construction: From Historical Wisdom to Modern Miracles*. Cham: Springer International Publishing, pp. 275–299. Available at: https://doi.org/10.1007/978-3-030-65562-4_13.

ang, C., Xiong, M. i, X. (2022) 'Influence of Accessibility to Urban Service Amenities on Housing Prices: Evid Beijing', *Journal of Urban Planning and Development*, 148(1), p. 05021063. Available at: https://doi.org/10.1061/(ASCE)UP.1943-5444.0000795.

u, X. and Yang, S. (2024) 'Di Characteristics and Influencing Factors of High-tech Enterprises Beijing', *Economic geography*, 44(8), pp. 126–136.

Research Paper

Redefining the roles and jurisdictions of civic bodies to provide efficient public service delivery: A case of Bengaluru Metropolitan region

Meenu S. NAIR, Research Scholar, National Institute of Technology Calicut, India
Dr. Anilkumar P.P., Professor, National Institute of Technology Calicut, India

Abstract

The Bengaluru Metropolitan Region, encompassing approximately 8,005 sq. km, is India's second-largest metropolitan area and fifth-largest by population. Rapid urban expansion has led to the creation of multiple civic agencies instead of consolidating responsibilities under the Bruhat Bengaluru Mahanagara Palike (BBMP), the primary governing body. This fragmentation includes various agencies such as the Bangalore Metropolitan Region Development Authority (BMRDA) and the Bangalore Development Authority (BDA), which complicates oversight and accountability, resulting in inefficiencies in public service delivery. The BBMP's constrained political representation along with the one-year term of the Mayor and its omission of a local Ombudsman for the city's issues creates more problems for the effective planning and governance of the city. The region grapples with severe issues such as insufficient urban planners, poor staff filling rates, and low public involvement in management. This paper explores the existing governance structure of Bengaluru in terms of public service delivery, followed by the review of the Greater Bengaluru Governance Bill, 2024. The study evaluates the pros and cons of the Bill and suggests how the weaknesses can be minimized, and ends with possibilities on further understanding of urban governance.

Keywords
Metropolitan region, public service delivery, civic bodies, fragmentation, accountability, redefine, efficiency

1. Introduction

1.1. Background

The demand for efficient public service delivery has become more important than ever, given the dynamic urban environment. Also, the civic bodies face exponential pressure to adapt their functions and structures to support the growing population and expanding urban areas. This paper focuses on the Bengaluru Metropolitan Region (BMR), which exemplifies the challenges and opportunities associated with public service delivery systems. Due to the diversity and complexity of its socio-economic landscape, BMR serves as a perfect case study for rethinking the roles and jurisdictions of the institutions. The present-day governance structure of the BMR has a complex interaction of multiple civic agencies that result in overlapping jurisdictions and inefficiency. The city is mainly governed by the Bruhat Bengaluru Mahanagara Palike (BBMP), its municipal corporation. It takes care of urban planning and infrastructure development within the city limits but the jurisdiction is limited to the core urban areas, excluding surrounding municipalities. In collaboration with the BBMP are several smaller municipalities and local bodies, such as the Bengaluru Development Authority (BDA) and the Karnataka Urban Infrastructure Development and Finance Corporation (KUIDFC). Alongside these, there is an array of other agencies involved in multiple facets of urban development such as land planning, housing, and infrastructural projects. The Karnataka Government is also an essential partner with BMR, owing to the policies and urban development projects that they usually sponsor. A top-down approach is followed by them which in many cases does not address

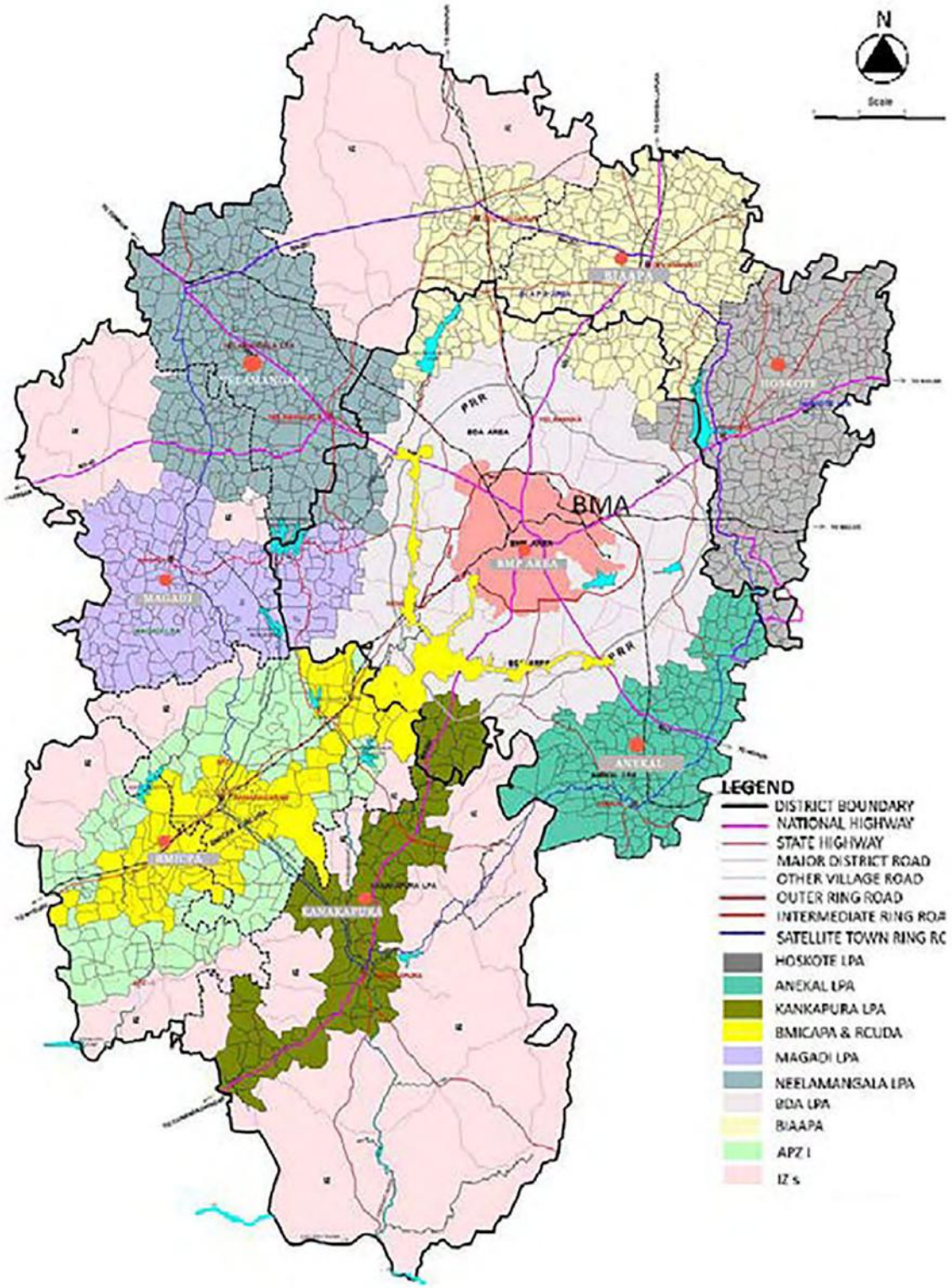


Figure 1 Bengaluru Metropolitan Region (Source: Revised Master Plan for Bengaluru - 2031(Draft): Volume-3)

the local needs of the people. The presence of multiple layers of governance, including state and local authorities, complicates accountability and citizen engagement. Over the years the emergence of numerous stakeholder agencies including private developers, NGOs, and citizen groups has added another perspective to the governance scene.

Figure 2 Planning Authorities in BMRDA (Source: Revised Master Plan for Bengaluru - 2031(Draft): Volume-3

Though they enhance service delivery through innovation and community participation their integration into the existing governance framework remains uncertain. The roles of these agencies need to be delineated and the coordination enhancement among the various agencies is important for improving the structure and function of these agencies. Alongside these, there is an array of other agencies involved in multiple facets of urban development such as land planning, housing, and infrastructural projects. The Karnataka Government is also an essential partner with BMR, owing to the policies and urban development projects that they usually sponsor. To address all the aforementioned problems, a legislative proposal - GBGB or The Greater Bengaluru Governance Bill - has been put forth. The goal of this research is to gather information about the City Bodies' current function in the BMR, resolve the issue of role duplication by providing examples and analyze the GBB 2024 for core concepts. Additionally, the strong points and flaws of the bill will be discussed. Therefore, this paper advocates that reconstructing the governance frameworks through a centralized and plan-oriented approach will better the structure of the public service delivery systems within the BMR and how GBGB is a constructive approach to the aforementioned.

2. Current Governance Structure

As discussed before the existing governance framework of the BMR is characterized by institutional overlap and fragmented responsibilities which often lead to inefficiency and service gaps. Some of the issues that highlight the limitations of current governance structures are traffic congestion, inadequate waste management, and insufficient access to public amenities. Consequently, rapid technological advancements, and increase in stakeholder participation initiatives call for a reassessment of how these civic agencies operate, collaborate and deliver services. BBMP being the parliament of Bengaluru has major discontent towards its bureaucracy as there are no citizens elected to serve as executives over the BBMP to provide representation or accountability. Additional activities such as urban planning, land use regulation and slum improvement are typically handled by the elected city government. The agenda for Bengaluru Infrastructure and Development Task Force has significant influence over city administration. There are no locally elected representatives for consultations in the panels of bodies like BESCOM or BWSSB. Additionally, there is a duplication of tasks among multiple organs. For example, the BBMP, the KSCB, and the BDA all share

responsibility for slum improvement, while the PWD constructs houses for economically weaker sections (EWS). Moreover, the maintenance of various roads and infrastructure projects is the responsibility of the BBMP, BDA, and PWD. The geographical areas that these organizations govern differ, and their sub-units do not align geographically. Due to their distinct jurisdictions, it is challenging to coordinate civic services. Urban residents are uncertain about the various civic agencies and their corresponding functions.

A few of the functional overlaps that are seen in the governance structure are discussed below. The Bengaluru Development Authority (BDA) is responsible for various urban development tasks. It implements land use zoning, regulates land use, and plans for urban areas, including identifying and providing sites for development. *(Mathew Prasad Idiculla MP, 2010)* This function is originally under the Bruhat Bengaluru Mahanagara Palike (BBMP) which is also partially carried out by BMRDA and ABIDe. The BMRDA is responsible for the urban planning and development activities of land in the larger BMR, which is a Municipal Corporation function currently fulfilled by BDA in the city limits. The Karnataka Urban Infrastructure Development and Finance Corporation financially support the urban institutional bodies in planning and developing infrastructure. Being a Municipal corporation function, similar tasks are also carried out by ABIDe. The Karnataka State Co-operative Bank (KSCB), Bangalore Development Authority (BDA), and Bruhat Bengaluru Mahanagara Palike (BBMP) are all responsible for the rehabilitation of designated slum areas. They oversee the development and upkeep of these areas. The Bangalore Water Supply and Sewerage Board (BWSSB) is tasked with the distribution of clean water, collection, and disposal of sewage, as well as treating wastewater to ensure a safe water source for the public. Certain functions, such as wastewater disposal, are also managed by the BBMP. BMTC oversees the bus-based public transportation system of the city. BESCOM manages the city's electricity distribution. Water supply, power, and transportation services are controlled by parastatals such as BWSSB, BESCOM, and BMTC rather than the city municipal corporation. *(Mathew Prasad Idiculla MP, 2010)*

3. Key Challenges in Public Service Delivery Systems

The primary difficulty facing civic agencies is the absence of locally elected representatives for consultations in their specific domains, as well as a lack of accountability to the BBMP or the populace. *(Janaagraha 2024)* They are only answerable to the state government, making it a complicated affair. According to the 12th Schedule of the Constitution, the functions executed by these civic bodies include urban planning, land use control, water supply management, and slum enhancement, among others, etc. are supposed to be performed by the elected urban local body. Additionally, the ABIDe Task Force, while not a statutory entity with operational authority, wields significant influence inside the municipal government. Bodies like BESCOM or BSSWB do not have any locally elected representatives for citizen interactions or consultations. Various agencies are tasked with analogous responsibilities; for instance, the BBMP, KSCB, and BDA are all engaged in slum enhancement, while the Public Works Department (PWD) constructs housing for economically weaker sections (EWS). (*Babu MD, 2016)* Similarly, the BBMP, BDA, and PWD are responsible for the maintenance of different roads and for different infrastructure projects.

However, the geographical extents which these bodies administer are different and the various sub-units of these bodies have also no geographical congruence. With each agency having a different jurisdiction, coordinating the different civic services is difficult. *(Idiculla M 2015)* The duplication in terms of functional structure and services handled leads to a wastage of resources. This also leads to inconsistent quality of service due to the multiplicity of agencies, consequently leading to a lack of accountability. The urban area of Bengaluru has a lot of ongoing projects in various sectors whose implementation is hindered due to the disturbed coordination leading to roadblocks in these projects that require cross-sectoral collaboration and communication. Continuous issues about service delivery have eventually lead to citizen apathy and distrust leading to reduced civic engagement and a lack of trust in public institutions. (*Janaagraha 2024)* The culmination of these factors results in urban residents being uncertain about the civic agency accountable for different services. Therefore, to achieve effective governance, it is imperative to

delineate the administrative scope and responsibilities of these agencies. However, for such reforms to be implemented, citizens must comprehend the operational framework of each civic agency to engage with them effectively. *(Janaagraha 2024)*

4. The Greater Bangalore Governance Bill, 2024

As a solution to the significant challenges in public services delivery that the urban area is facing the Greater Bengaluru Governance Bill, 2024 has been introduced. It marks a remarkable attempt to remodel the administrative framework of the BMR, addressing the long-standing issues of fragmented governance and inadequate service delivery in the city. Of the many things addressed in the bill, the most important that are relevant to this paper has been discussed below.

4.1 Decentralization and Participatory Governance

The new bill is motivated by the fragmentation of power and the construct of multi-tiered governance. It suggests the formation of not more than ten City Corporations in the Greater Bengaluru Area, each in charge of designated territories. The shift from the existing unitary authority of the Bruhat Bengaluru Mahanagara Palike is intended to make the governance of the people more efficient by allowing for better decision-making at a lower level. Moreover, the bill acts to enhance the role of ward committees as 'the building blocks' of urban governance. *(Source: Greater Bengaluru Governance Bill, 2024)*

4.2 Enhancing Responsibility in Governance

This plan establishes the Greater Bengaluru Authority (GBA) to oversee and govern the development of the Greater Bengaluru Area, considering the multitude of civic institutions and their interrelations in Bengaluru. The GBA's power of consolidating and simplifying the political accountability of varied public officials within the GB jurisdiction is a major advancement aimed at minimizing red tape and increasing ease of access. *(Source: Greater Bengaluru Governance Bill, 2024)*

4.3 The Greater Bengaluru Governance Bill, 2024 – Strengths and Weaknesses

Implementing the steps specified in the Greater Bengaluru Governance Bill can aid the Bengaluru Metropolitan Region in addressing its urban difficulties. The legislation envisions a decentralized three-tier governance framework and the creation of the Greater Bengaluru Authority. The structure provides for enhanced community participation and increased political accountability. There is a potential for better resource allocation if the plan is implemented efficiently and integrated planning is aimed at by the establishment of GBA. If attention is paid during execution and followed through with there is considerable potential to address many of the grievances that the Greater Bengaluru Authority has been facing while also improving the quality of life around the city. The bill on its own however fails to retain decentralized governance as it shifts its focus on a participatory approach alongside accountability. However, the success depends on addressing concerns regarding the delineation of responsibilities, ensuring the autonomy of the GBA, empowering Ward Committees, and incorporating robust safeguards for land acquisition and heritage conservation. A comprehensive and inclusive approach, incorporating stakeholder feedback and addressing potential challenges, will be crucial in translating the Bill's vision into a reality that benefits the citizens of Bengaluru.

Even though drafted with the best interests in mind and the effort laudable, there are both strengths and weaknesses which require attention. Firstly, the favourable result of the proposed decentralized structure hinges on the clear demarcation of responsibilities and revenue sharing mechanisms between the GBA, city corporations and ward committees. While the approach does seem appealing, by not implementing a

framework, there exists the risk of breaching the divide of conflict of interest and jurisdiction overlap. Furthermore, the bill lacks stipulations revolving around the formation and election of the Greater Bengaluru Authority which could result in a politicized outcome. Ensuring that GBA's autonomy and impartiality through a transparent and inclusive selection process is crucial for its effectiveness. Thirdly, empowering the ward committees before addressing the issues of capacity and financial autonomy might limit their ability to function effectively. The provision of adequate training, resources, and decision-making power to these committees for their meaningful participation in local governance. There is a lack of political representation as the Mayor has not been re-elected in the last 9 years. One of the major concerns with respect to fragmentation is the economic inequalities due to divisions into smaller corporations. From times immemorial the most difficult thing about a bill, that is meant to create a revolutionary impact, is the efficient implementation of the same. *(Janaagraha 2024)*

5. Proposals

5.1 Potential proposals to overcome weaknesses of the GBGB, 2024

Based on expert opinions the weaknesses of Greater Bangalore Governance Bill, 2024 have been discussed above. Therefore, potential tools/ideas that can address the shortcomings of the bill are discussed below. The first of such recommendations is the improvement of political representation because it will also enhance democracy and the voice of the people in the relevant process. Second, the terms of governance should be clearly specified as this will avoid conflicts of interest and indicate to the users what organization is responsible for the service. Third, measures for ensuring accountability should be recommended to enhance public confidence to ensure that civil society organizations are held accountable. Given the wide disparity, it is important to address economic inequality. To promote balanced growth across the metropolitan region there should be policies targeted to help mitigate disparities between the wealthier and underdeveloped areas. Since the stakeholders are the direct beneficiaries or loss bearers engaging them can lead to more informed decision-making and foster a sense of ownership among citizens regarding the governance structure. Ultimately, to evaluate the functionality and effectiveness of these measures, it is necessary to proceed with the implementation of pilot programs. Pilot programs help in mitigating any risks that may arise due to the incorporation of new and untested ideas at a large scale by allowing the solution to be adjusted based on real world experience.

5.2 Proposals to redefine hierarchy of jurisdictions

Redefining the jurisdictions and roles of a Metropolitan Region is a complex task, but useful in the disaggregation of the jurisdiction and functional domain of a Metropolitan Region, however, it is a prerequisite for Bangalore being more efficient and more transparent. It is paramount to first target metropolitan region agencies with overlapping functions, given the large number of these institutions and then amalgamate them, to limit the amount of confusion and improve the delivery of services. There shouldn't be a great deal of ambiguity and ambiguity in undertaking the functions of each agency *(Weerakkody et al., 2021)* It helps people understand the institutions and their roles. The Bruhat Bengaluru Mahanagara Palike should be empowered as the primary civic body, with greater autonomy and resources. *(Are citizens in Bangalore giving up because of poor governance? _IDR, 2023)* As a result, there is increased decentralization and subsequent responsibility for decision making. Allocate distinct tasks for service provision to the ward committees and enable citizen engagement and service provision responsiveness. (Legislature committee bats for a bigger role for MLAs in city administration, 2018). There is no doubt that in this time of technological innovations we must develop online tools that will be easy to use and give up to date information about budgets, projects and indicators of services. *(Mishra & Das, 2022)* It empowering citizens and encouraging them to ensure they obtain progress within their respective aims and hold the relevant agencies responsible. Strong and adequate systems need to be set up that enable citizens to file complaints and then track how the complaints are dealt with. *(Pareek & Sole, 2020)* Speed and clarity are of essence here. As already discussed Involve citizens in the planning and budgeting processes through consultations, surveys, and public forums. *(When Public Affairs Centre invited me to write a memorial for Dr.*

Samuel Paul, I took the…, 2019) This ensures that services align with actual needs and priorities. A strong partner with NGOs and resident welfare associations will use their local context knowledge and networks to achieve efficacy in the means of providing the services *(Chandran & Narayanan, 2016).* Additionally, rebuilding the capacity is tremendously essential, hence, investing in training for civic officials in order to build their technical and managerial skills better is paramount, Lastly, implementation of systems that reward efficiency and innovation in service delivery, motivates agencies to continuously improve.

6. Way Forward

The post-implementation of proposals/projects and the regular feedback analysis is the most crucial step which is not followed effectively, that leads to the failure of a project in most cases. The way forward in this research mainly outlines this crucial assessment. Firstly, it is critical to evaluate how the decentralization of governance into multiple municipal corporations affects service delivery efficiency and responsiveness. The focus area for the same should be the measurement of changes in citizen satisfaction, service response times, and resource allocation before and after the bill's implementation. The next stage is to analyze the level of inter-agency integration of the Greater Bangalore Authority GBA and the effect of such integration on the coordination of the service delivery. In the course of this event, the focus should also be taken on inter-agency interaction evaluation, service provision efficiency, and minimization of institutional delays. Finally, the effectiveness of the ward committees and citizen engagement initiatives in improving public service delivery has to be assessed. Analyzing the levels of citizen participation, the effectiveness of the feedback mechanisms, and how these two factors influence decision-making processes at the local level, is the focus area.

7. Conclusion

The study has delved into detail about the existing urban level governance structure and their functioning system in the Bengaluru Metropolitan Region. The existing structure and the key challenges of this structure have been discussed in detail. As a solution to this the Greater Bengaluru Governance Bill, 2024 was introduced. The core ideas of the bill as well its strengths and weaknesses have been discussed in this paper. Proposals that can overcome the weaknesses and those that can direct the redefinition of the hierarchy of urban institutions have been discussed. The paper concludes with the way forward i.e., the measures to be followed to pursue efficient public service delivery and stakeholder participation for the phase of hypothetical implementation of these proposals. This piece of literature will help researchers, scholars, etc. understand in detail the background, the present situation, the government solutions, and potential ways to move forward and work in the area of studying public service systems of the Bengaluru Metropolitan Region.

8. References

Babu MD (2016) Urban Governance and Planning: A Study of Selected Urban Local Governments in Karnataka. 2016th ed. In: *Urban Governance in Karnataka and Bengaluru: Global Changes and Local Impacts*, essay, Cambridge Scholars Publishing, pp. 46–62. Available from: https://www.researchgate.net/publication/312197082_Urban_Governance_in_Karnataka_and_Bengaluru_Global_Changes_and_Local_Impacts-4438-0125-6-sample.pdf (accessed 20 September 2024).

BASU, A.M., 2016. PUBLIC PARTICIPATION, URBAN GOVERNANCE AND PLANNING: PERSPECTIVES AND CONCERNS ANURIMA MUKHERJEE BASU. *Public participation in planning in India*, p.41.

Benjamin, S., 2010. The aesthetics of 'the ground up 'city: Some insights from Bangalore. In *Seminar* (Vol. 612, pp. 33-38). Malvika Singh.

Chandran, P. and Narayanan, S., 2016. A working observation on the dry waste collection centers in Bangalore. *Procedia Environmental Sciences*, *35*, pp.65-76.

Chattopadhyay, S., 2015. Contesting inclusiveness: Policies, politics and processes of participatory urban governance in Indian cities. *Progress in Development Studies*, *15*(1), pp.22-36.

Devas, N., 2001. Does city governance matter for the urban poor? *International Planning Studies*, *6*(4), pp.393-408.

Greater Bengaluru Governance Bill 2024 (2024) *OpenCity*. Available at: https://data.opencity.in/ (Accessed: 15 September 2024).

Harikrishnan, K. and Mahendra, B. (2020) 'Urban Governance and the Master Plan for Bangalore City,' in *Routledge eBooks*, pp. 48–74. https://doi.org/10.4324/9780367817930-4.

Idiculla M (2015) The Powerlessness of City Governments and the Transformation of Governance in Bangalore.

Janaagraha (2024) The Greater Bengaluru Governance Bill, 2024 - Hits and Misses. *Janaagraha*, NGO. Available from: https://www.janaagraha.org/ (accessed 10 September 2024).

Janaagraha (2024a) A Critical Review of Decentralized Participatory Governance in Cities of Karnataka. Bengaluru. *Janaagraha*. Available from: https://www.janaagraha.org/ (accessed 20 September 2024).

Kumar, S.K., 2007. *Greater Bangalore Governance Options*. Public Affairs Centre.

K V Aditya Bharadwaj (2018) https://www.thehindu.com.

Mathew Prasad Idiculla MP (2010) A guide to Bangalore's civic agencies.

N. Sivanna and Suresh L (2016) Urban Governance and Organizational Restructuring: The Case of Bruhat Bangalore Mahanagara Palike (BBMP). 2016th ed. In: *Urban Governance in Karnataka and Bengaluru: Global Changes and Local Impacts*, essay, Cambridge Scholars Publishing, pp. 190–207. Available from: https://www.researchgate.net/publication/312197082_Urban_Governance_in_Karnataka_and_Bengaluru_

Global_Changes_and_Local_Impacts (accessed August 2024).

Naik, G. *et al.* (2010) 'Public Value Creation through Private Partnership: Lessons from Public Service Delivery in Karnataka, India,' *SSRN Electronic Journal* [Preprint]. https://doi.org/10.2139/ssrn.2124372.

Paul S (2016) Making Voice Work: The Report Card on Bangalore's Public Services.

Pareek U and Sole NA (n.d.) Quality of Public Services in the Era of Guaranteed Public Service Delivery.

R. K. Das and H. Misra, "Smart city and E-Governance: Exploring the connect in the context of local development in India," *2017 Fourth International Conference on eDemocracy & eGovernment (ICEDEG)*, Quito, Ecuador, 2017, pp. 232-233, doi: 10.1109/ICEDEG.2017.7962540.

Savage, D. and Dasgupta, S., 2006. Governance framework for delivery of urban services. *India Infrastructure Report*, *2006*, pp.42-58.

SciSpace Copilot (2015,2022), response to researcher Meenu Nair. (AI-powered research platform to find comprehensive literature for review with top impact papers. (Finding relevant studies and synthesizing insights from multiple sources)

Sridhar KS (2016) Bangalore's Restructuring: For Better or For Worse. 2016th ed. In: *Urban Governance in Karnataka and Bengaluru: Global Changes and Local Impacts*, essay, Cambridge Scholars Publishing, pp. 208–224. Available from: https://www.researchgate.net/publication/312197082_Urban_Governance_in_Karnataka_and_Bengaluru_Global_Changes_and_Local_Impacts-4438-0125-6-sample.pdf (accessed August 2024).

Stren, R.E., 2007. Urban governance in developing countries: Experiences and challenges. In *Governing cities in a global era: Urban innovation, competition, and democratic reform* (pp. 57-69). New York: Palgrave Macmillan US.

Sudhira, H.S., Ramachandra, T.V. and Subrahmanya, M.H.B. (2007) 'Bangalore,' *Cities*, 24(5), pp. 379–390. https://doi.org/10.1016/j.cities.2007.04.003.

Vanka, S.P., 2014. *Public Space and Life in an Indian City: The Politics of Space in Bangalore* (Doctoral dissertation).

Weerakkody V, El-Haddadeh R and Al-Shafi SH (2011) Exploring the complexities of e-government implementation and diffusion in a developing country: Some lessons from the State of Qatar.

Case Study Report

The people without power: Exploring the governance within informal settlements of Surat city, India

Nitesh SHUKLA, Indian Institute of Technology Kharagpur, India
Arup DAS, Indian Institute of Technology Kharagpur, India
Tarak Nath MAZUMDER, Indian Institute of Technology Kharagpur, India

Abstract

Urban resilience discourse emphasizes the need for multi-stakeholder collaboration, including the state and citizens, formal and informal processes, and top-down and bottom-up efforts during disaster. Effective collaboration requires pre-disaster engagement through participatory governance and collective decision-making. A proactive, inclusive and equitable decision-making process is the core agenda of sustainable urban governance. The dynamics of urban governance dictates the decisions and actions of city administrations, thereby shaping the trajectory of development. Informal dwellers face reduced impact over administrative decisions, with state interventions often marginalizing them, increasing their vulnerability to livelihood insecurities, limited access to education and healthcare, and increased risk of disaster. This study aims to explore the duality of formal-informal governance processes within informal settlements of Surat city, India pre- and post- hazard conditions. Using Surat city, India, as a case study, it explores urban governance patterns within informal settlements, aiming to provide insights for inclusive and sustainable urban governance in the Global South.

Keywords

Urban governance, informal settlements, Inclusive and sustainable governance, Urban resilience, Global South

1. Introduction

The world is witnessing a rapid urban expansion mostly centred in the cities of the Global South. The demographic transition of the late 20th and early 21st centuries has moved the locus of urban growth from the Global North to the Global South (Parnell & Robinson, 2013; WRI, 2021). The whole spectrum of changes triggering and facilitating this rapid urbanization in the Global South is worth mentioning. The industrial and infrastructural development in the post-colonial Global South provided a momentum to the urbanization initially. Later, the liberalization and globalization of the economies across the developing world initiated multiple changes in industrialization and manufacturing patterns around globe. The global market's expansion led to a rise and expansion of the global competitive manufacturing, resulting in the growth of small-scale industries and workshops, particularly in developing countries like China, India, Indonesia, and Philippines due to supply of the 'cheap labour'. The rapid demand for low-cost housing for

this cheap labour and the state's failure to tackle the whole situation were among the primary reasons giving rise to informal settlements among these countries (Bhan, 2013). Nearly one billion urban dwellers are living within informal settlements without access to basic and emergency infrastructure (UN-Habitat, 2020).

However, the World Social Report 2020 by UN-DESA highlights that urbanization in the Global South expands opportunities on one hand while exacerbating the economic, spatial and social disparities on the other (UNDESA, 2018). The aspect of climate change is adding complexity within the particular context of urbanization in the GS (Shukla, et al., 2023). According to a report by World Bank, 77 million urban dwellers may be pushed below poverty line due to climate change (World Bank, 2015). The Intergovernmental Panel on Climate Change (IPCC) reported that melting glaciers and thawing permafrost will most severely impact populations in cities across the Global South (Sullivan, 2022). Nations such as India, Bangladesh, and Indonesia are facing heightened flood risks amid the growing challenges of climate change (Bera, et al., 2022).

Complex Adaptive Systems (CASs) thinking has proved to be an effective approach to visualize and analyse cities. It provides a holistic understanding of its underlying structures, identify stakeholders, processes, issues, and relationships of the urban system (McGee & Edson, 2014). Governance is simultaneously the cause and the outcome of these processes in SESs (May, 2022). Multiple studies have approached urban governance with CASs thinking considering cities as Socio-Ecological Systems (SESs). Governance refers to the institutions, organizations, communities, and individuals involved in and affected by practices including planning, research, design, management, construction, restoration, and conservation (May, 2022). CASs thinking is helpful in analysing the multi-stakeholders and multilevel governance frameworks, involving different institutions, associations, and individuals (Xiang, 2021).

Urban governance plays a vital role in shaping city's trajectory of development. Cities in the Global South are shaped by formal and informal processes acting simultaneously within urban space. Informal settlements, lacking the land tenure, regulatory and legal status, are reduced to lower position and influence within the hierarchy of governance framework. This issue impacts their claim on state's responsibilities including state's obligation to provide basic and emergency infrastructure and services to its citizens. The governance framework is structured and evolved in such a way that informal settlers are at the most vulnerable end exposed to the worst impacts of climate change (Anguelovski, et al., 2016; WIlllams, et al., 2019). As UN-Habitat underscores, urban governance systems in these cities are unfit for purpose and need critical reforms for an inclusive and sustainable urban development (UN-Habitat, 2021).

The above situation leads to emergence of various survival mechanisms within informal settlements during normal time as well as during emergence situations. The citizens deprived of access to formal means of governance self-organize, develop mechanism, and adapt to bridge the gap between the level of services required for survival and actual level of services. These bottom-up efforts and responses along with top-down interventions parallelly exist and interact within the urban space. How different actors and processes shape the governance and development in the informal settlements is a crucial inquiry to understand the formal-informal duality within the cities of the GS. This study aims to explore the governance within the flood affected informal settlements of Surat city, India.

2. Materials and Methods

The study does a cross-sectional analysis of the formal and informal entities and processes shaping the governance of the cities in the Global South.

The study employs Complex Adaptive Systems (CASs) thinking as the main approach to view and analyse urban system. CASs thinking views urban systems as dynamic, interconnected, and continuously evolving system. It involves interaction of different elements such as individuals, communities, government, public and private, space, infrastructure, technology, nature etc. CASs are open systems, continuously interacting with environment which permits feedback in the form of energy, material, or information. They have the capacity to self-organise and change under influence of such feedbacks or memory (learn from experiences) and thus evolve through adaptation. Fig. 2 shows the three vital characteristics of CASs and the conceptual framework of the study.

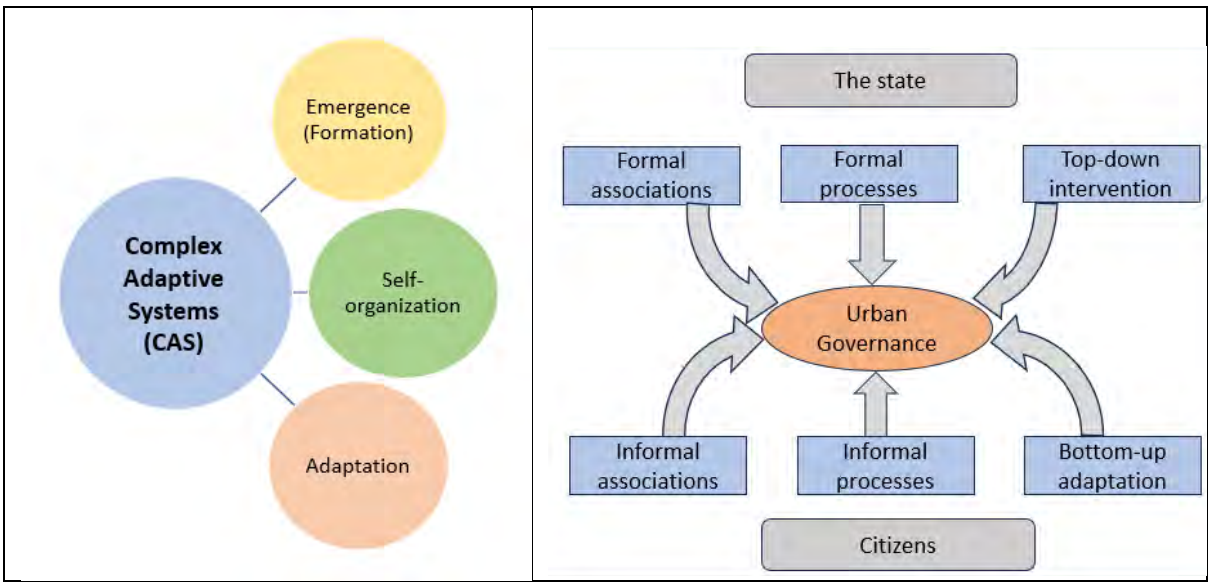


Figure 1: The framework of the study

Within the complex system of informal settlements, various informal associations and processes emerge and interact alongside their formal counterparts. The study explores the patterns of these associations, processes and their adaptive interventions within urban system. It includes investigation of three queries given as,

(i) The pattern of associations formed

(ii) The patterns of pre- and post-hazard process and activities

(iii) The pattern of informal adaptive response mechanism within urban space

For this purpose, a primary survey was conducted among flood affected wards of Surat city, India. The survey covered five flood affected wards of Surat city to collect quantitative and photographic data. Total 118 responses of individuals, shop owners, society representatives, community leaders/members were collected (Adajan-13, Rander-27, Umara-8, Limbayat-37, Parvat-33). Photographs were taken for the adaptive mechanisms at top-down as well as bottom-up levels. The data was analysed to infer insights of emerging governance within informal settlements shaping the urban space and activities through adaptive actions.

3. Urban Governance in the Global South

According to UN Habitat, governance refers to the structures and processes established to ensure accountability, transparency, responsiveness, adherence to the rule of law, stability, equity, inclusiveness, empowerment, and wide-ranging participation. It also represents the norms, values, and guiding principles

by which public affairs are managed. Urban governance is collective representation of the many ways in which individuals and institutions, public or private, plan and manage the common affairs of the city in a continuing process such that conflicting or diverse interests may be accommodated, and cooperative action can be taken (UN-Habitat, 2021). Urban politics and governance structures influence the character, form, and function of cities, shaping the planning strategies aimed at promoting justice, equity, and sustainability. The SDGs 11, 16, and 17 align themselves towards participatory governance.

Governance in the cities of the GS is simultaneously the cause and the outcome of the specific urbanization patterns of these cities. Urbanization in the GS is characterised by intermeshed formal and informal processes, conflicting public and private entities, and top-down and bottom-up interventions. One of the factors influencing and transforming urban governance in the Global South in the age of neo-liberalization and globalization, is the endeavour of cities to compete for Global capital (Korah, 2020). Informal labour market facilitates the harvest of the cheap labour but on the other hand leads to rise of informal settlements. Two of the interrelated problems associated with governance in informal settlements which exacerbate their vulnerability are:

A. Land tenure: Mostly these informal settlers are not the legal owners of the land (Fig. 3). It creates a bilateral impact. It reduces their status and influence in overall governance hierarchy (Alzamil, 2018). On the other hand, it creates a policy and regulatory hurdle for local administration to not provide basic services to these settlements to stop further growth of informal settlements. Fig.3 shows the land ownership scenario of informal slums in Surat.

B. Provision of basic infrastructure: As UN Habitat recognize it, the poor governance frameworks within the GS lead to poor service delivery, which results in citizens turning to costly, unsafe informal alternatives (UN-Habitat, 2021). The provision of partial services such as water supply, drainage at later stages is outcome of negotiations of local community or their leaders with the formal administration. The high density also restricts the provision of these services at later stage.

C. Informal labour policies

The informal labour practices are widely popular in the GS, especially within South Asian countries. It constitutes around 85% of the total workforce in Indian cities (Desai, 2020). Informal labour can either be working in totally informal economy or in formal sector with informal work status. In both cases they are underpaid and cannot afford formal means of survival. These informal labours, mostly migrants, form the major proportion of informal settlements.

4. Case Study: Surat City

Surat city is located in the state of Gujarat on the Western Ghats of India, known as the hub of textile and diamond cutting and polishing. The city lies between latitudes 21˚03 N to 21˚18 N and longitudes 72˚42 E to 72˚55 E. It is one of the fastest growing cities in the world with population 4.46 million as per Census 2011. The current population estimate is 6.94 million spread within the total area of 326.515 km2. Surat faces threefold threat from river Tapi flowing through the city, extreme precipitation, and coastal or creek flood. The major floods occurred in the year 1968, 1994, 1998, 2006, and 2013 (Bhat, et al., 2013). The 2006 flood was the most disastrous with more than 95% city's area submerged under water, over 15 lakh people affected and more than 150 people died (Joshi, et al., 2012). The low-lying areas of the city are flooded almost every year due to extreme rainfall or creek flood.

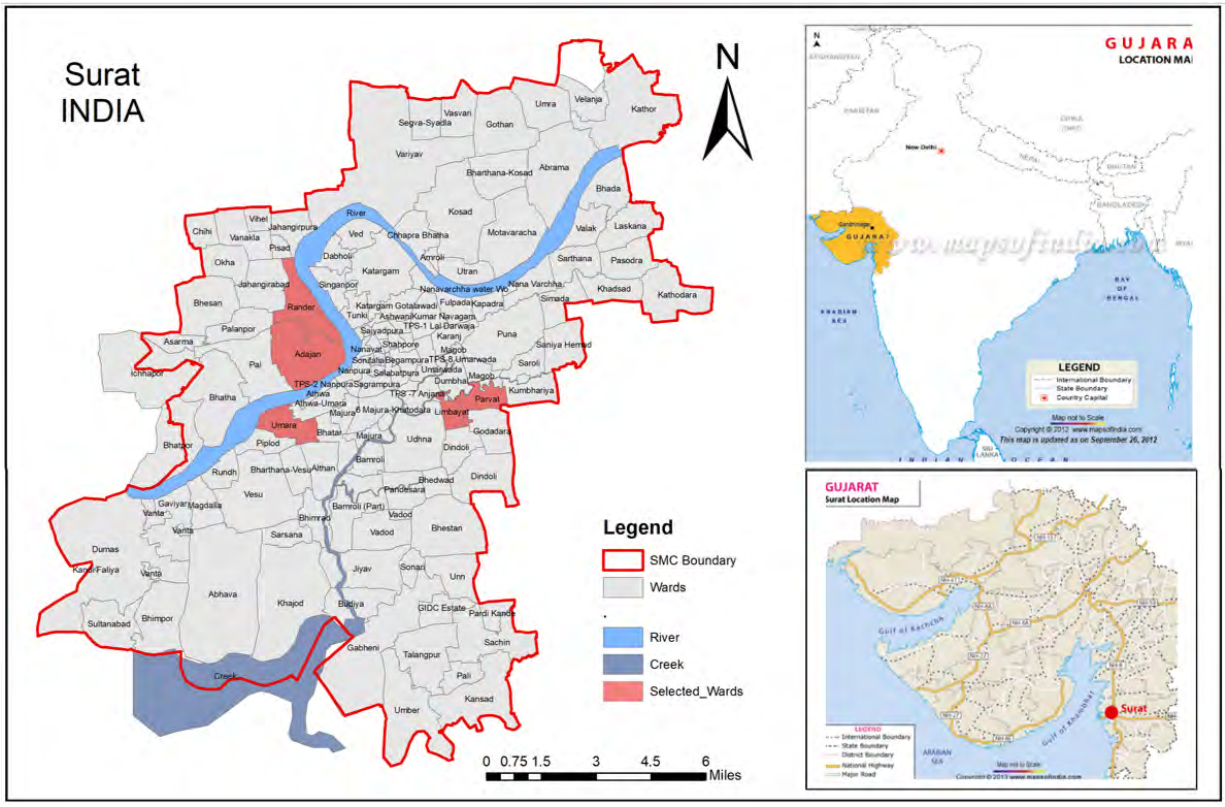


Figure 2: The selected wards on Surat city map (Source: www.mapsofindia.com and (Shukla, et al., 2025))

The primary survey and photographic data were collected in five flood affected wards of Surat city namely Rander, Adajan, Umara, Limbayat, and Parvat. The first three wards are on the banks of river Tapi, while Limbayat and Parvat wards lie on the banks of the Parvat-Dumbhal creek.

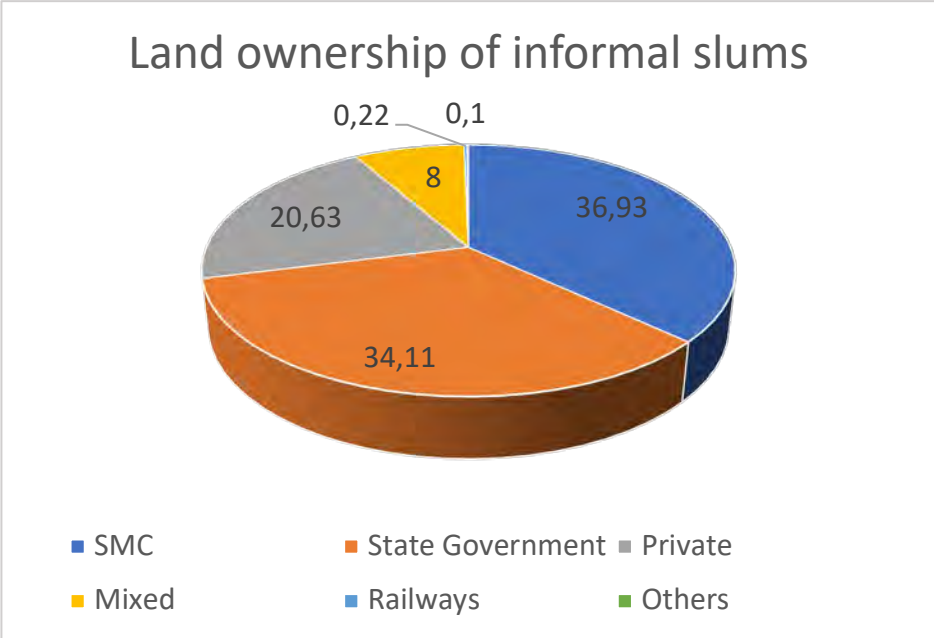


Figure 3: Land ownership pattern of informal settlements in Surat city

The survey was conducted within flood affected informal areas of these five wards. The respondents include individual households, shop owners, community group or society representatives, institute representatives. The questions related to (i) their association to any formal/informal group, (ii) access to formal/informal basic and emergency services such as waste management, bank debt, disaster rescue, shelter and (iii) adaptive response taken by them against flood were asked in the survey and photographs were collected for the adaptive responses. Total 118 responses were collected from Adajan (13), Rander (27), Umara (8), Limbayat (37), Parvat (33).

5. Results and Discussion

5.1. Formal and informal entities

State itself is fundamentally a formal organization, an organized concentration of power and resources (Acemoglu, et al., 2020). The formal entities are the channels through which state collect resources, delivers services, enforces rule of law and takes validation.

Within informal settlements local administration, political representatives and state administration are entities to practice formal governance. The inadequacy and inefficiency of administration lead to the necessity of informal entities to survive and grow. These Informal entities include religious groups, profession-based unions, community organizations, and social groups. They are not necessarily formed as a governance entity but they generally evolve to accommodate such functions. The observations of citizens' associations in formal/informal entities are presented in the following chart in Fig. 4. It shows that 32% of the respondents are associated to some formal or informal group.

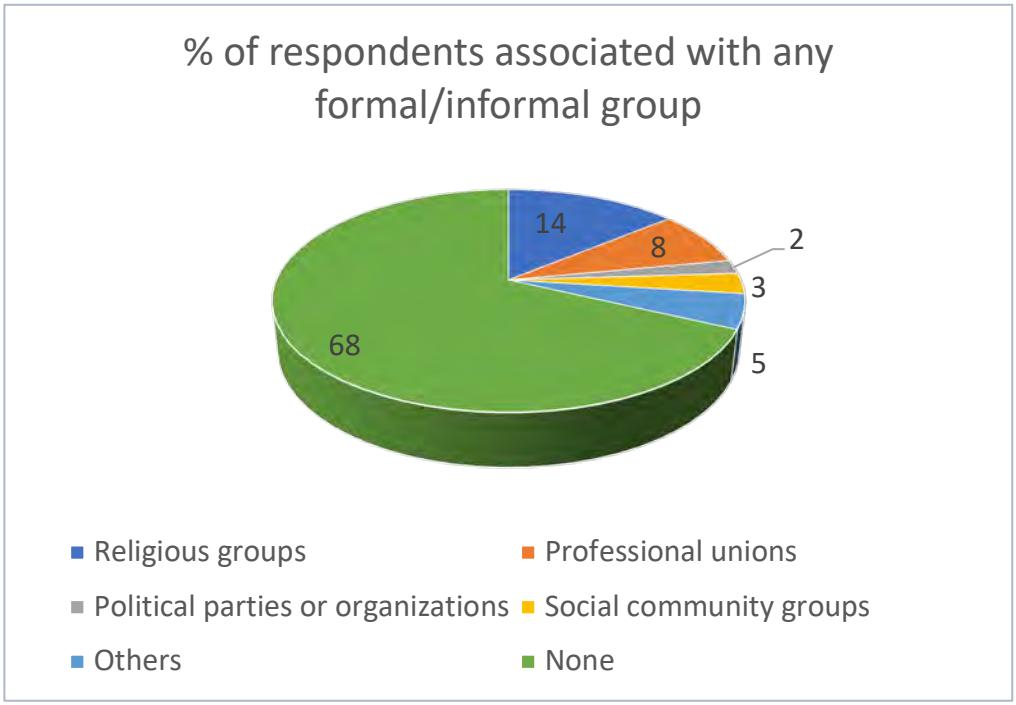


Figure 4: The pattern of formal/informal associations

5.2. Formal and informal processes

Formal process of governance includes regulatory processes and infrastructure development and management. Informal settlements are not created with regulatory process but they are maintained and

controlled by regulatory process. The land tenure and unregulated status not only affect the development permissions within informal settlements but also the right and access to basic infrastructure, formal banking, and formal decision making. The problem of regulation overall reduces the identity of the citizen having low participation and influence over urban governance.

The informal processes are outcome of the above gap. They are need based and generally involve individuals, private enterprises, NGOs and community groups. The observed process includes informal water supply, informal sewage discharge, informal waste picking and disposal, informal credit and saving mechanisms. During flood hazard, apart from formal disaster response, informal rescue, shelter and relief also co-function.

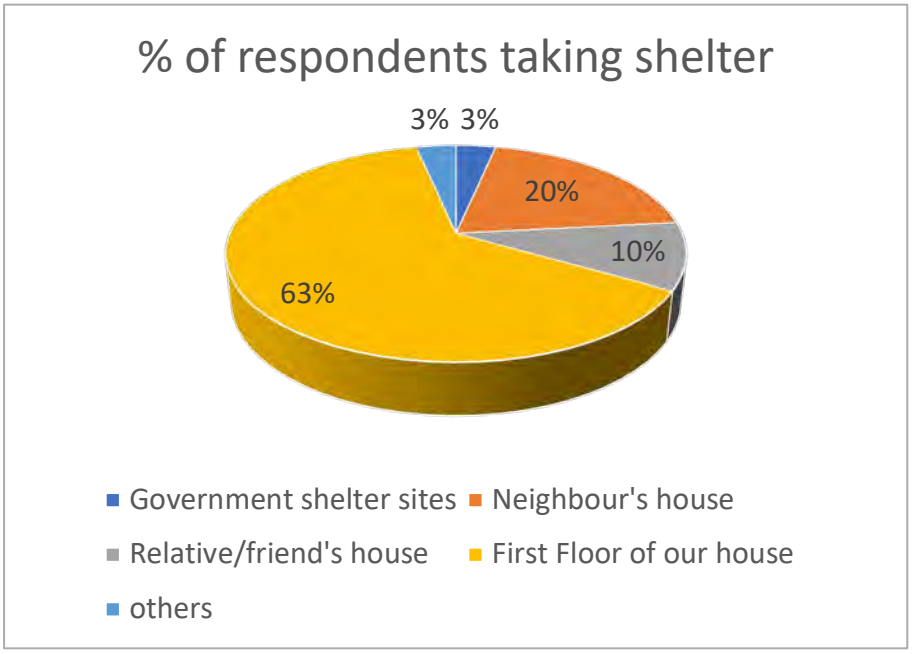


Figure 5: The pattern of taking shelter after flood hazard

The chart shows that taking informal shelter at neighbours, friends or relatives' houses is dominant behaviour with only 3% respondents taking shelter at government sites. Similar trend is observed in the access to credit mechanism, where only 13% respondents have access to formal banking for debt. Rest of the respondents took it from informal alternatives at significantly higher interest rates.

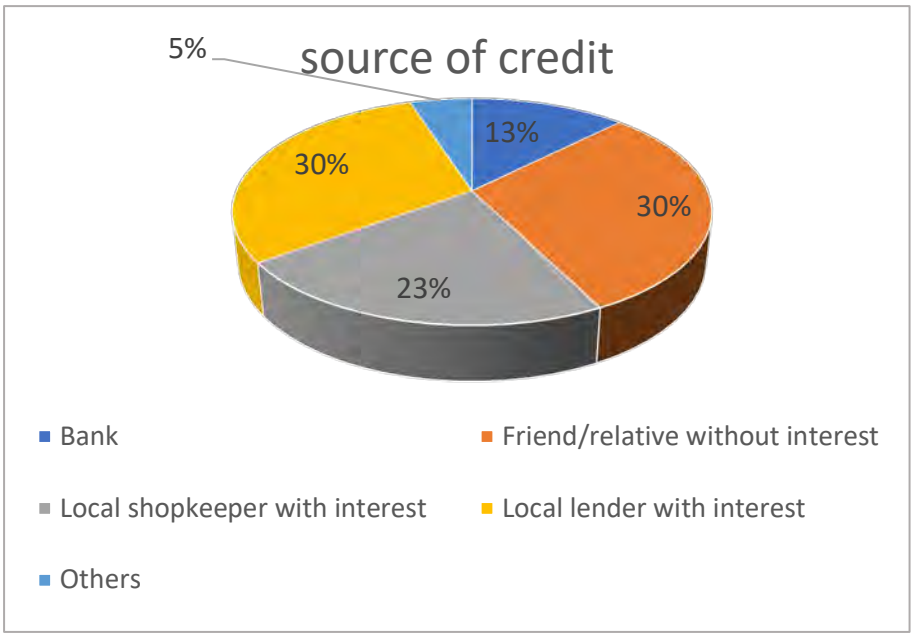


Figure 6: Access to source of credit

5.3. Top-down and bottom-up interventions

Top-down interventions are characterised by planned, long term, and informed actions. It includes road upgradation, sewage provision, SWD, slum upgradation, and development of protective measures against hazards. Conversely, bottom-up interventions within informal settlements are generally short term, need based make shift arrangements. The observed adaptive responses include individual adaptation in the private space, collective adaptation in the public space, and adaptations by institutes/private enterprises. The survey captures how bottom-up interventions are taken up by majority of flood affected communities.

Figure 7: Top-down adaptive intervention

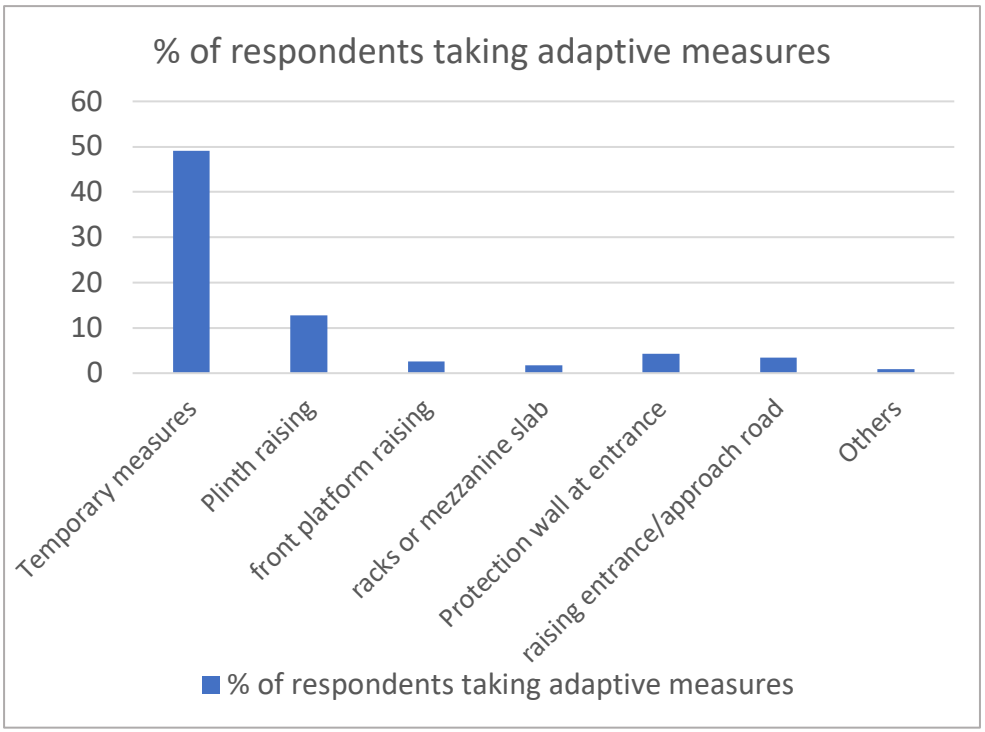


Figure 8: The pattern of bottom-up adaptive response

Bottom-up interventions are taken up by majority of flood affected communities with raising plinth level (12.7%) as the most popular adaptive response. These top-down and bottom-up adaptive actions create broader impacts. For example, raising plinth level creates pressure on other households to adapt. Similarly, the rising road level may increase the vulnerability of few households with lower plinth hight than the road.

Figure 9: Raising entrance or plinth level as an adaptive response against flood

Figure 10: Conflict of adaptive actions

Figure 11: Conflict of adaptive responses

6. Inferences

The study provides a cross-sectional view of how multiple formal/informal associations, processes, and interventions act within the informal urban space and shape the functioning and trajectory of urban development. Withing informal urban space both formal and informal entities interplay during normal times and in emergency situations. Informal entities and processes emerge out of the particular context of problems of land tenure, regulation, lack of infrastructure, waste management and access to formal banking. These informal process parallelly work along with the formal processes to provide shelter, relief, and financial support after a flood hazard.

The observations show that informal associations, mechanisms and processes dominate within informal areas. While 32% of the respondents are associated to some formal/informal entity, religious groups and informal profession-based organizations are the most popular forms of associations. People more rely on informal shelter during flood and informal credit sources for taking debt.

Bottom-up adaptive response against flood alters the physical form of the urban space. Raising plinth, or entrance or porch area is most popular adaptive response taken in the built form. In few cases, government intervention increases the vulnerability of individual households such as the case of raising road height, or road level increasing over repetitive constructions. In other instances, bottom-up intervention such as raising plinth hight creates pressure on other households to adapt.

The study recognizes the importance of informal associations, processes and adaptive responses in shaping and altering urban space. The endeavour of enhancing resilience and achieving sustainable governance in the GS may benefit from these aspects.

7. References

Acemoglu, D., Robinson, J. A. & Torvik, R., 2020. The political agenda effect and state centralization. *Journal of Comparative Economics,* 48(4), pp. 749-778. https://doi.org/10.1016/j.jce.2020.03.004.

Alzamil, W., 2018. Evaluating Urban Status of Informal Settlements in Indonesia: A Comparative Analysis of Three Case Studies in North Jakarta. *Journal of Sustainable Development,* 11(4), p. 148. https://doi.org/10.5539/jsd.v11n4p148.

Anguelovski, I. et al., 2016. Equity Impacts of Urban Land Use Planning for Climate Adaptation: Critical Perspectives from the Global North and South. *Journal of Planning Education and Research,* 36(3), pp. 333 –348, DOI: 10.1177/0739456X16645166.

Bera, S., Das, A. & Mazumder, T., 2022. Evaluation of machine learning, information theory and multi-criteria decision analysis methods for flood susceptibility mapping under varying spatial scale of analyses. *Remote Sensing Applications: Society and Environment,* Volume 25, pp. 100686, https://doi.org/10.1016/j.rsase.2021.100686.

Bhan, G., 2013. Planned Illegalities: Housing and the 'Failure' of Planning in Delhi: 1947-2010. *Economic & Political Weekly,* 158(24).

Bhat, G. K., KARANTH, A., DASHORA, L. & RAJASEKAR, U., 2013. Addressing flooding in the city of Surat beyond its boundaries. *Environment & Urbanization,* 25(2), p. 429–441. DOI: 10.1177/0956247813495002.

Desai, K., 2020. Exploitation and Liberation: Case Study of Women Workers in Surat's Unorganised Sector. *Social Change,* 50(1), p. https://doi.org/10.1177/0049085719901051.

Joshi, P. M., Sherasia, N. K. & Patel, D. P., 2012. Urban Flood Mapping by Geospatial Technique A Case Study of Surat City. *IOSR Journal of Engineering (IOSRJEN),* 2(6), pp. 43-51. DOI: 10.9790/3021-02634351.

Korah, P. I., 2020. Exploring the emergence and governance of new cities in Accra, Ghana. *Cities,* 99(April), p. 102639. https://doi.org/10.1016/j.cities.2020.102639.

May, C. K., 2022. Complex adaptive governance systems: a framework to understand instututions, organizarions, and people in socio-ecological systems. *Socio-Ecological Practice Research,* Volume 4, pp. 39-54. http://doi.org/10.1007/s42532-021-00101-7.

McGee, S. & Edson, R., 2014. Challanges of governance in Complex Adaptive Systems: A case study of U.S. public education. *Procedia Computer Science,* 36(2014), pp. 131-139. http://doi.org/10.1016/j.procs.2014.09.049.

Parnell, S. & Robinson, J., 2013. (Re)theorizing Cities from the Global South: Looking Beyond Neoliberalism. *Urban Geography,* 33(4), pp. 593-617. https://doi.org/10.2747/0272-3638.33.4.593.

Shukla, N., Das, A. & Mazumder, T., 2023. Assessment of urban form resilience: a review of literature in the context of the Global South. *Environment Development and Sustainability,* pp. https://doi.org/10.1007/s10668-023-04058-3.

Shukla, N., Das, A. & Mazumder, T. N., 2025. Decoding Urban Form Resilience and Adaptation in Flood Prone Wards of Surat, India: Exploring the duality of public-private discourse. *Environmental Development,* p. https://doi.org/10.1016/j.envdev.2025.101178.

Sullivan, F. O., 2022. *The World's Fastest-Growing Cities Are Facing the Most Climate Risk.* [Online] Available at: https://www.bloomberg.com/news/articles/2022-02-28/global-south-cities-face-dire-

climate-impacts-un-report
[Accessed 10 May 2023].

UNDESA, U. N. D. o. E. a. S. A. P. D., 2018. *The world's cities in 2018: data booklet (ST/ESA/ SER.A/417),* New York: United Nations.

UN-Habitat, 2020. *Global Urban Indicators Database 2020,* s.l.: United Nations Human Settlement Programme.

UN-Habitat, 2021. *Multi-Level Governance for Effective Urban Climate Action in the Global South,* s.l.: UN-Habitat.

WIlllams, D. S. et al., 2019. Vulnerability of informal settlements in the context of rapid urbanization and climate change. *Environment and Urbanization ,* 31(1), pp. 157-176. Doi: 10.1177/0956247818819694.

World Bank, 2015. *Investing in Urban Resilience: Protecting and Promoting Development in a Changing World,* Washington DC: World Bank.

WRI, 2021. *"Seven Transformations for More Equitable and Sustainable Cities.",* Washington, DC: World Resources Institute. https://doi.org/10.46830/wrirpt.19.00124.

Xiang, W. N., 2021. Seven approaches to research in socio-ecological practice & five incites from the RWC-Schon-Stokes model. *Socio-Ecological Practice Research ,* 3(2021), pp. 71-88. http://doi.org/10.1007/s42532-021-00073-8.

Research Paper

AI-Powered Feature Selection Techniques for Optimizing Urban Heat Island Factors

Assoc. Prof. Dr. Can Aydın, Dokuz Eylül University, Türkiye
Asst. Prof. Dr. Murat Kilinc, Karadeniz Technical University, Türkiye
Assoc. Prof. Dr. Gizem Erdoğan Aydın, İzmir Demokrasi University, Türkiye
Res. Asst. Damla Balcı, İzmir Demokrasi University, Türkiye

Abstract

Global climate change and urban sprawl have sped up the increase in cities' temperature and the urban heat island (UHI) effect. The urban heat island is a phenomenon whereby cities keep higher temperatures than their rural surroundings, which autonomously affects the ecology and public health disadvantageously. In order to reduce the impact of UHI, it is necessary to identify those most influential factors. Traditional methods rely on data from fixed weather stations, which is often inadequate and costly. In contrast, innovative technologies using remote sensing and geographic information systems (GIS) yield more comprehensive results in the identification of UHI but require high-resolution data. Deep learning can be a very powerful tool in overcoming these challenges by being able to analyze UHI more precisely as it processes data from satellite imagery. Especially, algorithms like YOLO detect the determinants of UHI with the detailed street-scale data. This paper attempts to use deep learning algorithms to analyze street imagery in exploring the influence of building density and green space amount on UHI. It is to come up with high-performance-rate UHI models by estimating the result using importance ranking and model improvement methods with fewer parameters.

Keywords

Urban Heat Island, Feature Selection, Deep Learning, Urban Analytics

1. Introduction

Global climatic change has been one of the major environmental problems that causes a rise in temperatures all over the world. The rise in temperature of the cities, especially due to dense construction and urban sprawl, makes the phenomenon called 'Urban Heat Island' (UHI) even more prominent. The UHI effect is a phenomenon that makes cities hotter than their surrounding rural areas, exacerbated by some factors such as heat retention of surfaces like asphalt and concrete, and the lack of green areas (Oke, 1982). This effect has impacts on health and quality of life for the population in cities, at the same increasing energy consumption and hindering the achievement of sustainable urbanism goals. Such negative impacts of UHI have been an important challenge to urban planners and policy makers. Critical to the mitigation and management of the impact of UHI is an understanding of underlying causes of this phenomenon and how these causes operate. Traditional methods of analyzing UHI are usually based on data from fixed meteorological stations. However, these methods are far from providing a comprehensive analysis in that they are based on a very limited set of data. Moreover, most of them are usually quite expensive and laborious, which has led cities and researchers to seek more efficient and economical solutions.

Recently, with the emergence of newer technologies such as remote sensing techniques and GIS more accurate and comprehensive results are being derived for the determination of UHI. The remote sensing technologies offer a great amount of data from sources such as high resolution satellite imagery and aerial photographs and GIS provides the means of analyzing this information. Besides, since these techniques generally require high resolution data, some limitations arise in their detailed analysis. While such data is really time-consuming and costly to acquire and process, deep learning is considered one of the capable methods that can help overcome such challenges. Since deep learning algorithms can cope with great volumes of data, and support the extraction of meaningful conclusions from such data, they are actually a very promising approach to UHI analysis. In particular, advanced deep learning algorithms like YOLO use streetscale data to sort out the contributing factors of UHI. Algorithms such as YOLO have efficient advantages in image analysis at street levels and show very high accuracy and speed in real-time object detection and classification.

The current work isolates the factor that would have the most influence on the UHI by training snapshot images of streets and deep learning algorithms. Emphasis is placed on such characteristics of the built environment as building density, quantity of greenery space, width of roads and sidewalks, paving material, amount of trees and cars in the street, those factors that would contribute to an automated labeling model through street view images. This would, in essence, be predefining those factors that would result in the utmost accuracy of the model's UHI score. In this context, this process would be done in comparison with attribute importance ranking. First, it gets the importance scores, as applied for determining each attribute's contribution to model performance from a model trained using a random forest algorithm. These scores have been used to eliminate unimportant or less important attributes. How the model is simplified, besides the introduction of more important attributes, is done this way. Besides, the model was retrained with more effective attributes selected by the ranking of importance. This will improve the performance of the model and make sure that similar or better results are obtained with fewer attributes. Later on, the obtained model was evaluated for accuracy, precision, and recall to check which attributes contributed a lot. Results in this paper indicate a good scope for highly performing UHI models with fewer parameters. Results from this study probably provide useful inputs for urban planners and policy makers to analyze in-depth the impact of UHI and hence come up with ways to mitigate this phenomenon. This

will have a better identification of those critical factors that are more likely to have their impact on the UHI in cities and how such factors could be better managed. It will then provide outcomes to assist in formulating appropriate sustainable urban planning and energy management strategies. It will also lead to new approaches in the adoption of green infrastructure, material use, and land management. Furthermore, the deep learning methods applied in this study will show how they can be applied effectively and efficiently in environmental analysis, hence guiding further research and application.

These are discussed in detail here as this paper covers the works carried out to achieve the above objectives. First comes the introduction; the second section does a review of the relevant literature; the third section describes the data and the methods used. The fourth section discusses the development and testing of the model, while in the fifth section, it discusses results obtained and their interpretation. The last section describes the general findings and recommendations for further studies. This paper, therefore, is intended to present the result of the study conducted that was aimed at contributing to developing methods of efficient mitigation of the urban heat island effect by means of deep learning techniques.

2. Related Works

In fact, during the years, several methodologies and technologies have been proposed in literature to understand and mitigate the negative impact of the UHI effect on human health and the quality of life in cities. Such methodologies and technologies are deeply related to the growing needs of more and more complete and precise detection of the UHI effect over time. These studies of literature can be grouped under two categories: traditional and based on innovative technologies. Traditional and innovative methods were used as the key words in this study while gathering the literature in this section.

2.1. Traditionals Methods

Traditional techniques have been used since the outset in studies of the urban heat island effect. The methods are most often based on temperature data taken from a meteorological station, in situ measurements made with a temperature-measuring device in the field, and data obtained from temperature sensors placed at some site (Bah et al. 2020; Sun et al., 2019). Generally, ground-based meteorological stations are set up at specified places to provide the general data source for monitoring temperature change over cities. However, they are often limited in number and unrepresentative for whole cities. As indicated by the research, meteorological stations only show the neighborhood in which they are placed and cannot fully represent the overall distribution of the temperature within the city (Oke, 1982; Fang et al., 2012). The traditional approaches also rely on land use and environmental factor analysis. Among the most relevant factors contributing to the increase in the impact of UHI, high building density and an overabundance of asphalt and concrete surfaces in cities were identified. Voogt & Oke, 2003 All these analyses have continued to guide the urban planning processes of the local governments and are often used in policy making. These tend to return just static data and thus are not useful for finding dynamic changes within cities.

2.2. Innovative Technologies

In the last two decades, new technologies have been developed which can overcome some of the deficiencies of the above-mentioned methodologies, thus enabling holistic and accurate analysis of UHI.

Remote sensing and GIS have emerged as key technologies for mapping urban temperature distribution and studying the impact of UHI. With remote sensing, it would be possible to monitor areas at large by means of high-resolution satellite imagery and aerial photographs. It allows the analysis and visualization of that data with GIS, providing very useful information to urban planners and researchers. Shi et al., 2021. Deep learning and Artificial Intelligence over the last years have brought changes in UHI analysis. Deep learning is a very promising approach to the analysis of UHI, given the capability of processing great datasets. It enables such algorithms to analyze in great detail and with high accuracy the effect of building density and the amount of green space on UHI in cities, by just processing information originating from big data sources like satellite imagery and street photographs. Advanced methods of analysis, combined with attribute selection, become extremely important in raising the accuracy of UHI analyses. In particular, deep learning algorithms such as YOLO (You Only Look Once) provide great benefit in determining the factors affecting UHI by using detailed data at street scale (Redmon & Farhadi, 2018). Techniques such as random forest algorithms allow the identification of important attributes that contribute to the performance of the model (Breiman, 2001). These are considered ranking importance and model refinement, and they tend to give better results due to the reduced model complexity. Approaches like this have contributed to obtaining high accuracy rates using a few parameters in UHI modeling.

In this chapter, a literature table was made that included both traditional and innovative methods (Table 1). This section gives a comparative overview of how the quantifications of the urban heat island effect were performed in literature and which parameters were researched by those methods. A summary of the scopes and study areas of the different techniques adopted by various studies tries to explain the effectiveness of traditional and innovative approaches.

Table 1 .Literature Table

Author(s) and Year	Measured Parameters	Method(s) Used	Workspace
(Oke, 1982)	Air temperature and humidity	Meteorological stations	Vancouver, Canada
(Voogt & Oke, 2003)	Surface temperature and radiation balance	Satellite data (Landsat)	London, England
(H. Li et al., 2018)	Surface temperature	Remote sensing (MODIS)	Germany
(Mendez-Astudillo et al., 2021)	Pressure, water vapor partial pressure and temperature	Global Navigation Satellite System (GNSS)	America

(Chen et al., n.d.,2022)	Surface albedo, land use/land cover, impervious surface and anthropogenic heat flux (AHF)	Remote sensing data and random forest (RF) model	Nanjing, China
(D. Li & Bou-Zeid, 2014)	Surface temperature, roof, wall, floor, canyon and air	Weather Research and Forecasting (WRF) model	Baltimore-Washington
(Oh et al., 2020)	Air temperature, Spectral brightness, surface albedo, sky visibility factor, total floor area of all buildings, area covered by green vegetation, building footprints, area covered by water and crops, and bare land area	Meteorological data, Landsat 8 remote sensing satellite, ANN model, Time series modeling	Seoul

A better understanding and mitigation of the urban heat island effect have become an environmental and social concern. Measurements of the urban heat island effect have thus gradually changed from traditional ground-based measurements to innovative techniques of remote sensing and modeling. New technologies consider a much wider perspective and understand the complex connection between urban morphology, land use, and temperature fluctuation, while classic ones do on a local scale and can hardly show any key parameters of UHI. Moreover, this approach enables more detailed and profound analysis of UHI with the help of such techniques as remote sensing, GIS, and deep learning. These can also have valuable contributions to the formulation of strategies for urban area planning and sustainability. Various works found in the literature prove that, combined with the innovation of technologies, the integration of traditional methods facilitates the elaboration of more effective management strategies concerning UHI. Further investigations will be carried out for the integration and development of this technology in order to offer, in the future, new innovative solutions against the impact of UHI.

3. Methodology

Various methods and algorithms go into consideration with a view to reducing its effect. This section outlines the methodology to be used in the approaches of the mitigation of UHI, methods to be used for

data collection and analysis, and the use and integration of the algorithms. This study is intended to determine what kind of parameter has more influence on UHI and proposes the most effective strategies in mitigating those parameters.

3.1. Data Collection and Preprocessing

It requires datasets of street view images to identify and further analyze UHI parameters. In this context, the street imagery data would contain those representative of the Karşıyaka district in Izmir, Turkey. The selection of the district of Karşıyaka for this study was for enough reasons. Izmir is a city prominent in its warm and mild climate, while Karşıyaka is a region that had a proper balance of dense housing and green areas (Çorumluoğlu, 2023; Yüksel & Coskun Hepcan, 2023). This diversity provides good ground for investigating a wide range of contributing factors to UHI formation. Further, the street texture of Karşıyaka, building density, and the amount of green space provide an ideal dataset to perform testing of performances of deep learning algorithms. Therefore, the region was selected for the analysis of our study, as seen in Figure 1 below.

On the other side, street image data would be the most important data fed into the deep learning algorithms. Thus, data gathered from various regions of Karşıyaka were gathered with the help of a Python-based automated script shown in Figure 2. Later, cleaning of images from noise and changing their format to suitable ones for training has been performed. Then, normalizing data and eliminating wrong entries also performed.

Figure 1: Karsiyaka District of Izmir

Figure 2: Street Images Collected from Karsiyaka

Images were labeled and the dataset was organized through the use of the Roboflow platform. High quality, provided by the facilities of Roboflow, allowed for highly qualitative processes of data labeling and management; thus, the data obtained from street images was more effective in deep learning algorithms. Thus, infrastructure provided by Roboflow allowed for more precise and faster analysis of factors that influence UHI.

3.2. Data Labelling

Labelling of data is generally regarded as one of the most key steps of UHI study, and it is prepared on a platform called Roboflow. First, street view images taken from Karşıyaka district were uploaded to Roboflow; then, labelling of objects in the images was done by using the automatic object detection features provided by the platform. Others also included buildings, roads, green areas, etc., which contributed to the occurrence of CIA so that the factors of CIA may be ascertained. Labeling is much quicker and more accurate since Roboflow has a very user-friendly user interface.

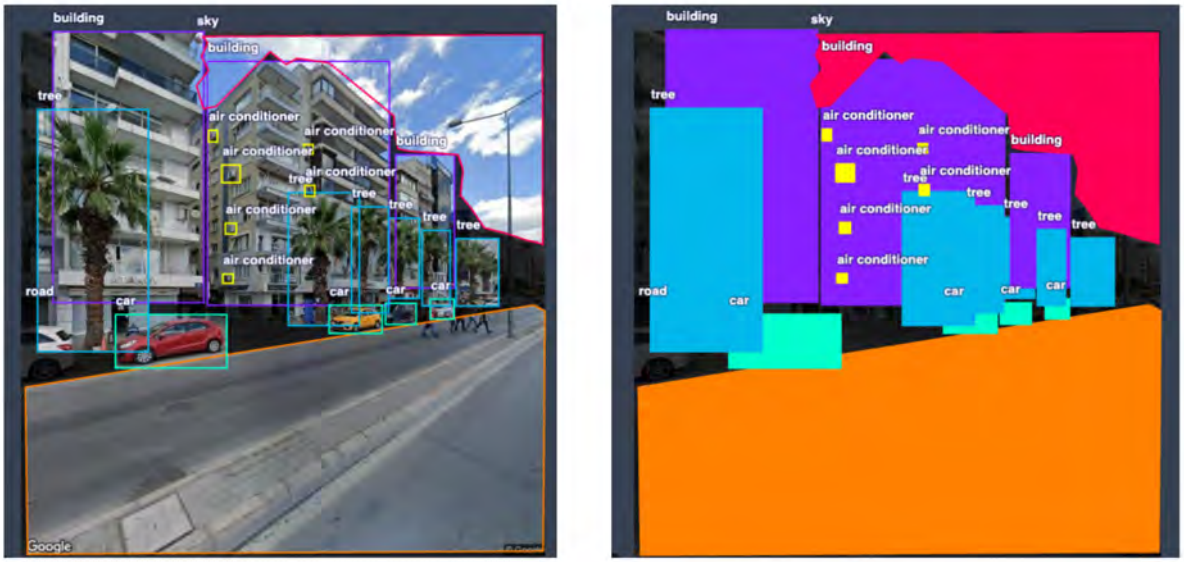


Figure 3: Data Labelling in Karsiyaka Street Images with Roboflow

During labeling, street texture was analyzed in great detail, using advanced object detection features available at Roboflow while manually labeling the objects - buildings, green areas, sidewalks, etc. - identified in each image - Figure 3. In such a way, it was made certain that the labeled dataset to be used in the training of the model was the right one. One other important feature the Roboflow software provides is data augmentation techniques. These techniques augment the dataset through image rotation, variation in brightness level, zooming amongst others that would improve the performance of the overall model. Figure 4: This is data augmentation that helped the model understand the variant scenarios and hence analyze the impact of UHI more correctly under real-world variant conditions.

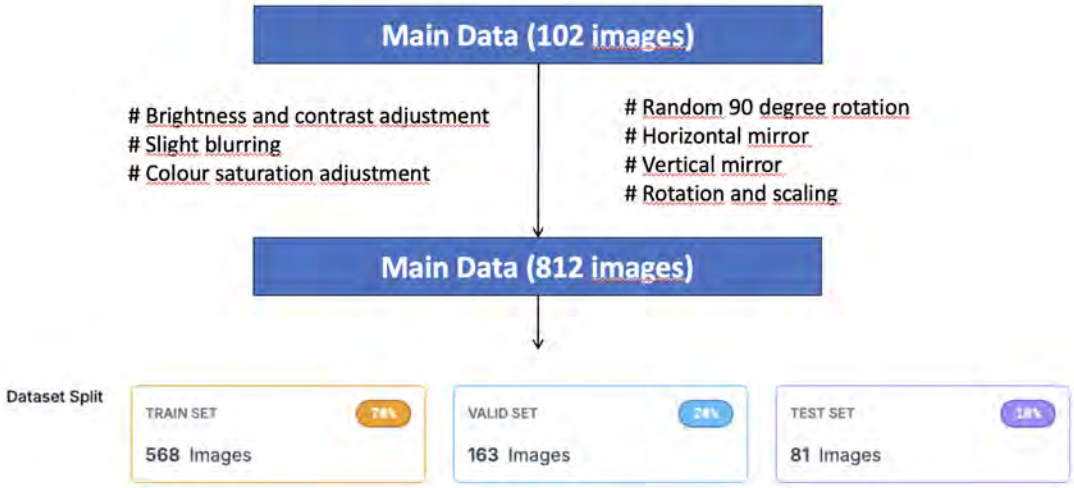


Figure 4: Roboflow Data Augmentation and Split

These labeled data were transformed into a deep learning training format and optimized by removing wrong labels from the dataset. In this way, the most important factors were shown that might have an impact on UHI and the model was enabled to present more accurate results. In the end, Roboflow contributed much to the increase in success with its flexible labeling and by increasing the number of datasets.

3.3. Parameter Analysis and Algorithms

Different algorithms have been applied for the parameters that influence UHI analysis, as well as planning strategies for reducing the impact given by the parameters. These entail feature selection/model development, optimization steps.

Feature Selection and Prioritization: The random forest algorithm has been adopted for identifying the important attributes that provide the most substantial performance to the model by Breiman (2001). This algorithm helps in the selection of important attributes from high-dimensional data sets and reduces model complexity for better outcomes (R. C. Chen et al., 2020). Finally, attribute importance ranking was done to identify which of the model parameters had more influence on UHI. Those attributes that were less important or not important would then be eliminated, hence optimizing efficiency within the model.

Deep Learning and Object Detection: Using the YOLO algorithm, the factors of UHI automatically detected from the data obtained by street images. YoLo has a good advantage in the analysis of street images because it is very accurate and swift in real-time object detecting and classifying tasks (Redmon and Farhadi, 2018). Other parameters that may go into determining strategies for reducing UHI include building density, width of the road and sidewalk, number of trees, and automobiles detected using YOLO.

The information obtained with the help of a YOLO algorithm can also be adapted to different geographical regions and different structures of cities. Especially for the analysis of the impact of various climatic conditions on UHI, such parameters obtained from street images can be tuned further according to the local needs of the cities. For example, while mitigating UHI, it might make use of dense tree cover and wide roads in one city, while in other regions, the height of the buildings and type of building material are something that needs to be considered. The loose structure in YOLO can process these variables with a lot of ease and present results to the decision-makers. The parameters estimated in this context by YOLO would give applicable data in the urban renewal projects of the city planners or environmental regulations and would aim at sustainable urban development. Such proposal ways to reduce the magnitude of UHI are increasing the areas for planting trees, increasing the widths of roads, and covering the buildings with reflecting materials. In this respect, the advantages of YOLO go critical in making cities resilient to the changes in the climate. That indeed does make YOLO effective at executing tasks related to urban planning and climate change mitigation studies with a vision toward making cities even more livable, with greater quickness and accuracy.

Data Analysis and Optimization: Based on the retrieval data and attribute importance ranking, the development of the UHI reduction strategy will be developed. The probable measures are reduction of building density, increasing green areas, and using high-albedo value materials. Such scenarios will be simulated for model performance by using simulations. In such a way, methods will enable coming out with the best effective strategies to reduce UHI.

3.4. UHI Score Calculation Method

The estimation of the urban heat island effect will play an important role regarding environmental sustainability and urban planning. The presented work applies a deep learning model, namely YOLOv9, for the object detection over the urban area for analyzing several variables affecting the UHI score. It will try to locate buildings, vehicles, green space, roads, trees, and other components composing the urban setting with the aim of quantifying their contribution toward the heat island.

Object detection in the test image was carried out using the pre-trained "yolo_v9_heatwatch_model.pt" YOLOv9 model. It further classifies the object that has been detected into different classes wherein, for each of the classes, the number or area detected is calculated. Further normalizing these data from the detected object is done. This was done through the normalization of each object type to use pre-calculated maximums for each class so that relative effects from different object types can be compared.

Herein, all the positive impacts mean the factor that reduces the UHI effect, including green space, trees, water area, and sky, while all negative impacts mean the factor that increases the UHI effect, including buildings, air conditioning, vehicles, roads, and stones. From the normalized values, the sum of the positive and negative impacts was calculated and the difference value was obtained by subtracting the negative impacts from the positive impacts. The difference value hence becomes the basis of the urban heat island score. When the negative prevails over the positive, the score of UHI will be high, and it can be concluded that the heat island effect of the urban area is more serious. The determination of the difference value obtained into specified ranges calculates the score of the urban heat island. This difference in magnitude brought the score in a range from 10 to 90. A low UHI score indicates lesser accumulation of heat in the urban area when the positive effects brought about are in dominance, whereas when the negative outweighs the positive, the computed UHI score is high, showing the intensity of the urban heat island effect.

4. Findings

While doing this, within the scope of the findings obtained in this study, different methods of deep learning and machine learning techniques like YOLOv9 and Random Forest Algorithm were applied. Focusing on the district of Karşıyaka in Izmir, this paper analyzes in minute detail various factors that increase or decrease the impact of UHI in this region. Some of the parameters observed include the visibility of buildings, visibility of sky, visibility of trees, count of vehicles, green areas, and proximity to water surfaces. Data set during the study was retrieved from Google Street View images.

Among the key findings of this research, object detection made via the YOLOv9 algorithm gave some performance measures like 67.2% mAP, 70.7% precision, and 63.4% recall (Table 1). The results obtained also show that the model is successful with object detection, as shown in Figure 7, providing an infrastructure that can be used for calculating the UHI effect, as depicted in Figure 5. Besides, it was observed that the increase of data actually improves UHI model results. Thus, some basic data augmentation like projections, adjusting brightness and contrast, slight blur, color saturation on the Images used in the dataset have been carried out.

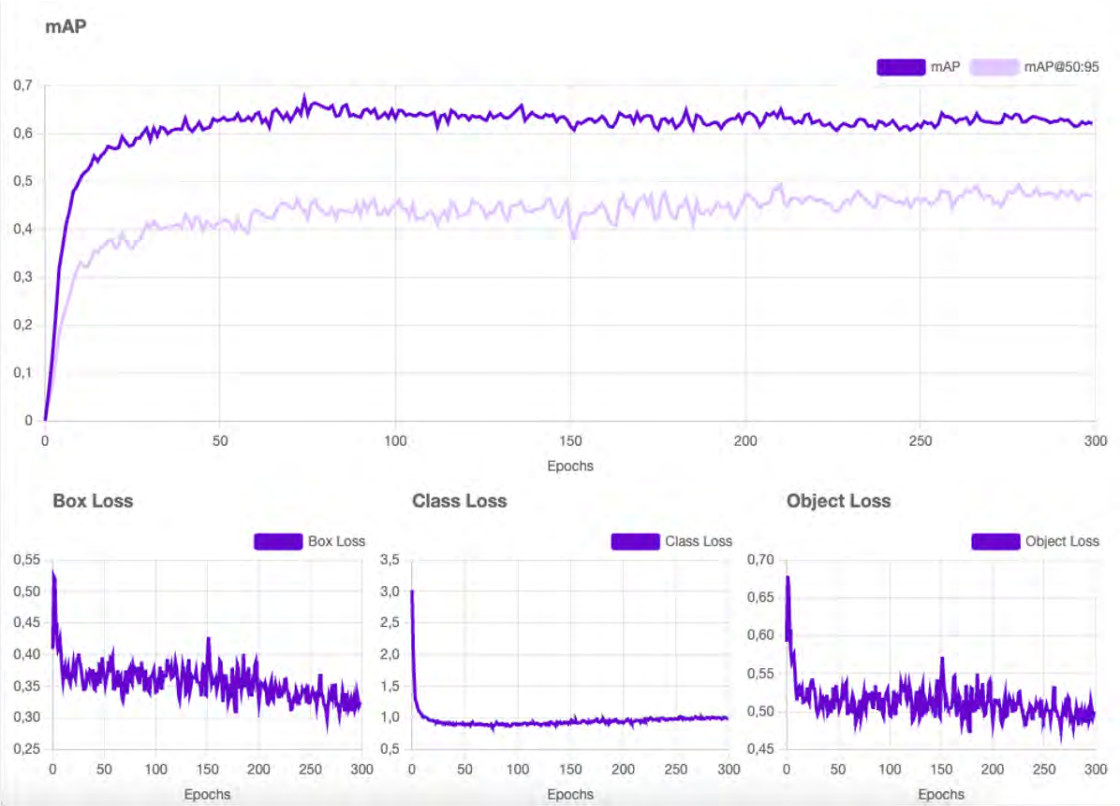


Figure 5: Findings of Model Development with YOLOv9

The main influential factors in these UHI score calculations include the water factor, building visibility factor - BVF, sky visibility factor - SVF, tree visibility - TVH, and road factor. All these factors mentioned will go through the analysis carried out by the Random Forest algorithm with a ranking regarding the effects that each presents to the UHI score; therefore, water area and building density are factors that drive higher impact. But the presence of green areas and trees, however, were not that effective in diminishing the UHI effect. Results show that more green area has to be taken into account and development has to be regulated while planning a city in order to avoid or minimize the urban heat island effect.

Table 1: YOLOv9 Model Development Scores

Metric	Score
mAP	%67.2
Precision	%70.7
Recall	%63.4

Further computation of the score was made together with the contribution of the positive and negative urban heat island for the calculation of the UHI score in the study of Karşıyaka. This indicates that because of the high density in constructions and the resultant temperature increase from the air conditioning, the

UHI effect increases very much in this region. With such high UHI scores, it would logically follow that the accumulation of heat greatly influences the environment and human health, therefore most likely contributing to further growth in the intensification of the rise of the temperature of cities-especially during summer-and deterioration in the quality of life.

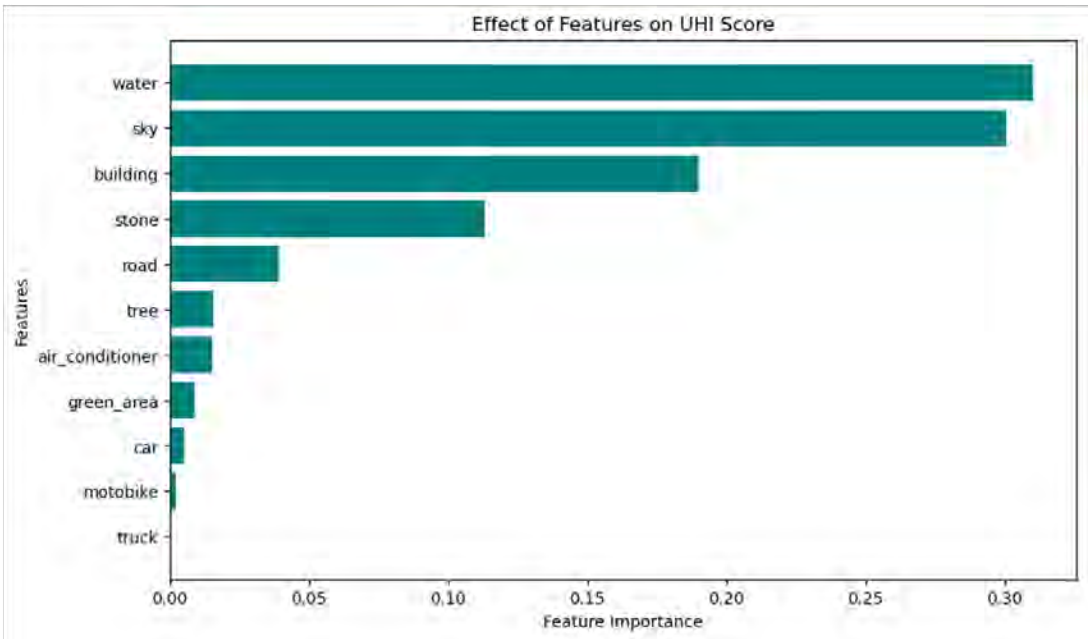


Figure 6: Importance Ranking of Features with Random Forest

The result of this study infers that the optimal UHI effect could be obtained by improving the stages of data augmentation, resizing the images, and labeling. Further extension of the model by the authors includes collecting bigger datasets and its analysis throughout the city of Izmir.

Figure 7: Testing the Developed Model in Real Environment

In the remainder of the study, recommendations on how these methods can be used for urban planning and mitigation of the urban heat island effect are developed. In conclusion, this study makes an important contribution to mitigating the urban heat island effect with AI-assisted methods and demonstrates the potential benefits of AI applications in urban planning.

5. Conclusion and Discussion

By focusing on an in-depth analysis of the impact of UHI, this study makes important contributions to urban planning processes. Using artificial intelligence and deep learning algorithms, this research has allowed us to understand the factors affecting UHI in more detail by analyzing the street scale, which has not been analyzed before. In particular, analyzing street images with the YOLO algorithm has identified the effects of factors such as building density, amount of green space and surface materials on UHI, and has provided feasible strategies for more efficient management of these parameters.

A key finding of the research is that green infrastructure projects play a critical role in mitigating the impact of UHI. Increasing green spaces not only reduces temperatures inside the city, but also provides social and economic benefits. Afforestation projects, green roofs and the expansion of parks have been found to be effective solutions to mitigate UHI. In addition, changing surface materials, especially the use of light-colored materials with high albedo values, has been suggested as an important strategy to reduce surface temperatures. In this way, the UHI effect can be reduced by preventing heat accumulation during the night and allowing the surfaces to cool down faster. The effect of building density on UHI is also among the remarkable findings of the study. The lack of air flow between buildings in densely built-up areas leads to microclimate differences and an increase in urban temperatures. In this context, a more balanced distribution of housing and ensuring air circulation within the city may be effective in mitigating the impact of UHI. Furthermore, the development of integrated strategies that take into account the impacts of UHI in urban planning is critical in achieving sustainable urbanism goals.

The results of the study can guide urban planning and the development of policies to reduce UHI. The proposed strategies to optimize the impact of UHI will enable urban planners and policy makers to make more informed decisions. However, in future research, it would be beneficial to include field-collected heat data in the analysis, apply more data augmentation techniques, and optimize the model with feature selection methods such as RFECV (Recursive Feature Elimination with Cross-Validation) to improve the accuracy of the model. Using these techniques can help to analyze the UHI effect on a larger scale and achieve more effective results. However, the study has some limitations. First, the number of images used in the study is limited and imbalances between classes were observed. This may have negative effects on the generalizability of the model and feature selection. In addition, the data collected from Karşıyaka region is limited to certain regions and the distribution among these regions is not homogeneous. In future research, ensuring homogeneous distribution by collecting data from a wider geographical area will increase the accuracy of the model and improve its generalizability.

In addition, the quality of the images used in the training process of the model is also an important limitation. There may be performance differences between the direct representation of objects on the street and the representation of these objects in the images used during training. Therefore, introducing direct images of objects with the model can be considered as a factor to be taken into account to increase the accuracy of the model. This approach may contribute to more accurate identification of the factors affecting the UHI and to the development of more effective strategies.

In conclusion, this study has revealed important findings in terms of identifying and implementing strategies to mitigate the impact of UHI through a deep learning-based approach. The results obtained in the study show that artificial intelligence applications have great potential in urban planning and UHI

management. In future research, using larger data sets and applying the model to more geographical regions will provide a more comprehensive analysis of the impact of UHI and help develop more effective policies for cities to combat this phenomenon.

6. References

Chen, S., Yang, Y., Deng, F., Zhang, Y., Liu, D., Liu, C., & Gao, Z. (n.d.). *A high-resolution monitoring approach of canopy urban heat island using a random forest model and multi-platform observations*. Retrieved October 15, 2024, from https://amt.copernicus.org/articles/15/735/2022/

Kılınç, E., Altındal, S., & Kocakalay, Ş. (2023). Doğal Afetler İçin Acil Durum Uygulaması: AfetAp. *Türk Deprem Araştırma Dergisi*, *5*(2), Article 2. https://doi.org/10.46464/tdad.1351700

Li, D., & Bou-Zeid, E. (2014). Quality and sensitivity of high-resolution numerical simulation of urban heat islands. *Environmental Research Letters*, *9*(5), 055001. https://doi.org/10.1088/1748-9326/9/5/055001

Li, H., Zhou, Y., Li, X., Meng, L., Wang, X., Wu, S., & Sodoudi, S. (2018). A new method to quantify surface urban heat island intensity. *Science of The Total Environment*, *624*, 262–272. https://doi.org/10.1016/j.scitotenv.2017.11.360

Mendez-Astudillo, J., Lau, L., Tang, Y.-T., & Moore, T. (2021). A new Global Navigation Satellite System (GNSS) based method for urban heat island intensity monitoring. *International Journal of Applied Earth Observation and Geoinformation*, *94*, 102222. https://doi.org/10.1016/j.jag.2020.102222

Oh, J. W., Ngarambe, J., Duhirwe, P. N., Yun, G. Y., & Santamouris, M. (2020). Using deep-learning to forecast the magnitude and characteristics of urban heat island in Seoul Korea. *Scientific Reports*, *10*(1), 3559. https://doi.org/10.1038/s41598-020-60632-z

Oke, T. R. (1982). The energetic basis of the urban heat island. *Quarterly Journal of the Royal Meteorological Society*, *108*(455), 1–24. https://doi.org/10.1002/qj.49710845502

Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment*, *86*(3), 370–384. https://doi.org/10.1016/S0034-4257(03)00079-8

Research Paper

Assessing Spatial Impacts of Digitalisation on Labour Markets: Methodological Approaches

Balázs CSERPES, HCU Hamburg, Germany

Abstract

Technological advancement is a major factor in shaping the future of work, which in consequence affects labour markets and economic geographies. Although concrete effects of digitalisation are challenging to predict, we can develop proxies based on tasks or skills and how they relate to abilities of humans and/or computers. These proxies consequently can be aggregated on an occupational level to describe the effects of digitalisation of certain jobs and to relate them to labour market statistics to understand implications on various geographic levels.

This paper presents the findings of a case study on the German labour market at the district (Kreise) level and analyses differences in the potential effects of digitalisation across regions. While no clear spatial patterns can be identified, results suggest a polarisation of labour markets both on a national and local levels, as well as deepening divides between urban and rural regions.

The study uses structured regional labour market statistics and two digitalisation indicators from existing research (Felten et al., 2021; Frey and Osborne, 2017) *to categorise employment concentrations into four typologies ("rising stars," "machine terrain," "human terrain," and "collapsing"). Based on the indicators of Potential Risk of Computerisation (PRoC) and Occupational/Geographic Exposure to AI (AIOE/AIGE) this approach provides an understanding of potential regional economic shifts.*

While focused on German data, this framework could be adapted internationally based on standardised labour market statistics. This allows an identification of regions with high concentrations of employments in sectors that are more vulnerable to transformative or destructive effects of technological advancement and digitalisation.

Keywords

Digitalisation, Labour Market, Artificial Intelligence

1 Introduction

1.1 Background

The current rise of deep learning and advanced computational methods, alongside the broad applicability of related tools in our everyday lives, has nourished research interest in the question of how new technologies might shape the ways we work (Deranty and Corbin, 2024; Frey and Osborne, 2024). Though comparisons of current developments with a new industrial revolution are generally regarded as overestimations (Frey and Osborne, 2024; Samaan, 2023), they impact how and where we perform our tasks and generate new ways of interactions with digital technologies.

Rapid advancements in technologies such as Generative Artificial Intelligence may give the impression that human abilities (and by extension, entire occupations) can easily be conducted by machines. In such cases,

digitalisation exercises a destructive effect, as jobs can be easily taken over by computers. However, the relationship between humans and computers is far more complex and goes beyond simple replication or substitution. Changes are more likely to happen on the level of tasks, instead of entire jobs or occupations (Frey and Osborne, 2024; Samaan, 2023), meaning that these effects are more transformative than disruptive in nature.

To attain a general (spatial) overview of the effect of such transformations, we can use digitalisation indicator sets as proxies to describe the extent of both destructive and transformative effects. Consequently, these proxies can be linked with occupational statistics of spatial units (e.g. on a regional level). This enables a better understanding of how technological advancements might affect different regions.

The following paper follows and extends an approach sketched up by Fossen & Sorgner (2019) and combines two indicators on an occupational level:

- the Potential Risk of Computerisation (PRoC), as defined by Frey & Osborne (2017), measuring the susceptibility of occupations being replaced through computerisation, describing the destructive
- and the Artificial Intelligence Occupational/Geographic Exposure (AIOE/AIGE), as defined by Felten et al. (2021), describing the transformative effects of digitalisation.

The two indicators are linked to labour market statistics of the German labour market on the national, as well as on the regional level within the countries 400 districts ("Kreise"). This enables an understanding of the regional variation of potential effects of digitalisation trends in the labour market.

1.2 Methods in assessing the effects of digitalisation

Though it is unlikely to predict the concrete effects of digitalisation on specific jobs (or the labour market as a whole), research based on occupational profiles can describe potential development paths and tendencies. Previous research has developed indicators of digitalisation based on either the tasks that are linked to occupations (Autor and Handel, 2013; Felten et al., 2021, 2018; Fernández-Macías and Bisello, 2022; Frey and Osborne, 2017), or on the skills that are needed need to perform these tasks (Barbieri et al., 2020; Colombo et al., 2019; Nedelkoska and Quintini, 2018).

An advantage of task- or skill-based approaches is their compatibility with standardised labour market statistics, which classify occupations into hierarchical taxonomies. Apart from providing a simple classification, these taxonomies also link occupations, tasks and skills with each other. This enables the analysis of effects of digitalisation across different geographical areas and/or industries.

The taxonomies are usually defined and maintained by a national or supra-national employment agency, such as the US Department of Labour, which publishes the O*NET/SOC taxonomy[1] as an example. This Taxonomy features 23 major groups (e.g. 17-0000 Architecture and Engineering Occupations) and 93 minor groups (e.g. 17-1010 Architects, Surveyors, and Cartographers), which are then broken down into 459 broad occupations (e.g. Surveyors, Cartographers, and Photogrammetrists) and 867 detailed occupations (e.g. 17-1021 Cartographers and Photogrammetrists). Each of the occupations can have specific skills and tasks assigned to them, which we can match with digitalisation (or other) indicators.

In the presented study, three taxonomies are of relevance:

[1] https://www.onetcenter.org/taxonomy.html

- The O*NET-SOC-taxonomy of the US Department of Labour, which provides the structure for both of the indicator sets (Felten et al., 2021; Frey and Osborne, 2017) used for the analysis
- The KldB-taxonomy[2] of the German Federal Employment Agency, which the available national and regional labour market statistics refer to
- The ISCO-taxonomy of the International Labour Organisation, which corresponds the ESCO-taxonomy[3] of the European Commission, as an intermediate to convert between O*NET-SOC and KldB

1.3 Digitalisation indicators

One of the most widely cited studies in the field of computerisation and labour is the report "Future of Employment" published in 2013 (Frey and Osborne, 2013), with an updated version in 2017 (Frey and Osborne, 2017). It uses a task-based approach to examine how certain computational bottlenecks determine the likelihood of tasks, and consequently of jobs, being automated. The assignment of tasks to occupations is queried from the US Department of Labor's SOC/O*NET database. Based on this, the report presents a classification system that assigns a potential risk of computerisation (referred to as PRoC in this article) to various occupations. These scores range from 0 (unlikely to be automated) to 1 (highly susceptible to automation), and can consequently be interpreted as a measure of the destructive effects of digitalisation (Fossen and Sorgner, 2019).

The report has been influential in urban and regional planning research (Sharifi et al., 2023) and the scores of computerisation (or the methods used to create these) have been projected onto the Austrian (Hat and Stoeglehner, 2020), Irish (Crowley and Doran, 2023) or the US (Frank et al., 2018) context on a (sub-)regional level. These studies point out economic differences in terms of regional vulnerability of labour markets towards computerisation, with especially rural, economically weaker regions being more at risk.

Transfers of "Future of Employment" report onto the German context exist on a national level, using a direct linkage of computerisation potential scores of US-occupations to their German counterparts (Bonin et al., 2015; Brzeski, 2015), or replicating their approach by not transferring occupational but task-level scores (Dengler and Matthes, 2018).

Using a similar approach, we can compare the Electronic Frontier Foundation (EFF) AI Progress Measurement with the 52 skills listed in the SOC/O*NET database. This comparison provides a metric to assess how advances in Artificial Intelligence might impact the labour market, offering a way to compare occupations (Felten et al., 2018). These scores can be considered to describe the transformative effects of digitalisation (Fossen and Sorgner, 2019).

By combining these two metrics, the (transformative) exposure to AI and the (destructive) susceptibility to replacement through automation, it becomes possible to assess the broader impacts of technological progress on the labour market. Fossen and Sorgner (2019) created a two-dimensional matrix combining these indicators to categorise occupations into four quadrants, offering a more structured description of future dynamics of work, as shown in Table 1.

On the X-axis of the matrix we find the scores of computerisation probability from the "Future of Employment" report (Frey and Osborne, 2017). The Y-axis relates to the Advances in AI (Felten et al., 2018)

[2]https://statistik.arbeitsagentur.de/DE/Navigation/Grundlagen/Klassifikationen/Klassifikation-der-Berufe/KldB2010-Fassung2020/KldB2010-Fassung2020-Nav.html
[3] https://esco.ec.europa.eu/en/classification

metric. The delimitations of the quadrants are based on the median, weighted by the US employment in the occupation groups.

Advances in AI (Felten et al., 2018) / transformative effects of digitalisation	**Q1: Rising Stars** Low destructive, high transformative effects e.g. Physicists (advances in AI-score: 5.91/ computerisation probability score: 0.10)	**Q2: Machine Terrain** High destructive, high transformative effects e.g. Accountants and Auditors (3.70/0.94)
	Q3: Human Terrain Low destructive, low transformative effects e.g. Teacher Assistants (2.54/0.56)	**Q4: Collapsing Occupations** High destructive, low transformative effects e.g. Manicurists and Pedicurists (1.97/0.95)
	Computerisation probability (Frey and Osborne, 2017) / destructive effects of digitalisation	

Table 1: Digitalisation matrix, as used in the reference study (Fossen and Sorgner, 2019)

The strength of this matrix relies in its simplicity and ease of interpretation. Important characteristics of occupations within the quadrants are described as follows (Fossen and Sorgner, 2019):

- **Rising stars occupations** (Q1) require social and creative intelligence, its workers will therefore not be easily replaced through computerisation, however they might need to acquire further skills and qualifications
- **Machine terrain occupations** (Q2) often feature manual skills and while in the short-term necessary qualifications can be obtained to work with new technologies, in the longer term, they might also run into the risk of being easily replaced
- **Human terrain occupations** (Q3) are least affected through digitalisation, minimising the risk of being replaced, however they are also profiting the least from technological advancement in their productivity
- **Collapsing occupations** (Q4) are easily replaced by machines already in the short-term perspective, meaning that workers in this category may need re-qualification

The presented research builds up on the classification according to the matrix described above and relates them to the German national and district-level labour market indicators to understand possible geographic implications of labour market developments.

Besides the application of the scores in a different geographic region, the key difference is the usage of a more recent score for assessing the effects of AI in the labour market: the Artificial Intelligence Occupational (or the derived Geographic) Exposure (AIOE/AIGE) indicator (Felten et al., 2021). This score is a relative metric of occupational scores based on the 52 abilities listed in the O*NET database and the progress of AI scores of the EEF. The scores for each occupational group are calculated by linking them with the importance and prevalence of skills in the respective groups. This enables a more up-to-date and more accurate measurement of possible effects of AI on the labour market.

2 Methods

2.1 Taxonomy classification

The most profound challenge in transferring the two sets of indicators to the German context lies in the conversion between the taxonomies that describe and structure the datasets related to the labour market and employment. There are several ways to match occupations across different taxonomies. One method involves aligning occupations of an external taxonomy with their local counterparts, as seen in the Austrian case study (Hat & Stoeglehner, 2020). A different approach is to use conversion tables, also called "crosswalks" (Bonin et al., 2015). The most accurate results are typically obtained by defining digitalisation scores at the task level and then re-compiling them at the occupational level (Dengler and Matthes, 2018).

For simplicity, the research presented here adopts a crosswalk-based method at the occupational group level. This method allows for the simultaneous comparison of two digitalisation metrics—PRoC and AIOE/AIGE. Moreover, we can assume that scores at the occupational group level are not significantly different from those at the task level when assessed on a relative scale (Nedelkoska and Quintini, 2018), which is the primary focus of this report.

A key limitation of this approach arises from the inherent fuzziness in occupational taxonomies. In many cases, an occupation in one taxonomy may correspond to multiple groups in another. As a result, a single German occupational group may be assigned several different digitalisation scores.

While averages or means of the occupational scores could be used to get one matching score to one occupation group, this tends to obscure extreme values (i.e., very high or low digitalisation scores). To address this, we can use the so-called "uniform distribution" approach, which assigns all potential digitalisation scores to the occupation groups (Bonin et al., 2015). For instance, if a KldB group with 100 workers in one region corresponds to two O*NET-SOC groups with different scores, 50 workers would be assigned to each score.

The hereby presented study follows this approach, taking the transfer of the “Future of Employment” report to Germany (Bonin et al., 2015) as a reference. In this case, we use however a newer and more accurate crosswalk table for ESCO to convert between the US and the European classification, provided by the European Commission (which is responsible for defining and maintaining the ESCO-classification)[4]. The German Federal Employment Agency provides a crosswalk[5] to convert between ESCO/ISCO and their own KldB-taxonomies. Besides the conversion across the three (supra-)national taxonomies, the original codes in the two base studies also needed to be updated, as the crosswalks relate to the newer version of the taxonomy. The Department of Labor provides the necessary conversion tables for this task.

In case of ambiguous matches between taxonomies, both crosswalks provide an estimation of the accuracies of the defined linkages. The SOC/O*NET crosswalk defines matches to be either “exact”, “narrow” (SOC/O*Net group covers more occupations and tasks than the linked ESCO occupational group), ”broad” (as before, just vice-versa) or “close” (with overlaps on both sides). The KldB-crosswalk defines and ranks possible alternatives. For the conversion, the two distinct accuracy metrics of the crosswalks were weighted and added to each other to get a joint weight. For further calculations all matches with the highest available weights were selected.

[4] https://esco.ec.europa.eu/en/about-esco/data-science-and-esco/crosswalk-between-esco-and-onet
[5] https://statistik.arbeitsagentur.de/DE/Statischer-Content/Grundlagen/Klassifikationen/Klassifikation-der-Berufe/KldB2010-Fassung2020/Arbeitsmittel/Umschluesselungstabellen.html

2.2 Employment data

Employment data for the German labour market was sourced from the Federal Employment Agency (Bundesagentur für Arbeit) and reflects the labour market as of March 2024. This research uses employment data at the 4th level (occupational sub-groups) of the KldB taxonomy on the national level and at the 3rd level (occupational groups) on the regional level to account for different scales of analysis. Based on this, we apply the equal distribution method proposed by Bonin et al. (2015). Occupations at the 4th level of KldB are distributed into the 3rd level based on national figures. These 4th level figures are then distributed evenly into 5th level (pseudo-)classes, where digitalisation indicators are assigned.

It needs to be pointed out that this method does not fully resolve classification issues and assumes the same proportional distribution of occupations across Germany within their respective groups. However, it avoids gravitating towards averages and retains digitalisation values that are located on the extreme ends of the two axes of the indicator matrix. It also facilitates the integration of both AIOE and PRoC indicators, as the same taxonomy conversion applies to both.

2.3 Evaluation

To check the validity of the results of taxonomy conversion, the distribution of scores were compared across taxonomies (Figure 1). The x-axis in both charts show the range of digitalisation scores (PRoC and AIOE) for Germany (orange) and for the US labour market (blue). The utilised uniform distribution approach preservers the shape of both graphs, with many jobs in the PRoC score located at the two extremes, and in the bi-modal distribution in case of AIOE.

Looking at the results of scores in the German labour market, we can see that around 45.60 per cent of the national work force is highly susceptible to automation (working in occupations with scores above 0.7). This number is close to both the estimation of the “Future of Work” report (47%) and the number obtained in Bonin et al. (2015) using the direct translation scores on the occupational level (42%). Deviances in these numbers can be attributed to the different structures of the labour market and the time the labour market statistics refer to.

There is no reference study of the AIOE scores in the German context, nevertheless the numbers of workers with a high AIOE-score (above 1) are comparable when applying the indicator set to the numbers of the US (27.38%) and to the German (26.12%) labour market.

2.4 Technological Approach

The employment data and digitalisation indicators were stored in a PostGIS database, data preparation, analysis and visualisation was performed with help of the libraries Pandas (Pandas development team, 2020), Geopandas (Jordahl et al., 2020) and Matplotlib (Hunter, 2007). Additionally, ChatGPT (OpenAI, 2024) was used for stylistic checking of the presented article.

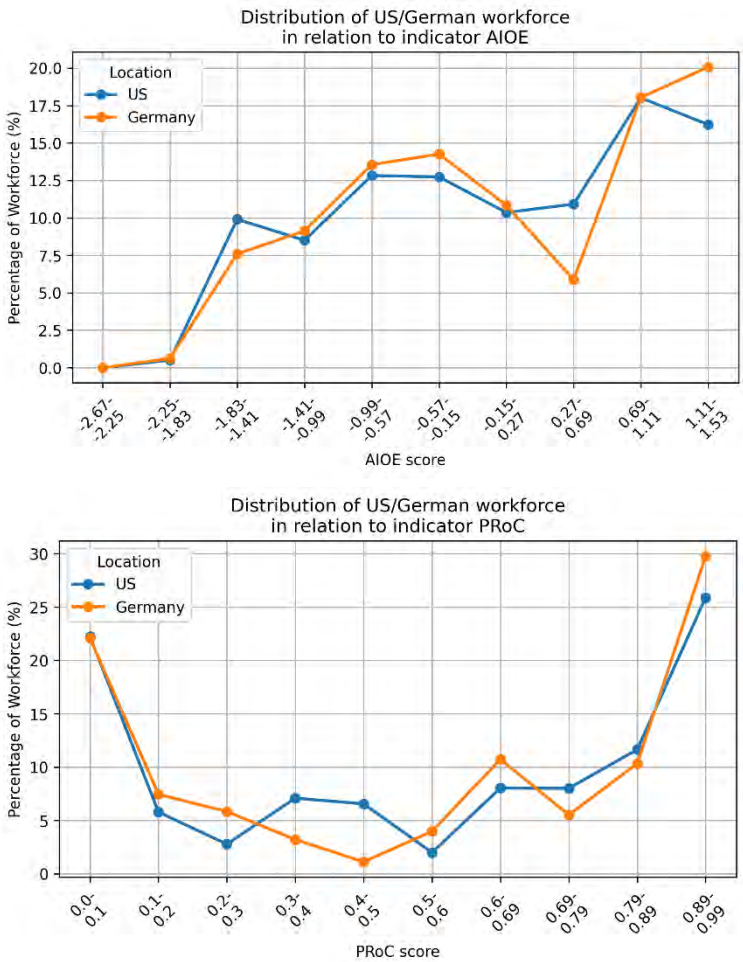


Figure 1: Comparison of the distribution of AIOE and PRoC scores in the German and US labour market (source: own elaboration, 2024)

3 Results

3.1 National level

Figure 2 presents the assignment of occupational groups in the matrix on the German national scale. The size of the bubbles corresponds to the size of the KldB-5-(pseudo)-class, with the two digitalisation indicators assigned to locate them along the x- (PRoC) and y-axis (AIOE). For the definition of the delimitations between the quadrants, we use the weighted medians as done in Fossen & Sorgner (2019), located at 0.66 along the PRoC, and at 0.09 along the AIOE-scale.

Comparing the results to the outcomes of the original study, we see a less narrow distribution of scores along the y-axis, while the AIOE scores used in the presented research seem to be more broadly scattered. This can be attributed to the differences in distributions between the original (Felten et al., 2018) and updated (Felten et al., 2021) AI-related scores.

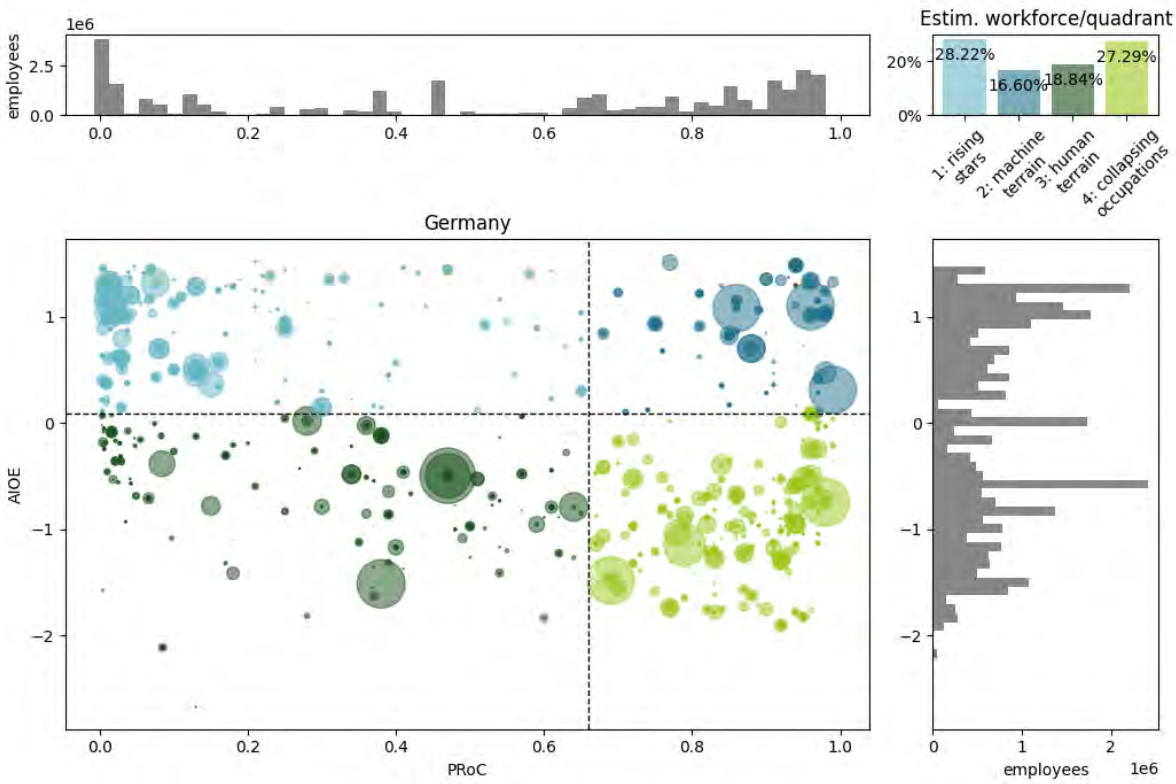


Figure 2: Distribution of occupational groups across the quadrants in the German labour market (source: own elaboration, 2024)

While PRoC scores display a distribution with many values on the both ends of the scale, AIOE follows a more bi-modal shape (as also displayed in Figure 1). Interestingly, a distribution of workers across the same four quadrants is similar throughout the country as either quadrant 1 (in 105, mostly urban districts) or quadrant 4 (in 295 districts) dominate the regional labour markets. There is no German district where workers within quadrant 2 or quadrant 3 make up the relative majority of the workforce.

3.2 Regional level

Figure 3 displays the distribution of workforce across the quadrants in the 400 German districts, presenting regional differences, which are discussed in more detail below.

Quadrant 1 (Rising stars)

While the share of workers in the "rising stars" quadrant is generally higher in urban regions, it is not exclusive to the regions with the largest absolute population sizes. Leading the list is the financial hub of Frankfurt, where 38.59% of employees work within the "rising stars" quadrant, primarily in banking, business organization, and strategy supervisory roles. Interestingly, the financial sector just makes up a smaller part of the workforce in this quadrant. The air travel industry, particularly skilled service roles in air traffic (including flight attendants, ground staff, and cabin crew), also plays a key part.

The air travel sector also boosts the share of first-quadrant workers in Freising (37.13%), which is home to Munich Airport. In Munich itself, a large share of the workforce (36.71%) falls into this category too. Besides this, employees in this quadrant are also assigned to the sectors of business organization and administration, banking, and software development. A good example for the role the IT sector plays within the "rising stars" quadrant is Böblingen (35.06%), a semi-rural district with a high share of skilled workers due to the presence of German headquarters for software companies like HP and IBM.

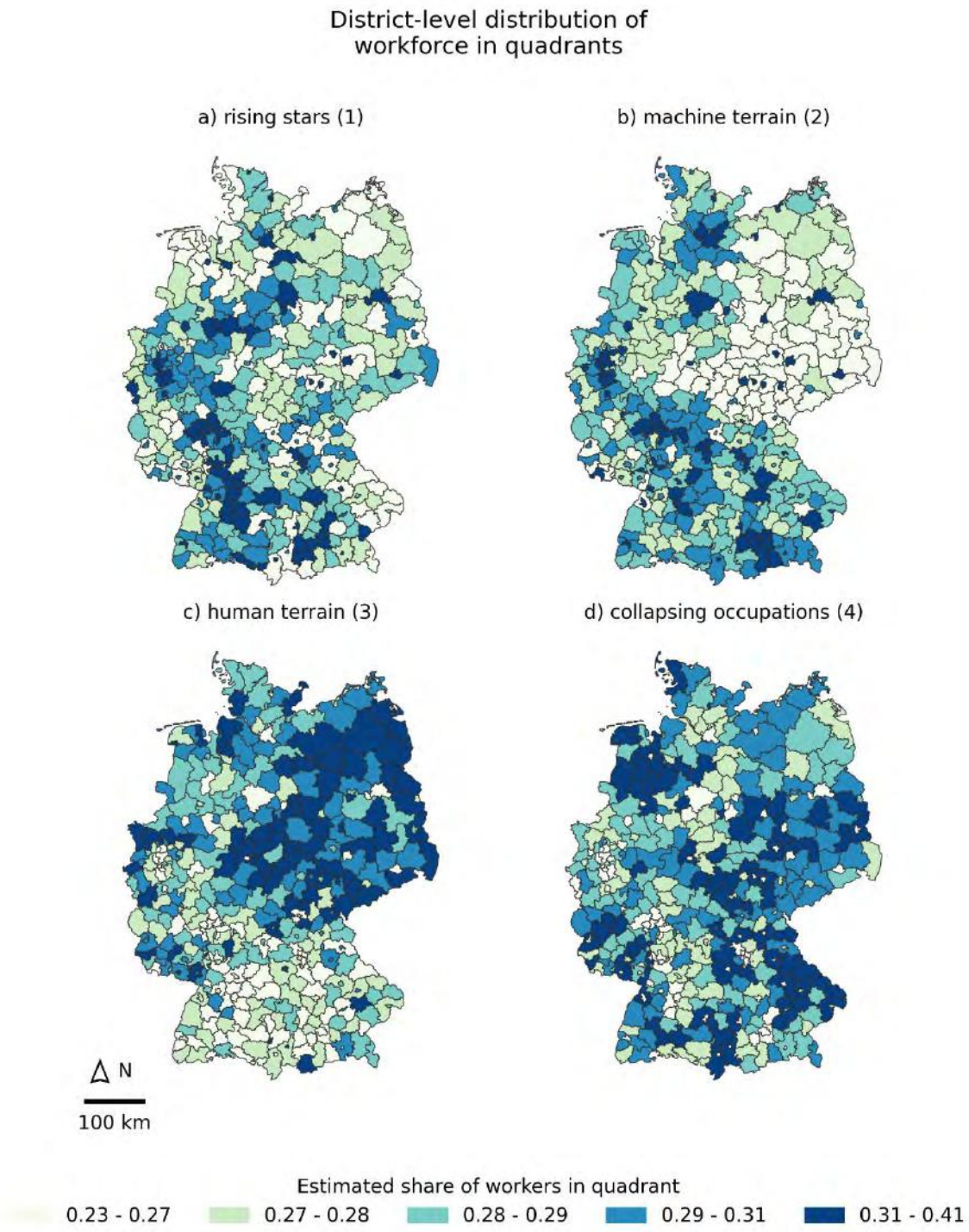


Figure 3: District level distribution of workforce in quadrants (source: own elaboration, 2024)

Other smaller, less populated districts with a high concentration of "rising stars" include Ingolstadt (36.23%), Darmstadt (34.76%), and Karlsruhe (34.62%). These districts are the seats of major companies, such as Audi in Ingolstadt, or have universities with strong technological programs, like the TU Darmstadt and the University of Erlangen–Nuremberg. Conversely, regions with the lowest scores in this quadrant are predominantly rural, such as Hersfeld-Rotenburg (20.79%), Teltow-Fläming (21.65%), and Garmisch-Partenkirchen (21.76%). Hersfeld-Rotenburg has a large share of workers in logistics and warehousing, working for example for Amazon, which operates two fulfilment centres in the area (Amalyze, n.d.). The logistics sector is also established in Teltow-Fläming. Here it is interesting to point out that this district is situated directly south of Berlin, demonstrating a constellation of strong contrasts despite a geographic proximity. In the German capital, 32.36% of the workforce is assigned to the first quadrant.

Quadrant 2 (Machine terrain)

In contrast to the "rising stars" quadrant, occupations in the "machine terrain" quadrant are more closely associated with the country's larger urban regions. Leading the ranking is the Main-Taunus district (28.03%), located next to the financial centre of Frankfurt am Main, followed by Düsseldorf (26.20%), Munich (23.43%), and Bonn (23.37%). However, in neither of these regions has this quadrant the most employees assigned to, in most cases the dominating quadrant is the first one. This suggests that with technological advancement, current population centres might become focal points for both the transformative and destructive effects of digitalisation. At the same time, the share of jobs in the "collapsing occupations" quadrant is relatively low in these districts, which may indicate some resilience of the local labour markets.

At the lower end of the spectrum, this category is more prevalent in rural regions, as seen in the three regions with the lowest scores: Dingolfing-Landau (8.33%), Börde (10.09%), and Sonneberg (10.36%). However, as in the case of regions with high shares of workers working in quadrant 1, we also find an urban region in this collection, namely Emden (10.51%), a small town in Lower Saxony. This district has a North Sea port, a shipyard and features a relatively high share of jobs in warehousing and logistics.

Quadrant 3 (Human terrain)

Higher scores in the third quadrant are mostly found in smaller, yet urban, regional centres such as Herne (26.52%), the above-mentioned Emden (24.47%), and Suhl, Stadt (24.46%). As with quadrant 2, quadrant 3 is also never the dominating one in the German districts. Interestingly, higher shares of the second quadrant are found in regions of the former East Germany, although in no region does the share of workers in this quadrant exceed 27%. In contrast, lower scores are found in the country's larger population centres, such as Frankfurt am Main (12.03%), the district of the city of Munich (12.73%), and region with the same name surrounding the Bavarian capital (12.92%).

Quadrant 4 (Collapsing occupations)

For decision-makers, the "collapsing occupations" quadrant is especially important, which is seemingly more prevalent in the labour markets of rural regions, such as Dingolfing-Landau (37.94%), Börde (36.38%), and Hersfeld-Rotenburg (35.92%). Regions with high shares of workers in this quadrant are spread relatively evenly across Germany and are predominantly rural. However, some mid-sized urban regions also feature a significant share of workers in this category. For example, Neumünster (35.51%) has a relatively high number of employees in the security and warehousing sectors.

Districts with low shares of workers in this quadrant are predominantly urban. These include cities with universities, such as Erlangen (17.80%), Heidelberg (19.37%), and Darmstadt (19.48%), as well as major economic centres like Munich (18.90%), Bonn (19.74%), and Düsseldorf (20.17%). Among the 10 regions

with the lowest share of employees in this quadrant, there are no rural areas represented, and, aside from Jena (19.74%), all are located in former West Germany.

3.3 Limitations

The combination of the two indicators (AIOE/AIGE and PRoC) provides easily interpretable results for assessing labour market transformations on a geographic level. At the same time, it is important to highlight the trade-offs that come with working with indicators that are based on standardised characteristics of occupations.

Occupational groups are difficult to capture in rigid taxonomies. Job roles and tasks vary across sectors and locations. Especially in the field of AI a more universal, skill-based approach to retrieve digitalisation indicators might prove to be more accurate (Frank et al., 2019), and can be used in case studies (Colombo et al., 2019; Lennon et al., 2023). Alternative indicators could also be incorporated, such as the Suitability for Machine Learning (Brynjolfsson et al., 2018), task routinisation (Biagi and Sebastian, 2020), and/or these could be complemented with information obtained through surveys, such as PIAAC (Nedelkoska and Quintini, 2018) to increase their validity even more.

The differences between labour markets in various countries should also be considered, especially when the indicators were developed based on taxonomies in another country than the one they are applied onto. Both the AIOE/AIGE and PRoC indicators relate to the US-labour market, which can be characterised through less strict worker protections and regulations in comparison to Germany. Therefore, we could expect that the transformative and disruptive effects of digitalisation might be unfolding faster in the USA than in Germany.

Regardless, such transformations seem to be ongoing in Germany as well, for example in car manufacturing: Volkswagen in Wolfsburg cited high labour costs as a reason for potential factory closures (Nilsson, 2024). The sector of logistics is also affected, as shown in the layoff of employees in the Amazon fulfilment centre FRA3 in Bad Hersfeld (Meier-Maaz, 2024). This fulfilment centre located in the district Hersfeld-Rotenburg, which features a high share of workers in the fourth quadrant.

Task-based classification offers a snapshot of the current state of jobs but does not predict future developments. Especially the “Future of Employment” report received criticism of generally overestimating the extent of computerisation potentials (Coelli and Borland, 2019; Frey, 2021), due to its premise being computational bottlenecks excluding policy decisions, organisational structures or the willingness of companies to replace workers through computerisation. Additionally, the more detailed the breakdown of tasks linked to an occupation is, the lower the automation potential of a given occupation becomes (Barbieri et al., 2020; Bonin et al., 2015). This means, differences between occupations assigned to different quadrants might be less severe than expected.

Another form of simplification lies in the concepts of "destructive" and "transformative" effects, their mechanisms can be more complex than they appear. Digitalisation can be disruptive for a particular occupational group, but at the same time it can also free its workers from certain duties, enabling them to take on new tasks within the same occupation (Samaan, 2023).

This means that the task distribution between humans and machines are more fluid and flexible, which can be interpreted in both optimistic and pessimistic ways. In this view it is also important to highlight the role of policy decisions and the potentials of job democratisation (such as unions) that might contribute to less severe destructive effects of digitalisation in the labour market (Spencer, 2023).

Data quality also presents a challenge. Regional employment statistics were available only at a relatively broad level for this study. For instance, the third level of the KldB taxonomy includes just 140 categories—

considerably fewer than the 702 classes used by Felten et al. (2021) and Frey and Osborne (2017)—which results in reduced granularity. While the equal distribution approach can assign digitalisation indicators reasonably well, it provides only broad estimations instead of precise predictions.

Furthermore, regional employment data is incomplete, as occupational groups with fewer than 40 employees are excluded from regional statistics. This exclusion affects data granularity, as 109 of the 400 districts have masked data for more than 50 of the 144 occupational groups.

To address this limitation, the available (un-masked) numbers on the third level of the taxonomy were removed from the totals on the second level and and the remaining employess were evenly distributed in across the remaining third level groups. In total 123,183 people in the worforce have been assigned to employment groups using this estimation method, which makes up just 0.36 per cent of the total workforce. Therefore, even with the missing information on the district level, the availably of data does not exercise a significant influence on the validity of the output. Data granularity however still remains an issue.

4 Discussion

Aim of this paper was to present a method for applying occupation-based labour market indicators of digitalisation onto regional labour market statistics. The presented approach is easily replicable and can contriubte to a better understanding of the structures and potential future trends of regional labour markets. Although the findings are preliminary, they reveal important patterns and show a potential for further polarisation of the German labour market at both the regional and the national level.

An interesting topic for further research could be an analysis of interactions between neigbhouring urban and rural regions with vastly different scores. The analysis shows that regions with a dominating role of quadrant 1 are in many cases (urban) ilsands sourrounded by regions where quadrant 4 employs the majority of the work force. A good example for this is the constellation between Berlin and Teltow-Fläming. The German capital shows a clear dominance of Q1 (35.43%) over Q4 (25.03%), while its neighbour, has an opposite distribution of the workforce (Q1 makes up 23.44 and Q4 38.49% of the workforce).

For this reason, further research should also focus on analysing labour market transformations not just at a national scale but also within local contexts. Understanding the structures of the labour market on a regional and local level can be relevant for planners and decision makers, for example in identifying an over-reliance on a a few economic sector or a dominant employer.

Aim of the presented research was to discuss a potentially viable way of projecting digitalisation indicators onto spatial labour market statistics. While the dominance of either quadrant 1 and 4 signalises potential polarisation tendencies within the labour markets, the definition of concrete policy decisions needs deeper, more focussed and local research. This would include additional dimensions of digitalisation, demographic attributes of the labour workforce, the dominance of certain sectors, stakeholders, or companies, or the physical infrastructure located within the regions. However, the presented method can provide a good overview of areas researchers should focus on and dive deeper in when discussing the above mentioned (or further) points and questions.

5 References

Amalyze, n.d. Amazon Logistikzentrum – Standorte der Versandzentren in Deutschland. Amalyze. URL https://www.amalyze.com/glossar/amazon-logistikzentrum/ (accessed 1.21.25).

Autor, D.H., Handel, M.J., 2013. Putting Tasks to the Test: Human Capital, Job Tasks, and Wages. J. Labor Econ. 31, S59–S96. https://doi.org/10.1086/669332

Barbieri, L., Mussida, C., Piva, M., Vivarelli, M., 2020. Testing the Employment and Skill Impact of New Technologies, in: Zimmermann, K.F. (Ed.), Handbook of Labor, Human Resources and Population Economics. Springer International Publishing, Cham, pp. 1–27. https://doi.org/10.1007/978-3-319-57365-6_1-1

Biagi, F., Sebastian, R., 2020. Technologies and "Routinization," in: Zimmermann, K.F. (Ed.), Handbook of Labor, Human Resources and Population Economics. Springer International Publishing, Cham, pp. 1–17. https://doi.org/10.1007/978-3-319-57365-6_8-2

Bonin, H., Gregory, T., Zieran, U., 2015. Übertragung der Studie von Frey/Osborne (2013) auf Deutschland. Zentrum für Europäische Wirtschaftsforschung, Mannheim.

Brynjolfsson, E., Mitchell, T., Rock, D., 2018. What Can Machines Learn, and What Does It Mean for Occupations and the Economy? AEA Pap. Proc. 108, 43–47. https://doi.org/10.1257/pandp.20181019

Brzeski, C., 2015. Die Roboter kommen : Folgen der Automatisierung für den deutschen Arbeitsmarkt.

Coelli, M.B., Borland, J., 2019. Behind the Headline Number: Why not to Rely on Frey and Osborne's Predictions of Potential Job Loss from Automation. https://doi.org/10.2139/ssrn.3472764

Colombo, E., Mercorio, F., Mezzanzanica, M., 2019. AI meets labor market: Exploring the link between automation and skills. Inf. Econ. Policy, The Economics of Artificial Intelligence and Machine Learning 47, 27–37. https://doi.org/10.1016/j.infoecopol.2019.05.003

Crowley, F., Doran, J., 2023. The geography of job automation in Ireland: what urban areas are most at risk? Ann. Reg. Sci. 71, 727–745. https://doi.org/10.1007/s00168-022-01180-4

Dengler, K., Matthes, B., 2018. The impacts of digital transformation on the labour market: Substitution potentials of occupations in Germany. Technol. Forecast. Soc. Change 137, 304–316. https://doi.org/10.1016/j.techfore.2018.09.024

Deranty, J.-P., Corbin, T., 2024. Artificial intelligence and work: a critical review of recent research from the social sciences. AI Soc. 39, 675–691. https://doi.org/10.1007/s00146-022-01496-x

Felten, E., Raj, M., Seamans, R., 2021. Occupational, industry, and geographic exposure to artificial intelligence: A novel dataset and its potential uses. Strateg. Manag. J. 42, 2195–2217. https://doi.org/10.1002/smj.3286

Felten, E.W., Raj, M., Seamans, R., 2018. A Method to Link Advances in Artificial Intelligence to Occupational Abilities. AEA Pap. Proc. 108, 54–57. https://doi.org/10.1257/pandp.20181021

Fernández-Macías, E., Bisello, M., 2022. A Comprehensive Taxonomy of Tasks for Assessing the Impact of New Technologies on Work. Soc. Indic. Res. 159, 821–841. https://doi.org/10.1007/s11205-021-02768-7

Fossen, F., Sorgner, A., 2019. Mapping the Future of Occupations: Transformative and Destructive Effects of New Digital Technologies on Jobs. Foresight STI Gov. 13, 10–18.

Frank, M.R., Autor, D., Bessen, J.E., Brynjolfsson, E., Cebrian, M., Deming, D.J., Feldman, M., Groh, M., Lobo, J., Moro, E., Wang, D., Youn, H., Rahwan, I., 2019. Toward understanding the impact of artificial intelligence on labor. Proc. Natl. Acad. Sci. 116, 6531–6539. https://doi.org/10.1073/pnas.1900949116

Frank, M.R., Sun, L., Cebrian, M., Youn, H., Rahwan, I., 2018. Small cities face greater impact from automation. J. R. Soc. Interface 15, 20170946. https://doi.org/10.1098/rsif.2017.0946

Frey, C.B., Osborne, M., 2024. Generative AI and the future of work: a reappraisal. Brown J. World Aff. 30.

Frey, C.B., Osborne, M., 2013. The Future of Employment, Oxford Martin Programme on Technology and Employment. University of Oxford, Oxford.

Frey, C.B., Osborne, M.A., 2017. The future of employment: How susceptible are jobs to computerisation? Technol. Forecast. Soc. Change 114, 254–280. https://doi.org/10.1016/j.techfore.2016.08.019

Frey, P., 2021. Visions of Automation: A Comparative Discussion of Two Approaches. Societies 11, 63. https://doi.org/10.3390/soc11020063

Hat, K., Stoeglehner, G., 2020. Spatial dimension of the employment market exposition to digitalisation—the case of Austria. Sustainability 12, 1–29. https://doi.org/10.3390/su12051852

Hunter, J.D., 2007. Matplotlib: A 2D graphics environment. Comput. Sci. Eng. 9, 90–95. https://doi.org/10.1109/MCSE.2007.55

Jordahl, K., Bossche, J.V. den, Fleischmann, M., Wasserman, J., McBride, J., Gerard, J., Tratner, J., Perry, M., Badaracco, A.G., Farmer, C., Hjelle, G.A., Snow, A.D., Cochran, M., Gillies, S., Culbertson, L., Bartos, M., Eubank, N., maxalbert, Bilogur, A., Rey, S., Ren, C., Arribas-Bel, D., Wasser, L., Wolf, L.J., Journois, M., Wilson, J., Greenhall, A., Holdgraf, C., Filipe, Leblanc, F., 2020. geopandas/geopandas: v0.8.1. https://doi.org/10.5281/zenodo.3946761

Lennon, C., Zilian, L.S., Zilian, S.S., 2023. Digitalisation of occupations—Developing an indicator based on digital skill requirements. PLOS ONE 18, e0278281. https://doi.org/10.1371/journal.pone.0278281

Meier-Maaz, N., 2024. Stellenabbau bei Amazon: Weitere Einschnitte am Bad Hersfelder Standort FRA3 [WWW Document]. HNA. URL https://www.hna.de/lokales/rotenburg-bebra/bad-hersfeld-ort56532/stellenabbau-amazon-bad-hersfeld-logistikzentrum-standort-fra3-93036122.html (accessed 10.28.24).

Nedelkoska, L., Quintini, G., 2018. Automation, skills use and training. OECD, Paris. https://doi.org/10.1787/2e2f4eea-en

Nilsson, P., 2024. 'There would be no Wolfsburg without Volkswagen': carmaker's plans shake home town [WWW Document]. URL https://www.ft.com/content/8332c930-0991-43db-b2c4-2e9121c9faeb (accessed 10.16.24).

OpenAI, 2024. ChatGPT (Oct 2024 version).

Pandas development team, 2020. pandas-dev/pandas: Pandas. https://doi.org/10.5281/zenodo.3509134

Samaan, D., 2023. Work in a new world, in: Introduction to Digital Humanism: A Textbook. pp. 543–556. https://doi.org/10.1007/978-3-031-45304-5_34

Sharifi, A., Khavarian-Garmsir, A.R., Allam, Z., Asadzadeh, A., 2023. Progress and prospects in planning: A bibliometric review of literature in Urban Studies and Regional and Urban Planning, 1956–2022. Prog. Plan., Progress and prospects in planning: A bibliometric review of literature in Urban Studies and Regional and Urban Planning, 1956–2022 173, 100740. https://doi.org/10.1016/j.progress.2023.100740

Spencer, D.A., 2023. Technology and work: Past lessons and future directions. Technol. Soc. 74, 102294. https://doi.org/10.1016/j.techsoc.2023.102294

Research Paper

A Digital-twin Based Conservation of Campus Historic Buildings under Sustainable Development Framework

Naifu Liu, School of Architecture and Design, Harbin Institute of Technology, China
Xiaoxu Liang, Department of Architecture and Design, Politecnico di Torino, Italy
Yu Zhang, School of Architecture and Design, Harbin Institute of Technology, China

Abstract

The construction of Chinese campuses has entered a phase focused on existing assets, and a number of campus buildings recognized as built heritage have emerged. However, there is a lack of a comprehensive sustainable development framework for the conservation and renovation of these buildings. This paper first identifies the sustainable development goals for historic buildings in campuses through literature review and theoretical analysis. Subsequently, a sustainable development framework for campus historic buildings integrated with Digital Twins technology is proposed, with applications of certain aspects of the framework illustrated through case studies. This research contributes to the theoretical understanding of digital twin applications in campus historic buildings, incorporating sustainable development principles. Additionally, it provides a reference for applying the digital twin sustainable development framework in other practical projects.

Keywords

Sustainable Development, Digital Twins, Campus, Historic Buildings, Framework

1. Introduction

The construction of Chinese campuses has gradually reached a saturation point, with campus buildings entering a phase of stock development. Many historic campuses have buildings recognized as cultural heritage that urgently need conservation and renovation. As an emerging computer technology, Digital Twins creates virtual simulation models of buildings, enabling real-time monitoring, fault diagnosis, and trend prediction for systems. This technology provides a new perspective and tool for building operation, maintenance, and renovation management. Although numerous studies have applied Digital Twins for the conservation and renovation of built heritage, a comprehensive Digital-Twin based sustainable development framework for campus historic buildings is lacking.

To address this gap, a literature review was conducted on related topics. By reviewing theories related to historic buildings, built heritage preservation, and relevant national laws and regulations, combined with existing research on campus historic buildings, sustainable development goals for campus historic

buildings were identified. Furthermore, an extensive review of Digital Twins applications in campuses and built heritage was conducted to outline existing frameworks. By integrating the existing frameworks with the sustainable development goals, a new framework is proposed. Based on this, the application of part of the theoretical framework was initially realized through the introduction of case-study building and the construction of a Digital Twins platform.

1.1. Sustainable development goals for campus historic buildings

The principles of authenticity and integrity mentioned in the Venice Charter remain central to the conservation of built heritage toady. These principles emphasize the authentic and complete preservation of a building's original appearance, materials, and surrounding environment, and have driven theoretical and regulatory developments in built heritage preservation worldwide. In 2015, China's Cultural Relics Protection Law specified that the protection of cultural relics should follow a process of investigation, assessment, planning, and implementation, with an evaluation of historical, artistic, and scientific value being key to determining graded protection levels (The Information Office of the State Council, 2016). Protection measures should focus on the structure, materials, techniques, functions, and environment of the heritage, maintaining its authenticity (Lin, 2012). Integrity, on the other hand, requires that the scope of heritage protection be defined based on its protection level and legal boundaries, emphasizing the coordinated protection of external and internal spaces (Chen *et al.*, 2022).

As modern built heritage, campus historic buildings in China should prioritize preventive conservation. For example, a Historic Building Information Model based multi-indicator preventive conservation platform can effectively reduce maintenance costs (Mora, 2021). Since the interior and exterior spaces of these buildings will continue to serve faculty and students for the long term, space performance and functionality should be optimized within permissible limits, promoting user well-being. A research in China used the Nanjing University clock tower as an example, explored reuse strategies under Chinese regulations that focus on authentically preserving architectural style, structure, materials, surrounding environment, and functional upgrades, following a process from value assessment to planned restoration (Wang *et al.*, 2022). Another research in China developed a conservation assessment framework for campus historic buildings, using quantitative methods such as AHP (Analytic Hierarchy Process), which includes value protection, use protection, safety measures, maintenance, and user perception dimensions(Huang *et al.*, 2024). With the development of emerging technologies like Digital Twins and artificial intelligence, the goals of sustainable building conservation are expanding to include human-centered values. Public participation in decision-making and social media promotion play increasingly important roles in heritage conservation and cultural value continuity (Rios, 2024). Resilience, as the capacity of heritage to withstand rapid disasters and long-term climate change, is also gaining importance

in conservation and maintenance decision-making (Esposito *et al.*, 2021). Lastly, sustainability encompasses areas such as sustainable tourism management, green performance improvements, and the use of eco-friendly materials (Galiano-Garrigós *et al.*, 2024).

In summary, the theoretical framework for the conservation of campus historic buildings proposed in this paper is based on three main sustainable goals:

1. Conservation of Historical and Cultural Value - Maintaining the building's appearance, storing digital data, and promoting online dissemination of building history to integrate both physical and digital environments.

2. Enhancement of Built Environment Resilience - Aiming to respond long-term environmental changes, it's necessary to ensure structural safety, improve energy performance to maintain indoor environmental stability, and reduce carbon emissions.

3. Promotion of Users' Well-being - Enhancing users' involvement in decision-making of heritage operation, maintenance, and renovation to increase their satisfaction with functional experiences and the heritage environment.

1.2. The application of Digital Twins technology in built heritage and campuses

Digital Twins can create a digital model by integrating static information and real-time data that reflect the state of physical entities. This enables a two-way interaction between the virtual and real systems, allowing for management, analysis, and prediction of the system (Dang, 2023). The establishment of a Digital Twins platform generally includes the setup of the Internet of Things (IoT), collection of static and real-time data, creation of a visual virtual model integrating multi-source data, and development of a decision support system based on computational technologies such as cloud computing or artificial intelligence.

Digital Twins technology has been widely applied in the conservation of built heritage, especially in older buildings. First, assessing and predicting the structural performance of heritage is crucial for preserving their integrity. A research proposed a risk assessment framework based on Digital Twins using low-cost IoT sensors and a Structural Health Monitoring system (Machete *et al.*, 2023). Another research developed a Digital Twins framework for assessing structural risk by comparing the geometric differences in 3D reconstruction models of heritage at different time points (Kong, 2023). Second, parameters of the physical environment within buildings, such as temperature and humidity, have been shown to impact heritage preservation. Thus, enhancing building energy performance not only promotes energy efficiency but also improves the physical environment surrounding the internal structure of the buildings. A research proposed a connected framework that integrates performance data detected by sensors within

Historic Building Information Model, enabling bidirectional data transfer (Moyano *et al.*, 2023). There is another study integrating Building Information Model and Building Energy Model to develop a comprehensive framework used to conduct real-time monitoring and assessment of building performance, as well as providing multi-criteria prediction for various intervention combination (Massafra, Predari and Gulli, 2022). Finally, many studies aim to apply Digital Twins in heritage management. For example, a project used system dynamics to incorporate stakeholder perspectives related to heritage usage into a conservation framework, which includes multi-source data collection, integration, and analysis to encourage public participation in decision-making (Lazari *et al.*, 2024).

Campuses have significant energy-saving potential, with lighting accounting for approximately 23-42% of the total energy consumption in educational buildings (Lizana, 2018). Therefore, current applications of Digital Twins in campuses mainly focus on enhancing energy performance and real-time safety management. A research in China introduced a smart campus system developed based on Unity3D, improving the teaching and management levels of the campus (Han *et al.*, 2022). Another researcher used a digital twin platform combined with a BP neural network model to predict campus building electricity consumption by considering various main factors to aid operational decisions (Han *et al.*, 2024). However, there are few Digital-Twin based frameworks applied for campus historic buildings, highlighting the need to adapt existing frameworks to meet the actual requirements of campuses.

According to what mentioned above, in first section, this study has reviewed related literature especially existing digital-twin based frameworks in these studies and proposed several main sustainable development goals for campus historic buildings. The second section explains the research methods and proposes the Digital-Twin based theoretical framework of this paper. In the third section, the study provides basic information of the case study building, including its history, cultural value, site situation, current condition and renovation needs. In addition, the fourth section presents the research results: the construction process of the Digital Twins platform for the campus and its applications in the conservation and renovation of the case study building have been demonstrated in this part. Finally, the last section covers the conclusion of the paper.

2. Methodology and framework

This is a preliminary study employing a series of qualitative research methods, including literature review, theoretical analysis, and case study. Therefore, the main contribution of this paper is the proposal of a digital-twin based sustainable development framework for campus historic buildings. On the basis of the framework proposed through reviewing of multiple related topics, historical and current information of the case study building are collected and analyzed to identify its renovation needs. In addition, the construction of a Digital Twins platform further demonstrates the practical application of parts of the

theoretical framework, partially validating its feasibility, and a future research plan focused on quantitative methods has been developed.

The proposed Digital-Twin based sustainable theoretical framework for campus historic buildings is as follows (see Fig.1): First, a Digital Twins platform is built following a sequence of IoT setup, data collection, visualization modeling, integrated simulation and prediction systems establishment. And the real-time data from the visualization platform will be imported into multi-criteria evaluation system to assess the current state of the building. In addition, by use of simulation and prediction system, relation mapping of multi-source data, including environmental parameters, structural vibration, energy consumption, and user behavior, are analyzed and established, which can be used for supporting decision-making. Finally, different Intervention plans can be simulated and evaluated to identify suitable decision, so that the mangers of the building can assess and manage in a closed loop process.

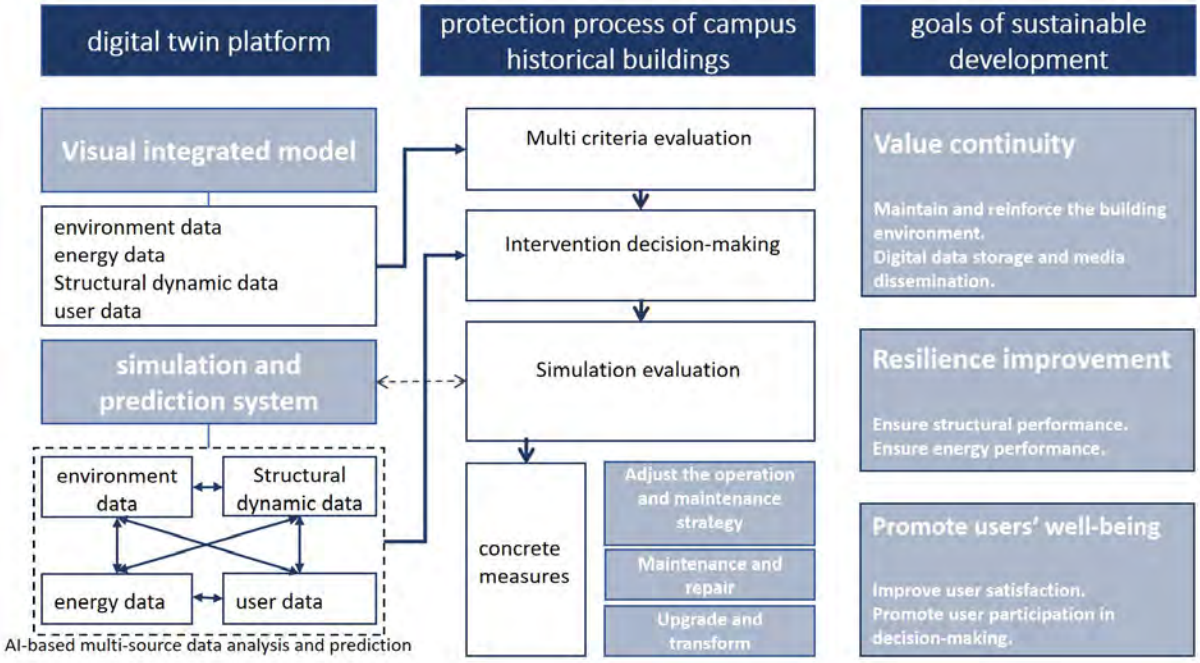


Figure 1. digital-twin based sustainable development framework . Source: Made by Author.

3. Case study

This paper takes the Zhu-Lou building in Harbin Institute of Technology (HIT) as an example, illustrating the construction process of Digital Twins platform and exploring its application on preservation and renewal of the case building.

3.1. Historical background

Harbin, the capital city of Heilongjiang Province is located in the northeast of China, with sever cold climate. At the end of the 19th century, Russia began building the China Eastern Railway in Harbin,

turning the city into an international commercial hub in the early 20th century, attracting many foreign settlers. The development during this period made the urban planning of Harbin obtain certain characteristics similar to European city, such as a radial road network and multiple city center nodes. It also left behind numerous buildings in European or Russian architectural styles (Harbin Municipal People's Government, 2024).

HIT was founded in 1920 with the mission of training engineering and technical personnel for the China Eastern Railway. In 1945, the school was jointly managed by China and the Soviet Union until it was taken over by China in 1950. Today, HIT has developed into a comprehensive university focusing on science and engineering. The Zhu-Lou building of HIT was initially constructed in 1959, located between the Electrical Engineering Building and the Mechanical Engineering Building, and was completed in 1965, marking a history of 59 years (see Fig.2). The overall floor plan of the building forms a T shape, with a central tower comprising 13 floors and two wings with 6 floors. It is connected to the Electrical Engineering Building and the Mechanical Engineering Building through a passage, forming a unified structure and enclosing a courtyard that faces the campus. The building includes spaces of different functions such as classrooms, laboratories, offices, and an auditorium, and is constructed with a reinforced concrete frame structure.

Figure 2. The location of the main building in campus one of HIT.
Source: Made by Author.

Figure 3. The picture of main building
Source: Made by Author.

3.2. Heritage value

The building adopts a Russian architectural style (see Fig.3), symbolizing the deep connection between HIT and Russian educational models, and fully reflecting the unique history of the institution. The facade of the main building facing Xidazhi Street serves as an important urban interface, becoming a symbol of the campus and the city alike, thus holding significant historical and cultural value.

Connected to the Electrical Engineering Building and the Mechanical Engineering Building, the Zhu-Lou building presents a dignified appearance. European architectural elements, such as columns and cornices, are used in the decoration, with intricate moldings, adding to its aesthetic appeal. Faculty and students highly recognize the building's aesthetic image, making it essential to the campus's identity and lending it high artistic value.

3.3. Current state of the building

The building is currently designated as a Category II protected structure by Harbin Planning Bureau. According to Article 44 of the *Regulations on the Protection of Historical and Cultural Cities in Harbin*, 'the original facade design, surface materials, main layout, and distinctive interior decorations of Category II protected buildings must not be altered' (Harbin Government Website, 2020). Thus, the appearance and primary spaces of the building cannot be modified. As the structure remains in good condition, exterior repainting, detailed repairs, and partial interior renovations were completed by 2020 (see Fig.4). Additionally, the main hall on the second and third floors in the center of the building was refurbished as a campus history exhibition area (see Fig.5). Thus, building's heritage value is preliminarily protected through physical restoration and the addition of exhibition spaces.

Currently, the building is primarily used by the School of Electronics and Information Engineering and the School of Astronautics, with its auditorium and exhibition areas open to the entire campus. However, the installation of modern office and research equipment has led to higher energy consumption. The changing behaviors and needs of students also call for more flexible learning spaces and greater autonomy in choosing study environments. Therefore, future updates and maintenance of the main building should prioritize enhancing the experience of faculty and students, optimizing energy performance, and improving the resilience of this heritage asset.

Figure 4. The renovated lobby staircase

Source: Made by Author.

Figure 5. The renovated school history exhibition hall.

Source: Made by Author.

4. Results

4.1. Digital Twins platform construction

Currently, Digital Twins models have been established across three campuses of HIT (see Fig.6). The main functions of this platform include safety management, teaching evaluation, and energy monitoring. The system is based on a C/S architecture model using the Unity3D engine, allowing for real-time transmission and rendering of model data and sensor data after programming setup. The architectural and environmental models are generated from integrated CAD drawings and elevation information of campus buildings. All sensors use the same data security protocols and are connected to the campus network. In addition to devices like cameras and electricity meters, controllable devices such as parking lot barriers are also included. By integrating and rendering static models with dynamic real-time information, a basic visual interactive platform has been formed.

Figure 6. The currently built campus digital twin platform. Source: Made by Author.

4.2. Application of the platform in campus historic building conservation

Given that the Zhu-Lou building's facade and structural body are well-preserved, and that some maintenance of the facade and interior was conducted before the platform's deployment, the current application of the platform focuses on enhancing energy performance and improving the user experience for faculty and students (see Fig.7).

The Digital Twins platform updates the detailed status of the building in real-time through IoT sensors, allowing for the collection of multi-source data including occupancy situation, energy consumption, and camera footage of different rooms. Specifically, the energy consumption and occupancy situation are uploaded to the managers, supporting to conduct better energy usage plans and reducing energy

consumption. What's more, the occupancy information is also synchronized to student service applications and the screens outside the classrooms, allowing students to choose study spaces conveniently.

Additionally, the camera footage can reflect the teaching quality as the status of teachers and students can be evaluated accurately by image recognition technology based on Artificial Intelligence. Also, with these cameras installed in the whole building, unexpected incidents can be monitored automatically to ensure users' safety.

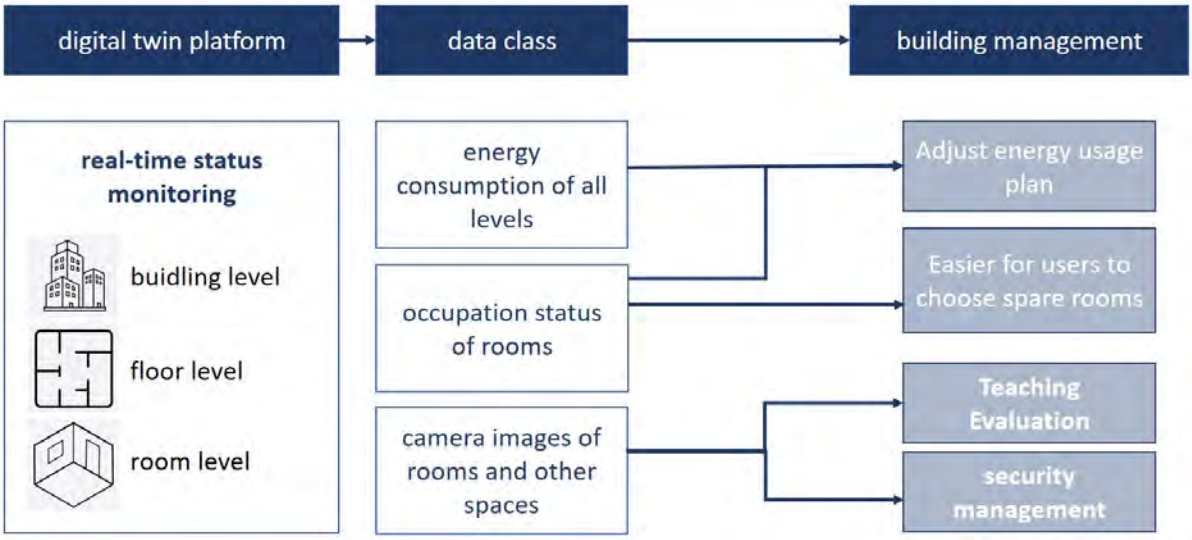


Figure 7. The current usage functions of the platform. Made by Author.

4.3. Future application plans of the platform

Currently, the platform's applications primarily focus on safety management and basic maintenance, but the potential value of the vast amounts of historical and real-time data stored on platform remains to be explored. Additionally, it is necessary to collect more types of building environmental data to develop an AI-based simulation and prediction system that can assist in decision-making from a quantitative perspective.

The theoretical framework proposed by the research institute is still relatively macro and foundational. To achieve the goal of protecting the historical architectural style and structural integrity through data-driven methods, it is critical to further refine the systems and pathways within the framework. For the multi-criteria assessment system, specific indicators and evaluation methods should be clarified, and the feasibility of further developments based on the platform should be assessed. For instance, periodic drone photography and 3D reconstruction can be utilized to identify physical changes in the facade. Moreover, a Structural Health Monitoring system can be employed for risk assessment and classification of structural components.

5. Conclusion

This paper focuses on the conservation and renovation of historical buildings in campuses, proposing a theoretical framework for the sustainable development of campus historic buildings based on Digital Twins technology and sustainable development concepts. Case studies illustrate the completed applications within the framework, providing preliminary references for the preservation and renovation of other campus historical buildings. Future research plans have also been formulated, with an emphasis on the collection of multidimensional data, the development of AI-based decision-making and assessment systems, and further quantitative and practical validation.

6. Funding

This research is funded by the National Natural Science Foundation of China: 'Research on the Space Paradigm Conversion and Architectural Generative Design for Primary and Secondary Schools' (grant number 52378013), 'Research on the Renewal Planning of Campus Buildings Based on Spatial Efficiency Evaluation' (grant number 52278026).

7. References

The State Council Information Office of the People's Republic of China. (2016) 'The Law of the People's Republic of China on the Protection of Cultural Relics', 26 February. Available at: http://www.scio.gov.cn/gwyzclxcfh/cfh/2016n_14283/2016n02y26r/xgzc_14330/202208/t20220808_294827.html (Accessed: 20 October 2024)

Lin, Y. (2012) *Basic Theory of Conservation of Chinese Architectural Heritage*. Beijing: China Architecture & Building Press.

Chen, M. et al. (2022) 'Value Analysis and Rehabilitation Strategies for the Former Qingdao Exchange Building—A Case Study of a Typical Modern Architectural Heritage in the Early 20th Century in China', *Buildings*, 12(7), p.980.

Mora, R. (2021) 'An historical building information modelling approach for the preventive conservation of historical constructions: Application to the Historical Library of Salamanca', *Automation in Construction*, 121 [online]. Available at: https://doi.org/10.1016/j.autcon.2020.103449 (Accessed: 20 October 2024)

Wang, H. et al. (2022) 'Construction Technologies and Conservation Strategies for the Bell Tower of Former Nanking University (Nanjing, China)—A Case Study of a Typical Architectural Heritage of the American Church School in the Late 19th Century', *Buildings*, 12(12) [online]. Available at: https://doi.org/10.3390/buildings12122251 (Accessed: 20 October 2024)

Huang, B. et al. (2024) 'Evaluation of the Protection of Historical Buildings in Universities Based on RCM-AHP-FCE', *Buildings*, 14(7) [online]. Available at: https://doi.org/10.3390/buildings14072078 (Accessed: 20 October 2024)

Rios, A.J. (2024) 'Industry 5.0, towards an enhanced built cultural heritage conservation practice', *Journal of Building Engineering*, 96 [online]. Available at: https://doi.org/10.1016/j.jobe.2024.110542 (Accessed: 20 October 2024)

Esposito, D. et al. (2021) 'A Multi Risk Analysis for the Planning, Management and Retrofit of Cultural Heritage in Historic Urban Districts', *Innovation in Urban and Regional Planning*, 146, pp.571-580.

Galiano-Garrigós, A. et al. (2024) 'The Influence of Visitors on Heritage Conservation: The Case of the Church of San Juan del Hospital, Valencia, Spain', *Applied Sciences*, 14(5) [online]. Available at: https://doi.org/10.3390/app14052065 (Accessed: 20 October 2024)

Dang, X. (2023) 'Digital twin applications on cultural world heritage sites in China: A state-of-the-art overview', *Journal of Cultural Heritage*, 64 [online]. Available at: https://doi.org/10.1016/j.culher.2023.10.005 (Accessed: 20 October 2024)

Machete, R. et al. (2023) 'A BIM-Based Model for Structural Health Monitoring of the Central Body of the Monserrate Palace: A First Approach', *Buildings*, 13(6) [online]. Available at: https://doi.org/10.3390/buildings13061532 (Accessed: 20 October 2024)

Kong, X. (2023) 'Preserving our heritage: A photogrammetry-based digital twin framework for monitoring deteriorations of historic structures', *Automation in Construction*, 152 [online]. Available at: https://doi.org/10.1016/j.autcon.2023.104928 (Accessed: 20 October 2024)

Moyano, J. et al. (2023) 'INTEGRATION OF DYNAMIC INFORMATION ON ENERGY PARAMETERS IN HBIM MODELS', *Remote Sensing and Spatial Information Sciences*, 48(2), pp.1089–1096.

Massafra, A., Predari, G. and Gulli, R. (2022) 'TOWARDS DIGITAL TWIN DRIVEN CULTURAL HERITAGE MANAGEMENT: A HBIM-BASED WORKFLOW FOR ENERGY IMPROVEMENT OF MODERN BUILDINGS', *Remote Sensing and Spatial Information Sciences*, 46(5) [online]. Available at: https://doi.org/10.5194/isprs-archives-XLVI-5-W1-2022-149-2022 (Accessed: 20 October 2024)

Lazari, V. et al. (2024) 'Digital twins-enabled heritage buildings management through social dynamics', *Journal of Cultural Heritage Management and Sustainable Development*, 14 [online]. Available at: https://www.emerald.com/insight/content/doi/10.1108/JCHMSD-08-2023-0136/full/html (Accessed: 20 October 2024)

Lizana, J. (2018) 'Energy assessment method towards low-carbon energy schools', *Energy*, 159 [online]. Available at: https://doi.org/10.1016/j.energy.2018.06.147 (Accessed: 20 October 2024)

Han, X. et al. (2022) 'Intelligent Campus System Design Based on Digital Twin', *Electronics*, 11(21) [online]. Available at: https://doi.org/10.3390/electronics11213437 (Accessed: 20 October 2024)

Han, F. et al. (2024) 'Predictive Analysis of a Building's Power Consumption Based on Digital Twin Platforms', *Energies*, 17 [online]. Available at: https://doi.org/10.3390/en17153692 (Accessed: 20 October 2024)

Harbin Municipal People's Government (2024) 'Historical evolution'. Available at: https://www.harbin.gov.cn/haerbin/c104476/list_rightcontent.shtml (Accessed: 20 October 2024)

Harbin Government Website (2020) 'Regulations on the Protection of Historical and Cultural Cities in Harbin City'. Available at: https://m.thepaper.cn/newsDetail_forward_6998436 (Accessed: 20 October 2024)

Research Paper

Construction of urban security risk intelligent attack and defense system based on TIM platform under climate change

——A case study of Lanxi City, Zhejiang Province, China

Wang Zijing, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, Shanghai 200092, China
Wen Xiaoyi*, Tongji Architectural Design (Group) Co., Ltd, Shanghai 200092, Country
College of Architecture and Urban Planning, Tongji University, Shanghai 200092, China
Shanghai Tongji Urban Planning & Design Institute Co., Ltd, Shanghai 200092, China
Wen Xiaosen, Ideal Space (Shanghai) Creative Design Co., Ltd, Shanghai 200092, China

Abstract

Currently, the world is experiencing unprecedented extreme weather, with some regions suffering from severe flooding. Against the backdrop of the rapid development of digital infrastructure such as big data, mobile internet, and cloud computing, how to apply the latest achievements in information technology to urban flood control and drainage is an urgent problem to be addressed. This study takes full advantage of new technologies and methods such as big data and AI, based on the TIM (Threat Intelligence Management) platform, to construct an intelligent offense-defense system for urban safety risks. Compared with the existing systems that are characterized by single functions, slow data loading, complex core algorithm steps, and a lack of defense systems, this system boasts significant advantages such as wide monitoring scope, scientific and efficient algorithms, rapid real-time response, and intelligent offense-defense. The study takes the flood risk attack and defense simulation of Lanxi City, a key flood control city in Zhejiang Province, China, as an example, focusing on the key technologies of urban intelligent "real-time perception, data analysis, monitoring and evaluation early warning, command and decision-making, and intelligent offensive and defensive simulation " in five aspects. It achieves real-time dynamic monitoring and simulation of all elements in the urban area, including "precipitation, runoff, pipe network, river network, surface, sluices, and pumps," By using the risk and disaster factors to simulate the attack to different degrees, calculate the attack scope and influence scope, take defensive measures, propose solutions and damage analysis. The application of the intelligent offense-defense system for urban safety has improved the scientificity and effectiveness of urban risk management, ensuring the safety and sustainable development of the city.

Keywords

climate change, urban flood risk, intelligent offense-defense, risk warning

1. Introduction

As global climate change intensifies, the frequency and intensity of extreme weather events are rapidly increasing. According to the United Nations Office for Disaster Risk Reduction's "Cost of Disasters 2000-2019" statistics, the number of disasters worldwide has risen "alarmingly" since the beginning of the 21st century, with the number of reported disasters rising from 4,212 to 7,348 compared with 1980-1999 and 2000-2019, including a 134% increase in floods. The risk of urban rainstorms and floods has greatly increased, posing a great threat to people's lives and property safety and social and economic development. In March 2022, the World Meteorological Organization (WMO) also asked relevant organizations and scholars around the world to take action to promote the construction of disaster early warning systems from the aspects of science and technology, policy and funding in the "Action Plan for All Early Warning".

At present, typical studies on intelligent urban flood management systems at home and abroad are quite abundant. Huang Jing et al. (Huang et al., 2019) proposed a simulation method of urban rainstorm and flood disaster early warning strategy based on agent modeling, and set three early warning strategies based on rainfall forecast, flood inundate and population exposure. The change of urban flood disaster risk under different early warning strategies was analyzed. Based on digital twin technology, Zhao Mengqi et al. (Zhao et al., 2024) established a digital-intelligent water control system in Binjiang district, including twin data mapping, mathematical model deduction, virtual and real interactive prevention, intelligent service linkage and other modules, for intelligent flood control in Binjiang district. Nardo et al. [3] (Nardo et al., 2013) put forward the application of the new water network in the Intelligent Water network (SWAN), which can do the early warning and monitoring of pipe network, and can also do the flood management of water resource basin, forecast water supply demand analysis and other functions through big data analysis. However, these studies often have different focuses and are not comprehensive enough. Some studies lack real-time monitoring and early warning function, and some lack the ability of attack and defense simulation of virtual and real game.

In view of these deficiencies, this study further optimized, through the combination of big data and artificial intelligence technology, fully filled the current five gaps in urban risk management - "no awareness of risk", "no technology with awareness", and then "no platform with technology", "no data with platform", "no learning and deduction with data". It has realized the four-step leap from instant perception, data fusion analysis, intelligent learning to offensive and defensive reasoning, and built a comprehensive monitoring and early warning platform for urban safety risks with an international perspective of "monitoring, warning, and quick disposal", effectively improving the city's response ability in the face of flood disasters.

2. Materials and key technologies

2.1. Overview of the study area

Lanxi City, located in the middle reaches of Qiantang River, China and the north edge of Jinqu Basin, is known as "the convergence of three rivers", "the waist of six rivers" and "the thoroughfares of seven provinces" since ancient times (Figure 1). Lanxi is an area with high incidence of Meiyu heavy rainfall. Affected by the backwater of Fuchunjiang Reservoir downstream, floods have always occurred frequently. The flood peak water level rises year by year and the flood control pressure increases sharply. In the 68 years from 1950 to 2017, there were 144 times of over-warning water level floods in 54 years, of which 48 times of over-critical water level floods occurred in 30 years. Frequent flood disasters cause great losses in Lanxi City, which seriously restricts the sustainable development of urban economy and ecological environment.

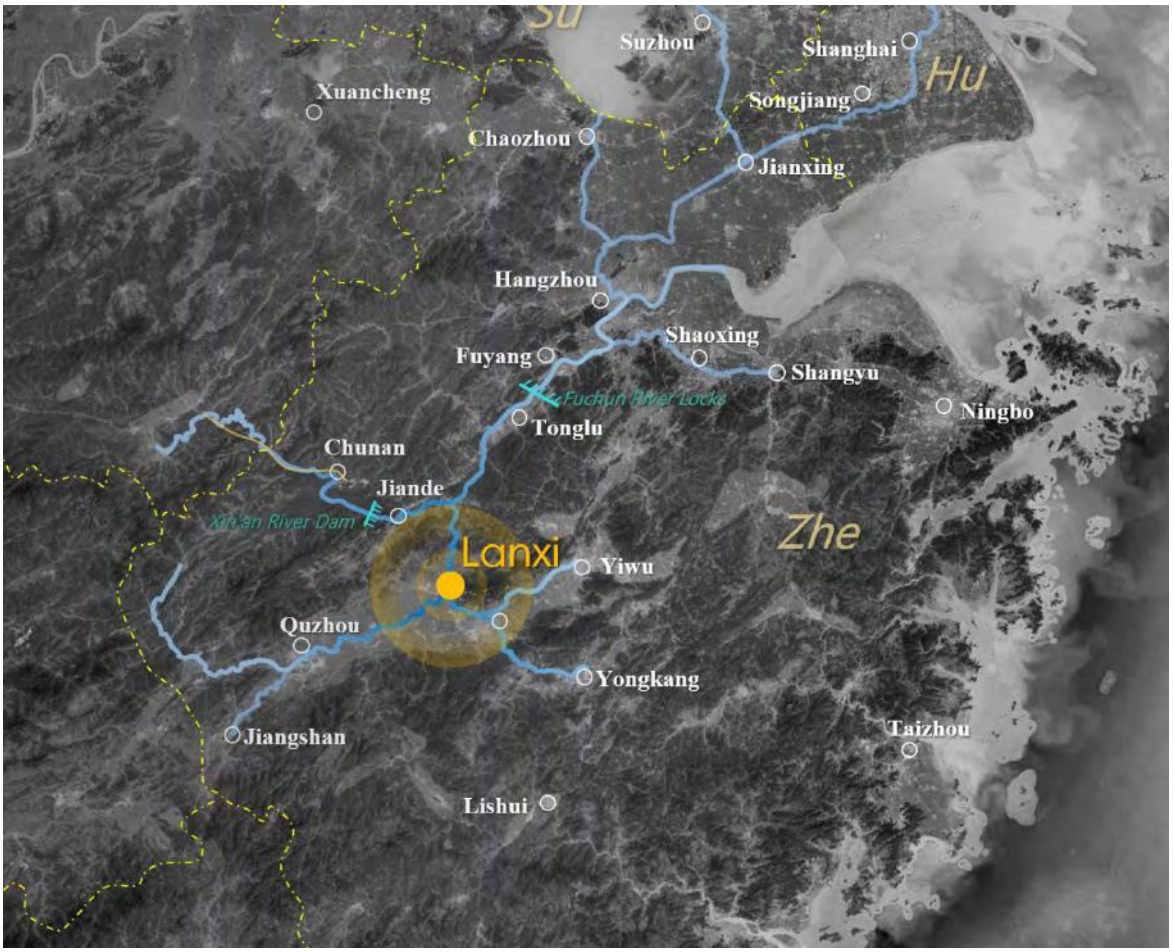


Figure 1. Overview of the study area. Source: ISOCARP.

2.2. The key technical problem of urban security risk intelligent attack and defense system construction

2.2.1. Integration and processing of multi-source data

This process involves collecting and standardising information from sensors, satellite imagery, weather data, GIS and historical flood data, and using advanced algorithms and machine learning to analyze the data to quickly and accurately predict flood risk. In addition, it is necessary to address the challenges of real-time data transmission and storage to ensure that the system can respond to emergencies in a timely manner. The system must have high scalability and reliable security measures to protect data integrity and privacy. This is the core technical problem of realizing efficient and accurate urban intelligent flood warning system.

2.2.2. Multi-party collaboration and resource scheduling

Urban security incidents often require multi-party collaboration between the government, relief agencies, and public service departments. How to consider the coordination and resource allocation among different roles in the simulation and simulation, and how to quickly and effectively organize the forces of all parties to linkage before, during and after the flood disaster is the key to achieve efficient distribution and use, and ensure the efficient, accurate and timely flow of emergency materials, rescue forces and information.

2.2.3. Population factor analysis and decision response

In urban security incidents, human behavior and decision-making often play a key role. The system should integrate multi-level and multi-dimensional data such as population density, socio-economic status, traffic flow, and historical flood disaster data in the simulation and calculation, fully consider factors such as crowd response, evacuation path selection, and emergency response decision-making, and incorporate them into the overall risk assessment to ensure personal safety and social stability in flood disasters.

2.2.4. Emergency decision support mechanism for emergencies

In the face of such a complex and fast-changing natural event as flood disaster, it is very important for the system to make efficient and scientific decisions at all stages of the event by combining the results of attack and defense calculation with actual operation and maintenance, so as to realize the sustainable guarantee of urban safe operation.

2.2.5. Verification and optimization of simulation results

In order to ensure the accuracy and reliability of the simulation results, the system should compare the game results with the dynamic monitoring data, and timely feedback and update. In the process of multiple inferences, machine learning and feedback mechanism are used to continuously optimize the algorithm, adjust and improve the model parameters and emergency strategies, so as to achieve the system to provide high-precision and high-reliability prediction and decision support under various complex situations.

2.3. Urban security risk intelligent attack and defense system to build the overall framework

The overall framework of the system is shown in Figure 2.

2.3.1. Integration and processing of multi-source data

Through the satellite communication network - satellite remote sensing, UAV detection, monitoring feedback, etc.; Internet - social forums, online public opinion, etc.; The mobile communication network - mass reporting, enterprise response, etc., and the electronic financial external network - surface sensing, statistical data, planning reports, etc., provide basic data support.

2.3.2. Integration and processing of multi-source data

The data layer is the foundation of the system and is responsible for storing and managing all kinds of raw data. The Internet monitoring database and government department database have been built. Through real-time perception, the system can obtain a variety of key data, including hydrology, meteorology, satellite remote sensing, geographic information, water-prone point information, flood rainfall, water level data and other Internet monitoring data, as well as population information, historical disaster records, urban roads, pipe networks, base stations and sluice layout and other government data.

2.3.3. Integration and processing of multi-source data

The system integrates many cutting-edge technologies such as video analysis, big data analysis, AI recognition, 3D GIS, Unreal Engine and workflow engine to build a powerful and intelligent core architecture. Video analysis technology processes surveillance video in real time to quickly identify and warn of potential flood risks; Big data analytics dig deep into massive data to provide accurate trend prediction and risk assessment; AI recognition uses machine learning and deep learning algorithms to improve the intelligence level of detection and decision making; 3D GIS builds a fine geographic information

model to realize the overall control of urban space and the three-dimensional display of flood situation. Unreal Engine creates realistic virtual scenes for disaster attack and defense simulation and drills to enhance the actual emergency response capability; The workflow engine efficiently manages and schedules tasks and resources to ensure smooth collaboration between technical modules and efficient operation of the system.

2.3.4. Integration and processing of multi-source data

The system can be accessed through the large-screen system, PC or mobile terminal. Among them, the large screen is mainly used by the municipal emergency Management Bureau; The PC terminal is suitable for the district (city) county emergency management Bureau and relevant city departments; Mobile provides services for city safety managers, emergency responders and ordinary citizens.

2.3.5. Integration and processing of multi-source data

Based on the business needs, management mode and work flow of urban flood control and drainage, five functional modules are set up: flood disaster related data collection, intelligent monitoring and early warning, risk analysis and assessment, attack and defense drills and simulation, and emergency command and dispatch. The data collection module integrates baseboard data, site survey and real-time data to provide an overview and in-depth analysis of historical disasters. The intelligent monitoring and early warning module obtains real-time monitoring information through front-end equipment, issues accurate early warning and supports joint handling; The risk analysis and assessment module carries out structural assessment, disaster-induced environment analysis and post-disaster loss assessment; The attack and defense drill and simulation module builds realistic scenes, designs solutions, implements drills, and monitors and improves them in real time; The emergency command and dispatch module quickly starts the response mechanism, supports dynamic command decision-making, real-time communication coordination and resource optimization, and realizes efficient response to flood disasters.

Figure 2. Overall platform architecture. Source: ISOCARP.

3. Construction of urban security risk intelligent attack and defense system

3.1. Instant perception: Building a one-stop big data repository

3.1.1. Eight sources of data perception and three sources of micro perception

In the construction process of urban security risk intelligent attack and defense system, instant perception is the cornerstone of accurate prediction and scientific decision-making. The system integrates eight data perception sources and three micro-perception sources to build a multi-level and multi-dimensional data perception network. The eight major sources of data perception include high-resolution satellite image data (space imaging), ground-based sensor networks (surface sensing), aerial image data of drones and aviation equipment (aerial photos), historical flood data, population and economic data (statistical data), urban planning and design documents (planning reports), interview data, Internet crawl data (network data), and data All kinds of data collected by the independent research and development platform (acquired by the self-built platform). Three micro-perception sources cover the integration of the public security network and the government affairs network: the public reporting disaster information (data reported by the masses), the people-centered urban group perception: news media, social media and online forum data (online public opinion data), and the comprehensive and objective perception of social organizations: the response data of public service departments and enterprises (enterprise response data). These multi-source data together form a comprehensive and three-dimensional real-time perception network, which provides a solid data foundation for the early warning system.

3.1.2. Sensing device application

In order to ensure the comprehensiveness and real-time data perception, the system has deployed a variety of advanced sensing equipment. These devices include high-precision weather stations, rain gauges, water level gauges and soil moisture sensors, distributed in key areas of the city for dynamic monitoring; Using LiDAR, multispectral and thermal infrared imaging equipment to capture more detailed surface and atmospheric data; Unmanned aerial vehicles and satellite imaging technology are used to collect dynamic data at high altitudes and on the surface. At the same time, the system also integrates ground surveillance cameras, mobile sensors, sonar and radar systems to achieve all-round and three-dimensional monitoring of urban flooding. And intelligent traffic sensor real-time detection of road water; The intelligent manhole cover monitoring device monitors the underground drainage system in real time. All of these sensing devices can transmit data instantly to a one-stop platform data repository via wireless networks and iot technologies.

3.2. Data fusion: multi-source data fusion and analysis

3.2.1. Data fusion management

The system has made a remarkable breakthrough in data processing. First, through advanced data preprocessing technologies, including data cleaning algorithms, data conversion and formatting, and automated data type matching, data formats from different sources are converted to a unified standard and data fields and types are ensured to be consistent across different data sources. Next, the system aligns the data in time and space, ensuring that different data sources are compared and analyzed within the same point in time, coordinate system, or resolution. Data integration and standardization is an important part of data fusion. The system uses multivariate data standardization, complex feature extraction and transformation, and dimension normalization technology to standardize data from different sources into the same measurement unit and data range, and to extract key information points from data in common

format and specific industry. In the stage of data matching and fusion, the system combines rule-driven fusion, statistical fusion and machine learning algorithms to achieve efficient data fusion and intelligent processing. In order to ensure the orderly storage and efficient management of data, the system builds a unified data storage system, and implements detailed metadata management of the merged data. Finally, through real-time data analysis and iteration, feedback information is collected systematically, data fusion and analysis methods are continuously improved, data fusion strategies and models are continuously optimized, and the prediction and decision support capabilities of the platform are enhanced. Diversified data sources combined with sophisticated algorithms make risk identification more profound, risk assessment and diagnosis more accurate, and effectively solve the actual needs of urban planning personnel and data barriers.

3.2.2. Data analysis method

The system covers a variety of data analysis methods, including metadata analysis and verification, statistical analysis, machine learning and data mining, geospatial analysis, time series analysis, and text and semantic analysis. These methods work together to achieve high precision prediction and decision support.

Specifically, metadata analysis and verification ensures the relevance, consistency and reliability of data through correlation analysis, consistency verification and metadata comparison analysis; Statistical analysis uses regression analysis, Bayesian analysis and survival analysis to provide accurate estimation of the probability and impact range of flood events. Machine learning and data mining use cluster analysis, classification algorithms, anomaly detection and cluster analysis to identify potential risk patterns and anomalies; Geospatial analysis uses spatial hotspot analysis, spatial interpolation and buffer analysis to accurately locate and predict flood hotspots. The time series analysis provides the dynamic prediction of the future flood development through the autoregressive integrated moving average model (ARIMA), long short-term memory network (LSTM) and moving average analysis. Text and semantic analysis involves topic extraction and keyword extraction, natural language processing (NLP), topic modeling, and sentiment analysis to help extract valuable information and public sentiment from large amounts of text data. The synergy of these diverse data analysis methods enables the system to effectively respond to urban flood risks, providing comprehensive and accurate early warning and decision support.

3.3. Intelligent learning: Integrating AI methods and technologies

In terms of intelligent learning, the system integrates a large number of advanced artificial intelligence technologies to strengthen its application in the fields of natural language processing, computer vision, risk identification and offensive and defensive early warning. By integrating law learning, model structure optimization, inference acceleration and training strategies, the system has a strong feature depth mining and intelligent inference ability. Specifically, deep learning neural network technologies such as Figure Neural network (GNN), generative adversarial network (GAN) and spatio-temporal Convolutional neural network (ST-CNN) are used for the recognition and prediction of complex data patterns. Deep reinforcement learning and multi-agent reinforcement learning are used to optimize the decision-making process. Self-supervised learning is applied to disaster early warning and post-disaster UAV image analysis. Transfer learning and multimodal learning play an important role in social risk analysis. Time series analysis technology is used to monitor emergencies and detect network attacks; Automated machine learning realizes the efficient construction of disaster risk model. In addition, natural language processing technology is being used to analyze social media and news data to extract key information related to flood risk. The integration of these AI learning technologies improves the calculation power of risk rules, enabling the system to provide efficient and accurate flood warning and risk management support.

3.4. Attack and defense exercise: disaster attack and defense exercise and early warning

By carrying out disaster attack and defense early warning and deduction, the system provides a dynamic risk management means. It uses digital twin technology to simulate and deduce various operating mechanisms of real cities, and realizes all-directional, multi-level and real-time dynamic simulation of urban flood disasters by constructing highly realistic virtual security threat rings. By building an urban security simulation system based on multi-party attack behaviors and defense decisions, this function helps planners and city managers to explore the complex interaction between sudden floods and floods and formulate the best response strategy in time, which improves the emergency response ability and the spatio-temporal allocation of resources. In this process, game theory, artificial intelligence algorithm and multi-party collaborative model are used to simulate different reactions and decisions of government departments, emergency response teams and ordinary citizens, and analyze the game behaviors of all parties, so as to formulate the best defense countermeasures. This dynamic game and deduction ability makes the security protection of the city more three-dimensional and comprehensive, and allows citizens to get more sense of security.

3.4.1. Attack inference simulation

(1) Scene construction

Aiming at the problem of urban macro and micro data collaborative management, a multi-disaster simulation framework based on 3D GIS platform and driven by UnrealEngine is proposed by using digital twin technology. The framework can extract and integrate information from 3D GIS platform, and turn it into urban risk intelligent attack and defense analysis model. The system takes Lanxi City, Zhejiang Province as an example, and constructs the intelligent attack and defense analysis model of rain-flood safety risk in Lanxi City (Figure 3).

Figure 3. Analysis model of intelligent attack and defense of rain-flood safety risk in Lanxi City. Source: ISOCARP.

(2) Lanxi flood disaster attack simulation

1) Dynamic adjustment of attack degree

The system can simulate flood disaster events under different rainfall and water level conditions. In this study, the ten-year, 50-year and 100-year flood events were simulated in Lanxi City (Figure 4). The once-in-a-decade flood simulation shows that the moderate intensity flood mainly affects low-lying areas, which provides basic data for the design of flood control facilities. The one-in-50-year flood simulation shows that the impact of larger floods is wider, and it is necessary to strengthen key flood control nodes and emergency evacuation plans. The once-in-a-century flood simulation highlights the full threat of extreme flooding to cities and calls for more comprehensive flood prevention and public education.

Figure 4. Lanxi City ten years, fifty years, one hundred years flood simulation. Source: ISOCARP.

2) Analysis of different attack paths

When the rainfall in each area of Lanxi City will reach more than 100mm within 3 hours, or has reached more than 100mm and the rainfall may continue, the water level exceeds 20m(Wusong meter), and the water points in each area (roads, Wells, tunnels, etc.) reach the warning line or preset threshold, that is, the flood disaster attack, the system will automatically trigger the alarm mechanism and enter the defense mode.

3.4.2. Defense simulation

(1) Urban equipment testing

The system can fully test and evaluate all types of urban infrastructure in flood simulation, accurately monitoring and analyzing the flood resistance and operation of critical infrastructure such as roads, Bridges, drainage systems, communications facilities and power supplies. At the same time, a large amount of real-time data is collected and processed to simulate urban response under various flood scenarios, identify

potential weak links and failure points, and carry out targeted reinforcement, so as to improve the overall flood resistance level of the city.

(2) Monitoring and early warning test

Combined with high-precision weather sensors, water level monitoring equipment, terrain monitoring technology and camera surveillance, the system will respond to disaster data in real time. Through open real-time information platforms and mobile applications, the latest disaster situation and evacuation information are released to the public (Figure 3), ensuring efficient organization and information transparency of emergency response, minimizing disaster losses and ensuring the safety of residents.

(3) Emergency response drill

1) Intelligent drainage management: the drainage pump station starts the pump in advance and adjusts the operation strategy in real time to remove the water in the optimal path; 2) Optimization of multi-party coordination ability and resource scheduling efficiency: rapid transmission and response of medical rescue resources, intelligent dispatch of rescue materials, and efficient linkage of different agencies; 3) Intelligent evacuation planning: Based on the traffic flow database of the professional map website, the data capture algorithm is designed to analyze the Volume-Dclay curve and traffic capacity requirements of the target area, and the safest and fastest evacuation route is developed for the personnel and materials in the disaster-stricken area; 4) Real-time data update: Collect and update the disaster situation and disaster risk level data of various regions in real time, and provide decision support through the visual interface. (Figure 5)

Figure 5. Intelligent emergency response measure module. Source: ISOCARP.

(4) Defense effect evaluation and plan optimization

After the disaster, the system will conduct emergency assessment and post-disaster resilience recovery. Using a large language model and social media data, the system proposes a rapid disaster assessment method and simulates urban restoration under a variety of complex constraints. In addition, the system

can automatically generate detailed diagnostic reports covering the current risk status, potential hazards and specific safety recommendations, helping urban planning managers to make scientific and reasonable decisions in a timely manner, thereby improving the city's emergency response capacity and resilience.

4. Results and discussion

Through the combination of big data and artificial intelligence technology, this study realized the following aspects: "instant perception, building a one-stop big data resource library, data fusion: realizing multi-source data fusion and analysis, intelligent learning: integrating artificial intelligence methods and technologies to offensive and defensive reasoning: The four-step leap of "carrying out disaster attack and defense early warning and prediction" has upgraded from static risk assessment to dynamic real-time monitoring, providing a new perspective and solution for urban flood risk management, effectively improving the accuracy and response speed of urban risk identification, and effectively guaranteeing the safe operation of the city.

In the future, the system will not only be limited to flood disasters, but also expand to other natural disasters, man-made disasters and man-made disasters and other fields, covering spatial planning, traffic management, disaster prevention and reduction and emergency response, etc., to build a national urban safety artificial intelligence diagnosis platform. In the context of "dual use", we continue to improve innovative service capabilities, optimize solutions, and actively explore new markets to better support urban safety management and development.

5. References

Huang J., CAI S.Q., Pang T.T., et al. Simulation of urban rainstorm and flood disaster warning strategy based on agent modeling [J]. Journal of Geo-Information Science, 2019,26(05):1151-1165.Book: Author surname(s), initials(s), (Year published) Title. Edition. Place of publication: Publisher.

Zhao M.Q., Hu M.X., Daytime, et al. Application of digital twin technology in urban flood intelligent control: A case study of digital intelligent water control system in Binjiang District [J]. Water Conservancy Information Technology,2024,(02):29-35.DOI:10.19364/j.1674-9405.2024.02.005.

Nardo A., Natale M., Santonastaso F G, et al. An Automated Tool for Smart Water Network Partitioning [J]. Water Resources Management, 2013, 27(13): 4493 − 4508.

Case Study Report

SPAZIAMO: Revitalizing Locarno through Tactical Urbanism

Alice JELMINI, ISOCARP Institute, The Netherlands
Nicolò D'ANDREA, Collettivo Urbano, Switzerland

Abstract

This report introduces the Tactical Urbanism (TU) initiative SPAZIAMO, outlining its main lessons learned and providing some important recommendations for future initiatives. "Spaziamo", which combines in Italian "spazio"(space) and "agiamo" (let's act!), is a 3-year initiative taking place in the municipality of Locarno (Switzerland), with the goal of activating and revitalizing a public space in the centre of the city that was highly underused. The report highlights the tactical urbanism design method of the initiative, analysing how such temporary, low-cost and experimental interventions allow and support municipalities to quickly and affordably test innovative solutions, while fostering inclusiveness, cooperation and collaboration.

Keywords

Tactical Urbanism, Citizen engagement, Temporary Interventions, Urban Voids

1. Introduction

1.1. Background of the initiative

Multi-functional, comfortable, inclusive, and accessible public spaces are a key component of urban life, fostering social interactions and making cities more livable (Stagias, 2024). Yet, traditional urban planning practices often face challenges related to slow rates of implementation, with projects taking a significant amount of time to materialize, resulting in residents' dissatisfaction. This is due to several reasons, including limited budgets dedicated to urban development, constraints on available space, and tedious bureaucratic processes. Although innovative ideas and solutions to enhance public spaces are frequently proposed, they can remain mere visions for extended periods, and as a consequence, many spaces remain unused or underused (Elrahman, 2016), creating urban voids.

As first analyzed by Jane Jacobs in her book "The Death and Life of Great American Cities", urban voids can be described as areas within a city whose designs and functions have not yet been defined, failing to fulfil any concrete function within the urban systems and therefore representing gaps in the city fabric (Jabos, 1961).

It is therefore important to adopt alternative approaches that can support traditional urban planning, ensuring that these essential aspects of public spaces are created and maintained. In this regard, Tactical Urbanism (TU) emerges as an effective solution, as it can quicken the process and fill urban voids [TD3] [AJ4] [AJ5] by adopting a phased and responsive approach[AJ6] (Lydon & Garcia, 2015).

TU is a form of urban regeneration that aims to improve public spaces through punctual, temporary, low-cost and experimental interventions that can be quickly implemented, dismantled, and adjusted (Collettivo Urbano, 2024). This approach allows cities to quickly and affordably test new ideas and gather feedback from citizens before committing to larger, more permanent (Lydon & Garcia, 2015).

The approach has been successfully implemented in various cities in Europe, from Milan with the "Piazze Aperte" initiative, to Barcelona, where TU is complementing the Superblocks. Another smaller-case and interesting example is the SPAZIAMO initiative, taking place in Largo Zorzi. The area (see figure below) is situated in Locarno, municipality in the Italian part of Switzerland, known for its beautiful landscapes and growing tourism. Locarno has the largest number of public spaces in the Canton (Swiss equivalent of an administrative region), yet some of them, particularly in Largo Zorzi, remain underused, despite their strong potential for social interaction and community events. While elaborate planning narratives and actions have been established for the city, following the "2040 vision," there remains a significant gap between the present state of public spaces and the plans set for 2040 (D'Andrea, 2024).

Figure 1 The Largo Zorzi area, in Locarno. The Swiss Search Engine

This is why the Collettivo Urbano (Urban Collective), a group of 4 young professionals based in the city, had the idea to develop SPAZIAMO, (combining "spazio"(space) and "agiamo" (let's act!)), a TU initiative meant to enhance the urban void in Largo Zorzi for the benefits of the public.

The project was developed with the goal of activating and revitalizing the public space so that it can reach its full potential. From this premise, an important collaboration emerged between the Collettivo Urbano and the municipality of Locarno, which responded positively to the initiative and provided full support. The project will be developed gradually over the next three years, in anticipation of a more definitive redevelopment plan that is set to begin in 5 years.

2. SPAZIAMO - Project Overview

2.1. The Collettivo Urbano

The Collettivo Urbano is a group composed by 4 young professionals – Georgina Cavalli, Alex Furgiuele, Jordan Kouto and Nicolo' D'Andrea – which share a passion for urbanism and revitalization of public spaces. They are respectively an architect, graphic designer, construction technician, and spatial planner.

Figure 2. Collettivo Urbano Frame, in Locarno. Source: Collettivo Urbano

The goal of the Collettivo is to act in public spaces with the intention of enhancing and valorizing the existing urban voids that are unused or underused, for the benefits of the citizens. Their actions address primarily the people that live in the city, providing them with spaces for aggregation and recreation, with the goal of addressing their needs and preferences. They achieve this through initiatives of tactical urbanism, meant as a design method complementary to the development policies and plans. This approach gives them the possibility to test solutions that are low-cost, temporary, creative and impactful, and where citizens are involved.

2.2. Project Emergence & Development

SPAZIAMO emerged as a proactive solution for Largo Zorzi, where a long-term redevelopment plan named the "Nouvelle Belle Époque" is expected to begin its implementation phase, if everything proceeds as assumed by the municipality, starting in 2028. However, this timeline may vary depending on future decisions and possible appeals. Rather than leaving the space unused during this period, the Collettivo decided to create a project to occupy, activate, and give the space back to the people. The street was merely a space for movement, where citizens crossed on sidewalks, rather than a place for public gathering and social interactions.

The goal was therefore to fill the void and accompany the more permanent, long-term changes that will come with the Nouvelle Belle Époque. The project emphasizes the importance of taking immediate action rather than waiting for long-term plans to materialize. This proactive approach allows residents to reacquaint themselves with and rediscover the concept of public space. Recognizing the potential benefits, the municipality of Locarno approved the project and provided robust support, resulting in a crucial collaboration in the development of SPAZIAMO.

Launched in November 2023, SPAZIAMO is designed as a three-year initiative that unfolds in various stages.

2.2.1 The Project Phases

The first phase concentrated on transforming the road surface to alter perceptions of the space, raise awareness of its existence, and encourage engagement among residents. The choice of colors was intentional, but the theme selected for the painting—digital clouds—was even more significant. These "clouds" symbolize the containers of digital messages and represent communication in the digital era. This symbol was chosen to express a desire for people to communicate not just through digital means, but also face-to-face, within public spaces.

Figure 3. Phase 1 of the initiative - painting of the road. Source: Collettivo Urbano

Painting the clouds on a tangible and highly trafficked surface symbolically aimed to restore conversations and exchanges to a space that belongs to everyone.

Following the completion of the street painting, the second phase commenced with the installation of multifunctional structures designed to encourage people to stop, rediscover, and interact with each other and the space in Largo Zorzi.

An exhibition space was created, complete with benches to provide additional seating and invite people to stop, sit, and utilize the area, even in a more passive manner. This installation serves a dual purpose: offering seating while also creating a venue for small exhibitions that showcase ongoing urban projects and inform the public about current initiatives.

Additionally, a pétanque court was installed. While this may seem like a trivial idea, it serves to unite people of all ages and has had an immediate positive impact on community interactions. The final addition is a basketball court featuring three baskets of varying heights, accommodating players of all ages and skill levels.

Figure 4. Phase 2 - the structures. Source: Collettivo Urbano

All these structures were designed and built in collaboration with local artisans, utilizing low-cost construction materials that are easily reusable. Despite their simplicity, these materials have a strong visual impact. This approach not only helps to keep costs down but also emphasizes the temporary, creative, and experimental nature of tactical urbanism.

The strategy aimed to demonstrate to the municipality that such initiatives are feasible, as they can be easily assembled and dismantled according to community preferences. Moreover, these structures can be

relocated to other public spaces in the city, ensuring continuity for the project. Continuous evaluation is conducted to assess whether the structures attract and engage the public, with a readiness to adapt and change them as necessary.

3. SPAZIAMO - Project Results

SPAZIAMO has brought a positive impact to Largo Zorzi, benefiting both the residents of Locarno and the municipality. The TU initiative by the Collettivo Urbano serves as a design strategy that can complement the existing development policy of the "Nouvelle Belle Époque" in Locarno that is set to begin in 5 years. By allowing the piloting of new structures and ideas before committing to the larger project, it ensures a more responsive and impactful urban approach. The initiative has also enabled a collaboration between the municipality and the collective, as well as participation of the residents, providing an opportunity for discussing the current and future use of Largo Zorzi.

3.1 Community Reaction

The perception of public space among the people of Locarno has been quite revealing. Before the initiation of the SPAZIAMO project, it seemed as though residents felt they needed permission from authorities to engage with public spaces, as they were not accustomed to taking ownership of these areas. This observation significantly influenced the approach taken with SPAZIAMO.

The project was launched with the intent of changing this mindset by providing more reasons for people to return to the space, stop, engage, and interact. However, the first phase alone did not achieve the desired effect. Many individuals continued to walk along the sidewalks without stopping or acknowledging the space, and a common question arose: "Where do the cars go now?" This was particularly striking, given that cars and buses had been prohibited from passing through the area for the past two years. Such inquiries indicated that, in the perception of the community, the area was still viewed as a thoroughfare for vehicles rather than a public space meant for engagement.

With the second phase, the situation has shown improvement. The installation of multifunctional structures has encouraged people to stop and interact. While it takes time for changes in perception to take root, there are now signs of positive transformation. Many individuals are beginning to stop in the street, utilizing the space as intended and engaging more with their surroundings.

3.2 Stakeholder Engagement

The success of SPAZIAMO is heavily dependent on an effective stakeholder engagement process. This involved collaboration and input from various groups within the community, each contributing to the project's development and implementation.

Key Stakeholders:

- **Citizens**: from the beginning, citizens participated through interviews and discussions aimed at gathering opinions and feedback on ideas, mission, and phases of the project.
- **Municipality**: the SPAZIAMO initiative facilitated collaboration with the city, leading to a co-creation process that enriched the project's development.

- **Local Artists and Artisans**: local creatives collaborated in the development of structures and art installations, enhancing the project's aesthetic and cultural value.
- **Schools**: engagement with local schools was initiated to discuss strategies for involving younger generations and students in the project, fostering a sense of ownership and community among youth.

This inclusive approach not only ensured that the project met the needs of various stakeholders but also fostered a sense of community ownership and engagement in the transformation of public spaces.

4. Looking Forward - Integrating TU interventions into traditional urban planning practices

4.1 An Innovative Approach for Planners

Tactical Urbanism can offer several important benefits and serve as a catalyst for positive change. Tactical Urbanism initiatives have strong potential to contribute to traditional urban planning practices. TU provides a more dynamic and responsive approach for planners to address urban planning challenges by enabling quicker, more flexible and affordable interventions. In this regard, TU serves as a design strategy that can complement existing development policies, allowing the piloting of new ideas before committing to larger projects.

Mobility and the way public spaces are experienced are often deeply rooted in people's minds and habits, forming mental "infrastructures" that can be difficult to change (López et al., 2020). Therefore, planners should leverage on TU initiatives as they support gradual change, and help effectively bring about lasting and positive transformation of the public space and the way it is used.

TU initiatives provide opportunities for collaboration between municipalities, urban practitioners, and the community. TU initiatives also allow residents to participate directly in the use and shaping of the public space, ensuring they meet their needs and preferences (Lydon & Garcia, 2015). This fosters a more democratic process of public-space building (Stagias, 2024), which is essential for understanding, exploring and discussing the future of the public space. This collaborative approach is key for developing multifunctional, inclusive, and well-managed spaces (Child in the City, 2024), fostering a sense of ownership and engagement crucial for long-term success. Additionally, by engaging the local community, TU offers the possibility for local creativity and art to be incorporated into public spaces (Stagias, 2024), enriching the urban environment and strengthening the cultural and artistic identity of the area.

However, to ensure an equitable urban transformation that is sustainable in the long-term, some key aspects must be considered for TU initiatives.

4.2 Key Factors to address for successful TU initiatives

Tactical Urbanism (TU) initiatives can play a key role in developing gender-informed and inclusive public spaces, yet they **need to establish and ensure widespread, inclusive processes** (Cosgrove, 2024). This inclusive citizen engagement process must start at the **beginning of the planning process** to effectively reach all citizens and address the needs of all community members, including women and girls, as well as individuals who are not cisgender white men. By doing so, TU can help design public spaces that are safe,

equitable, accessible, and enjoyable for everyone, avoiding the production of beneficial outcomes for only a specific socioeconomic group.

TU initiatives **should ensure that the root issues of urban development** in the area are addressed and continued to be addressed also after the end of the project, through ongoing advocacy and participation in city planning processes (Cosgrove, 2024).

Additionally, urban practitioners **should integrate quantitative and qualitative research** to collect, validate and disseminate within the municipality the positive effects of TU initiatives and the lessons learned (Cosgrove, 2024). This would further support the development of more adequate urban interventions.

Figure 4. Painting of the road. Source: Collettivo Urbano

In sum, building upon the demonstrated benefits of TU, and following the positive example of SPAZIAMO, cities and urban planners should actively support the integration of TU initiatives as key strategies for more effective and inclusive transformation of public spaces that remains successful in the long-term.

Anyone can carry out a TU intervention, and we invite anyone who has the capacity and the sensitivity to take action for this. We need to reverse the paradigm and make sure we transform car-dominated cities into inclusive, functional and community-oriented spaces (Collettivo Urbano, 2024).

5. References

Abd Elrahman, A.S., 2016. *Tactical Urbanism: A pop-up local change for Cairo's built environment*. Procedia - Social and Behavioral Sciences, 216, pp.224–235.

Barcelona City Council, n.d. *Barcelona Superblocks*. [online] Available at: https://www.barcelona.cat/pla-superilla-barcelona/mapa/en/#a_0__& [Accessed 15 May 2025].

ChatGPT, n.d. To increase the readability of this paper, the AI tool (ChatGPT) was used in section 2 and 3 (Project Overview and Project Results) of this paper.

Child in the City, 2024. *Making public spaces better for children: A new blog series*. [online] Child in the City. Available at: https://www.childinthecity.org/2024/01/09/making-public-spaces-better-for-children-a-new-blog-series/?gdpr=accept [Accessed 15 May 2025].

Collettivo Urbano, 2024. *Chi siamo e cosa fa il Collettivo Urbano*. [online] LinkedIn. Available at: https://www.linkedin.com/posts/collettivo-urbano_chi-siamo-e-cosa-fa-il-collettivo-urbano-activity-7134910913500831744-Tiuw [Accessed 15 May 2025].

Comune di Milano, 2023. *Piazze Aperte: A Public Space Program for Milan*. [online] Available at: https://www.comune.milano.it/en/aree-tematiche/quartieri/piano-quartieri/piazze-aperte [Accessed 15 May 2025].

Jacobs, J., 1961. *The death and life of great American cities*. New York: Random House.

Cosgrove, J., 2024. *Exploring the Rising Movement of Tactical Urbanism*. [online] Insights. Available at: https://insights.grcglobalgroup.com/exploring-the-rising-movement-of-tactical-urbanism/ [Accessed 15 May 2025].

Locarno Film Festival, n.d. *Home*. [online] Available at: https://www.locarnofestival.ch/home.html [Accessed 15 May 2025].

López, I., Ortega, J. and Pardo, M., 2020. *Mobility infrastructures in cities and climate change: an analysis through the superblocks in Barcelona*. Atmosphere, 11(4), p.410.

Lydon, M. and Garcia, A., 2015. *A tactical urbanism how-to*. Washington, DC: Island Press/Center for Resource Economics, pp.171–208.

Moon&Stars Locarno, n.d. *Moon&Stars Festival*. [online] Available at: https://moonandstars.ch/de [Accessed 15 May 2025].

Pmax, 2024. *La Nouvelle Belle Époque Presentation*. [online] Available at: https://www.locarno.ch/files/documenti/Presentazione_PMax_LNBE_27-03-2024.pdf [Accessed 15 May 2025].

Stagias, A., 2024. *Evaluating tactical urbanism initiatives through the prism of placemaking: A case study on Milan's Piazze Aperte*. [unpublished].

Webb, D., 2018. *Tactical urbanism: Delineating a critical praxis*. Planning Theory & Practice, 19(1), pp.58–73.

Research Paper

Leveraging the Olympics for waterfront revitalization
Insights from Tokyo 2020 Olympic Village

Xiaoxuan Du, School of Architecture and Design, Harbin Institute of Technology, China
Shiliang Lu, School of Architecture and Design, Harbin Institute of Technology, China

Abstract

With an upswing trend of embedding Olympic projects into long-term urban planning documents, the changing spatial strategy arises the rethinking of the growing uncertainty of mega-event-led catalyst effect. It is crucial to examine how the Olympic infrastructures are negotiated to facilitate regional updates, and further assess whether they are effective in contributing to waterfront revitalization. To address this issue, Tokyo 2020 Olympic Village was selected as a notable example for its objective transform Harumi Island into residential and commercial complexes. This programme is affiliated to Tokyo Waterfront City plan (rinkaifukutoshin) which was issued in 1986 and aimed to elevate the seaside area into a sub-centre. This leads to a detailed exploration of the strategic spatial pathway during planning, implementation, and post-event stages to explore its impaction on advancing the waterfront revitalization. Incorporating results were valid from documents of Bureau of Urban Development Tokyo Metropolitan Government and 1st Urban Development Projects Office. Special attention was given to evaluation and critically review the (in)active role played by Olympic Village within context of regional and architectural concepts since winning the bid in 2013. Furthermore, the study highlights the role of multi-level governance, characterized by collaboration and rivalry between the Tokyo Metropolitan Government (TMG) and national authorities in facilitating urban renewal. The study conclude the Olympic Village development was a path-dependent approach, and it was the historical and geographic factors influenced planning decisions to promote sustainable development.

Keywords

Olympic-led Urbanization; Metropolitan Planning; Waterfront; Urban Policy COVID crisis; Urban resilience.

1. Introduction: planning mage-events for urban transformation

It is academically recognized that mega-events act as a catalyst for area-based rebranding both materially and symbolically (Andranovich, Burbank and Heying, 2001; Gold and Gold, 2008; Chen, 2012; Cantillon, 2022). However, the so-called catalyst is tailored to the characteristics of Olympic cities (Husukić and Zejnilović, 2020), and evolved in accordance with International Olympic Committee (IOC) guidelines, local policies, and national vision. Recent studies pointed out that the growing uncertainty of Olympic-led urbanization highlights the interactions between detailed Olympic strategies and urban transformation (Jones, Di Vita and Ponzini, 2022; Ricordel, 2023). In 2014, Agenda 2020 marked a turning point for Olympic implementations to reduce investment and decentralizing the scope of the event to ease the pressure (IOC (International Olympic Committee), 2014). Subsequent bids embedded Olympic projects into certain urban development plans to advance new urban agendas and reconfigure the urban scale with appropriate

intervention, instead of ambitious urban development plan (Müller, 2015; Hu, 2024; Raco and Di Vita, 2024).

The Olympic initiative on waterfront revitalization evolves over the course of modern history. "Barcelona Model" stands as a repetitive approach to leverage the Olympics for urban projects such as Vila Olímpica and Diagonal Mar district (Camerin, 2019). The former industrial area was regenerated and decontaminated (International Olympic Committee, 2022b). The model exemplifies the importance of launching the projects ahead to the bid process, and effective governance and participatory processes are key to achieving and lasting positive outcomes in urban regeneration (Baroghi and Ribeiro, 2024). In the case of Athens, heavy investment for Olympic venues could result in a risk condition without support from strategic long-term plan. The Faliro Coastal Zone Olympic Sports Complex was built in the coastal zone, consisting of two indoor arenas and a beach volleyball centre. The budget was drained after the construction, leading to the desolation of several multi-million-euro stadiums and training centres for years. Afterwards, they have been demolished to build private residential complex, casino, and park. Rio de Janeiro 2016 basically followed the successful Barcelona model, but the outcomes raise doubts since it potentially exacerbated challenges for low-income communities through land valorization, unequal public funding (Baroghi and Ribeiro, 2024). Additionally, examples from London 2012 shows its aims to improve the environment for ethnically diverse and deprived communities in east London, and the 'Grand Paris' project accelerated by Paris 2024 for the development in Seine-Saint-Denis, shows that the Olympic urbanization could only be efficient with clear execution and legacy plan, as well as robust policy tools(Azzali, 2017; Geffroy *et al.*, 2021).

Meanwhile, there is an upswing trend of Olympic cities rehosting the Olympics, such as London (1908, 1948, 2012), Paris (1900, 1924, 2024), Beijing (2008, 2022), Tokyo (1964, 2020), and Los Angeles (1932, 1984, 2028). It is evident that the urban environment, social and economic benefits of historic Olympic cities have been indispensable with the repetitive events and failed bids(Hiller, 2006; Faure, 2024). Among these events, the newest approach exhibits a mix of historical memories and gentle urban acupuncture, facilitating the venues rooting into existing urban fabric (Languillon-Aussel, 2024; Ponzini *et al.*, 2024). Overall, successful Games haven't always led to successful urban waterfront projects. Consideration should be given to the geographic endurance and challenges of waterfront programs. In some cases, the thrive of waterfront region was an afterthought—a missed opportunity. With the uncertainty happens at every stage of the Olympic cycle, projects that fully integrated Olympic waterfronts into a broader urban planning could be more effective (Pinto and Lopes dos Santos, 2022).

2. Methodology

Aiming to contribute to the debate on Olympic facilities from urban scopes, the methodology of this research fundamentally combines three approaches. Firstly, Tokyo 2020 Olympic Village was selected as a notable case study for its objective to foster the Harumi area into residential and commercial complexes. This initiative is a staged urban development project advanced by the Tokyo Metropolitan Government (TMG), spanning from 2013 to 2025. It is affiliated to a broader Tokyo Waterfront City plan (rinkaifukutoshin) which was issued in 1986 and aimed to elevate the seaside area into a sub-center. In this context, the historical development process of the Harumi Island is explored in order to contextualizing the urbanization of the 2020 Olympic Games. Secondly, the study reviewed relevant literature in terms of Olympic village, Tokyo Olympic history, as well as the development plans and design proposals of Tokyo Bay area from government department and private firms. This also sources from Olympic Committee

archives and the Organizing committees of each Olympics. With special focus on Harumi, we expanded desk study to academic publications from Olympics bid for 1940, 1964 and 2016. Lastly, the field work has been conducted in July 2022 and July 2023, including the site visits to historical zone and Tokyo Bay Zone for Tokyo Olympics. Additionally, some quantitative data from periods before, during, and after the Tokyo 2020 Olympics were collected from TMG, Statistics Bureau Ministry of Internal Affairs and Communications Japan, and Policy Bureau of Ministry of Land, Infrastructure, Transport and Tourisms. These serve as supplementary references for outcomes, encompassing metrics as sociated with housing, transportation, and economic development.

3. Olympic waterfront: spatial strategies for Tokyo 2020 Olympic Village

Tokyo has been significantly impacted by major events such as the 1964 and 2021 Olympics, as well as the G7 summits in 1979, 1986, and 1993 as a global city. Today, it becomes a vibrant metropolis of Japan's financial, cultural, and industrial hub with 37 million people. The turning point, however, is commonly recognized as the 1964 Olympics that brought modernity and global reputation to Japan (Languillon-Aussel, 2024). The 1964 scheme primarily located in the western and southern areas of Tokyo's hyper-center, leading to rapid urban transformations in Meiji, Komazawa, and Jingu. In the following decades, Tokyo experienced upswing economic growth and extensive urban expansion. While it comes to the 2020 Olympics, Japan has left behind the industrial age and advanced information era as a mature society (Gold and Gold, 2008). The bay area undoubtedly shoulders the ambition of waterfront subcenter and the new focus of the Tokyo metropolitan region.

3.1. Historical evolution of Tokyo waterfront sub-center

Land reclamation has been carried out along the coast of Tokyo Bay during Meiji period totalled an area of 249 km^2. It was initially set up as industrialized land with severe air and land pollution. Against the backdrop of rapid economic growth in the 1980s, Tokyo Teleport Plan (later named Waterfront Subcenter, Rinkai Fuku Toshin) was adopted in 1986 comprising several islands such as Harumi, Tokyosu, Daiba, Ariake (Faure, 2023b). The project was a comprehensive long-term development plan which aimed to transfer the teleport into a subcentre of Tokyo (Saito, 2003). The plot has been restructured since industry declined in the next few years. Despite the coordination issue has long been existed in the implementation process between Tokyo Metropolitan Government (TMG), Waterfront Development Account (WDA), the General Account (GA) and the Reclamation Account (RA), the objectives were united and articulated as a new business centre led by private sectors.

However, the project went stagnant soon after the bubble economy bursting out (Fig. 1). The economic recession hit the city, resulting in the inability of the private sector to finance the development program. During the Japan's "Lost Decade", several efforts was made to promote the construction but eventually to be fruitless. The project faced delays in 1992 and scaled down in 1993. It was ultimately cancelled in 1995 by Governor Yukio Aoshima. Within the period, debated existed between functional objectives and implementation approach in a changing landscape. Overall, Tokyo is characterized a 'state-centered' city planned and controlled by the national government alone (Saito, 2003). This ensured the sub-centre strategy in conjunction with built-up areas. It's slow but never stopped. As the construction proceeded in Daiba and Ariake, the islands were pictured as a new paradise of *Work, Live, Learn, and play*. The approaches greatly promoted the vitality of the area, where approximately 920 companies operated, 42,000 people worked and 7,900 people lived in 2007, and the number was steadily growing.

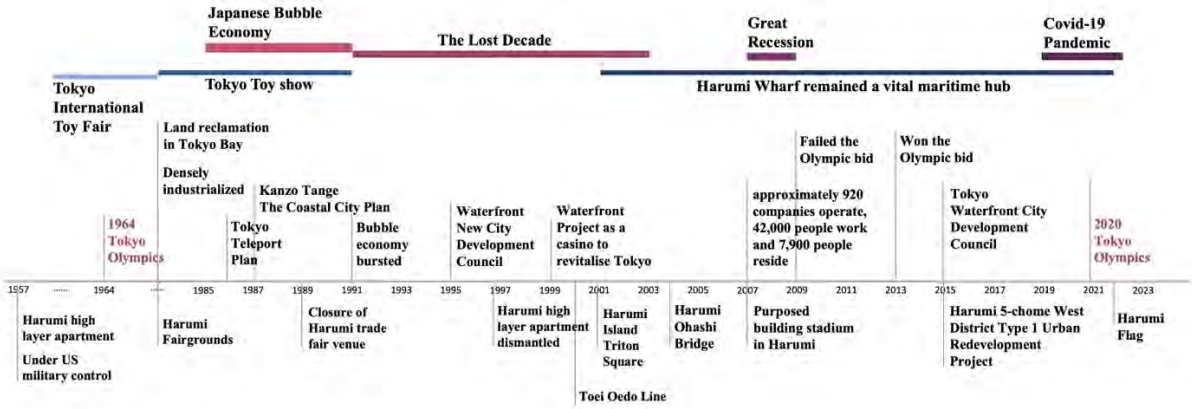


Figure 1. Timeline of Tokyo waterfront subcenter strategies. Source: Authors.

In Tokyo's case, the major goal is to increase the vitality of the sub-center by attracting the upper-middle-class and global investors, making it more competitive with other global cities. By the time of 2013, Tokyo's successful bid for the 2020 Olympics arises amid a grand rethinking of sustainable transition and technological innovation. The Olympic Village reflected this vision and support housing for the emerging waterfront subcenter while setting an example for ecological balance in dense areas. In 2015, the Olympic scheme was adopted and supervised by Tokyo Waterfront City Development Committee. Olympic Games provided the opportunity to advance major construction project on Harumi and Ariake, including the Olympic Village, Tokyo Ariake Arena, Aquatics Center, and Ariake Sports center. Along with the venues, transport infrastructures were built to connect these artificial islands and transport athletes during the Games. Even though all these projects were completed by 2020, the bay remained silenced for over a year before the actual Olympic Games were held in 2021.

3.2. Path dependency in the Olympic Village development

Zooming in the scopes to Harumi Island, it was filled as an artificial island in 1930s. Different from other bay islands, Harumi has long been a pioneer in Japanese residential complex and a transportation base. In 1957, Japan's first high-rise residences was built in Harumi which brought big shock through the nation. In the following decades, the International Trade Centre hosted several international exhibitions including Tokyo auto show, Tokyo International Toy Fair. Along the line, Harumi created the long-term imprinting effect of the residential and global reputation on cultural practices across local communities in Bay area. Additionally, there is no doubt that Tokyo 2020 aims to reverse the urbanization frontier towards the waterfront area, consolidating its multipolar urban structure. In the proposal for the 2016 Olympic bid, Harumi was delineated as the site for the stadiums while the Olympic Village located in Ariake-Kita. This proposal was restructured in the 2020 Olympic bid plan which holds most of the newly built Olympic venues in the larger islands of Ariake and Daiba. Harumi was set up to build Olympic village and railroad line connecting the islands to the central city. Since Tokyo 2020 is under the ambition of linking the existing area and waterfront area (Lützeler, 2020), Harumi is exquisitely located at the intersection of so-called "Historical Zone" and "Tokyo Bay Zone" (Fig. 2) (Languillon-Aussel, 2024). The intersection symbolizes the trend from tradition to modernity, as well as the link between 1968 Olympics and 2020 Olympics.

In this sense, the Olympic Village is essentially a housing scheme to create a sustainable neighbourhood. It takes advantage of the general recognition of innovative residential complex. The construction was incorporated into a compact, phased, and resilient plan with the investment of $2 billion. The Olympic Village includes 21 towers with each between 14 to 18 stories high, consisting of 5,632 units and capacity

of 12,000 residences (Fig. 3). It has been sold to the developers for a sixth of its market value before the game begins (Purkarthofer, 2020), and soon transformed into "Harumi Flag" after the games—a mixed-use development featuring schools, shops, apartments, restaurants, daycare centres, and senior welfare facilities (International Olympic Committee, 2022a). It would be not aligned with Agenda 2020 considering the events alone. However, with growing global companies housing in the bay area, HarumCi Flag provides essential support for the workforce of digital and technology companies in Toyosu, Daiba, and Ariake. While it was equipped with energy-saving technologies, the residential complex was set up as a model for waterfront infrastructures targeting digital and high-tech industries.

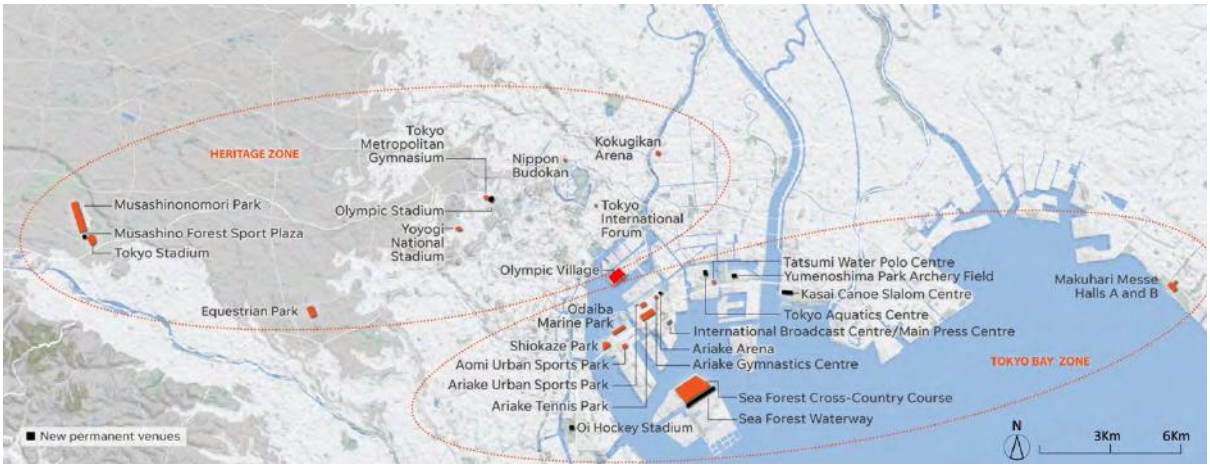


Figure 2. Two zones of Tokyo 2020 venue's map. Source: https://eu.usatoday.com

Figure 3. Harumi Flag. Source: Carl Court/Getty Images.

3.3. The role of policy network in the development process

As discussed, the construction of Olympic Village is clearly a path-dependent approach in the context of Harumi's residential reputation. In the governance of the waterfront development, it was the Tokyo Metropolitan Government (TMG) set up the basic framework while negotiating with central government. The relationship between the TMG and the national government is "mutual dependence with strong

rivalry" (Saito, 2003). Prior to the *Waterfront New City Centre Urban Development Promotion Plan* was released in 2005, the development of bay area was controlled by multiple strategies (table 1). This plan shifted the priorities to accommodate Olympic-related projects. This has proven to be an invigorating approach since the Olympic projects greatly enrich the vision with sports and leisure functions, instead of technology alone. During the bidding process, private sectors played a key role as Harumi Flag, Waterfront City Plaza, and Creation Centre was advanced under the Public–Private Partnerships. This approach mitigates the government fund and addresses the risk of overinvestment from income and enhances resilience to potential crises. Additionally, the bottom-up coordination bridges the gap between local needs and top-down planning, addressing the disparity in waterfront vitality and scarcity. As the advisory committee assists the decision-making process, the local community has kept a strong voice in the residential programme and raised the expectation for Olympics.

Table 1 Development strategy on Tokyo Waterfront area Source: Authors.

Years	Urban plan/programme
1986	Tokyo Teleport Plan
1987	Basic Concept for Development of the Waterfront Subcenter
1988	Basic Plan for Development of the Waterfront Subcenter
1989	Waterfront Subcenter Development Project Plan
1996	Basic Policy for the Development of the Waterfront New City
1997	Toyosu and Harumi Development Plan
2005	Waterfront New City Center Urban Development Promotion Plan
2022	Tokyo Waterfront New City Digital Transformation Promotion Project
2022	Tokyo Bay eSG Project

It cannot be neglected that Tokyo 2020 was essentially hosted in the year of 2021. As the consequences of the Covid-19 pandemic, Japanese central government announced its decision to postpone by one year the Tokyo Olympic and Paralympic. The delay also led to numerous lawsuits from residents regarding postponed move-ins at the Harumi Flag housing complex. To date, most residence moved in after two-year waiting, however, the compensation remains unclear. In order to control the spread of pandemic, the "Bubble" was set up as an intricate system to surround certain Olympic venues for containing the movement (Dimmer and Solomon, 2024). This approach did limited people's activity— though it was necessary for the emergency, resulting in limited economic and branding benefits of the new facilities. It could be significant but vague of the full financial impact.

Only one year after the Olympics, TMG took over the land together with the government and adopted the Tokyo Bay eSG project—a detailed action plan to restructure the waterfront after the Olympic. It soon acted to address the delayed handover of the Harumi Flag with most residents moving in by 2023. The project set four main objectives for the bay area, including the goal of achieving "net zero emissions and creating a city full of water and greenery." As mentioned, the Olympic Village serves not only a residential support for the subcentre but also a pioneer of sustainable community of Harumi Island. What we can conclude from Tokyo's case is that the Olympics accelerated urban transformation by enhancing risk resilience (Faure, 2023a). Mega-events have the potential to act as a piece within a compact, phased, and resilient urban framework, rather than being the decisive force.

4. Conclusion and discussion

Since 1984, the development of Tokyo's waterfront area lies in the relentless effort of government-led approaches. The policy network of waterfront development illustrates the importance of mutual corporation and rivalry of TMG and central government, while the private sector advanced and revised the plan in accordance with the local needs. It was this friction promoted the strategy innovation for challenges to ensure the waterfront vision in compliance with the broader urban goals. The history path of Harumi

also proved the fragile implementation during the slumping economy. Since Tokyo 1964, TMG refined its reputation through a series of mega-events and built modern infrastructures. These events helped to rehabilitate the environment and set up its global image. With the shrink of Olympic investment, Olympic cities are trying to upgrade the Olympic pattern after the Barcelona Model. Tokyo 2020 also provided an example of waterfront area as a long-term legacy, while its connection with the built-up area is far more than Barcelona's practice. To facilitate this connection, the Olympic Village played a tie. Moreover, it has long existed in urban transformation practice, instead of the Olympics alone. This study analyses the contribution of Olympic for Tokyo waterfront revitalization, and the spatial correlation with the heritage urban zones.

Firstly, this study shifted the academic focus from the critique for overinvestment for mega-events to testify the investments. It is inevitable to build more structures for the Olympics to create resilient legacy. According to the Olympic report, the budget of $7.3 billion budget has expanded to over $25 billion in true outlays. Despite the criticism towards the "irrational" input for Olympic, Tokyo and Beijing did shorten the investment by centralizing the venues compared to Paris 2024. However, what is discussed in this paper is the growing practice to incorporate the Olympic projects into long-term urban plan. As a global city with over 400-year history, Tokyo basically rebuilt itself after the WWII. It should be justified to leverage the Olympics for the urban regeneration, especially given the limited land of Tokyo. Secondly, Harumi Island exhibits a path-independence approach in Olympic Village development. The character of the island was shaped by its history and geographical condition, leading to the decision for Olympic Village instead of venues. This also decided not only the Olympic projects served the athletes during the games, but also switched the emotion gap between the local community and upper-middle-classes. After the events, the renovation of "Harumi Flag" residential and commercial complex shows its commitment to sustainable and resilient urban community to match the upswing technology areas in the bay islands. These islands carry its character as an artificial islands and Tokyo's industrialization history, which was intentionally removed in the development of Daiba and Ariake but remained in Harumi. It was a deliberate approach rooted in its local identity. Third, the governed framework of Olympic projects highlights the corporation of public and private sectors. The non-publicly owned organisation could meet the local needs while in compliance with the top-down policies. Tokyo Olympics was proved to bridge the gap between the waterfront vitality and pandemic isolation crisis, which is fundamentally a method to enhance local governance system. The Olympic also enhance its ability of crisis management and urban resilience, especially under the circumstances that the Olympic scheme was submissive to urban development plan. As Tokyo moves forward, the legacy left by Olympic scheme in bay area would consistently impact the urban policy and strategy. It demonstrates how the strategy for mega-events bring benefits for the locals, and how to meet the contemporary challenges of growing population and severe climate.

5. References

Andranovich, G., Burbank, M.J. and Heying, C.H. (2001) *OLYMPIC CITIES: Lessons Learned from Mega-Event Politics*.

Azzali, S. (2017) 'Queen Elizabeth Olympic Park: an assessment of the 2012 London Games Legacies', *City, Territory and Architecture*, 4(1), p. 11. Available at: https://doi.org/10.1186/s40410-017-0066-0.

Baroghi, F. and Ribeiro, P.J.G. (2024) 'Olympics-related urban interventions in Barcelona and in Rio de Janeiro: A look at territorial equality legacies', *Cities*, 155, p. 105503. Available at: https://doi.org/10.1016/j.cities.2024.105503.

Baroghi, F., Ribeiro, P.J.G. and Fonseca, F. (2024) 'Towards a Holistic Framework for the Olympic-Led Sustainable Urban Planning Process', *Sustainability*, 16(3), p. 951. Available at: https://doi.org/10.3390/su16030951.

Camerin, F. (2019) 'From "Ribera Plan" to "Diagonal Mar", passing through 1992 "Vila Olímpica". How urban renewal took place as urban regeneration in Poblenou district (Barcelona)', *Land Use Policy*, 89, p. 104226. Available at: https://doi.org/10.1016/j.landusepol.2019.104226.

Cantillon, Z. (2022) 'Urban Reimaging, Heritage and the Making of a World-class City: The Commonwealth Walkway as Mega-event Legacy Project', *Heritage and Society*, 15(3), pp. 259–276. Available at: https://doi.org/10.1080/2159032X.2022.2127177.

Chen, N. (2012) 'Branding national images: The 2008 Beijing Summer Olympics, 2010 Shanghai World Expo, and 2010 Guangzhou Asian Games', *Public Relations Review*, 38(5), pp. 731–745. Available at: https://doi.org/10.1016/J.PUBREV.2012.04.003.

Dimmer, C. and Solomon, E.G. (2024) 'Tokyo Olympic "Bubble": The Spatialisation of Corona Politics for and around the 2020 Games', in, pp. 63–77. Available at: https://doi.org/10.1007/978-981-99-9599-8_5.

Faure, A. (2023a) 'How the Tokyo Olympic and Paralympic Games were embedded in urban planning documents: The enforcement of a metropolitan strategy in the Bay Area', *Contemporary Japan*, 35(1), pp. 136–157. Available at: https://doi.org/10.1080/18692729.2023.2169462.

Faure, A. (2023b) 'The preparation of the Tokyo 2020 Games: Completing the Waterfront Subcenter Plan', *Journal of Convention & Event Tourism*, 24(2), pp. 205–221. Available at: https://doi.org/10.1080/15470148.2022.2156644.

Faure, A. (2024) 'Introduction: Rethinking the Role of Historic Olympic Cities', in, pp. 3–14. Available at: https://doi.org/10.1007/978-981-99-9599-8_1.

Geffroy, D. *et al.* (2021) 'Projecting the Metropolis: Paris 2024 and the (re)scaling of metropolitan governance', *Cities*, 114. Available at: https://doi.org/10.1016/j.cities.2021.103189.

Gold, J.R. and Gold, M.M. (2008) 'Olympic Cities: Regeneration, City Rebranding and Changing Urban Agendas', *Geography Compass*, 2(1), pp. 300–318. Available at: https://doi.org/10.1111/j.1749-8198.2007.00080.x.

Hiller, H.H. (2006) 'Post-event Outcomes and the Post-modern Turn: The Olympics and Urban Transformations', *European Sport Management Quarterly*, 6, pp. 317–332. Available at: https://api.semanticscholar.org/CorpusID:153703969.

Hu, R. (2024) 'The transformation of Beijing as a dual Olympic city: growth, post-growth, and the reimagining of the capital', *Planning Perspectives*, 39(3), pp. 575–594. Available at: https://doi.org/10.1080/02665433.2024.2324356.

Husukić, E. and Zejnilović, E. (2020) 'Beyond the Sarajevo 1984 Olympicscape: An evaluation of the Olympic Villages.', *Cities*, 106, p. 102924. Available at: https://doi.org/10.1016/J.CITIES.2020.102924.

International Olympic Committee (2022a) *A year after the Games, a new life begins for Tokyo 2020 venues*.

International Olympic Committee (2022b) *Barcelona 1992: a city turning towards the sea and winning the hearts of the world*. Available at: https://olympics.com/ioc/news/barcelona-1992-a-city-turning-towards-the-sea-and-winning-the-hearts-of-the-world (Accessed: 29 October 2024).

IOC (International Olympic Committee) (2014) *Olympic agenda 2020: 20+20 recommendations*. Lausanne: International Olympic Committee.

Jones, Z.M., Di Vita, S. and Ponzini, D. (2022) 'Changing mega-events' spatial strategies and cultural policy: scaling down, spacing out, and assembling organizations in the cases of London and Milan', *City, Territory and Architecture*, 9(1). Available at: https://doi.org/10.1186/s40410-022-00175-0.

Languillon-Aussel, R. (2024) 'Tokyo as an Olympic city across modern history: planning culture as the intangible heritage from a century of hosting the Olympic and Paralympic Games', *Planning Perspectives*, 39(3), pp. 551–573. Available at: https://doi.org/10.1080/02665433.2024.2338883.

Lützeler, R. (2020) 'Tokyo 2020 and neighborhood transformation', in *Japan Through the Lens of the Tokyo Olympics*. London: Routledge, pp. 39–45. Available at: https://doi.org/10.4324/9781003033905-10.

Müller, M. (2015) 'The Mega-Event Syndrome: Why So Much Goes Wrong in Mega-Event Planning and What to Do About It', *Journal of the American Planning Association*, 81(1), pp. 6–17. Available at: https://doi.org/10.1080/01944363.2015.1038292.

Pinto, P.J. and Lopes dos Santos, G. (2022) 'Olympic Waterfronts: An Evaluation of Wasted Opportunities and Lasting Legacies', *Sustainability*, 14(4), p. 1968. Available at: https://doi.org/10.3390/su14041968.

Ponzini, D. *et al.* (2024) *Milan Cultural Mega-events: From the 2015 Expo through the 2026 Winter Olympics*. Milan: Lettera Ventidue.

Purkarthofer, F. (2020) 'Tokyo's architecture and urban structure', in *Japan Through the Lens of the Tokyo Olympics*. London: Routledge, pp. 47–51. Available at: https://doi.org/10.4324/9781003033905-12.

Raco, M. and Di Vita, S. (2024) 'Replacing place with space: the influences and the challenges of the new norm on the Milan-Cortina Winter Games 2026', *Planning Perspectives*, 39(3), pp. 701–719. Available at: https://doi.org/10.1080/02665433.2024.2336124.

Ricordel, P. (2023) 'The circular heritage model of Paris 2024 and its possible local legacy perspective', *Local Economy: The Journal of the Local Economy Policy Unit*, 38(4), pp. 405–417. Available at: https://doi.org/10.1177/02690942231213828.

Saito, A. (2003) 'Global City Formation in a Capitalist Developmental State: Tokyo and the Waterfront Sub-centre Project', *Urban Studies*, 40(2), pp. 283–308. Available at: https://doi.org/10.1080/00420980220080281.

Research Paper

Research on demand for public space for residents' daily leisure activities in old communities based on KANO-IPA analysis

——a case study of Harbin, China

Haozhe Zhang, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Qing Luo, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Abstract

China's rapid urbanization has left many old communities in central urban areas with issues like insufficient public space, aging facilities, poor transportation, and degraded landscapes, severely impacting residents' quality of life. Simultaneously, in the Internet era, more residents favor online entertainment, significantly reducing outdoor leisure time. This trend may pose various physical, psychological, and social health challenges for some residents. In addition, the current practice of renovating old communities in China tends to apply mature design techniques, which makes the renovated space unable to meet the complex and diverse needs of residents for daily leisure activities. This study takes some old communities in Harbin, China as the research object, obtains data through questionnaire survey, and uses the combined KANO-IPA analysis method to analyze the data. The results show that residents have a stronger demand for facilities and environments that ensure the safety, hygiene and rest of their daily leisure space. These spatial environment indicators should be given priority in the improvement of public spaces in old communities; while spatial indicators that enhance spatial interest and beauty should be considered only when there is sufficient funding for space transformation. The research results can provide a reliable theoretical basis for the reconstruction and construction of outdoor public spaces in old communities in a more humane and efficient way, which will contribute to the sustainable development of community public spaces and the construction of healthy cities.

Keywords

daily leisure activities; old communities; outdoor public space; demand analysis

1. Introduction

Due to the rapid urbanization and socio-economic development in China over the past few decades, there are a large number of widely distributed old communities in the central urban areas of cities. At present, many old communities are built early and poorly managed, and generally have many problems such as insufficient public space, aging facilities, poor traffic, and poor landscape environment. They cannot meet

the high-quality life needs of residents. How to optimize and improve the stock of public space in old communities has received widespread attention.

In addition, with the advent of the Internet era, people may tend to reduce offline activities in the real world due to more attractive online leisure and entertainment activities. The "China Better Life Survey (2022-2023)" shows that in 2022, the average leisure time of Chinese people on weekdays is 2.76 hours. During their leisure time, about 51.87% of people choose mobile entertainment, and health status becomes the first consideration for people to define a happy life. The reality that the time for outdoor daily leisure activities is severely compressed by online entertainment activities is obviously contrary to people's psychological state of wanting to pursue a healthy lifestyle. There may be a key problem that the real public space cannot meet people's outdoor leisure needs, especially in old communities.

As people pay more attention to healthy lifestyles, their demands for public spaces have become more diverse and personalized, which requires more diverse leisure facilities and more diversified activity scenarios. However, the current public space configuration and environment creation in old communities cannot create conditions for residents to engage in a wider range of leisure activities, and cannot resolve possible conflicts between different leisure activities, which is not conducive to the formation of a more active lifestyle.

As propositions such as community aging-friendly renewal(Mao et al., 2019), 15-minute community life circle community renewal guidance(Yu, 2019), and community multi-governance renewal(Li et al., 2020)are constantly put forward, the optimization and renewal of community public spaces pay more attention to how to make residents more comfortable to use community public spaces for public life and public space. Whether it can adapt to the needs of disadvantaged groups, the most significant feature is based on environmental behavior, using diversified methods to explore the relationship between space and user behavioral activities.

As an important part of the neighborhood environment, community outdoor public spaces directly carry the daily activities of residents. Research on community public space based on residents' behavioral activity needs is to explore the relationship between public space and residents' activities, clarify what residents' activities require of community public space and how to construct space to promote residents' activities, so as to achieve satisfaction Spatial optimization goals for residents' behavioral activity needs.

Generally speaking, in terms of space, since community public space has dual physical and social attributes, the discussion of spatial environment in relevant research can be divided into two dimensions: physical environment and social environment. The content of the physical environment includes the number(Kaczynski and Henderson, 2007), accessibility(Wang et al., 2015), layout(Mouratidis, 2018), etc. of public spaces at the community level, as well as the form and scale(Tang and Long, 2019), facility configuration(Stewart et al., 2018), landscape environment(Cohen et al., 2017), etc. at the site level. It explores how to build material conditions suitable for residents' outdoor activities; while the social dimension includes The overall atmosphere composed of crowd activities and the environment(胡 et al., 2021), the emotions between users and the place(Guan et al., 2020), and human-made management and governance measures for the place(Holy-Hasted and Burchell, 2022), etc.

Commonly used methods for demand analysis and demand evaluation include analytic hierarchy process(Wang et al., 2022), fuzzy comprehensive evaluation(Wei, 2006), KANO model(Zhang et al., 2022), IPA analysis(Chen et al., 2022), etc. to establish a corresponding evaluation system to explore the relationship between crowd needs and spatial elements, and these methods will be used in conjunction with each other(Shao et al., 2018). The overall form of relevant research shows a trend of combining

qualitative and quantitative, subjective and objective. By constructing a composite model, the methodological advantages are further added to form better support for the research.

This paper aims to truly start from the perspective of residents, take daily leisure activities as the starting point, and study the material and social environmental characteristics of outdoor public spaces in old communities through a review of relevant literature, field investigations, and interviews with residents on their daily leisure activity needs, in order to explore the relationship between daily leisure activities, needs, and spatial environment. First, the existing research on community public spaces and residents' daily leisure activities at home and abroad is summarized, and a spatial demand index system for residents' daily leisure activities is constructed; secondly, some old communities in Harbin, China are taken as the research objects, and questionnaire surveys are conducted to obtain relevant data such as residents' daily leisure activities and their positive and negative satisfaction and perceived importance of community public space environmental indicators; finally, the KANO-IPA analysis method is used to analyze the data, identify the demand attitudes of residents' daily leisure activities on the outdoor public space environment of old communities, and clarify the optimization and improvement order of relevant spatial environmental indicators. Combined with the results of quantitative model analysis, this paper provides a reference theoretical and practical basis for the planning, design and renewal of the outdoor public space environment of old communities based on the satisfaction of residents' daily leisure activity needs. (Figure 1.)

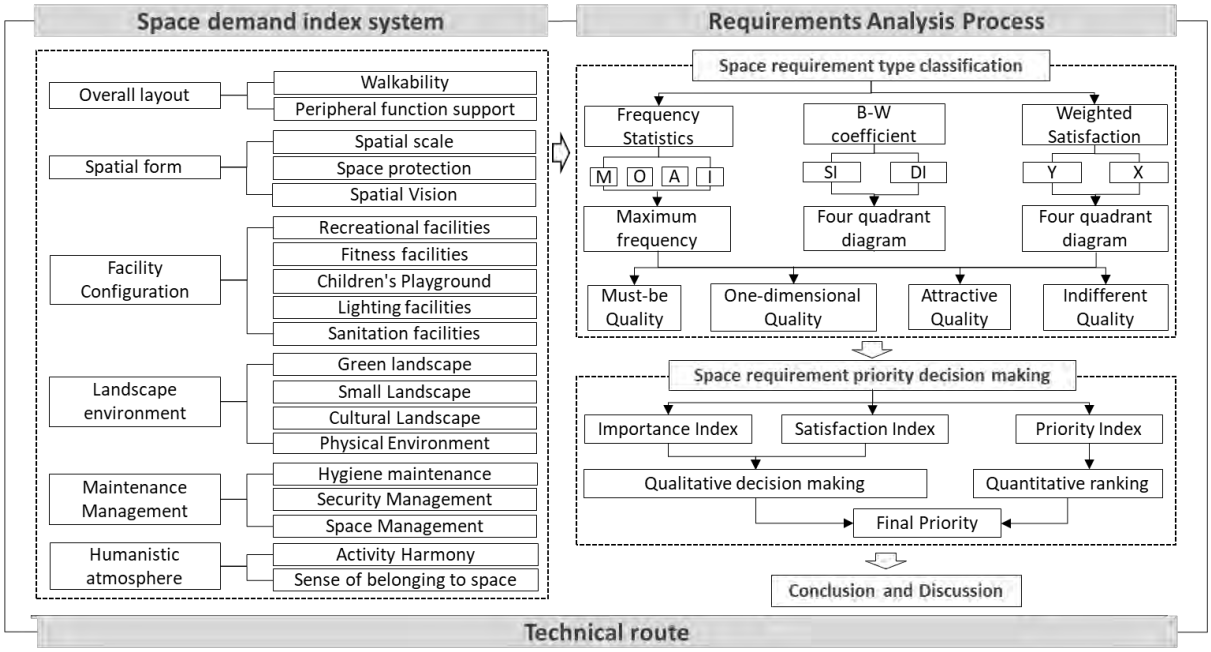


Figure 1. Research Framework. Source: Author.

2. Methodology

2.1. Model Methods

2.1.1. KANO model analysis

The KANO model was formally proposed by Noriaki Kano, a scholar at Tokyo Institute of Technology, in 1984 to classify and prioritize user needs, pointing out the nonlinear relationship between the satisfaction

of demand elements and user satisfaction(Füller and Matzler, 2007). The model breaks the traditional one-sided perspective and asks about the user's satisfaction when the demand items are "satisfied" or "unsatisfied" by setting positive and negative questions for demand elements, thereby dividing demand elements into six types: Must-be Quality (M), One-dimensional Quality (O), Attractive Quality (A), Indifferent Quality (I), Reverse Quality (R), and Questionable Quality (Q). (Table 1.)

demand indicators		Reverse question (this requirement cannot be met)				
		Like	Must-be	Neutral	Live with	Dislike
Forward question (can provide this requirement)	Like	Q	A	A	A	O
	Must-be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q

Table 1. KANO model requirement type assessment table. Source: Author.

However, by using the "maximum value" principle to determine the classification of a demand item, it is easy to have the percentages of different classifications of a demand item be equal or very close. Berger et al. proposed the concept of customer satisfaction index in 1993, and calculated the satisfaction coefficient (Better/SI) and dissatisfaction coefficient (Worse/DI) to express the average perception of users on a demand item, so as to avoid the occurrence of classification uncertainty(Yang, 2005). The specific calculation formula is as follows:

$$SI=(A+O)/(M+O+A+I) \quad (2.1)$$

$$DI=(M+O)/(M+O+A+I) \quad (2.2)$$

The traditional Kano model that classifies needs according to the proportion of the user's perceived classification results of a certain demand indicator belongs to the category of qualitative research. Matzler et al. proposed to assign values to the user's perceived satisfaction level of the demand indicator to achieve quantitative Kano model research(Matzler and Hinterhuber, 1998). Xu proposed a construction method for an analytical Kano model, and investigated the user's satisfaction and perceived importance of positive and negative questions on demand indicators by designing an analytical Kano model questionnaire(Xu et al., 2009). The demand indicator set is represented as $F=\{f_i,i=1,2,\ldots\ldots,n\}$, f_i represents the i-th demand indicator in the set, and the total number of participants is defined as j, x_{ij} represents the reverse question score of resident j on demand indicator f_i, y_{ij} represents the positive question score of resident j on demand indicator f_i, and z_{ij} represents the perceived importance score of resident j on demand indicator f_i. The comprehensive evaluation of resident j on demand indicator f_i is expressed as $w=(x_{ij}, y_{ij}, z_{ij})$.

For each demand indicator f_i, the average weighted score of the participants for negative questions is represented by X_i, and the average weighted score for positive questions is represented by Y_i. The calculation formula is as follows:

$$\bar{X}_i = \frac{1}{J} \sum_{j=1}^{J} z_{ij} x_{ij} \quad (2.3)$$

$$\overline{Y_i} = \frac{1}{J} \sum_{j=1}^{J} z_{ij} y_{ij} \qquad (2.4)$$

At the same time, the (X_i, Y_i) corresponding to the demand index f_i can be represented by a point in this coordinate diagram. With this point as the end point of the vector and the origin of the coordinate as the starting point of the vector, the comprehensive evaluation of the demand index f_i can be converted into a vector r_i, f_i (X, Y) $\rightarrow$ f_i (r, α), where the length of the vector represents the overall importance of the demand index to the user, that is, the importance index, and the angle of the vector represents the relative level of satisfaction and dissatisfaction, that is, the satisfaction index. Based on this, the priority index (β_i) can be calculated to quantitatively determine the priority of the demand index. The calculation formula is as follows:

$$|\vec{r_i}| = \sqrt{\overline{X_i^2} + \overline{Y_i^2}}, \ 0 \le r_i \le \sqrt{2} \qquad (2.5)$$

$$\alpha_i = tan^{-1} \left(\frac{\overline{Y_i}}{\overline{X_i}} \right), \ 0 \le \alpha_i \le \frac{\pi}{2} \qquad (2.6)$$

$$\beta_i = \frac{2\sqrt{2}}{3} \left(1 - \frac{\alpha_i}{\pi} \right) r_i \qquad (2.7)$$

2.1.2. IPA model analysis

The IPA analysis method is to analyze by constructing a function model of the user's expectations and performance evaluation of the product value. It mainly studies the difference between the two variables of importance and satisfaction. Among them, importance refers to the user's attention to the service and special requirements provided by the various indicators of the product, and satisfaction refers to the user's perceived evaluation of the actual use of the various indicators of the product. The X-axis represents the importance of the evaluation factors, and the Y-axis represents the actual performance. A two-dimensional matrix is formed and divided into four quadrants to establish the IPA model.

Quadrant I is the advantage maintenance area, and the importance and satisfaction values of the indicator elements in this quadrant are both high; Quadrant II is the status quo maintenance area, and the importance of the indicator elements in this quadrant is low, but the satisfaction value is high; Quadrant III is the temporary improvement area, and the importance and satisfaction values of the indicator elements in this quadrant are both low; Quadrant IV is the key improvement area, and the importance of the indicator elements in this quadrant is high, but the satisfaction value is low. (Figure 2.)

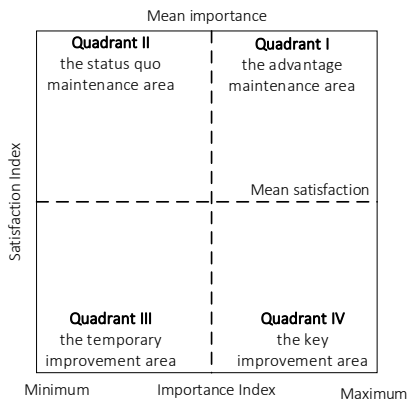


Figure 2. IPA Four-quadrant Diagram Example. Source: Author.

2.1.3. Integrating the KANO-IPA model

This study discusses the optimization of outdoor public spaces in old communities under the needs of residents' daily leisure activities. Therefore, firstly, the spatial demand indicators of residents' daily leisure activities are classified according to the three KANO demand classification methods, and the demand type of each indicator is determined. Then, the analytical KANO-IPA analysis is combined to determine the optimization order of spatial demand indicators. The satisfaction index and importance index in the analytical KANO model are used as the satisfaction and importance in the IPA analysis to construct the IPA four-quadrant diagram, and the priority index is combined to determine the priority of different spatial demand indicators.

2.2. Selection of space demand indicators

Through the review of each sample literature, it can be seen that although the index system has different dimensions, in general, the community public space element index system includes material environment elements and social environment elements, among which the material environment elements are composed of two levels: the place itself and the overall layout. The material environment elements of the place itself are composed of a series of related material foundations such as the site form, facility configuration, and landscape environment in the space; the material environment elements at the community level mainly refer to the layout, accessibility, and richness and proximity of the surrounding functions of the public space; the social environment elements of the public space are the level of artificial maintenance and management and a series of place atmospheres.

Based on the previous review, combined with the actual survey of Harbin's old communities, 19 evaluation indicators for construction and evaluation were finally determined. From the two levels of material environment and social environment, the dimensions are divided according to the attributes and functions of each evaluation indicator, and the Harbin old community public space element evaluation system under the needs of residents' daily leisure activities is constructed from the overall layout, site form, facility configuration, landscape environment, maintenance and management, and humanistic atmosphere. (Table 2.)

Dimensions	serial number	index
Overall layout	f1	Walkability
	f2	Peripheral function support
Spatial form	f3	Spatial scale
	f4	Space protection
	f5	Spatial Vision
Facility Configuration	f6	rest facilities
	f7	Fitness facilities
	f8	Children's Playground
	f9	Lighting facilities
	f10	Sanitation facilities
Landscape environment	f11	Green landscape
	f12	Small Landscape
	f13	Cultural Landscape
	f14	Physical Environment
Maintenance Management	f15	Hygiene maintenance
	f16	Security Management
	f17	Space Management
Humanistic atmosphere	f18	Activity Harmony
	f19	Sense of belonging to space

Table 2. Interpretation of Space Environment Indicators. Source: Author.

2.3. Study Area and Data collection

This study selected the old residential areas in the Dayoufang-Nanzhi Road Street area of Daowai District, Harbin as the research object. On the one hand, the community public space in this area has a relatively rich level and system. The old residential areas in the area were mainly built during the period from the 1990s to the early 21st century when the residential community model was widely developed. They usually have a relatively complete outdoor public space system, ranging from courtyard activity spaces enclosed by residential neighborhoods to community life streets and community concentrated activity spaces. At the same time, the area has many community parks and green spaces such as Nanzhi Park, Guliyuan, Taiping Park, and Majiagou Riverside Green Space, where there are residents with various preferences for daily leisure activities, which is suitable for discussions on the different daily leisure activity needs of residents.

In order to ensure that the selection of survey subjects is not repeated, 9 old communities were selected from north to south in the study area as survey sites. Since it is impossible to survey every household in the sample community, this survey adopts a random sampling method. The questionnaire survey was conducted from March 26, 2024 to April 14, 2024. During the survey period, a total of 350 questionnaires were distributed, 11 invalid questionnaires were eliminated, and finally a total of 339 valid questionnaires were obtained, with an efficiency of 96.86%.(Table 3.)

serial number	Research community	Construction Year	Greening rate	Number of households	Number of valid questionnaires	total
A-1	Songdian Community	2000	30	2145	37	
A-2	Honghe Fifth District	2000	35	2058	34	1 11
A-3	Honghe Seventh District	2001	15	2572	40	
B-1	Honghe Teachers' Residential Quarter	2000	35	3340	35	
B-2	Hongwei Garden	2002	36	2997	40	1 20
B-3	Hongping Residential Area	1999	32	4018	45	
C-1	Yuxuan Garden	2001	31.52	2078	28	
C-2	Hongqi Community District 2	1994	30	5214	40	1 08
C-3	Songshan Community	2000	27	2716	40	
						3 39

Table 3. Questionnaire Distribution. Source: Author.

3. Result

3.1. Data Descriptive Statistics

3.1.1. Questionnaire reliability and validity test

This article uses SPSS software to analyze the reliability and validity of the forward questions, reverse questions, importance questions and forward and reverse questions in the questionnaire as a whole. The results show that the reliability coefficients are all greater than 0.8, and the KMO values are all greater than 0.7, and the significance is all <0.0, indicating that the scale questionnaire used in this study has high internal reliability and structural validity in reflecting residents' positive and negative demands and importance for public spaces in old communities. (Table 4、5.)

	Cronbach Alpha	Cronbach's Alpha based on standardized items	Number of items
The issue of importance	.875	.881	1 9
Positive Questions	.825	.835	1 9
Reverse Problem	.809	.823	1 9
Positive and negative problems as a whole	.889	.898	3 8

Table 4. Reliability test results. Source: Author.

		The issue of importance	Positive Questions	Reverse Problem	Positive and negative problems as a whole
KMO sampling suitability measure		.860	.815	.794	.795
Bartlett's test of sphericity	Approximate Chi-Square	2201.461	1572.045	1514.616	5089.722
	degrees of freedom	171	171	171	703
	Significance	.000	.000	.000	.000

Table 5. Validity test results. Source: Author.

3.1.2. Sample basic information

Based on 339 valid questionnaires collected in the public spaces of 9 sample old communities, descriptive statistics of the basic attribute characteristics of the valid samples were conducted. The questionnaire survey was conducted among residents of different age groups, genders, educational levels and occupations, taking into account both the representativeness and diversity of the survey samples. (Table 6.)

variable	Classification	quantity	percentage
gender	male	168	49.56%
	female	171	50.44%
age	<18 years old	25	7.37%
	18-40 years old	118	34.81%
	4 0-60 years old	108	31.86%
	>60 years old	88	25.96%
Education	Junior high school and below	93	27.43%
	High school (including technical secondary school and vocational high school)	97	28.61%
	Undergraduate, junior college	138	40.71%
	Master degree and above	11	3.24%
Profession	student	58	17.11%
	Full-time job	106	31.27%
	No work	38	11.21%
	Freelancing	48	14.16%
	retire	89	26.25%
Residence time	Less than 1 year	9	2.65%
	1-5 years	65	19.17%
	5-10 years	95	28.02%
	1 0-15 years	72	21.24%
	1 More than 5 years	98	28.91%
Home ownership	yes	313	92.33%
	no	26	7.67%
Living Status	Living alone	27	7.96%
	Living together	80	23.60%
	Two generations living together	183	53.98%
	Three generations living together	49	14.45%

Table 6. Sample basic properties. Source: Author.

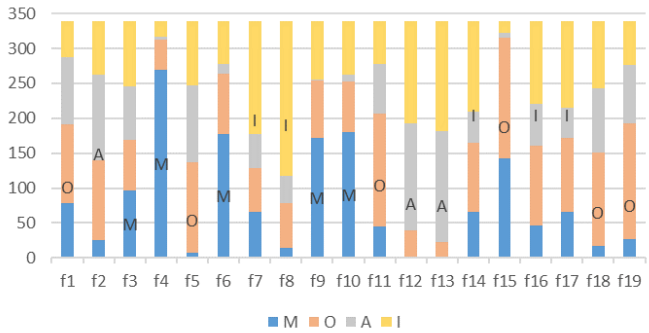
3.2 Space requirement type classification

In determining the types of outdoor public space use needs of residents in old communities in Harbin, first, according to the demand determination mechanism of the Kano model, the Kano demand evaluation table was used to count the evaluation of each respondent on 19 demand indicators. After preliminary screening, the spatial element indicators were divided into preliminary demand levels based on the principle of maximum frequency, but some spatial element indicators had similar frequency distributions of different demand attributes. For example, the frequency values of spatial scale in the two demand types M and O

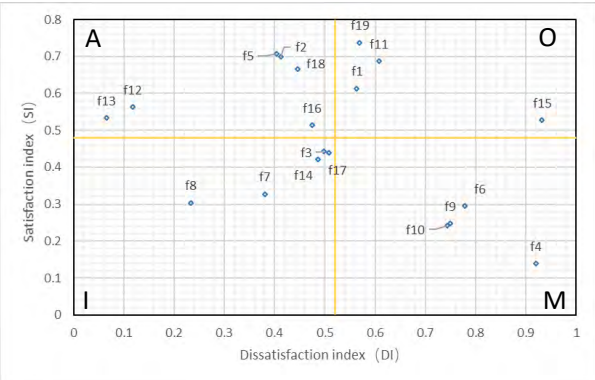
are similar, the frequency values of small landscape and cultural landscape in the two demand types A and I are similar, and the frequency values of security management in the two demand types O and I are similar. Therefore, it is necessary to further divide the spatial demand types based on the satisfaction and dissatisfaction coefficients. (Figure 3-a.)

With the dissatisfaction coefficient (DI) as the horizontal axis and the satisfaction coefficient (SI) as the vertical axis, the average score of the index coefficient is calculated as the standard to draw two vertical intersecting lines, and the 19 demand items are scattered, and finally an analysis matrix with 4 quadrants is formed, which intuitively displays the attributes of all demands. (Figure 3-b.)

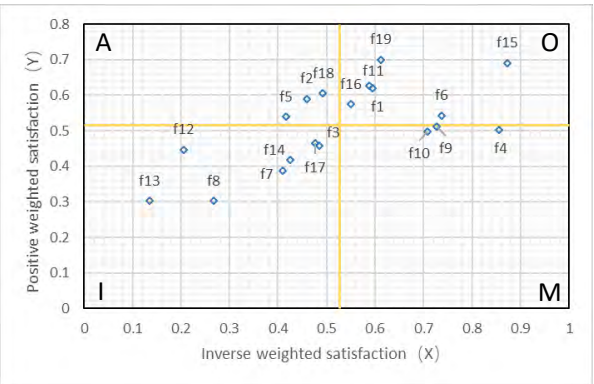
With reverse weighted satisfaction (X_i) as the horizontal coordinate and positive weighted satisfaction (Yi) as the vertical coordinate, the average score of the positive and negative weighted satisfaction index coefficients is calculated as the standard to draw two vertically intersecting lines, draw a coordinate graph, and scatter the 19 demand items. Finally, an analysis matrix with 4 quadrants is formed to intuitively display the attributes of all demands. (Figure 3-c.)



(a) Kano demand type frequency distribution diagram



(b) Better-Worse coefficient change distribution



(c) Four-quadrant diagram of positive-negative weighted satisfaction

Figure 3. Illustration of the results of three types of demand classification. Source: Author.

Comparing the results of the three demand classification methods, the types of some demands have changed. For example, the spatial scale belongs to M according to the maximum frequency principle, but belongs to I according to the other two methods; the spatial vision and activity harmony index belong to O according to the maximum frequency principle, but belong to A according to the other two methods; the recreational facilities belong to O according to the analytical Kano classification, but belong to M according to the other two methods; the small landscape and cultural landscape belong to I according to the analytical Kano classification, but belong to A according to the other two methods; the three classification methods of security management belong to I, A, and O respectively. Therefore, the results of the three demand

classification methods and the actual needs of residents are combined to obtain the results of the spatial demand type classification of residents' daily leisure activities in the outdoor public spaces of old communities in Harbin. Necessary needs (M) include four indicators: space protection, rest facilities, lighting facilities, and sanitation facilities. Expected needs (O) include five indicators: walkability, green landscape, hygiene maintenance, security management, and sense of belonging to space. Attractive needs (A) include five indicators: peripheral function support, space vision, small landscape, cultural landscape, and activity harmony. Indifferent needs (I) include five indicators: space scale, fitness facilities, children's playground, physical environment, and space management. (Table 7.)

serial number	Classification frequency				Category	SI	D I	Category	Positive weighted satisfaction	Inverse weighted satisfaction	Category
	F (M)	F(O)	F (A)	F(I)							
f1	79	112	96	52	O	0.563	0.614	O	0.619	0.594	O
f2	25	115	122	77	A	0.413	0.699	A	0.590	0.459	A
f3	96	73	77	93	M	0.499	0.442	I	0.458	0.485	I
f4	270	42	5	22	M	0.920	0.139	M	0.502	0.855	M
f5	7	130	110	92	O	0.404	0.708	A	0.539	0.416	A
f6	178	86	14	61	M	0.779	0.295	M	0.543	0.737	O
f7	66	63	48	162	I	0.381	0.327	I	0.389	0.409	I
f8	14	65	38	222	I	0.233	0.304	I	0.302	0.266	I
f9	172	82	2	83	M	0.749	0.248	M	0.511	0.727	M
f10	180	72	10	77	M	0.743	0.242	M	0.498	0.708	M
f11	45	161	72	61	O	0.608	0.687	O	0.627	0.588	O
f12	2	38	153	146	A	0.118	0.563	A	0.447	0.205	I
f13	1	21	160	157	A	0.065	0.534	A	0.303	0.134	I
f14	66	99	44	130	I	0.487	0.422	I	0.418	0.425	I
f15	143	173	6	17	O	0.932	0.528	O	0.691	0.872	O
f16	46	115	59	119	I	0.475	0.513	A	0.575	0.551	O
f17	66	106	43	124	I	0.507	0.440	I	0.464	0.476	I
f18	17	134	92	96	O	0.445	0.667	A	0.605	0.493	A
f19	27	166	84	62	O	0.569	0.737	O	0.700	0.612	O

Table 7. Comparison of the results of three demand classifications. Source: Author.

3.3 Prioritization of space requirements

In the IPA quadrant diagram, the decision result of the needs in the first and second quadrants is "maintain strategy", and the priority is: first quadrant > second quadrant; the decision result of the needs in the third and fourth quadrants is "improve strategy", and the priority is: fourth quadrant > third quadrant. Based on this, the quadrants of each indicator in the 19 demand indicators of daily leisure activities of residents in outdoor public spaces in old communities in Harbin are sorted out, and the corresponding decision results are obtained.

serial number	Importance index (r_i)		Satisfaction index (α_i)		Difference	Priority index (β_i)	
	value	Sorting	value	Sorting		value	Sorting
f1	0.858	8	0.805	10	0.053	0.602	7
f2	0.748	11	0.909	4	-0.161	0.501	11
f3	0.667	13	0.756	14	-0.089	0.477	12
f4	0.991	2	0.531	19	0.461	0.777	2
f5	0.681	12	0.914	3	-0.232	0.456	14
f6	0.915	4	0.635	16	0.281	0.689	3
f7	0.564	16	0.760	13	-0.195	0.403	16
f8	0.403	18	0.848	7	-0.446	0.277	18
f9	0.889	5	0.613	18	0.276	0.675	4
f10	0.866	6	0.613	17	0.252	0.657	5
f11	0.860	7	0.817	8	0.043	0.600	8
f12	0.492	17	1.140	2	-0.648	0.295	17
f13	0.331	19	1.154	1	-0.822	0.198	19
f14	0.596	15	0.777	11	-0.181	0.423	15
f15	1.113	1	0.670	15	0.443	0.825	1
f16	0.796	9	0.807	9	-0.011	0.558	9
f17	0.665	14	0.772	12	-0.107	0.473	13
f18	0.780	10	0.887	5	-0.107	0.528	10
f19	0.930	3	0.852	6	0.077	0.639	6

Table 8. Importance (r_i), satisfaction (α_i), Priority index (β_i) index calculation results. Source: Author.

The above research has classified the spatial needs of residents' daily leisure activities in the public spaces of old communities in Harbin. However, when the renovation conditions are limited, more precise renovation project selection is usually required. In order to better assist in renovation decision-making, the priority index βi is used to sort the needs, and finally the demand type classification of 19 demand indicators and the priority sorting of improved decision-making are obtained. (Table 9.)

Requirement Type	decision making	Indicators and prioritization
Must-be Quality (M)	promote	Space protection > rest facilities > lighting facilities > sanitation facilities
	Keep	
One-dimensional Quality (O)	promote	Hygiene maintenance
	Keep	Sense of spatial belonging > Walkability > Green landscape > Security management
Attractive Quality (A)	promote	
	Keep	Activity harmony > Peripheral function support > spatial vision > small landscape > cultural landscape
Indifferent Quality (I)	promote	Space scale > Space management > Physical environment > Fitness facilities
	Keep	Children's Playground

Table 9. Final sorting of space requirements priorities. Source: Author.

4. Conclusion and Discussion

Through a case study of old communities in Harbin, this study found that residents' daily leisure activities have different types of demands for community public space environmental elements and the priority differences between demand elements, and thus the following conclusions were drawn. The renovation of public spaces in old communities should be optimized in stages and levels according to the priority of demand elements. First, the basic needs of residents' daily leisure activities should be met, and then other levels of needs should be gradually improved and enriched. Limited funds are a practical problem often faced in the promotion of the renewal of old communities. Therefore, taking into account the order of needs can ensure more effective use of funds and gradually improve the quality of life of residents.

By meeting the basic needs of community residents and providing them with safe, sanitary and easily accessible public spaces, it is possible to effectively ensure the residents' leisure activities and lay a solid foundation for the further optimization of public spaces. For example, ensuring the safety of community public spaces, including the improvement of lighting facilities, the installation of monitoring systems, the implementation of safety measures, etc., is the most basic need; maintaining the sanitation of the space environment, the configuration and timely cleaning of public toilets and trash cans; providing convenient and accessible conditions for the space, such as barrier-free passages, reasonable walking paths, and clear signs to facilitate the use of residents of different ages and physical conditions. After meeting basic needs, further attention should be paid to residents' expectations, charm and personalized needs. For example, the transformation of the physical environment should be carried out on the premise of maintaining residents' sense of belonging to the original activity space and not destroying the harmony of the original activities; the shaping of sketches and cultural landscapes can be considered when funds are sufficient. Scientifically and rationally arrange the optimization order of public spaces in old communities so that both the basic needs and higher-level needs of residents can be effectively met, thereby comprehensively improving the experience and quality of residents' daily activities.

At the same time point, the spatial demands represented by different groups of people are different and contradictory; at the same spatial point, the physical spaces occupied by different groups of people overlap, showing extremely mobile people and complex demands. An overall analysis of the spatial demands of

residents' daily leisure activities alone may obscure the actual demand information of groups with different activity preferences. In subsequent studies, the commonalities and differences in the demands of different preference groups for community outdoor public spaces can be explored in combination with the content characteristics of residents' daily leisure activities, and specific and detailed optimization strategies can be formed to reasonably invest capital, so as to improve the environmental resource utilization rate and satisfaction of the results of the transformation of public spaces in old communities.

5.References

Cohen, D.A., Han, B., Evenson, K.R., Nagel, C., McKenzie, T.L., Marsh, T., Williamson, S., Harnik, P., 2017. The Prevalence and Use of Walking Loops in Neighborhood Parks: A National Study. Environ. Health Perspect. 125, 170–174. https://doi.org/10.1289/EHP293

Füller, J., Matzler, K., 2007. Virtual product experience and customer participation—A chance for customer-centred, really new products. Technovation 27, 378–387. https://doi.org/10.1016/j.technovation.2006.09.005

Guan, P., Xu, X., Xu, N., Wang, W., 2020. ANALYSES OF THE IMPACT OF BUILT ENVIRONMENT FACTORS OF SMALL PUBLIC GREEN SPACES ON PUBLIC HEALTH —A CASE STUDY ON THE OLD CITY CENTER OF NANJING, JIANGSU PROVINCE. Landsc. Archit. Front. 8, 76–92. https://doi.org/10.15302/J-LAF-1-020036

Holy-Hasted, W., Burchell, B., 2022. Does public space have to be green to improve well-being? An analysis of public space across Greater London and its association to subjective well-being. Cities 125, 103569. https://doi.org/10.1016/j.cities.2022.103569

Kaczynski, A.T., Henderson, K.A., 2007. Environmental Correlates of Physical Activity: A Review of Evidence about Parks and Recreation. Leis. Sci. 29, 315–354. https://doi.org/10.1080/01490400701394865

Matzler, K., Hinterhuber, H.H., 1998. How to make product development projects more successful by integrating Kano's model of customer satisfaction into quality function deployment. Technovation 18, 25–38. https://doi.org/10.1016/S0166-4972(97)00072-2

Mouratidis, K., 2018. Built environment and social well-being: How does urban form affect social life and personal relationships? Cities 74, 7–20. https://doi.org/10.1016/j.cities.2017.10.020

Stewart, O.T., Moudon, A.V., Littman, A.J., Seto, E., Saelens, B.E., 2018. Why neighborhood park proximity is not associated with total physical activity. Health Place 52, 163–169. https://doi.org/10.1016/j.healthplace.2018.05.011

Tang, J., Long, Y., 2019. Measuring visual quality of street space and its temporal variation: Methodology and its application in the Hutong area in Beijing. Landsc. Urban Plan. 191, 103436. https://doi.org/10.1016/j.landurbplan.2018.09.015

Wang, D., Brown, G., Liu, Y., Mateo-Babiano, I., 2015. A comparison of perceived and geographic access to predict urban park use. Cities 42, 85–96. https://doi.org/10.1016/j.cities.2014.10.003

Xu, Q., Jiao, R.J., Yang, X., Helander, M., Khalid, H.M., Opperud, A., 2009. An analytical Kano model for customer need analysis. Des. Stud. 30, 87–110. https://doi.org/10.1016/j.destud.2008.07.001

Yang, C.-C., 2005. The refined Kano's model and its application. Total Qual. Manag. Bus. Excell. 16, 1127–1137. https://doi.org/10.1080/14783360500235850

Yu, Y.F., 2019. From traditional residential area planning to community life circle planning. City Planning Review 43, 17–22.

Zhang, J., Li, J.Y., Lv, Y., Li, M., 2022. Analysis and optimization suggestions on public space demand behavior in subway stations based on KANO model. Architectural Journal 131–135.

Li, D.Z., Gu, T.T., Zhu, S.Y., 2020. Study on residents' willingness to participate in governance and its influencing factors in the renovation of old residential areas: A case study of Nanjing. Modern Urban Research 19-25+41.

Mao, H.S., Song, Y.J., Chen, X., 2019. Study on the renewal strategy of age-friendly landscape in work unit communities under social transformation: A case study of Chongqing Cotton Factory community. Landscape Architecture 26, 95–99. https://doi.org/10.14085/j.fjyl.2019.04.0095.05

Wang, Z.Y., Li, G., Li, D., Yu, L., 2022. Research on the evaluation of public space demand in old neighborhoods based on AHP. Popular Standardization 75-77+80.

Hu, Y.T., Yu, Y.F., Zhang, Q.L., 2021. A study on the impact of green open space on social interaction of the elderly and its environmental characteristics: A survey based on public housing communities in Yangpu District, Shanghai. Shanghai Urban Planning Review 96–103.

Shao, J.Y., Zhang, H.B., Li, J.X., 2018. Research on the evaluation of square space quality based on elderly-friendly cities——Taking the squares in the main urban area of Harbin as the research object. Building Energy Efficiency 46, 78–83.

Chen, L.Y., Tan, S.H., Yang, C., He, Q.X., 2022. Evaluation of urban greenway environmental recreation satisfaction from the perspective of perceived value: A case study of Jiulongpo Greenway in Chongqing. Chinese Landscape Architecture 38, 76–81. https://doi.org/10.19775/j.cla.2022.01.0076

Wei, L.K., 2006. Comparative Study on Kano Model and Service Quality Gap Model. Standard Science 10–13.

Research Paper

Research on recreational environment optimization of waterfront parks in winter cities based on IPA-Kano model

Take Daqing as an example

Ming LU, School of Architecture, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Ke NING, School of Architecture, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Abstract

In the new stage of urban construction and development, the recreation demand of urban residents is increasing day by day, and the recreational environment of urban park green space is paid much attention. Among them, the waterfront park has been favored by urban residents for its strong natural attributes and resource advantages. The unique climate attribute of the winter cities has caused a certain degree of influence on the recreational environment of the waterfront parks. How to build and optimize the recreational environment of the waterfront parks in the winter climate has become an urgent problem to be solved. Therefore, this research takes the urban waterfront parks in winter cities as the research object. Daqing City, a typical winter city in China, as an example to evaluate recreational environment in waterfront parks and put forward targeted optimization strategies. The research results can provide guidance for the construction and renewal of waterfront parks recreational environment in the cold region climate.

Keywords

waterfront park; recreational environment; winter cities; IPA-Kano model

1. Introduction

The construction and development of cities have entered a new stage, and the recreational needs of urban residents in the new era is increasing day by day. Urban green spaces are important spatial carriers of urban recreational services (Zhai and Fan, 2023). Park green spaces, as one of the most important components of the urban green space system, provide the most important recreational services for urban residents (Kovacs, 2012) (Poudyal et al., 2009). Being hydrophilic is a natural instinct of human beings. In the process of urban development, waterfront spaces are intertwined with cities, and people prefer to go to public spaces with water bodies for leisure and recreational activities (Lv et al., 2022). As a type of urban park with dual attributes of water bodies and green spaces (Christopher and Towill, 2001) , waterfront parks are more closely related to residents' recreational needs and have gradually entered the research field of relevant scholars (Othman and Jafari, 2019).

Research on the recreational environment of waterfront parks is mostly based on the main research perspectives of urban park green space recreational services, such as recreational demand (Hasani et al., 2017), recreational behavior and preferences (Bertram et al., 2017), and recreational environment evaluation and optimization (Mao et al., 2022). Multiple research methods are used and combined with the environmental characteristics of waterfront parks to analyze the recreational environment and ultimately propose optimization strategies for the recreational environment of waterfront parks. Using the three-level coding analysis method based on grounded theory, taking five coastal parks in Qingdao as examples, this study explores the factors that affect the satisfaction of recreational activities in waterfront parks. The results show that layout and site selection, resource conditions, landscape characteristics, management services, and subjective feelings are the core elements that affect the satisfaction of recreational activities in coastal parks (Meng et al., 2022); By constructing an evaluation index system for recreational satisfaction, based on the evaluation results, optimization strategies for the recreational environment of waterfront parks are proposed from five aspects: water environment, supporting facilities, waterfront space, historical culture, and ecological science popularization (Hu et al., 2020). Overall, the number of recreational environments in waterfront parks is relatively small, and research still needs to be further improved, especially the optimization strategies for their recreational environments still need to be further explored.

In addition, the climate in winter cities is cold and the landscape is relatively monotonous, which has a certain degree of adverse impact on the recreational environment of parks and green spaces (Leng and Li, 2017). Scholars have conducted research on the park environment under the background of cold climate, such as starting from the needs of the elderly, taking cold city community parks as the research object, analyzing their spatial characteristics, usage factors, and population needs, and proposing optimization strategies for winter city community parks (Ma et al., 2023). Some studies have focused on waterfront parks under cold climate backgrounds, such as establishing an environmental indicator system in cold climate backgrounds to explore the impact of waterfront parks environmental elements on physical activity (Yuan et al., 2024). Overall, there is a particular lack of research on the recreational environment of waterfront parks under cold climate backgrounds. Recreation, as the most fundamental spatial functional attribute of park green spaces, requires more comprehensive and in-depth research.

Therefore, this research takes waterfront parks in winter cities as the research object. Firstly, based on relevant literature and field research, an indicator system for the recreational environment of waterfront parks in winter cities is formed. Then, basic research data is obtained through questionnaire surveys and analyzed. Finally, based on the analysis results, optimization strategies for the recreational environment of waterfront parks in winter cities are proposed, providing guidance for the construction and optimization of the recreational environment of waterfront parks in winter cities.

2. Research program design and methods

2.1. Research Area

Daqing City is located in the western part of Heilongjiang Province, China. It is a typical winter city with a total of 13 waterfront parks within the central urban area, as shown in Figure 1.

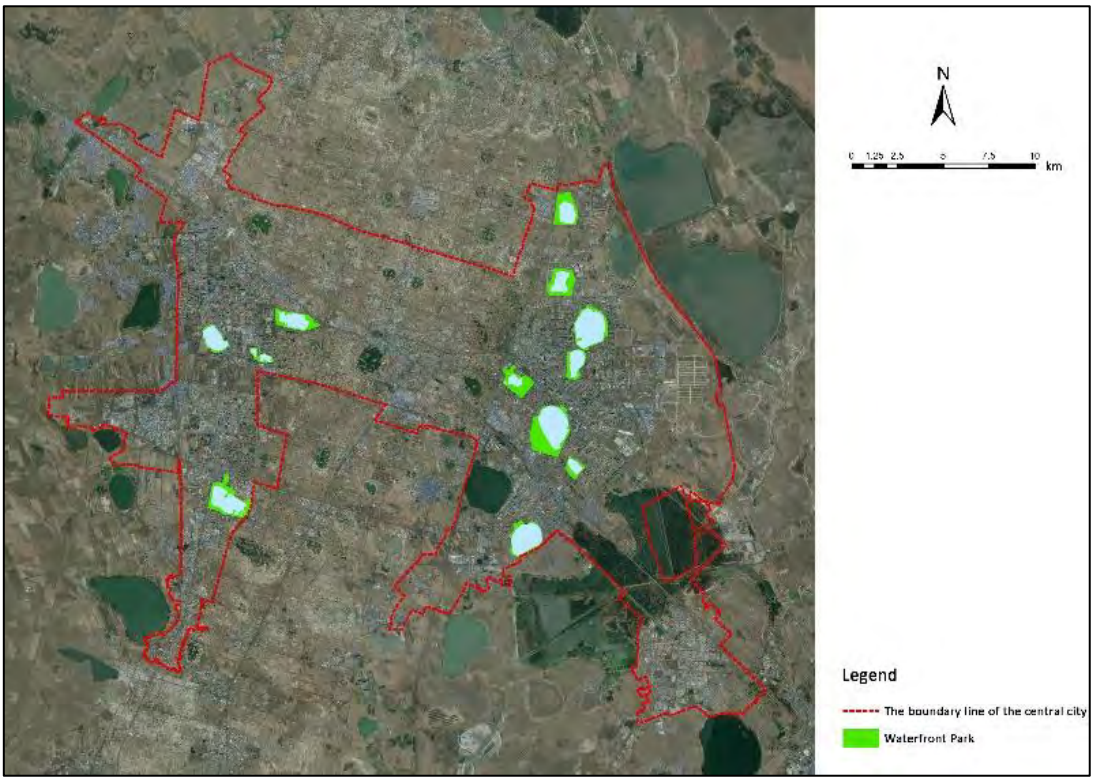


Figure 1. Distribution of Waterfront Parks. Source: self-drawn.

2.2. Indicator System Research Content

Recreation Opportunity System theory took shape in the late 19th century in the United States and has undergone a development process of approximately 60 years. This theory proposes that recreational opportunities are the most important factor affecting the recreational experience, composed of tourists' preferences and expectations, and are the entire process of tourists subjectively choosing recreational environments and engaging in recreational activities (Xiao et al., 2011). The operating procedure involves constructing an indicator system that includes natural, social, and management elements to measure recreational opportunities in the recreational environment. It is widely used in the planning and management of urban recreational spaces such as parks, forests, and rivers (Li et al., 2021).

Based on the theory of Recreation Opportunity System, the three dimensions of natural environment, social environment, and management environment that have the most significant impact on recreational environment are classified and summarized. The selected indicators and their questionnaire items are shown in Table 1. The questionnaire design is based on the Likert five level scale to code each indicator item, with importance code 1=very unimportant~5=very important, and satisfaction code 1=very dissatisfied~5=very satisfied.

Table 1. Evaluation Indicators and Questionnaire Items for recreational environment. Source: self-drawn.

Dimension	Indicators	Questionnaire Items
natural environment	Total amount of greenery	The total amount of trees, lawns and other types of greenery
	Plant richness	Richness of plant species and color

	Seasonal changes in plants	Plants present different landscapes in different seasons
	Landscape aesthetics	The aesthetic degree of natural or artificial landscape arrangement and collocation
	Water quality	The cleanliness of the water body
	Aesthetic level of shoreline	The lakeside shoreline has a sense of hierarchy and beautiful layout
	Resistant to mosquito disturbances	Fewer mosquitoes do not affect activities
Social environment	Local culture	The setting of landscape pieces or facilities can express the local culture
	Characteristics of ice and snow Regions	In winter, there are ice sculptures, snow structures and other ice and snow landscapes or ice and snow amusement facilities
	Public art icon	A unique landmark structure or attraction
	Popularity situation	The number of visitors is appropriate, rich in popularity
	Richness of activity programs	Degree of diversity of activities offered
	Activity Program Participation	The activities provided can be participated
management environment	The completeness of infrastructure	The completeness of seating, pavilion and other facilities
	The completeness of service facilities	The completeness of public toilets, shops and other facilities
	The completeness of fitness facilities	There are numerous and complete types of fitness facilities
	The completeness of children's amusement facilities	There are numerous and complete types of children's amusement facilities
	The completeness of hydrophilic recreational facilities	Set up water friendly recreational spaces without fences that come into direct contact with the water surface
	The completeness of shielding and protective facilities	Facilities such as chairs, walkways should be equipped with shelters and protective canopies in winter
	The completeness of directional marking system	The completeness of facilities such as park instructions, signage

	The completeness of popular science education facilities	The completeness of facilities for popularizing science on animal and plant species
	The completeness of safety protection facilities	The completeness of safety signs, warning facilities
	Comfort level of trail paving	Comfort level of pedestrian walkway paving
	Accessibility of the site	The completeness of accessible ramps and facility settings
	Night scene quality	Night scenery aesthetics
	Environmental sanitation maintenance level	Good level of environmental sanitation maintenance
	Plant conservation condition	Regular pruning and watering of plants, well maintained
	Facility management and maintenance	Regular maintenance and repair of facilities, well managed

2.3. Data Source

The questionnaire was randomly distributed to the recreational population in the waterfront parks. To ensure the accuracy of the questionnaire, it was filled out on-site and collected. 420 questionnaires were actually distributed and 420 questionnaires were collected. 24 questionnaires with incomplete information and unreasonable data were screened out, resulting in 396 valid questionnaires.

2.4. Analysis Methods Research Methods

Importance Performance Analysis, proposed by Martila and James in 1977, is a method for analyzing customer satisfaction. This method in order to optimize the product or service from both the importance and satisfaction levels in order to be more targeted (Martilla and James, 1977). Although Importance Performance Analysis has been applied in many disciplines, there are still shortcomings. Firstly, the two dimensions of importance and satisfaction are not independent of each other, and there is a certain correlation between them; The second is that the relationship between the satisfaction of evaluation factors and overall satisfaction is non-linear and symmetrical, while the linear and symmetrical relationship analysis assumed by Importance Performance Analysis method may result in significant discrepancies between the analysis results and the actual situation.

Kano model was proposed by Noriaki Kano, a scholar in Japan, in 1984. This theory divides users' demand factors into five categories: basic factors (M), expected factors (O), attractive factors (A), undifferentiated factors (I), and reverse factors (R) (Berger et al., 1993). Compared with the Importance Performance Analysis method, the Kano model considers the non-linear relationship between user satisfaction with evaluation factors and overall satisfaction, which expands its scope of application. However, it cannot intuitively reflect the importance and satisfaction of evaluation factors, which is not conducive to transforming the analysis results into practical recommendations that are actionable.

IPA-Kano model solves the problems in the analysis and application of Importance Performance Analysis method and Kano model. Firstly, based on the five types of demand elements in Kano model, the indifference element (I) and reverse element (R), which have no significant impact on satisfaction improvement, are eliminated. The demand elements are finally classified into three categories: basic element (M), expectation element (O), and charm element (A). Based on the three factor theory, the IPA analysis method was improved by placing these three types of elements in the Importance Performance Analysis quadrant, with the horizontal axis representing explicit importance and the vertical axis representing implicit importance (Kuo et al., 2012). The first quadrant represents key performance elements with high explicit and implicit importance. The second quadrant represents charismatic elements, characterized by high implicit importance and low explicit importance. The third quadrant represents non important performance factors, with both explicit and implicit importance being relatively low. The fourth quadrant represents the basic elements, which have the characteristics of low implicit importance and high explicit importance.

IPA Kano model was initially applied in product or service quality management and customer satisfaction research. Yin et al. first introduced the IPA Kano model into urban research to study residential area satisfaction and propose optimization suggestions (Yin et al., 2016). Subsequently, the use of this model for research on cities, architecture, landscapes, etc. has gradually increased (Li and Chen, 2024), indicating that this model has good analytical effectiveness and guiding significance in urban planning related fields.

3. Result

3.1. Reliability and validity testing

The SPSS 26.0 statistical software was used to analyze the 28 indicator layer elements in the questionnaire, and the Cronbach's Alpha and Kaiser Meyer Olkin/Bartlett values of each element were calculated. The Cronbach's alpha of the importance scale is 0.865, and the Cronbach's alpha of the satisfaction scale is 0.897, both greater than 0.8, indicating that the reliability of the questionnaire in this study is good. The Kaiser Meyer Olkin value of the Importance Scale is 0.864, and the Kaiser Meyer Olkin value of the Satisfaction Scale is 0.893. Both Kaiser Meyer Olkin values are greater than 0.7, and the Bartlett's sphericity test significance probability Sig values for both are 0.000, indicating good validity of the questionnaire in this study.

3.2. Explicit Importance and Satisfaction Analysis

3.2.1. Explicit Importance Analysis

Explicitim portance refers to the direct evaluation of the importance of various elements in the recreational environment of the waterfront parks by the recreational population. Overall, there are certain differences in the explicit importance of various dimensions of the recreational environment in waterfront parks. The explicit importance score of the natural environment dimension is 4.127, the explicit importance score of the social environment is 3.833, and the explicit importance score of the management environment is 3.988. The explicit importance of the natural environment dimension is much higher than that of the social environment dimension and the management environment dimension, which reflects that the recreational population has higher expectations and importance for the natural environment of the waterfront parks, and the recreational population expects to have a better natural environment experience in the waterfront parks.

Specifically, the analysis results of the explicit importance of each element in the waterfront parks are shown in Figure 2. There is also a certain degree of difference in the explicit importance scores of each element in the recreational environment of the waterfront parks. The explicit importance scores of each element are in the range of 3.591-4.412, among which the element with the highest explicit importance score is the Total amount of greenery, reflecting the high degree of importance that the recreational population attaches to the overall quantity of greenery. The element with the lowest explicit importance score is the popularity situation, indicating that whether the number of visitors is appropriate and whether the waterfront park has popularity has a small impact on the quality and willingness of recreational activities in the waterfront parks.

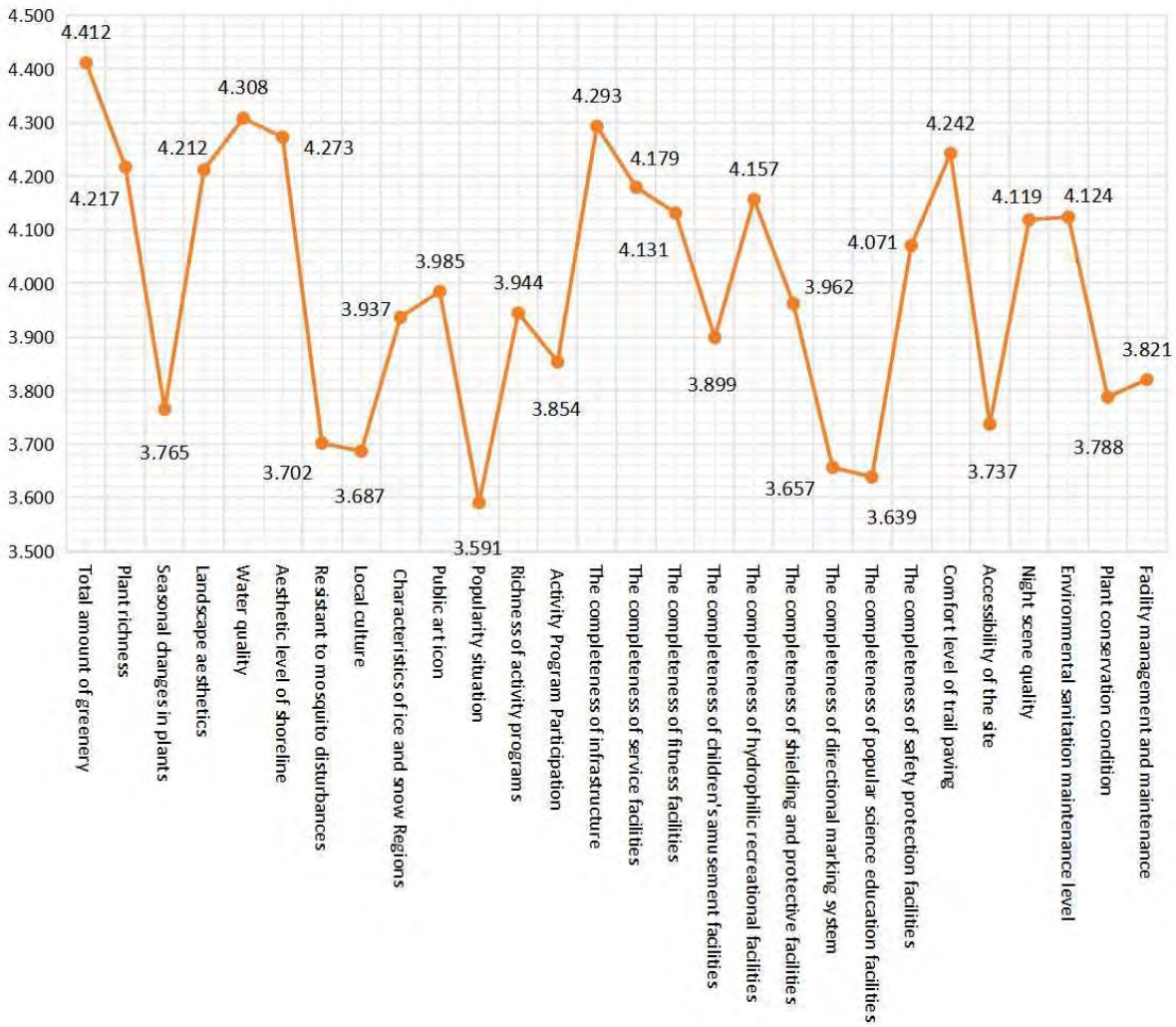


Figure 2. Results of Explicit Importance Analysis. Source: self-drawn.

3.2.2. Satisfaction Analysis

The overall satisfaction of the recreational environment is the comprehensive evaluation of the recreational population towards the waterfront parks. Overall, there are certain differences in the satisfaction levels of various dimensions of the recreational environment in waterfront parks. The satisfaction score for the natural environment dimension is 3.554, the satisfaction score for the social environment is 3.440, and the explicit satisfaction score for the management environment is 3.680. The

satisfaction with the management environment dimension is higher than that of the natural environment dimension and social environment dimension, which reflects that the construction level of the management environment in the current situation of waterfront parks construction is relatively good, while the construction of the natural environment dimension and social environment dimension is lacking.

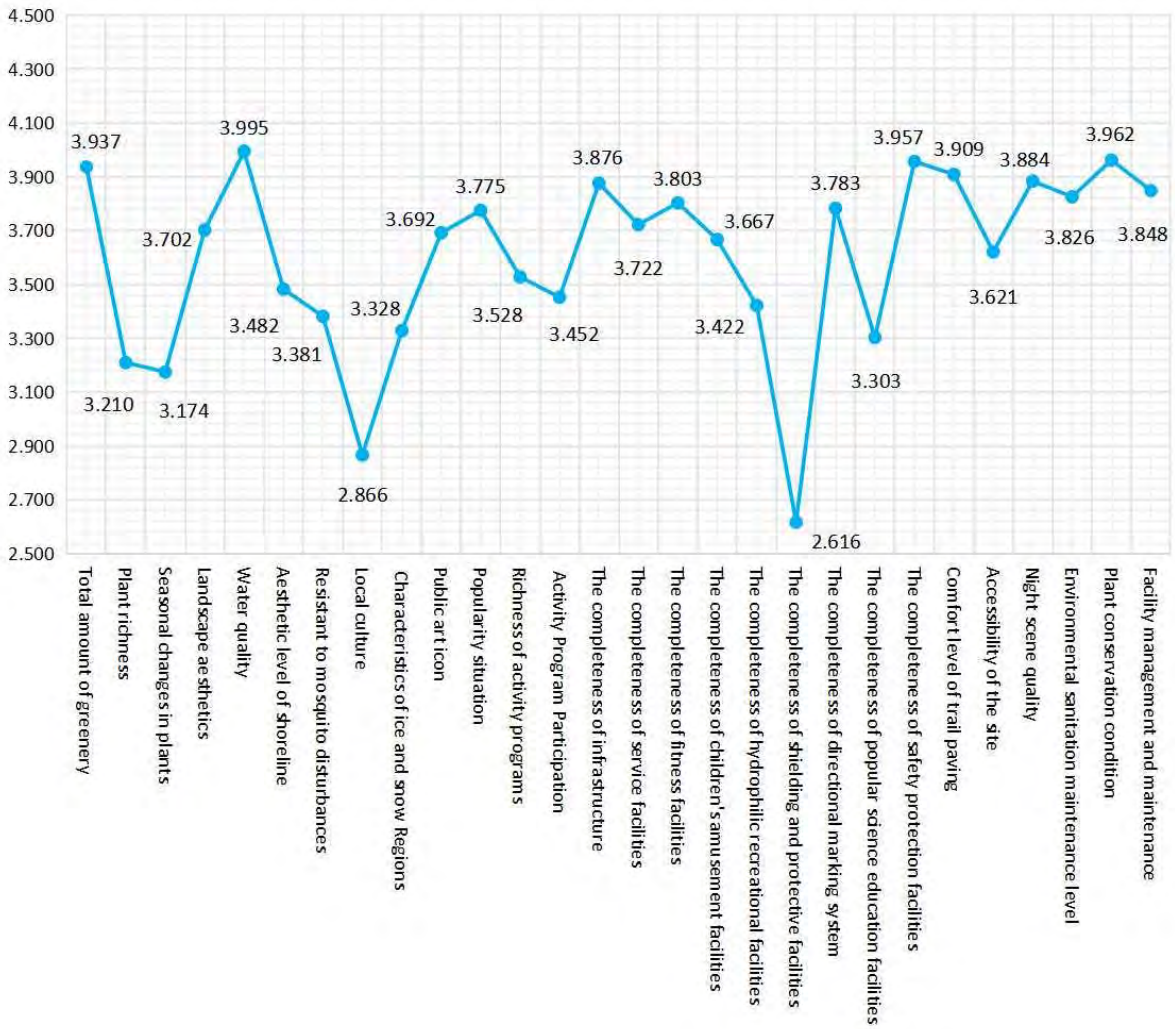


Figure 3. Results of Explicit Importance Analysis. Source: self-drawn.

The satisfaction analysis results of various elements in the waterfront parks are shown in Figure 3. There are also differences in the satisfaction scores of various elements in the recreational environment of the waterfront parks, with satisfaction scores ranging from 2.616 to 3.995. Among them, the element with the highest satisfaction score is Water quality, reflecting the high level of water governance and maintenance in the construction of the waterfront parks. Water is an important natural element of the waterfront parks and the foundation for ensuring a good recreational environment level in the parks. The completeness of shielding and protective facilities, which has the lowest satisfaction score, reflects the lack of construction of shading, windproof, and cold proof facilities in waterfront parks. We should actively address the adverse effects of climate and build corresponding shading and protective facilities to bring a more comfortable recreational experience to the recreational population.

3.3. Placing the figures

Implicit importance is the result of bivariate correlation analysis between the satisfaction evaluation scores of each element and the overall satisfaction score, usually characterized by correlation coefficients, reflecting the contribution of each element's satisfaction to overall satisfaction. That is, the larger the correlation coefficient, the greater the impact of the element on overall satisfaction, and the higher the implicit importance. Conversely, the smaller the impact, the lower the implicit importance. Import the satisfaction scores of each element and the overall satisfaction score data into SPSS for correlation analysis. The results of the correlation analysis are shown in Table 3.

Table 3. Implicit Importance Extraction result. Source: self-drawn.

Number	Indicators	Spearman correlation coefficient
1	Total amount of greenery	0.203**
2	Plant richness	0.198**
3	Seasonal changes in plants	0.219**
4	Landscape aesthetics	0.292**
5	Water quality	0.275**
6	Aesthetic level of shoreline	0.411**
7	Resistant to mosquito disturbances	0.163**
8	Local culture	0.221**
9	Characteristics of ice and snow Regions	0.347**
10	Public art icon	0.169**
11	Popularity situation	0.277**
12	Richness of activity programs	0.362**
13	Activity Program Participation	0.331**
14	The completeness of infrastructure	0.265**
15	The completeness of service facilities	0.356**
16	The completeness of fitness facilities	0.311**
17	The completeness of children's amusement facilities	0.226 **
18	The completeness of hydrophilic recreational facilities	0.348**
19	The completeness of shielding and protective facilities	0.344**
20	The completeness of directional marking system	0.246**

21	The completeness of popular science education facilities	0.143**
22	The completeness of safety protection facilities	0.260**
23	Comfort level of trail paving	0.283**
24	Accessibility of the site	0.166**
25	Night scene quality	0.298**
26	Environmental sanitation maintenance level	0.271**
27	Plant conservation condition	0.215**
28	Facility management and maintenance	0.274**

***Indicates p<0.01*

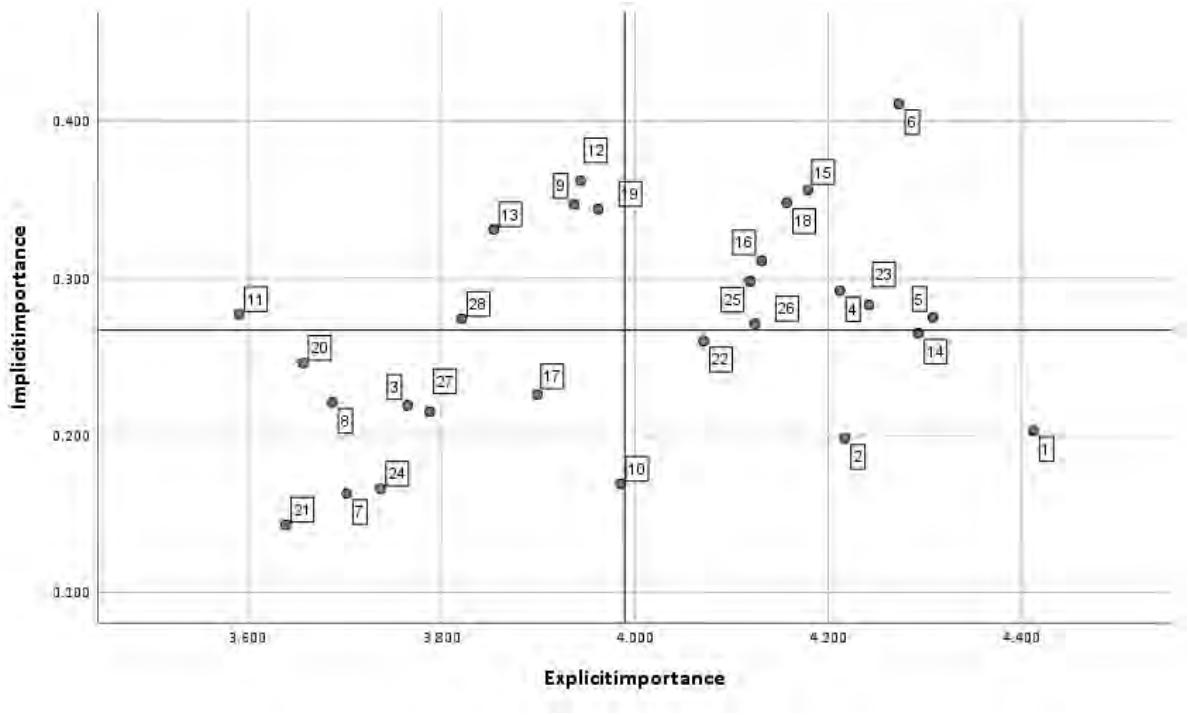
Overall, there are differences in the mean values of implicit importance dimensions compared to explicit importance. The average implicit importance of each element is 0.267, with the natural environment dimension having an average implicit importance of 0.252, the social environment dimension having an average implicit importance of 0.285, and the management environment dimension having an average implicit importance of 0.267. The implicit importance of the social environment dimension is higher than that of the natural environment dimension and the management environment dimension. Although recreational visitors have higher expectations and importance for the natural environment of the waterfront parks, the social environment has a greater impact on their overall satisfaction with the recreational environment of the waterfront parks.

Specifically, the element with the highest implicit importance is Aesthetic level of shoreline, with a correlation coefficient of 0.411, reflecting the high demand of travelers for waterfront space; The element with the lowest implicit importance is The completeness of popular science education facilities, with a correlation coefficient of 0.143.

3.4. Attribution of Element Quality

The analysis results of the explicit and implicit importance of each element were imported into SPSS for scatter plot drawing, and IPA Kano analysis grid for waterfront park recreation services was obtained as shown in Figure 4. The first quadrant represents key performance oriented elements, with both explicit and implicit importance being high. The elements located in this quadrant include Landscape aesthetics, Aesthetic level of shoreline, The completeness of service facilities, The completeness of fitness facilities, The completeness of hydrophilic recreational facilities, Comfort level of trail paving, Night scene quality, Water quality, and Environmental sanitation maintenance level. The second quadrant represents charismatic elements, with high implicit importance and low explicit importance. The elements located in this quadrant include Characteristics of ice and snow Regions, Richness of activity programs, Activity Program Participation, The completeness of shielding and protective facilities, Popularity situation, and Facility management and maintenance. The third quadrant represents non important performance elements, with low explicit and implicit importance. Elements located in this quadrant include Local culture, Seasonal changes in plants, Resistant to mosquito disturbances, The completeness of children's amusement facilities, The completeness of directional marking system, The completeness of popular science education facilities, Accessibility of the site, Plant conservation condition, and Public art icon. The

fourth quadrant represents basic elements, with low implicit importance and high explicit importance. The elements located in this quadrant include Total amount of greenery, Plant richness,The completeness of infrastructure, and The completeness of safety protection facilities.



(The indicators' numbers are shown in Table 3.)

Figure 4. IPA Kano analysis grid diagram. Source: self-drawn.

4. Strategies

IPA Kano analysis grid divides the elements that affect the recreational environment of waterfront parks into four categories, located in different quadrants, which can effectively guide the optimization order of each element. The priority of the optimization order is basic elements (fourth quadrant)>key performance elements (first quadrant)>attractive elements (second quadrant)>non important performance elements (third quadrant). For the determination of optimization factors, firstly, the elements with satisfaction scores lower than the mean are taken as the overall range of factors that need to be optimized for the level of recreational services in this study. Secondly, the quadrants of the elements within this optimization range in the IPA Kano analysis grid are clarified. The finally determined optimization elements and optimization strategies are shown in Table 4.

Table 4. Priority and Strategies for Optimizing the Level of Recreation Services. Source: self-drawn.

Optimize priority	Optimize indicators	Optimize strategy
Priority One	Plant richness	Strategy One: Enrich the plant hierarchy and build diverse plant landscapes.
Priority Two	Aesthetic level of shoreline	Strategy Two: Improve the beauty of the shoreline and

	The completeness of hydrophilic recreational facilities	improve the hydrophilic recreational facilities.
Priority Three	The completeness of shielding and protective facilities	Strategy Three: Resist climate interference and build snow and ice recreational environment
	Characteristics of ice and snow Regions	
	Richness of activity programs	Strategy Four: Plan a variety of activities and stimulate the participation efficiency of activities
	Activity Program Participation	

4.1. Enrich the plant hierarchy and build diverse plant landscapes

When configuring plants, it is not only necessary to ensure that the total number of plants meets the standard, but also to carefully consider the richness of plant species, and to increase the number of plant species in the waterfront parks as much as possible, forming a rich and diverse plant landscape composition. The selection of specific types should be based on the morphological characteristics, color matching, and flowering intervals of the plants. Emphasize the introduction of plant species with prominent ornamental value. By introducing and utilizing local plants, the richness of plants in the waterfront parks can be increased and a unique green landscape can be formed. In addition, it is recommended to use plants that can maintain a certain degree of landscape in the cold winter. Based on selecting a certain number of evergreen plants, the micro topography of local areas such as slopes and rocks can be combined with winter plant landscapes to create a layered and three-dimensional winter landscape.

4.2 Improve the beauty of the shoreline and improve the hydrophilic recreational facilities

It is recommended to form a shoreline shaping form that combines multiple shorelines within the waterfront parks, such as natural shorelines, hard shorelines, and waterfront shorelines. For natural shorelines, it is recommended to use local plants as the basis and select terrestrial plants, emergent plants, floating plants, and submerged plants from the shore to the water area for landscape design, highlighting the hierarchy and transition from the shore to the water area, and forming artificial plant natural shorelines with local characteristics. For waterfront shorelines, it is recommended to add stepped waterfront shorelines in waterfront parks and combine them with waterfront recreational facilities to form diverse waterfront recreational activity spaces. In addition, it is recommended to increase the number and form of hydrophilic recreational facilities, such as setting up various flat forms of hydrophilic recreational facilities such as zigzag and curved shapes.

4.3 Resist climate interference and build snow and ice recreational environment

The shaping of the recreational environment in waterfront parks should actively respond to adverse factors in the cold climate background by adding wind and cold prevention facilities, such as using existing corridors and other facilities to renovate glass enclosures, setting up shading and protective spaces, covering with plants in spring, summer, and autumn to provide shade, and providing wind and cold prevention in winter, providing a more suitable activity space for recreational activities. At the same time,

active utilization of ice and snow resources in winter cities should be carried out, and ice and snow landscapes such as ice sculptures and snow structures should be set up for tourism. Ice and snow activity venues such as ice rinks and ski resorts can also be set up. In addition, local cultural elements can be integrated into the design of landscapes and facilities within waterfront parks, and combined with ice and snow landscapes.

4.4 Plan a variety of activities and stimulate the participation efficiency of activities

It is recommended to hold activities related to festival themes in the waterfront parks based on important festivals, and to organize cultural and sports activities based on regional characteristics. At the same time, smooth activity planning, promotion, and participation platforms should be established, with online and offline interactive channels respectively, forming a good interactive mode, timely and effectively collecting feedback information, ensuring that the activity planning content better meets the needs of the recreational population, and improving the participation and overall quality of activities in the recreational environment of the waterfront parks.

5. Conclusion

Based on field research and questionnaire survey data, this research used IPA Kano model to identify the elements that need further optimization in the recreational environment of winter cities waterfront parks, including Plant richness, The completeness of hydrophilic recreational facilities, Aesthetic level of shoreline, The completeness of shielding and protective facilities, Characteristics of ice and snow Regions, Richness of activity programs, and Activity Program Participation. The optimization priorities of these elements were determined, and optimization strategies were ultimately proposed to provide guidance for the construction and optimization of recreational environments winter cities waterfront parks.

6. References

Bertram, C., Jürgen Meyerhoff, Rehdanz, K., Henry Wüstemann, 2017. Differences in the recreational value of urban parks between weekdays and weekends: A discrete choice analysis. Landscape and Urban Planning 159, 5–14. https://doi.org/10.1016/j.landurbplan.2016.10.006

Christopher, M., Towill, D., 2001. An integrated model for the design of agile supply chains. International Journal of Physical Distribution & Logistics Management 31, 235–246. https://doi.org/info:doi/10.1108/09600030110394914

Hasani, M., Sakieh, Y., Khammar, S., 2017. Measuring satisfaction: analyzing the relationships between sociocultural variables and functionality of urban recreational parks. Environment Development & Sustainability. https://doi.org/10.1007/s10668-016-9856-x

Kovacs, K.F., 2012. Integrating property value and local recreation models to value ecosystem services from regional parks. Landscape & Urban Planning 108, 79–90. https://doi.org/10.1016/j.landurbplan.2012.08.002

Kuo, Y.F., Chen, J.Y., Deng, W.J., 2012. IPA–Kano model: A new tool for categorising and diagnosing service quality attributes. Total Quality Management & Business Excellence 23, 731–748. https://doi.org/10.1080/14783363.2011.637811

Li, Z., Chen, H., Yan, W., 2021. Exploring Spatial Distribution of Urban Park Service Areas in Shanghai Based on Travel Time Estimation: A Method Combining Multi-Source Data. IJGI 10, 608. https://doi.org/10.3390/ijgi10090608

Mao, Z., Wang, W., Ren, Z., Zhang, D., He, X., 2022. Recreational Attractiveness of Urban Parks and Implications for Their Management: A Case Study in Changchun, China. Chinese Journal of Geography: English Edition 32, 11. https://doi.org/10.1007/s11769-022-1273-5

Martilla, J.A., James, J., 1977. Importance-Performance Analysis. Journal of Marketing 41, 77–79. https://doi.org/10.1177/002224297704100112

Othman, J., Jafari, Y., 2019. Economic Valuation of an Urban Lake Recreational Park: Case of Taman Tasik Cempaka in Bandar Baru Bangi, Malaysia. Sustainability 11. https://doi.org/10.3390/su11113023

Poudyal, N.C., Hodges, D.G., Merrett, C.D., 2009. A hedonic analysis of the demand for and benefits of urban recreation parks. Land Use Policy 26, 975–983. https://doi.org/10.1016/j.landusepol.2008.11.008

Yin, J., Cao, X. (Jason), Huang, X., Cao, X., 2016. Applying the IPA–Kano model to examine environmental correlates of residential satisfaction: A case study of Xi'an. Habitat International 53, 461–472. https://doi.org/10.1016/j.habitatint.2015.12.013

Leng, H., Li S.Y., 2017. Research on Spatial Planning Strategies for Cold Regions Cities from the Perspective of Winter Public Health. Urban Planning of Shanghai 1-5.

Lv, L., Zhu, J., Wang Z.M., 2022. A GIS-based comprehensive evaluation of the suitability of recreational space land use in Fuzhou's coastal areas. Modern Urban Studies 67-72.

Li, X.Y., Chen, J.Y., 2024. A Study on the Perceptual Differences of Rural Cultural Landscape Elements from the Perspective of Host and Guest - Taking Huanglongxi Tea Cultural Village in Nanjing as an Example. Modern Urban Studies 125-132.

Zhai, Y.L., Fan, Z.Q., 2023. Analysis of Recreational Service Satisfaction Evaluation in Urban Park Green Space - Taking the Central Urban Area of Wu Zhong District in Suzhou as an Example. Architecture and Culture 235-238. https://doi.org/10.19875/j.cnki.jzywh.2023.05.075

Xiao, S.L., Jia,L.M., Wang,P., Li, J.J., 2011. Construction of recreational opportunity spectrum in suburban mountain forest in Beijing. Progress in Geography 30, 746-752.

Hu, G.M., Zheng,H.C., Yu,H.M., Li,F.Y., 2020. Research on the optimization strategy of urban riverfront park based on the satisfaction of recreational users: A case study of Jinan River Park in Fuzhou City. Fujian Construction technology 1-3+16.

Meng,Y.P., Li,C., Zhao,Y., 2022. Research on influencing factors of recreation satisfaction in coastal parks based on grounded theory. Urban Architecture 19, 191-193+198. https://doi.org/10.19892/j.cnki.csjz.2022.21.40

Yuan, J.C., An,T.Y., Zhou,Y.Q., 2024. Study on the influence mechanism of environmental factors on physical activity in waterfront park in cold region -- A case study of Shenyang Olympic Ecological Park. Journal of Urban Sciences 60-66.

Ma, X.L., Meng,X., Yu,M.H., Zhang,X.N., 2023. Research on the optimization of community park in cold region based on the needs of the elderly. Cryogenic building Technology 45, 21-25.https://doi.org/10.13905/j.cnki.dwjz.2023.10.005

Research Paper

Tourism destination images analysis and tourism development indicators evaluation based on perceived gap

Bridging Online Perceptions and Reality

Cheng SHI, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology Ministry of Industry and Information Technology, China

Xiaoxiang, YI, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology Ministry of Industry and Information Technology, China

Haoxin, WANG, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology Ministry of Industry and Information Technology, China

Lei, XIA, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology Ministry of Industry and Information Technology, China

Shuai, YU, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology Ministry of Industry and Information Technology, China

Abstract

With the rapid rise of social media, "internet celebrity cities" have emerged as significant players in tourism, driving urban tourism growth. However, social media often presents biased representations of these destinations, leading to discrepancies between online images and actual visitor experiences. This study addresses these issues by constructing a comprehensive evaluation framework for tourism development indicators based on expectancy disconfirmation theory and experience determines theory, focusing on Harbin, a prominent Chinese internet celebrity city. We assess 28 indicators across five dimensions—transportation environment, supporting services, natural environment, cultural environment, and tourism trends—using a questionnaire survey. Our findings reveal high satisfaction in the natural and cultural environments, while supporting services and transportation fall short of expectations. Principal component analysis indicates that tourists prioritize service construction, culture, and natural indicators. Despite the perceived importance of many indicators, a significant gap exists between expectations and actual experiences. This study offers a framework for prioritizing tourism indicator development, highlighting the need for improvements in supporting services, which has both theoretical innovation and practical implications for tourism management.

Keywords

Destination image, Perceived gap, Tourism management, Tourism satisfaction.

1. Introduction

With the rapid development of social media, "internet celebrity city" has gradually become a new trend in tourism. The internet celebrity city effect quickly attracts a large number of tourists, significantly promoting rapid urban tourism growth(Govers, Go and Kumar, 2007). However, social media often portrays tourism destinations in a biased or incomplete manner, leading to discrepancies between online city images and actual visitor experiences, such as "overly beautified scenes"(BBC, 2017; Hoeller, 2018; Moussalli, 2019). These issues not only hinder city tourism development but also increase visitor dissatisfaction(Smith *et al.*, 2015; Tseng *et al.*, 2015). Therefore, ensuring consistency between a city's online tourism destination image and its actual image has become a crucial consideration in tourism development practices worldwide(Henseler, Ringle and Sarstedt, 2015).

In response, this study constructs a comprehensive evaluation framework for tourism development indicators based on "expectancy disconfirmation theory" and "experience determines theory"(Lee *et al.*, 2016), taking Harbin, one of the most popular Chinese internet celebrity tourism cities, as the research area. We evaluate 28 indicators across five dimensions—transportation environment, supporting services, natural environment, cultural environment, and tourism trends—through the questionnaire survey. Here, "perceived gap" reflects the consistency between perceived online images and actual experiences, "importance" indicates subjective importance of tourism indicators to visitors, and "actual performance" represents the visitor satisfaction with their real tourism experiences.

Firstly, based on survey results, the study analyzes satisfaction levels and perceived gaps in Harbin's tourism development indicators, employing principal component analysis to understand visitors' perceptions of the importance of these indicators. Subsequently, it cross-analyzes perceived gaps and actual performances of each indicator under varying perceptions, and further examines the alignment between perceived importance and actual performances, categorizing them accordingly. Finally, integrating these evaluations, the study prioritizes development recommendations based on indicator performance.

2.Literature review

Tourist satisfaction is a critical factor for the survival and development of tourism destinations (Williams and Soutar, 2009). Therefore, understanding tourist satisfaction and expectations has been a focus in tourism research. Howard and Sheth (1969) defined customer satisfaction as the "cognitive state of being adequately or inadequately rewarded for the sacrifices made." However, more scholars prefer Oliver (1999) definition, considering satisfaction as the consumer's feelings of fulfilment, desires, and goals and describing this fulfilment as a pleasurable experience.

The expectation-disconfirmation theory is widely used to explain satisfaction, suggesting that satisfaction is formed by comparing expected returns with actual returns (Lee *et al.*, 2016). In tourism research, the formation of expectations and their impact on satisfaction is a complex process. Tourist-generated content (TGC) influences satisfaction before, during, and after travel (Narangajavana Kaosiri *et al.*, 2019). This impact ranges from the impressions formed before selecting a destination to evaluations during and after the experience (Nezakati *et al.*, 2015; Narangajavana Kaosiri *et al.*, 2019; Wang *et al.*, 2019).

Tourist satisfaction with a destination is influenced not only by the actual experience but also by the gap between the expected destination image and the actual experience. When actual experiences exceed expectations, tourists tend to feel satisfied and may even experience surprise and pleasure (Chon, 1991; Kim and Perdue, 2011; Lee, Jeon and Kim, 2011). Conversely, when actual experiences fall short of

expectations, tourists may feel disappointed and dissatisfied. This negative gap reduces satisfaction and affects tourists' overall evaluation of the destination (Yilmaz *et al.*, 2009). Furthermore, according to the loss aversion principle in prospect theory, the impact of a negative discrepancy on behavior is often greater, even when the magnitude of the negative and positive gap is identical (Levin and Gaeth, 1988; Tversky and Kahneman, 1991).

3. Study Area and Methodology

3.1. Study Area

To better reflect the Destination Image Gap, this study selects Harbin, a “top trending” tourist city in China, as a case area due to its surge in online popularity at the end of 2023. Harbin, the capital of Heilongjiang Province, covers an area of 53,076.4 square kilometres and serves as a central city in Northeast China and a national historical and cultural city. It has been designated as a "City of Music" by UNESCO and is recognized as one of China's top ten ice and snow tourist cities. At the end of 2023, Harbin gained extensive attention on the Chinese internet due to its ice and snow tourism. According to statistics, during the Spring Festival holiday in 2024, Harbin welcomed 10.093 million tourists, a year-on-year increase of 81.7%, generating total tourism revenue of 16.42 billion yuan, a year-on-year increase of 235.4% at comparable rates. Popular attractions among tourists include Central Street, Harbin Ice and Snow World, St. Sophia Cathedral, and the Flood Control Memorial Tower. This study will select some of the more popular attractions as research areas and distribute questionnaires to tourists.

3.2 Research Design and Data Collection

This study focuses on destination satisfaction. Initially, it designs and distributes questionnaires to collect data, then analyzes pre-visit expectations, post-visit satisfaction, and the importance of various elements. Following this, it examines the perceptual gaps before and after the visit and the differences in importance-satisfaction through Gap-Performance Analysis (GPA) and Importance-Performance Analysis (IPA), ultimately proposing tourism development strategies based on the comprehensive analysis.

In terms of indicator design, in order to balance the image of both online and offline destinations, a semantic network analysis combining UGC and semi-structured interviews was used to determine the evaluation elements, and an indicator system (table) was summarized, including five primary indicators of transportation environment, accommodation and catering, natural landscape, cultural landscape, and tourism trend, and 28 secondary indicators. On UGC, the study selected Xiaohongshu and Weibo, which have a wide user coverage and a large number of daily active users, as data sources. During the semi-structured interviews, various tourists across different age groups are randomly approached to gather conversational material, which is then analysed using Gephi software for semantic network analysis, identifying several clusters and key factors of interest, and constructing the final indicator system in conjunction with related research.

For questionnaire design, each indicator is examined from three dimensions: pre-visit expectations, post-visit satisfaction, and importance. A five-point Likert scale is employed for the survey. Ultimately, several hundred questionnaires are distributed and collected, achieving a response rate of over 70%.

3.3 Data Analysis

This study utilizes GPA (Gap-Performance Analysis) and IPA (Importance-Performance Analysis) methods to systematically analyze the collected data, assessing the effectiveness of Harbin's tourism development indicators.

Firstly, conduct GPA analysis by calculating the perceived gap between the online image and the actual experience of tourists. This gap reflects the difference between the information tourists obtain online and their actual experience. Specifically, by comparing tourists' ratings of their "expectations" and "actual performance" for each tourism indicator in the questionnaire, areas where the online image is overly idealized or lacking can be identified. For example, if the "expected" score of a certain indicator is higher than the "actual performance" score, it indicates that the online representation of that indicator has not met the expectations of tourists. This negative gap may lead to tourist dissatisfaction, thereby affecting their overall travel experience and willingness to revisit the city. GPA analysis is a cross validation of the "perceived gap" and "importance" of each indicator to determine the key factors that affect tourist satisfaction. Among them, "importance" will use principal component analysis (PCA) to extract weights, in order to gain a deeper understanding of tourists' perceptions of the importance of various indicators.

Then perform IPA analysis, draw "importance" on the X-axis and "satisfaction" on the Y-axis to construct four quadrant partition types. This method not only helps identify areas with low tourist satisfaction, but also clarifies tourists' needs and expectations by comparing the score differences in importance and satisfaction. For example, if an indicator scores high in "importance" but low in "satisfaction", priority should be given to improvement to increase overall tourist satisfaction.

By integrating the results of both GPA and IPA, this study will propose specific strategic recommendations for Harbin's tourism development, aiming to enhance tourist experiences and satisfaction levels.

4. Analysis of Expectations, Satisfaction, Perception Gaps, and Importance

4.1 Analysis of pre-visit expectation levels

An analysis of the online expectations for the five major dimensions (Figure 1) indicates that, under the influence of online destination images, tourists express a greater interest in the cultural environment of Harbin prior to their visit. This is followed in order by the natural environment, tourism trends, and transportation environment. The dimension with the lowest expected value is supporting services, suggesting that the cultural environment is perceived as the most influential aspect of Harbin in the minds of potential visitors, while supporting services are viewed less favourably. Insights from interviews reveal that elements such as "ice and snow culture" and "European-style charm" serve as significant cultural symbols that shape tourists' impressions of Harbin during their online searches and are key factors driving their desire to visit. Conversely, concerns regarding issues such as rising hotel prices and exploitative taxi services highlight aspects of uncivilized tourism practices, negatively impacting Harbin's online destination image.

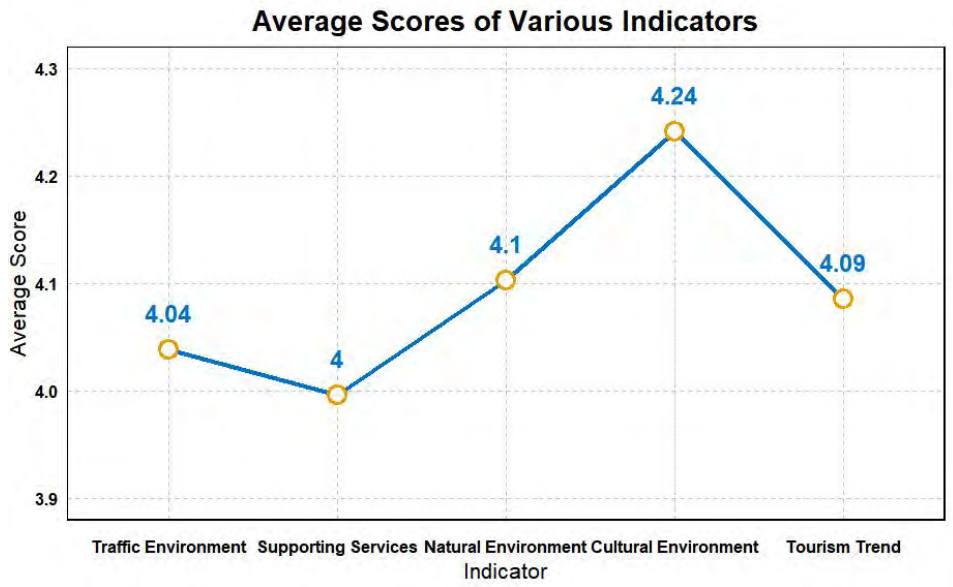


Figure 1. Average Scores of Dimensions of Online Expectations. Source: Calculated and drawn by the authors (2024).

Specifically (Figure 2) , among the various indicators of the cultural environment, the statement "architectural style is distinctive" received the highest average score, followed by "the city has a rich historical and cultural heritage." This indicates that Harbin's unique architectural style and its diverse, inclusive historical culture are more appealing to potential visitors as reflected in the online destination image. Conversely, within the supporting services category, the indicators "reasonable accommodation and dining prices" and "reasonable prices for cultural souvenirs" received noticeably lower scores. This suggests that, prior to their visit, tourists perceive accommodation and dining prices in Harbin to be relatively high, leading to lower expectations. However, the indicators "renowned traditional restaurants" and "distinctive dining experiences" scored relatively high, indicating that tourists have high expectations for Harbin's unique culinary offerings. Insights from interviews reveal that local dishes such as "Guo Bao Rou" and "Tie Guo Dun" have gained significant popularity online, while snacks like "Chimney Bread" and "Madi'er Ice Cream" have become must-try delicacies for visitors to Harbin. Furthermore, the indicator "beautiful riverside scenery" in the natural environment category also received a high score in terms of online expectations. Interviews indicated that tourists are particularly excited about the promotional content related to the Songhua River, especially the sunset views and winter ice activities along the river. In contrast, the indicator "good environmental hygiene" within the tourism trends category received a low score in terms of online expectations. This low expectation is largely attributed to negative news regarding poor hygiene maintenance at certain attractions and hotels, which has adversely affected tourists' perceptions.

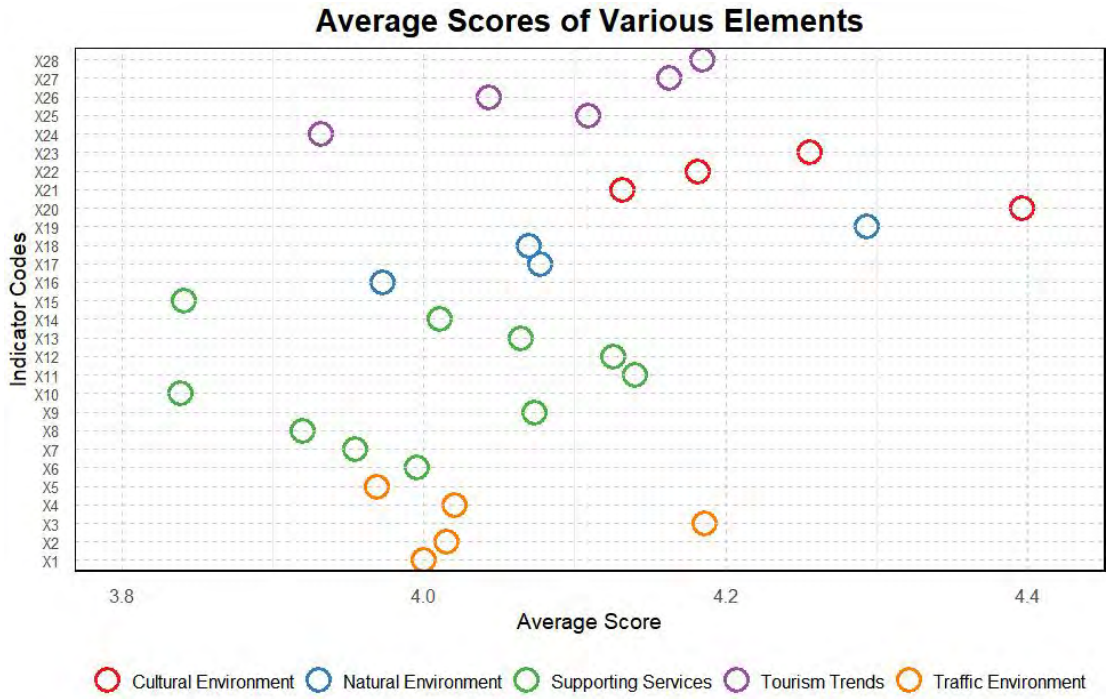


Figure 2. Average Scores of Various Elements of Online Expectations. Source: Calculated and drawn by the authors (2024).

4.2 Analysis of post-visit satisfaction levels

The analysis of post-visit satisfaction across the five major dimensions (Figure 3) indicates that tourists express the highest level of satisfaction with Harbin's cultural environment, followed by the natural environment, tourism trends, and transportation environment. The dimension with the lowest satisfaction score is supporting services. This ranking aligns with the pre-experience expectations across these dimensions, suggesting that actual experiences correspond closely with the promotional narratives presented online.

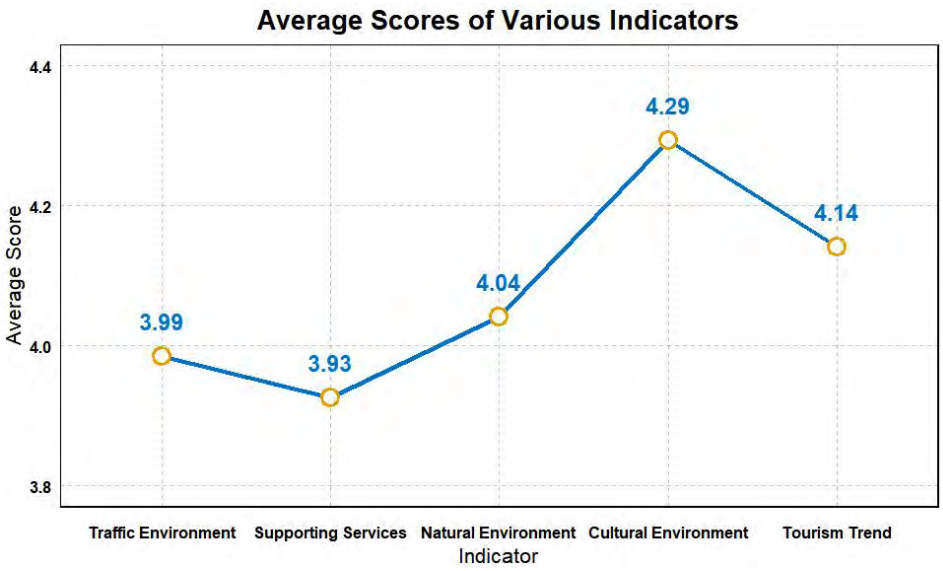


Figure 3. Average Scores of Dimensions of Post-Visit Satisfaction. Source: Calculated and drawn by the authors (2024).

Specifically (Figure 4), satisfaction with natural environment, cultural environment, and tourism trends is higher, with higher scores for indicators such as "unique architectural style", "profound historical and cultural heritage", and "beautiful riverside scenery"; In addition, in the dimension of tourism trends, the indicators of "public safety" and "enthusiasm and initiative of local residents" also achieved high satisfaction, indicating that tourists are particularly satisfied with the local safety environment and the friendly behavior of Harbin residents.

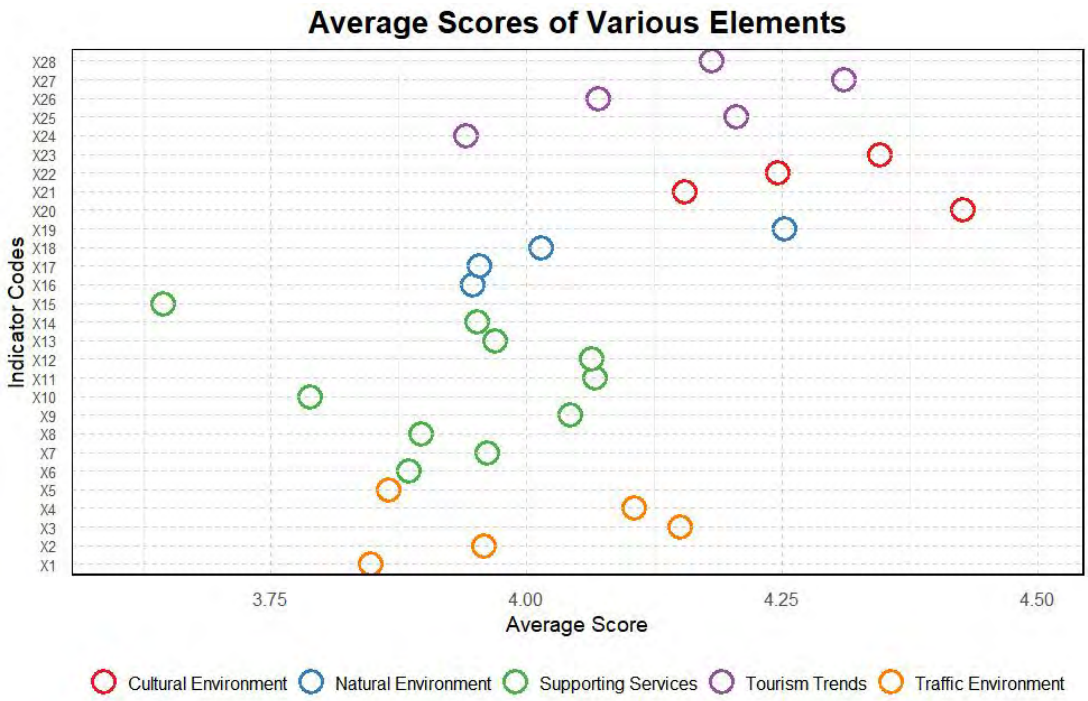


Figure 4. Average Scores of Various Elements of Post-Visit Satisfaction. Source: Calculated and drawn by the authors (2024).

4.3 Analysis of gaps between online and on-site perceptions

To analyze the differences between online and on-site perceptions across five key dimensions (Table 1), the results indicate that satisfaction with both tourism trends and cultural environments in physical experiences surpasses expectations based on online information. This suggests that the development of these aspects at the destinations exceeds the online Destination Image (DI), where expectations were already high, highlighting the strong development in Harbin's tourism sector. Conversely, supporting services, natural landscapes, and transportation conditions show lower on-site satisfaction compared to online expectations, indicating that their portrayal online may be more favorable than the actual experience. Furthermore, these areas, which already had lower online expectations, have not been effectively addressed in physical development to mitigate the dissatisfaction reflected in the online DI.

Table 1. Comparison of Average Online and On-Site Scores for Primary Indicators. Source: Calculated and drawn by the authors (2024).

Primary Indicator	Average Online Score	Average On-Site Score	Online - On-Site
Transportation Environment	4.037891595	3.985103242	0.052788352
Supporting Services	3.996232166	3.926612253	0.069619914
Natural Environment	4.10310947	4.042086665	0.061022805
Cultural Environment	4.241036915	4.293309295	-0.05227238
Tourism Trend	4.085949904	4.141463415	-0.05551351

Specifically (Table 2), in the transportation sector, only the reasonableness of transportation costs achieves higher on-site satisfaction compared to online expectations, while actual experiences regarding transportation convenience, safety, and public transport accessibility still fall short. In supporting services, most experiences do not meet tourist expectations, with the exception of accommodation and restaurant locations, where the placement of facilities aligns better with tourist routes. In the natural environment category, overall tourist experiences are below expectations. However, in cultural environments and tourism trends, most experiences exceed online expectations, with only service-related experiences falling short.

Table 2. Comparison of Online and On-Site Scores for Primary and Secondary Indicators.. Source: Calculated and drawn by the authors (2024).

Primary Indicator	Code	Secondary Indicator	Online	On-Site	Online - On-Site
Transportation Environment	X1	Transportation Convenience	4	3.846689895	0.15331
	X2	High Public Transport Accessibility	4.014778325	3.958333333	0.056445
	X3	High Transportation Safety	4.185929648	4.15034965	0.03558
	X4	Reasonable Transportation Costs	4.02	4.104895105	-0.0849
	X5	Reasonable Internal Route Design	3.96875	3.865248227	0.103502
Supporting Services	X6	Variety in Accommodation and Dining Options	3.995098039	3.884210526	0.110888
	X7	Good Accommodation and Restaurant Locations	3.954773869	3.960992908	-0.00622
	X8	Clean and Hygienic Accommodation and Dining Environments	3.91959799	3.896057348	0.023541
	X9	High Accommodation Security	4.073298429	4.043010753	0.030288
	X10	Reasonable Accommodation and Restaurant Prices	3.83902439	3.787985866	0.051039
	X11	Famous Traditional Restaurants	4.140096618	4.066666667	0.07343
	X12	Unique Dining Experiences	4.125	4.063380282	0.06162
	X13	Meeting Various Shopping Needs	4.064356436	3.968641115	0.095715
	X14	Wide Variety of Cultural and Creative Souvenirs	4.010050251	3.951048951	0.059001
	X15	Reasonable Prices for Cultural and Creative Souvenirs	3.841025641	3.644128114	0.196898

Natural Environment	X16	Pleasant Climate	3.972222222	3.947552448	0.02467
	X17	Good Air Quality	4.077294686	3.954225352	0.123069
	X18	High Level of Greenery	4.069651741	4.013937282	0.055714
	X19	Beautiful Riverside Scenery	4.293269231	4.252631579	0.040638
Cultural Environment	X20	Unique Architectural Style	4.396313364	4.427083333	-0.03077
	X21	Attractive and Suitable Signage	4.131067961	4.154385965	-0.02332
	X22	Uniform Street Landscape Style	4.180952381	4.245614035	-0.06466
	X23	Rich Historical and Cultural Atmosphere	4.255813953	4.346153846	-0.09034
Tourism trend	X24	Good Environmental Hygiene	3.931372549	3.940766551	-0.00939
	X25	Safe Public Security	4.108374384	4.205574913	-0.0972
	X26	Interesting and Fun Street Activities	4.042857143	4.069686411	-0.02683
	X27	Warm and Friendly Attitude of Local Residents	4.162679426	4.31010453	-0.14743
	X28	Attentive and Considerate Service with Good Attitude	4.184466019	4.181184669	0.003281

4.4 Analysis of the importance of elements

To further understand the key factors that tourists consider important for Harbin tourism, a survey on factor importance was conducted (Table 3), and classification and ranking were performed using Principal Component Analysis (PCA). According to the results of the PCA, the 28 indicators established in the questionnaire can be extracted into four principal components. By summarizing the indicators within each principal component, they can be categorized into four major factors: service construction elements, cultural shaping elements, natural and cultural elements, and public transportation elements.

Table 3. Results of Principal Component Analysis on Factors. Source: Calculated and drawn by the authors (2024).

Principal Component	Factor	Factor 1	Factor 2	Factor 3	Factor 4
F1: Service Construction Factors	X5 Reasonable Design of Internal Tour Lines	0.128	-0.007	-0.076	0.048
	X6 Variety of Accommodation and Dining Types	0.179	-0.011	-0.065	-0.052
	X7 Good Location of Accommodation and Restaurants	0.128	-0.003	-0.013	-0.044
	X8 Clean and Sanitary Dining Environment	0.213	-0.088	-0.05	-0.001
	X9 High Safety of Accommodation	0.223	-0.102	-0.055	0.006
	X10 Reasonable Prices of Accommodation and Restaurants	0.201	-0.045	-0.07	-0.039
	X24 Good Environmental Hygiene	0.149	-0.09	0.053	-0.006
	X25 Safety and Security	0.162	-0.098	0.007	0.017
	X27 Friendly and Positive Attitude of Local Residents	0.15	0.038	-0.045	-0.081

	X28 Attentive and Considerate Service	0.157	0.033	-0.083	-0.05
	X11 Famous Traditional Restaurants	0.007	0.109	0.087	-0.12
	X12 Unique Characteristics of Dining	-0.035	0.124	0.117	-0.117
	X13 Ability to Meet Various Shopping Needs	-0.028	0.19	-0.036	-0.024
F2: Cultural Shaping Factors	X14 Variety of Cultural and Creative Souvenirs	-0.074	0.275	-0.109	0.037
	X15 Reasonable Prices of Cultural and Creative Souvenirs	-0.014	0.25	-0.216	0.102
	X21 Appropriate and Aesthetic Signage	-0.108	0.217	0.015	0.025
	X22 Unified Style of Street Scenery	-0.097	0.259	-0.041	0.012
	X26 Rich and Interesting Street Activities	0.113	0.134	-0.133	-0.059
	X16 Pleasant Climate	-0.063	-0.05	0.28	-0.033
	X17Good Air Quality	-0.076	-0.105	0.358	0.015
F3: Natural and Cultural Factors	X18High Level of Greening	-0.09	-0.102	0.348	0.045
	X19Beautiful Riverside Scenery	-0.052	-0.062	0.276	0.011
	X20Distinctive Architectural Style	-0.032	0.098	0.107	-0.052
	X23Rich Historical and Cultural Heritage of the City	0.043	0.059	0.064	-0.08
	X1 Convenient Transportation	-0.09	0.003	-0.02	0.322
F4: Public Transportation Factors	X2Strong Accessibility of Public Transportation	-0.053	-0.017	-0.037	0.326
	X3High Safety of Transportation	-0.037	-0.047	-0.02	0.315
	X4Reasonable Prices of Transportation	-0.007	-0.037	-0.016	0.237

To quantitatively describe the impact weights of various indicators on the principal components and the weights of these components on satisfaction, Using PCA for analysis (Table 4 & Table 5). The results indicated that the weight of service construction was the highest at 0.336, followed by cultural shaping and natural cultural heritage, with transportation conditions having the least impact. Within the service construction factors, environmental hygiene, residents' attitudes, the cleanliness of accommodation and dining environments, and accommodation safety were predominant. In the cultural shaping factors, signage design, traditional restaurants, street scenery style, varieties of cultural and creative souvenirs, and street activities were predominant. In terms of natural cultural heritage, the importance was ranked as follows: air quality, greening level, riverside scenery, architectural style, and historical culture. For transportation conditions, the importance was ranked as follows: public accessibility, transportation safety, transportation prices, and convenience.

Table 4. Weight Analysis of Major Dimensions. Source: Calculated and drawn by the authors (2024).

Independent Variables	Regression Coefficient	Normalized Weight
Transportation Conditions	0.174	0.145
Cultural Shaping	0.322	0.269
Service Construction	0.402	0.336
Natural Cultural Heritage	0.299	0.25

Table 5. Weight Analysis of Secondary Indicators. Source: Calculated and

drawn by the authors (2024).

Dimension	Independent Variable	Regression Coefficient	Weight
Service Construction	X5 Reasonable Internal Tour Line Design	0.2609	0.0403
	X6 Diverse Accommodation and Dining Options	0.2641	0.0408
	X7 Good Location of Accommodation and Restaurants	0.2605	0.0403
	X8 Clean and Sanitary Accommodation and Dining Environment	0.2878	0.0445
	X9 High Accommodation Safety	0.2866	0.0443
	X10 Reasonable Prices for Accommodation and Restaurants	0.2557	0.0395
	X24 Good Environmental Hygiene	0.3116	0.0482
	X25 Safety of Public Order	0.2689	0.0416
	X27 Warm and Positive Attitude of Local Residents	0.2955	0.0457
	X28 Attentive and Courteous Service	0.271	0.0419
Cultural Shaping	X11 Famous Time-Honored Restaurants	0.2318	0.0359
	X12 Unique Dining Features	0.2177	0.0337
	X13 Ability to Meet Various Shopping Needs	0.2167	0.0335
	X14 Diverse Cultural Creative Souvenirs	0.227	0.0351
	X15 Reasonable Prices for Cultural Creative Souvenirs	0.2164	0.0335
	X21 Appropriate and Aesthetic Signage	0.2347	0.0363
	X22 Unified Street Landscape Style	0.2289	0.0354
	X26 Rich and Interesting Street Activities	0.2267	0.0351
Natural Cultural Heritage	X16 Pleasant Climate	0.1884	0.0291
	X17 Good Air Quality	0.244	0.0377
	X18 High Level of Greening	0.2389	0.0369
	X19 Good Riverside Scenery	0.2374	0.0367
	X20 Distinctive Architectural Style	0.2222	0.0344
	X23 Rich Urban Historical and Cultural Heritage	0.2114	0.0327
Transportation Conditions	X1 Convenient Transportation	0.1293	0.02
	X2 Strong Accessibility of Public Transport	0.1479	0.0229
	X3 High Transportation Safety	0.1432	0.0221
	X4 Reasonable Transportation Prices	0.1415	0.0219

5. Gap-performance analysis and importance-performance analysis

To enhance the effectiveness of perception elements in improving tourist satisfaction, this paper integrates Expectancy Disconfirmation Theory and Experience-Determining Theory to construct an assessment method for tourism perception elements that combines Gap-Performance Analysis (GPA) and Importance-Performance Analysis (IPA), categorizing various tourism perception factors and providing targeted optimization recommendations. The pathway through which tourism perception factors influence tourist satisfaction primarily operates from two perspectives: perceptual differences and key factors.

According to the theory of expectation negation, tourist satisfaction not only depends on the actual performance of perceived elements, but is also influenced by the gap between the emotional expectations established before the trip and the actual perception level. For example, when tourists have high expectations for a certain perceived element, if their actual performance is slightly worse than their expectations, even if the actual performance of that element is relatively high compared to other elements, it will lead to a decrease in satisfaction; If tourists have low expectations for a certain perceived element, and their actual performance is slightly better than their expectations, even if the actual performance of that element is relatively low compared to other elements, it will lead to an increase in satisfaction. Therefore, from the perspective of perceived differences, the impact of measurement factors on satisfaction should be evaluated by integrating perceived differences and performance.

According to the experience determination theory, tourist satisfaction is also influenced by the level of importance that tourists have in their perception of tourism elements. For example, when tourists consider a certain perceived element to be very important, even if the actual performance of that element is relatively high compared to other elements, they may not be able to improve satisfaction because they have not reached their inner perception of the importance of that element; If tourists consider a certain perceived element to be unimportant, even if the actual performance of that element is relatively low compared to other elements, it may not reduce their overall satisfaction with tourism due to its insignificance. Therefore, from the perspective of importance level, the impact of measurement factors on satisfaction should also be evaluated by integrating importance level and performance.

5.1 Gap-performance analysis

By integrating perceived differences and performance effectiveness to assess tourism perception factors, these factors are classified into four categories: " Enhancing Leadership " "Image Building" "Key Quality Enhancement" and "Steady Assurance" The specific meanings of these categories are detailed in the following table (Table 6).

Table 6. Gap-Performance Analysis of Primary Indicators. Source: Calculated and drawn by the authors (2024).

Category Type	Performance (Satisfaction)	Perception Gap	Description
Enhancing Leadership	High Rating	Expectations exceed actual experience	Performs well but still falls short of tourist expectations
Image Building	High Rating	Expectations are lower than actual experience	Performs well and exceeds tourist expectations
Key Quality Improvement	Low Rating	Expectations exceed actual experience	Performs poorly and falls short of tourist expectations
Steady Assurance	Low Rating	Expectations are lower than actual experience	Performs poorly but exceeds tourist expectations

Based on the analysis (Table 7), the category with the highest number of indicators is the Key Quality Enhancement type, which includes 13 indicators—nearly half of all perceived tourism elements—indicating that a majority of Harbin's tourism perception elements perform poorly and fall short of tourists' expectations. The next most common category is the Image Building type, comprising 8 indicators, suggesting that while many elements perform well, there is still a lack of effective communication in establishing appropriate tourist expectations. Following this is the Enhancing Leadership type with 5 indicators. The least common category is the Steady Assurance type, with only 2 indicators. These findings reveal that, among well-performing elements, actual experiences tend to

surpass tourist expectations, highlighting deficiencies in expectation-setting efforts. Conversely, for poorly performing elements, most fall below tourists' expectations, indicating a lack of sufficient improvement in addressing these weaker areas.

Table 7. Gap-Performance Analysis of Secondary Indicator. Source: Calculated and drawn by the authors (2024).

Primary Indicator	Code	Secondary Indicator	Type
Transportation Environment	X1	Convenient Transportation	Key Quality Enhancement
	X2	High Public Transportation Accessibility	Key Quality Enhancement
	X3	High Traffic Safety	Enhancing Leadership
	X4	Reasonable Transportation Pricing	Image Building
	X5	Reasonable Internal Travel Route Design	Key Quality Enhancement
Supporting Services	X6	Diverse Accommodation and Dining Options	Key Quality Enhancement
	X7	Good Location of Accommodation and Restaurants	Steady Assurance
	X8	Clean and Hygienic Dining and Accommodation Environments	Key Quality Enhancement
	X9	High Accommodation Safety	Key Quality Enhancement
	X10	Reasonable Accommodation and Dining Prices	Key Quality Enhancement
	X11	Famous Traditional Restaurants	Enhancing Leadership
	X12	Unique Dining Options	Enhancing Leadership
	X13	Satisfies Various Shopping Needs	Key Quality Enhancement
	X14	Rich Variety of Cultural and Creative Souvenirs	Key Quality Enhancement
	X15	Reasonable Pricing of Cultural and Creative Souvenirs	Key Quality Enhancement
Natural Environment	X16	Pleasant Climate	Key Quality Enhancement
	X17	Good Air Quality	Key Quality Enhancement
	X18	High Level of Greenery	Key Quality Enhancement
	X19	Beautiful Riverside Scenery	Enhancing Leadership
Cultural Environment	X20	Distinctive Architectural Style	Image Building
	X21	Appropriate and Aesthetic Signage	Image Building
	X22	Unified Street Landscape Style	Image Building
	X23	Rich Historical and Cultural Heritage	Image Building
	X24	Good Environmental Hygiene	Steady Assurance
Tourism trend	X25	Public Safety	Image Building
	X26	Diverse and Interesting Street Activities	Image Building
	X27	Friendly and Warm-Hearted Locals	Image Building
	X28	Thoughtful and Attentive Service	Enhancing Leadership

From the perspective of enhancing overall satisfaction (Figure 5), the primary focus should be on the "key improvement" factors, which include three transportation-related elements, three natural environment elements, and seven supporting service elements. Based on the outermost envelope model, the relatively most urgent factors are identified as X16 (pleasant climate), X8 (sanitary conditions of accommodation

and dining), X10 (accommodation and dining prices), X15 (prices of cultural and creative souvenirs), X1 (transportation convenience), X17 (air quality), X13 (variety of shopping options), X18 (level of greening), and X9 (accommodation safety). Among these, the first three issues are predominantly associated with low satisfaction, while the remaining six reflect an excessive gap between high expectations and actual performance.

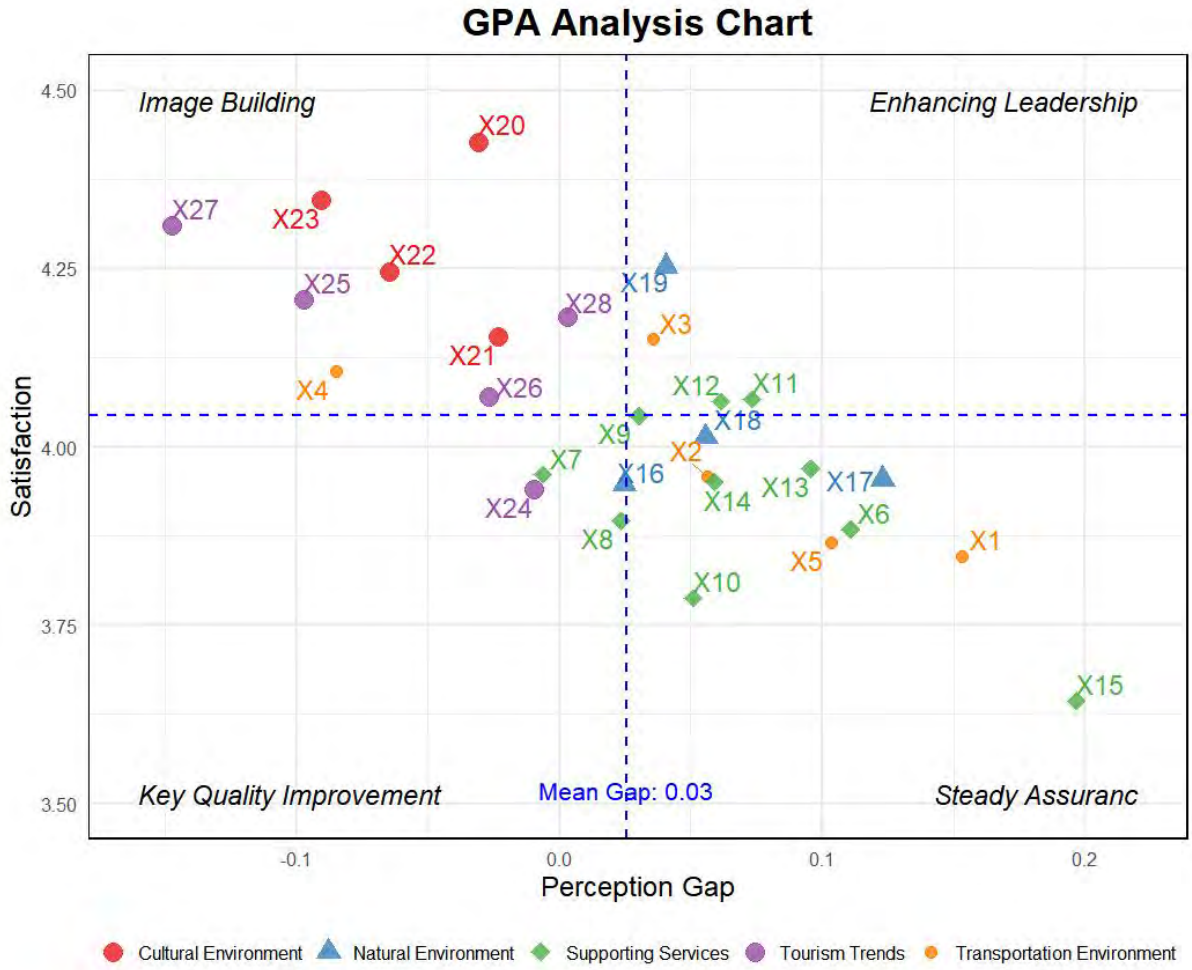


Figure 5. GPA Analysis Chart. Source: Calculated and drawn by the authors (2024).

5.2 Importance-performance analysis

By integrating the importance level and performance assessment of tourism perception elements (Table 8), the various elements are classified into four categories: Advantage Enhancement Type, Maintenance Type, Follow-up Opportunity Type, and Continue Improvement Type. Their definitions are provided in the table below.

Table 8. Importance-Performance Analysis of Primary Indicators. Source: Calculated and drawn by the authors (2024).

Element Classification Type	Performance (Satisfaction)	Importance	Meaning
Advantage Enhancement	High	High	Performs well and is

			important
Continuation Maintenance	High	Low	Performs well but is not important
Follow-up Opportunity	Low	Low	Performs poorly and is not important
Continue Improvement	Low	High	Performs poorly but is important

According to the analysis results (Table 9), the distribution of the various types of elements is relatively uniform. The most prevalent category is the Continue Improvement Type, which includes nine indicators, accounting for nearly one-third of all tourism perception elements in Harbin. This indicates that many of these elements are important but perform poorly. The Maintenance Type, Advantage Enhancement Type, and Follow-up Opportunity Type comprise seven, six, and six indicators, respectively, showing similar quantities.

Table 9. Importance-Performance Analysis of Secondary Indicators. Source: Calculated and drawn by the authors (2024).

Primary Indicator	Code	Secondary Indicator	Type
Transportation Environment	X1	Transportation Convenience	Follow-up Opportunity
	X2	Strong Public Transport Accessibility	Follow-up Opportunity
	X3	High Transportation Safety	Continuation Maintenance
	X4	Reasonable Transportation Prices	Continuation Maintenance
Supporting Services	X5	Reasonable Internal Tour Route Design	Continue Improvement
	X6	Diverse Accommodation and Dining Options	Continue Improvement
	X7	Good Location of Accommodation and Restaurants	Continue Improvement
	X8	Clean and Hygienic Dining and Accommodation Environment	Continue Improvement
	X9	High Safety of Accommodation	Continue Improvement
	X10	Reasonable Prices of Accommodation and Dining	Continue Improvement
	X11	Famous Time-Honored Restaurant Brands	Advantage Enhancement
	X12	Unique Dining Characteristics	Maintenance
	X13	Ability to Meet Various Shopping Needs	Follow-up Opportunity
	X14	Rich Variety of Cultural and Creative Souvenirs	Follow-up Opportunity
	X15	Reasonable Prices of Cultural and Creative Souvenirs	Follow-up Opportunity
Natural Environment	X16	Pleasant Climate	Follow-up Opportunity
	X17	Good Air Quality	Continue Improvement
	X18	High Level of Greening	Continue Improvement
	X19	Good Riverside Scenery	Advantage Enhancement
Cultural Environment	X20	Distinctive Architectural Style	Continuation Maintenance
	X21	Appropriate and Aesthetic Signage	Advantage Enhancement
	X22	Unified Street Landscape Style	Continuation Maintenance
	X23	Rich Historical and Cultural Heritage	Continuation Maintenance
Tourism Trend	X24	Good Environmental Hygiene	Continue Improvement

X25	Safety and Security	Advantage Enhancement
X26	Diverse and Interesting Street Activities	Continuation Maintenance
X27	Warmth and Positive Attitude of Local Residents	Advantage Enhancement
X28	Attentive and Thoughtful Service	Advantage Enhancement

To enhance overall satisfaction, it is crucial to prioritize the development of the Continue Improvement Type elements (Figure 6). This category encompasses one indicator from the transportation environment, one from tourism trends, two from the natural environment, and five from supporting services. In the transportation environment, particular emphasis should be placed on the design of internal travel routes. In terms of tourism trends, environmental sanitation warrants focused attention. For the natural environment, it is imperative to prioritize air quality control and the enhancement of greening levels. Within supporting services, improvements should concentrate on the diversity of accommodation and dining options, spatial layout, hygiene management, safety regulations, and price monitoring.

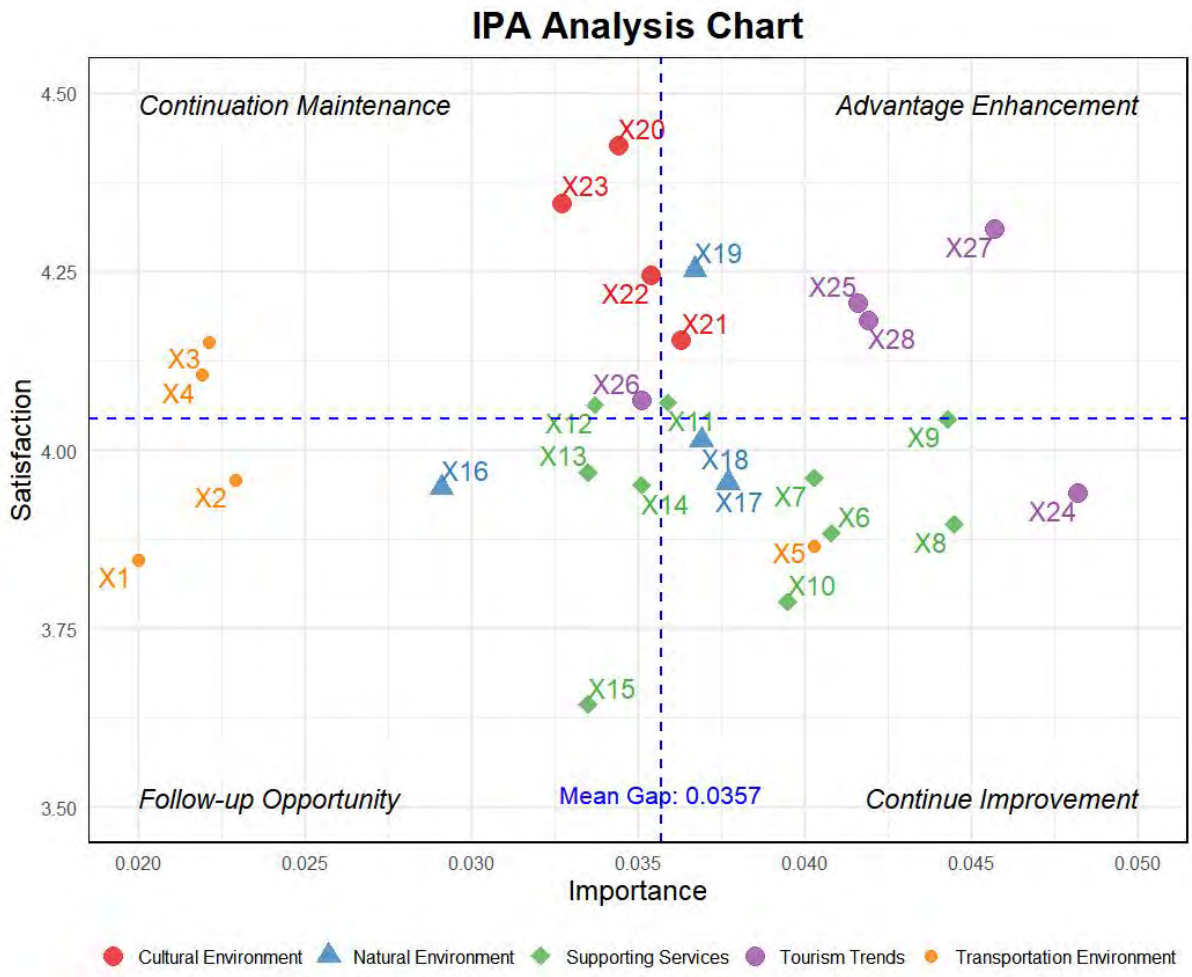


Figure 6. IPA Analysis Chart. Source: Calculated and drawn by the authors (2024).

5.3 Comprehensive Analysis of Elements

Incorporating the insights gained from both GPA and IPA analyses allows for the prioritization of element development and the formulation of targeted development strategies based on the characteristics of these elements (Table 10).

Table 10. Classification and Priority Analysis of GPA and IPA Types. Source: Calculated and drawn by the authors (2024).

GPA Classification Type	Priority	IPA Classification Type	Priority
Enhancing Leadership Type	2	Advantage Enhancement Type	2
Image Building Type	3	Continuation Maintenance Type	3
Key Quality Improvement Type	1	Follow-up Opportunity Type	4
Steady Assurance Type	4	Continuous Improvement Type	1

Based on the prioritization analysis, the highest-priority elements include six factors, all of which exhibit higher expectations than actual experiences (Table 11). Among these, four are related to supporting services, covering aspects such as the variety, hygiene, safety, and pricing of accommodation and dining services. Additionally, the rationality of internal route design and air quality also fall into this top priority category. Following these, greening levels are ranked second in priority. The third priority level includes the experience of renowned local dining establishments and service attitudes, both of which also show a discrepancy between expectations and experiences. In contrast, most indicators related to the transportation environment, supporting services, and tourism trends are categorized under the next priority level. Finally, the lowest-priority elements largely pertain to cultural environment indicators, many of which also exhibit a gap between high expectations and lower actual experiences.

Table 11. Priority Levels and Perception Differences of Key Indicators in Tourism Evaluation. Source: Calculated and drawn by the authors (2024).

Primary Indicator	Code	Secondary Indicator	Priority Level	Perception Difference
Transportation Environment	X5	Reasonable Design of Internal Travel Routes	2	0.103501773
Supporting Services	X6	Variety of Accommodation and Dining Options	2	0.110887513
Supporting Services	X8	Cleanliness of Accommodation and Dining Environment	2	0.023540642
Supporting Services	X9	High Safety of Accommodation	2	0.030287677
Supporting Services	X10	Reasonable Pricing of Accommodation and Dining	2	0.051038525
Natural Environment	X17	Good Air Quality	2	0.123069334
Natural Environment	X18	High Level of Greening	3	0.055714459
Supporting Services	X11	Renowned Local Dining Establishments	4	0.073429952
Tourism Trends	X28	Attentive and Friendly Service	4	0.00328135
Transportation Environment	X1	Convenient Transportation	5	0.153310105
Transportation Environment	X2	Strong Accessibility of Public Transportation	5	0.056444992
Transportation Environment	X3	High Transportation Safety	5	0.035579998

Supporting Services	X7	Good Location of Accommodation and Restaurants	5	-0.006219038
Supporting Services	X12	Unique Characteristics of Dining	5	0.061619718
Supporting Services	X13	Ability to Meet Various Shopping Needs	5	0.095715321
Supporting Services	X14	Variety of Cultural and Creative Souvenirs	5	0.0590013
Supporting Services	X15	Reasonable Pricing of Cultural and Creative Souvenirs	5	0.196897527
Natural Environment	X16	Pleasant Climate	5	0.024669775
Cultural Environment	X21	Suitable and Aesthetic Signage	5	-0.023318004
Tourism Trends	X24	Good Environmental Hygiene	5	-0.009394002
Tourism Trends	X25	Safety of Public Security	5	-0.097200529
Tourism Trends	X27	Warmth and Attitude of Local Residents	5	-0.147425104
Transportation Environment	X4	Reasonable Transportation Pricing	6	-0.084895105
Natural Environment	X19	Good Riverside Scenery	6	0.040637652
Cultural Environment	X20	Distinctive Architectural Style	6	-0.030769969
Cultural Environment	X22	Unified Street Landscape Style	6	-0.064661654
Cultural Environment	X23	Rich Historical and Cultural Context of the City	6	-0.090339893
Tourism Trends	X26	Rich and Interesting Street Activities	6	-0.026829268

6. Findings and discussion

This study presents a comprehensive evaluation of Harbin's tourism development indicators, revealing critical insights into the alignment between visitor expectations and actual experiences. Results indicate: 1) High satisfaction with Harbin's actual tourism experiences mainly in natural and cultural environments and tourism trends dimensions; 2) Tourism trend and cultural environment indicators surpass expectations, while supporting services, natural environment, and transportation environments fall short; 3) According to principal component analysis, tourists' subjective ranking of the importance of tourism indicators is in the order of service construction indicators, culture shaping indicators, natural and human indicators, and public transportation indicators; 4) Most of the indicators of Harbin's tourism development indicators are rated low and pre-trip expectations exceed the actual experience, indicating that the perceived gap in Harbin's tourism is mainly negative and significant; 5) Many indicators in Harbin's tourism development are deemed important but underperform, showing low alignment between importance and actual performances; 6) Overall, Harbin should prioritize developing supporting service indicators such as accommodation, dining options, hygiene, and pricing.

This study constructs a comprehensive evaluation framework of "perception gap-importance-actual performance" for tourism development indicators, takes into account the gap between the online images and actual experiences of the tourism network in the era of streaming media as well as the mismatch between the importance of the indicators and the actual development of the indicators, which has good generalizability. This framework is practiced in Harbin as an example to prioritize and classify the development of tourism indicators and put forward specific suggestions, which has certain theoretical innovation and practical value.

7. References

BBC, B. (2017) 'Lithuania tourism advert used fake photos', *BBC News*, 10 February. Available at: https://www.bbc.com/news/world-europe-38928864 (Accessed: 7 August 2024).

Chon, K.-S. (1991) 'Tourism destination image modification process: Marketing implications', *Tourism Management*, 12(1), pp. 68–72. Available at: https://doi.org/10.1016/0261-5177(91)90030-W.

Govers, R., Go, F.M. and Kumar, K. (2007) 'Promoting Tourism Destination Image', *Journal of Travel Research*, 46(1), pp. 15–23. Available at: https://doi.org/10.1177/0047287507302374.

Henseler, J., Ringle, C.M. and Sarstedt, M. (2015) 'A new criterion for assessing discriminant validity in variance-based structural equation modeling', *Journal of the Academy of Marketing Science*, 43(1), pp. 115–135. Available at: https://doi.org/10.1007/s11747-014-0403-8.

Hoeller, S.-C. (2018) 'Disappointing pictures that show what 17 popular tourist attractions look like in real life', *Business Insider*, 25 January. Available at: https://www.businessinsider.com/famous-sites-reality-versus-fantasy-2017-5 (Accessed: 7 August 2024).

Howard, J. and Sheth, J. (1969) 'The Theory of Buyer Behavior'. Available at: https://doi.org/10.2307/2284311.

Kim, D. and Perdue, R.R. (2011) 'The Influence of Image on Destination Attractiveness', *Journal of Travel & Tourism Marketing* [Preprint]. Available at: https://www.tandfonline.com/doi/abs/10.1080/10548408.2011.562850 (Accessed: 10 August 2024).

Lee, S. *et al.* (2016) 'Heritage Tourism in Singapore Chinatown: A Perceived Value Approach to Authenticity and Satisfaction', *Journal of Travel & Tourism Marketing*, 33(7), pp. 981–998. Available at: https://doi.org/10.1080/10548408.2015.1075459.

Lee, S., Jeon, S. and Kim, D. (2011) 'The impact of tour quality and tourist satisfaction on tourist loyalty: The case of Chinese tourists in Korea', *Tourism Management*, 32(5), pp. 1115–1124. Available at: https://doi.org/10.1016/j.tourman.2010.09.016.

Levin, I.P. and Gaeth, G.J. (1988) 'How Consumers Are Affected by the Framing of Attribute Information Before and After Consuming the Product', *Journal of Consumer Research*, 15(3), pp. 374–378. Available at: https://doi.org/10.1086/209174.

Moussalli, I. (2019) 'That's not Melbourne, that's the Gold Coast! Tourism's problem with false advertising', *ABC News*, 27 July. Available at: https://www.abc.net.au/news/2019-07-27/when-photos-of-the-wrong-destination-appear-in-tourism-ads/11351702 (Accessed: 7 August 2024).

Narangajavana Kaosiri, Y. *et al.* (2019) 'User-Generated Content Sources in Social Media: A New Approach to Explore Tourist Satisfaction', *Journal of Travel Research*, 58(2), pp. 253–265. Available at: https://doi.org/10.1177/0047287517746014.

Nezakati, H. *et al.* (2015) 'Review of Social Media Potential on Knowledge Sharing and Collaboration in Tourism Industry', *Procedia - Social and Behavioral Sciences*, 172, pp. 120–125. Available at: https://doi.org/10.1016/j.sbspro.2015.01.344.

Oliver, R.L. (1999) 'Whence Consumer Loyalty?', *Journal of Marketing*, 63(4_suppl1), pp. 33–44. Available at: https://doi.org/10.1177/00222429990634s105.

Smith, W.W. *et al.* (2015) 'Tracking destination image across the trip experience with smartphone technology', *Tourism Management*, 48, pp. 113–122. Available at: https://doi.org/10.1016/j.tourman.2014.04.010.

Tseng, C. *et al.* (2015) 'Travel blogs on China as a destination image formation agent: A qualitative analysis using Leximancer', *Tourism Management*, 46, pp. 347–358. Available at: https://doi.org/10.1016/j.tourman.2014.07.012.

Tversky, A. and Kahneman, D. (1991) 'Loss Aversion in Riskless Choice: A Reference-Dependent Model*', *The Quarterly Journal of Economics*, 106(4), pp. 1039–1061. Available at: https://doi.org/10.2307/2937956.

Wang, R. *et al.* (2019) 'Examining destination images from travel blogs: a big data analytical approach using latent Dirichlet allocation', *Asia Pacific Journal of Tourism Research*, 24(11), pp. 1092–1107. Available at: https://doi.org/10.1080/10941665.2019.1665558.

Williams, P. and Soutar, G.N. (2009) 'VALUE, SATISFACTION AND BEHAVIORAL INTENTIONS IN AN ADVENTURE TOURISM CONTEXT', *Annals of Tourism Research*, 36(3), pp. 413–438. Available at: https://doi.org/10.1016/j.annals.2009.02.002.

Yilmaz, Yusuf *et al.* (2009) 'Destination Image: A Comparative Study on Pre and Post Trip Image Variations', *Journal of Hospitality Marketing & Management*, 18(5), pp. 461–479. Available at: https://doi.org/10.1080/19368620902950022.

Research Paper

Conceptual Differentiation of City Spatial from the Heritage Conservation Perspective

Xinyi WU, Southeast University, China

Abstract

The city serves as a carrier of diverse activities and a foundation for the study of urban and rural planning. In the context of global heritage protection, research on city heritage protection and spatial planning has advanced, shifting from individual static protection to regional dynamic approaches. This change has expanded the meaning of heritage protection and requires further study. Currently, the definitions of professional terms in city planning have become conventional, yet their interpretations are often similar, repetitive, or contradictory. This paper focuses on three key ideas: 'City Spatial Pattern,' 'City Spatial Structure,' and 'City Functional Layout.' It explains these concepts and reviews their traditional definitions. It also examines how they are applied in different countries to protect heritage. This research aims to enhance the historical interpretation of city space concepts and explore the cultural connotations and planning values underlying spatial planning.

Keywords

Heritage conservation, Spatial concept, Spatial pattern, Spatial structure, Functional layout

1. Overview of City Protection and Development from the Perspective of Heritage Conservation

1.1. The Historical Development of World Cultural Heritage Protection

Since the 20th century, the focus of international heritage conservation has gradually shifted from a single high-value architectural monument to a broader exploration of material spaces, such as the heritage value of local architecture, city neighborhoods, and city fabric. Patrimonialisation has spread across Europe, prompting the issuance of key academic documents on cultural heritage protection. In 1913, the first International Conference on the Conservation of Historic Buildings was held in Athens, where the Charter of Athens was signed. Later, in 1964, the second conference in Venice resulted in the Venice Charter, which emphasized the need to preserve the integrity of historic monuments. In 1972, UNESCO's World Heritage Center published the 'Convention Concerning the Protection of the World Cultural and Natural Heritage,' clarifying cultural and natural heritage definitions. The 1976 Nairobi Recommendation, adopted by the UNESCO General Conference, provided a comprehensive framework for preserving historic areas and their environmental contexts and defined environment as both natural and artificial backgrounds that impact historic areas visually or spatially, either directly or through socio-economic and cultural connections.

Entering the 21st century, international heritage conservation has broadened to encompass the built environment as a whole, with globalization progressively advancing architectural and city heritage conservation. Faced with large-scale heritage environments, planners have shifted focus to the planning and design aspects of heritage. The concept of heritage planning has also increased awareness of regional

landscapes represented by historic city systems, as well as city landscape features like architectural textures and street networks. This new perspective extends to historic areas, cities, architectural clusters, and villages (Ye, Li and Wu, 2020). In 2004, the European Commission introduced the Sustainable Development of City Historical Areas Through Active Integration Within Towns, which introduced the concept of built heritage. This report emphasized the significance of complex systems, human habitats, city morphology, and city structures, underscoring the inherent planning value of historic built environments (European Commission, 2004). At the 15th ICOMOS Congress in Xi'an, China, in 2005, the Xi'an Declaration expanded cultural heritage preservation to include not only heritage sites but also their surrounding settings and all associated historical, social, spiritual, customary, economic, and cultural activities. This inclusive approach highlights the unity of tangible and intangible heritage as vital components of local cultural systems. In 2011, UNESCO adopted the Recommendation on the Historic Urban Landscape (HUL), marking the first application of the Historic Urban Landscape concept as a methodological approach for heritage protection and management. This evolving approach demonstrates a shift toward a more comprehensive understanding of city heritage, with emphasis on regional landscapes represented by complete historical cities and city features like architectural textures and street networks, thereby expanding the scope of integrated conservation in both international research and practice.

1.2. The Evolution of Global Cultural Heritage Conservation

As far as traditional heritage conservation methods are concerned, although the isolated conservation of a single heritage building can protect the physical entity itself, with the ever-changing city renewal and development, fragmented architectural entities cannot, on the one hand, support the significant cultural heritage and historical value behind them, and, on the other hand, cannot play a substantial role in the overall city conservation, renewal, and future construction. Therefore, it is necessary to combine the heritage conservation of individual buildings with the overall city planning and to enhance their importance in regional and town planning and development planning, which is precisely the direction that heritage conservation needs to work in at present. Under this path, the object of heritage conservation is being enriched, and its scope is expanding. When the object of heritage conservation is the city as a whole, it is necessary to interpret the city space historically and to understand the reasons and mechanisms of the formation of city space accurately through the study of the intangible cultural wisdom such as specific theoretical ideas, design methods, and systematic systems of the history of city planning and their mapping and projection of the built heritage in the city and rural space, so as to understand the causes and mechanisms of the formation of city space. By studying the intangible cultural wisdom such as specific theoretical ideas, design methods, and institutional systems in the history of city planning and their mapping and projection in city and rural spaces, we can understand the causes and mechanisms of city space formation in order to accurately identify the historical value of city heritage. This city planning wisdom has long existed in the dynamic process of city development and construction, which makes the perspective of heritage conservation not only include the tangible physical space in the city but also the intangible yet stable laws of city development.

Within the confines of the physical environment, city space is organized in different ways in terms of form, pattern, structure, texture, and layout. As the understanding of historical cities and spatial cultural heritage is being enriched worldwide, different city development trajectories also reflect different cultural connotations, which are constantly changing in the historical evolution of the city to meet the functional needs of the city, forming the city spatial characteristics of a certain historical period. The definitions of various concepts related to them have also been extended and expanded to a certain extent, but regarding the definitions of the terminology therein, it seems that they have become the agreed-upon basic concepts, and fewer people compare and analyze them, leading to some similarities, repetitions, or contradictions in

the interpretation of their connotations. Therefore, this paper extracts several key city spatial concepts, namely 'City Spacial Pattern', 'City Spacial Structure', and 'City Functional Layout', and firstly gives an overview of the research on these concepts, extracts the classical interpretations of these concepts in the academic world, and then analyzes the connotation of these concepts in different countries in the context of city planning and heritage preservation, and then further explains them with the combination of case studies, so that we can achieve the goal of comprehensive research and analysis of these concepts in the context of heritage preservation.

2. Analysis of the Connotations of Three City Spatial Concepts

2.1. City Spatial Pattern

2.1.1 Concept Development and Related Research on City Spatial Pattern

Pattern in English is a particular way in which something is done, organized, or happens, or can also be interpreted as any regularly repeated arrangement, especially a design made from repeated lines, shapes, or colors on a surface. When put in a Chinese context, it is translated as 'Geju', which on the one hand is used to describe the spatial structure and form of an object, and on the other hand, it also has the meaning of layout, distribution, and location of elements. Initially, the interpretation of urban geography was more from the perspective of visual form; for example, Edmund Bacon's *Design of Cities*, published in 1967, considered geography to be the visual framework constituted by the natural base of the city and man-made developments (Bacon, 1967) . Paul D. Spreiregen in 1981 considered urban geography to be the geometrical form of the city, either regular or irregular, or the shape of the city. It is either regular or irregular and can usually be seen in its intersection and street pattern(Spreiregen, 1965). In Alexander's book *A Pattern Language: Towns, Buildings, and Construction*, he explains the term 'pattern' in the context of the professional study of architecture and cities and argues that patterns help design cities and buildings(Alexander et al., 1977). The concept of collecting 'patterns' or typical samples is much older. One can think of these collections as forming a language of patterns, the elements of which can be combined and governed by certain rules. Pattern in architecture is the idea of capturing architectural design ideas as archetypal and reusable descriptions. It can be seen that early studies of the city pattern were interpreted as a representative geometric pattern, which could either be applied in other suitable cases or referred to only as an ideal template in the conception of relevant design solutions.

2.1.2 Understanding of City Spatial Pattern in Different Background

Early studies in Western countries were mainly based on the ideas of theocracy and monarchy, emphasizing the city spatial layout with patriarchal shrines and temple markets as the core, as well as the ideal pattern of ordering, such as the city spatial pattern proposed by the ancient Greek architect Hippodamus, with the chequered road network as the skeleton and the distribution of city plazas and public buildings. The ideal city pattern envisaged by the ancient Roman Vitruvius was a spiderweb octagonal pattern conducive to military defense. At this time, the concept of city pattern began to be widely accepted by scholars and had an important impact on the city spatial planning of the Renaissance in the late 15th to 16th centuries (Zhang,2008) .

At the beginning of the 20th century, the Industrial Revolution emerged, and modern cities developed towards a functional mode, with new types of city layout theories, such as strip cities, industrial cities, idyllic cities, and satellite cities, arising one after another. However, due to the lack of accurate and complete city maps and land survey valuation books, coupled with the demand for rapid city development and the increase in the cost of trial and error, there were very few cases in which the concepts and ideas of these city models were really put into practice. Therefore, in the later stages of city research, scholars

began to look back at history, conduct archaeological and current research, and perform morphological analyses of original historical towns to refine the ideal regular pattern of certain historical city neighborhoods, as well as continue this planning methodology to the blocks that need to be planned and renovated. The large size and uniformity of these planned medieval plots are important in the study of later development patterns (Larkham,1992). Most studies that refer to the concept of city spatial patterns focus on the pattern of a neighborhood, a central part of the city, or a plot of land in the historic city. By summarizing this medium-scale city model, it is hoped that it will provide guidance or reference for the design of alternative new areas.

Under the influence of traditional ethical and philosophical thoughts and a highly centralized political system, Eastern countries have also formed their own interpretation of city spatial patterns within their unique historical contexts, focusing more on the harmonious relationship between city habitat and the natural environment. The scale of perception of city patterns has begun to increase. The city spatial pattern is an overall framework formed by the association and fusion of the natural landscape around the city, city man-made constructions, history, and other spatial elements. In addition to extracting the orderly elements of city form, the city pattern needs to pay more attention to the important element of the 'natural pattern,' grasping the overall form of the city from a wider scope and reflecting the relationship between humanity and nature.

Instead of focusing on local material details, the systemic and holistic characteristics of the city pattern are emphasized, representing the overall macroscopic manifestation of the city's material spatial composition (Yang, 2000). Taking the study of China's city spatial pattern as an example, a review of the development of China's city civilization shows that cities and politics have always been closely related, forming part of the national governance system. Historically, China's city and rural patterns have shown clustered development from a very early stage (Dong, 2022), with cities serving as part of the regional central city and city spatial system relying on the administrative structure. Such a spatial system of 'historical city clusters' and the clustering characteristics revealed therein can truly reflect the basic characteristics of China's historical city space (Li et al.,2022).

2.2. City Spatial Structure

2.2.1 Concept Development and Related Research on City Spatial Structure

City spatial structure refers to the distribution and association of city spatial elements within city space, which, together with the city social structure, economic structure, ecological structure, and other elements, constitutes the city structure in a broad sense. The city spatial structure is the material bearing of the other components and is also affected by other structures, connecting through various relationship networks to form an indivisible whole. The spatial structure of the city reflects both the spatial relationships between productive and non-productive sectors and among all buildings, natural objects, and people within the city. Analyzing current research on city spatial structure reveals its multifaceted nature, including population, employment, built-up area, traffic network distributions, and land use (Parr, 2014). Many scholars treat city pattern and city structure as similar elements, leading to unclear definitions. Edmund N. Bacon argues that design structure must be produced to activate city-building processes (Bacon, 1967). In Design of Cities, he explains city structure's attributes: 'This picture can portray both the representation on the picture plane of an already existing reality or, conversely, the projection of an imaginary three-dimensional concept that exists in the form of an imaginary city. These two phases interact with each other.' This explanation emphasizes that the city fabric is the foundation for developing a city's two-dimensional plane and three-dimensional concept. It summarizes the abstract forms of city spatial elements and aids understanding of formal transformations from planning to actual construction.

2.2.2 Understanding of City Spatial Structure in Different Background

The hierarchical division of city structure is more diverse than that of city pattern and can be divided into the spatial structure of city groups, the spatial structure outside the city—including s suburban satellites cities and the countryside—and the spatial structure inside the city, with the centralized construction area as the core and the decentralized construction area as the periphery. The current academic debate on heritage conservation focuses on the spatial structure of the city as a whole. Current academic research on city structure from the perspective of heritage conservation has common features. One type of research explores the internal spatial structure of the ancient city based on the city wall, using it as the research boundary. This involves refining typical city spatial elements, such as 'boundary-axis-centre-sign'(Wang, Liu and He, 2022), 'water system-axis-street'(Li et al., 2016) , 'road-palace-garden-agricultural land' (Yang, 2006) to summarize the internal spatial structure and provide a basis for subsequent conservation planning and new construction. Another type of research focuses on modern city areas, tapping into important heritage values in historical city spaces through city spatial features left by the evolution of different layers of the city. This research structures the intertwined spatial elements of modern and ancient land plots and coordinates the connection between the plots and their surrounding environment through contemporary planning methods such as urban renewal and neighborhood renovation, as well as the integration of point, line, and surface elements in design.

If the city pattern captures the characteristics of city layout from the perspective of the entire city, such as landscape and chessboard patterns, then city structure is more abstract, involving concepts such as 'radial', 'circular', and 'grid-like'. The former describes framework spatial elements in city layout, while the latter refines the spatial structure by analyzing the distribution, combination, and overall layout characteristics of each element. All material elements in city space (center, boundary, node, path, etc.) exist in a state of change and constancy, and finding the scale and logic of 'simplicity' is significant for interpreting changes in city form and identifying historical values (Zhang, 2008).

2.3. City Functional Layout

2.3.1 Concept Development and Related Research on City Functional Layout

City function, also known as Urban function, is the task and role of the city in national and regional political, economic, cultural, social, and other activities. The city functional layout is the regional division and land use arrangement based on different functions in city construction planning. It is believed that city function is an embodiment of city structure, and different elements of city structure will lead to different city functions. Changes in the structural relationship will also affect changes in city function, even when the elements of city structure remain the same. The phenomenon of the same city structure performing different city functions can also occur.

Although the functional layout of the city, functional zoning, land use, and other elements are modern city concepts proposed in the context of modern urbanization, they also demonstrate that ancient cities, in their planning and construction, took into account the allocation of functions across different two-dimensional land and three-dimensional spaces. In the context of heritage preservation, the functional layout of ancient cities is an integral part of city planning and architectural practice, inspiring us to interpret ancient city planning heritage through the lens of modern urban planning expertise.

2.3.2 Understanding of City Functional Layout in Different Background

The 1913 Athens Charter introduced the concept of the functionalist city, dividing cities into zones for living, working, recreation, and transportation. Le Corbusier's conception and design of the Radiant City became the blueprint for city planning under modernism in the 1920s. At the core of Le Corbusier's plan stood the

notion of zoning: a strict division of the city into segregated commercial, business, entertainment, and residential areas (Kohlstedt,2018). The layout of Corbu's ideal city was abstractly inspired by the arrangement and functions of the human body. The functional zoning advocated by these modernist city planners and architects represented a commitment to building a new, better, more organized, and more functional city, which has had a huge influence on subsequent approaches to urban design and architecture.

The functional layout of ancient cities was also influenced by the city's functions. Yejui He found that the zoning planning of ancient Chinese cities was based on functional zoning, and according to the attributes of this zoning, the zones were aggregated into comprehensive units of different natures, forming structural units (He, 1996). Zheng Le compares the changes in industrial development in ancient and modern Chinese cities, analyzing how Chinese cities transitioned from being politically function-driven in ancient times to increasingly emphasizing economic functions in modern times, which has become key to the modernization of Chinese cities (Le, 1993). Alfred Schinz's The Magic Square: Cities in Ancient China (Schinz, 2009) and S. Paro Kostov's The City Shaped both analyze in detail the reasons behind the layout of the political (Kostof, 1993), defensive, and trade functions of ancient cities in the East. It can be found that the layout of the functional space of ancient cities was influenced by the needs of city development and the thoughts of city planners, embodying valuable wisdom in combining city space and land use. However, the current study of city functional space layout focuses more on the external characteristics of ancient city planning, necessitating further exploration of the deeper meanings of ancient city functional space.

3. Conclusion

City spatial concepts have been interpreted differently in modern city planning terminology due to various national development contexts and linguistic environments, and these spatial concepts have been given different cultural connotations at different stages of urban planning in various historical periods. These connotations have been changing and iteratively updated over time, but the essence of these concepts has been carried over from ancient times to the present day, which is not only a content to be deeply excavated and reflected upon in heritage preservation but also an important part of the planning heritage, reflecting the wisdom of planning from the construction of settlements to the construction of cities in the history of human societies.

Currently, the existing research on city patterns is more of a summary of one or a type of urban planning model, which lacks consideration of the natural environment surrounding the city and also lacks a more macroscopic regional perspective. Therefore, in order to understand the concept of city pattern, on the one hand, we should focus on the overall relationship between the built environment of the city and the natural landscape, so as to enhance the depth of the research on the spatial framework of 'mountain-water-city.' On the other hand, in addition to the individual city as the research object, city spatial patterns can also include the connection between cities, and it is necessary to further explore the spatial pattern of urban agglomerations and systems to enhance the understanding of the systematic and holistic nature of this concept.

Secondly, academics often confuse the concept of city spatial structure with terms such as city pattern, resulting in unclear hierarchical relationships between the two concepts. City spatial structure has two-dimensional and three-dimensional attributes, and the study of city spatial structure from the perspective of heritage conservation should be based on the city spatial pattern, focusing on the distribution status and organizational logic of the material and immaterial elements within the modern city area with the ancient city as the center, in order to correspond to the needs of existing city regeneration and heritage conservation at different scales and to provide historical guidance for the existing urban planning and design.

Finally, the research on the functional space of the city is relatively comprehensive but mainly describes the physical appearance and lacks reflection on the wisdom of the inner layout of the ancient city. We can analyze the layout of city functional space through the historical lineage of ancient city development and interpret it from the perspective of modern urban planning, so as to achieve the purpose of learning from history and remedying deficiencies.

4. References

Alexander, C., Ishikawa, S., Silverstein, M., Jacobson, M., Fiksdahl-King, I., & Angel, S. (1977a). A pattern language: towns, buildings, construction. In Oxford University Press eBooks (Vol. 1, Issue 5). https://ci.nii.ac.jp/ncid/BA00163982 (Accessed: 20 October 2024).

Bacon, E. N. (1967). Design of cities. First Edition. United Kingdom: Thames & Hudson.

Dong,W. (2022) An Initial Approach to the Establishment of National Historic and Cultural Spatial System, City Planning Review,46(02):pp. 71-78.

European Commission, Directorate-General for Research and Innovation, Teller, J., Ruelle, C., Dupagne, A. (2004) SUIT, sustainable development of urban historical areas through an active integration within towns : guidance for the environmental assessment of the impacts of certain plans, programmes or projects upon the heritage value of historical areas, in order to contribute to their long-term sustainability : research report n° 16. Publications Office.

He,Y.J (1996) History of Urban Planning in Ancient China, First Edition, Beijing: China Construction Industry Press.

Kohlstedt,K. (2018) Ville Radieuse:Le Corbusier'sFunctionalist Plan for a Utopian'Radiant City, 99% Invisible[online], Available at: https://99percentinvisible.org/article/ville-radieuse-le-corbusiers-functionalist-plan-utopian-radiant-city/ (Accessed: 20 October 2024).

Kostof, S. (1993) The City Shaped: Urban Patterns and Meanings Through History, First Edition, United Kingdom: Thames & Hudson.

Larkham,P.J. (1992) Conservation and the changing urban landscape, Progress in Planning, Volume 37, Part 2, pp. 83-181.

Le,Z. (1993) Recent Changes in Urban Functional Structure, Journal of Sun Yat-sen University (Social Science Edition), (01):p61-69.

Li,B.H., Li,N.(2022) Historic city conservation in China: evolution, planning, and strategies, Journal of Urban and Regional Planning, 14(2): pp. 1-19.

Li,X., et al. (2016) Historical Structures of Urban Form: Characteristics, Evolution and Significance --- Chengdu as an Example, City Culture, 23(08):p52-59.

Parr, J. B. (2014). The regional economy, spatial structure and regional Urban systems. Regional Studies, 48, pp. 1926–1938.

Schinz, A. (2009) The Magic Square: Cities in Ancient China. Translated from the [Chinese] by Mei,Q. Beijing, First Edition, China: China Building Industry Press.

Spreiregen, P. D. (1965). Urban design, the architecture of towns and cities. Internet Archive [online]. Available at: https://archive.org/details/urban-design-the-architecture-of-town-and-cities-by-spreinger-paul-d (Accessed: 20 October 2024).

Wang,Z.Y., Liu,Y.S., He,Y. (2022) Study on the Evolution and Protection of the Historical Pattern of the Site Cities in Shanxi Province, Planning and Cinstruction, (02):p90-95.

Yang,J.Q. (eds.)(2000). Modern Urban Renewal, Nanjing,China: Southeast University.

Yang,Y.L.(2006) Study on the Evolution of Xi'an City's Regional Structure, Xi’an University of Architecture and Technology.

Ye,Y.L., Li,B.H., Wu,T.H. (2020) Concepts of Planning Heritage and Corresponding Practices in the World, Urban Planning International, 37(02), pp. 82-87.

Zhang,X.J. (2008) Observations and Analyses on the Evolution of Lanzhou's Urban Pattern. TongJi University,pp. 1-2.

Research Paper

Study on Regional Differences and Configuration Paths of Factors Influencing Population Outflow

Empirical Analysis from 26 Resource-based Shrinking Cities in China

Qing Yuan, Harbin Institute of Technology, China
Xinfang Zhang, Harbin Institute of Technology, China
Hong Leng, Harbin Institute of Technology, China

Abstract

Taking 26 resource-dependent shrinking cities in China for example, this study aims to explore the spatial distribution differences of influencing factors and their multiple concurrent causal relationships using variance analysis and fsQCA. The results shows that differential distribution exists in overall industrial structure upgrading, local government fiscal strength, employment absorption capacity of the tertiary industry, the radiating capacity of central cities, the stringency of environmental regulations, and the level of public service provision. There is no necessary condition influencing high population loss in resource-dependent shrinking cities: the coupling of various factors has formed three high population loss pathways. The research results can provide reference for population control and social governance in China's resource-dependent shrinking cities.

Keywords

Resource-based Shrinking Cities; Population Outflow; Influencing Factors; Spatial Differentiation; Configuration of Conditions; Fuzzy-set Qualitative Comparative Analysis (fsQCA)

1. Introduction

1.1. Research Background

The concept of "shrinking cities" refers to cities with populations exceeding 10,000 people, suffering from successive population decline for more than two years, accompanied by deep-seated economic recession phenomena (Wiechman, T,2007). In recent years, the city shrinkage phenomena has spread globally, and that in China has also become prominent day by day. According to data collected by the sixth and seventh national censuses, 152 prefecture-level cities in China have shrank for population loss.

Resource-depletion shrinking cities is a typical example among shrinking cities. There is a mutual influence and feedback relationship between resource depletion and population loss. As resource

depletion will cause environmental degradation, economic constraints, and a decline in living standards, forcing residents to leave. Serious population loss leads to severe challenges to the socio-economic development in cities (Gu, H.Y., 2020), directly placing a long-term unfavourable situation for these urban areas. As a result, it's urgent to fix the issue of population loss in resource-depletion shrinking cities, while classifying the regional differences and configurational pathways of the factors influencing population loss is a crucial prerequisite for achieving this goal.

1.1. Literature review

Regarding population decline and resource-depletion city decline, current studies include aspects such as concept definition and identification, causal mechanisms, and response strategies. Among these, the influencing factors constitute the key content of the studies on population loss in shrinking cities. The influencing factors in China's shrinking cities are mainly concentrated in fields including the economy [10], industry(Zhang, M.D., 2019), policy(Luo, F.Z., 2021),employment (Zhang, X.D.,2023), finance (Du, Z.W., 2019), public services(Zheng, J.,2022),inter-regional siphoning (Zhang,M.D.,2019), regional development disparities (Du, Z.W., 2019),environmental climate (Liu, F.B.,2018). The driving mechanisms for population loss in different regions often greatly vary. Scholars in China have analyzed various factors leading to urban population loss at national scales (Zhang, X.D.,2023), municipal levels (Chen, R. ,2021), and regional scales such as the Pearl River Delta (Wu, K.,2015), the Yangtze River Midstream Urban Agglomeration (Zhang,M.D.,2019), the Guanzhong Plain Urban Agglomeration (Luo, F.Z., 2021), and the Northeast region (Yan, G.H.,2021). However, there is a lack of comparative research on the regional differences in influencing factors for different types of shrinking cities. While domestic and international studies have provided some enlightening conclusions about the relationship between different influencing factors and population loss, most research focuses on the impact of individual core factors on population loss and their linear effects, with limited discussion on the relationships between various condition combinations and population loss.

In light of this, the present study uses 26 resource-based shrinking cities in China as a case study. Variance statistical analysis is applied to explore the spatial distribution differences of influencing factors. Building on this, fuzzy-set qualitative comparative analysis (fsQCA) from a configurational perspective is employed to uncover pathways leading to high population loss. The aim is to provide targeted recommendations for mitigating population loss and achieving sustainable development in resource-depletion shrinking cities.

2.Research method and data collection

2.1. Research method

The principle of one-way ANOVA specifically refers to the significant impact of a single independent variable on a dependent variable across different levels. This study utilizes one-way ANOVA to compare the current characteristics of factors influencing population loss and the extent of population decline in 26 resource-depleted shrinking cities, focusing on the significance of regional differences. Qualitative Comparative Analysis (QCA) (Ragin, C.C. 1987) is employed to explore the necessity of individual antecedent conditions and how combinations of multiple antecedent conditions affect outcomes through set theory and Boolean algebra. This method reveals the complex causal relationships behind observed phenomena. The study uses fuzzy-set qualitative comparative analysis (fsQCA) to determine whether there are necessary conditions affecting population loss and to further investigate pathways leading to high levels of population decline.

2.2. Study area

This study screened resource depleted cities in China with population shrinkage phenomenon through literature review. The selection of cities follows three criteria: firstly, the principle of diversity. The selected cities include the eastern, central, and western regions, ensuring the breadth and diversity of the research. Secondly, based on the principle of homogeneity and comparability, all 26 cities are facing the phenomenon of population outflow due to the depletion of mineral resources, oil, forestry and other resources, and population outflow is influenced by multiple factors such as economy, society, industry and environment. Thirdly, the principle of data accuracy, based on data from 2018 to 2022, uses the 5-year mean as the measurement standard for variables. 26 cities in China facing resource depletion were selected as the analysis objects (see Table 1). All relevant data are obtained through public channels such as the China Urban Statistical Yearbook, official websites of various city governments, and the National Economic and Social Development Bulletin.

Area type	Province	Prefecture-level city
The Northeast	Liaoning Province	Fushun, Benxi, Fuxin, Chaoyang, Liaoyang, Huludao
	Jilin Province	Liaoyuan, Baishan, Jilin, Tonghua
	Heilongjiang Province	Jixi, Hegang, Shuangyashan, Yichun, Qitaihe, Heihe
Central region	Inner Mongolia Autonomous Region	Wuhai
	Anhui Province	Huaibei and Tongling
	Jiangxi Province	Jingdezhen and Pingxiang
	Hubei province	Yellowstone
Southwest region	Guangdong Province	Shaoguan
	Shaanxi province	Tongchuan
	Gansu Province	Baiyin
	The Ningxia Hui Autonomous Region	Shizuishan

Table 1. Overview Table of Resource Exhausted Shrinkage Case Cities. Source: Author's self-made.

2.3. Data measurement

In this study, six antecedent variables were identified: Industrial Structure Upgrading (ISU), Local Government Fiscal Strength (GFS), Tertiary Sector Employment Absorption Capacity (TEA), Public Service Provision Level (PSL), Central City Radiating Capacity (CRC), and Environmental Regulation Intensity (ERE), with Population Loss Degree (PL) as the outcome variable. For the measurement of antecedent variables, the approach of Wang Wei (Wang, W.,2015) was adapted for Industrial Structure Upgrading. The first, second, and third industries were all included, leading to the construction of an index approximating the level of industrial structure optimization and upgrading. The fiscal strength of local governments can refer to the research by Chen Shuyun and Zeng Long (Chen, S.Y.,2016). planning to use the ratio of planned fiscal revenue to fiscal expenditure, i.e., the fiscal strength of local governments, and this indicator was used to gauge the government's role and regulatory capacity in income distribution.

Tertiary Sector Employment Absorption Capacity was assessed following the research of Qi Yudong (Qi, Y.D.,2020), using the proportion of employment in the tertiary sector relative to total employment. The Public Service Provision Level was evaluated using the method of Lü Wei, Dan Shu, and Jiang Yang (Lv, W.,2009). The ratio of public budget expenditure to the local population was calculated to assess public service provision. Central City Radiating Capacity was measured using the breakpoint model, based on the work of Zhao Zheng and Du Chuangjiang (Zhao, Z.,2017). Environmental Regulation Intensity was represented by the ratio of local fiscal environmental protection expenditure to general fiscal budget expenditure, as per the method of Chen Yubin (Chen, Y.B.,2022). The outcome variable, Population Loss Degree, followed the definition of Ma Zuopeng (Ma, Z.P.,2021) on urban and regional population shrinkage. The population change rate within a given period was used as a key indicator to assess population loss in shrinking cities, and the population change conditions of each city were calculated.

3. Results and discussion

3.1. Analysis of regional differences

From the perspective of the antecedent variables influencing population loss in resource-depleted shrinking cities, the overall upgrading of the industrial structure shows significant regional differences among the eastern, central, and western regions. In the eastern region, there is a pronounced weakness. The cities within the eastern region exhibit relatively large disparities, while those in the central region show comparatively smaller disparities. Cities such as Liaoyuan, Baishan, and Tonghua represent the eastern region, where the industrial structure upgrading displays a spindle-shaped distribution. In the Heilongjiang Province, multiple cities exhibit poor overall upgrading of the industrial structure. In contrast, the central region, represented by Jingdezhen, Huaibei, and Pingxiang, demonstrates a funnel-shaped distribution of industrial structure upgrading. There are significant outliers in this region, showing an extremely significant difference compared to the eastern cities. The western region, with Tongchuan as a representative city, displays a leaf-shaped distribution of industrial structure upgrading. This region shows a pronounced difference compared to the eastern cities(see Figure1,2).

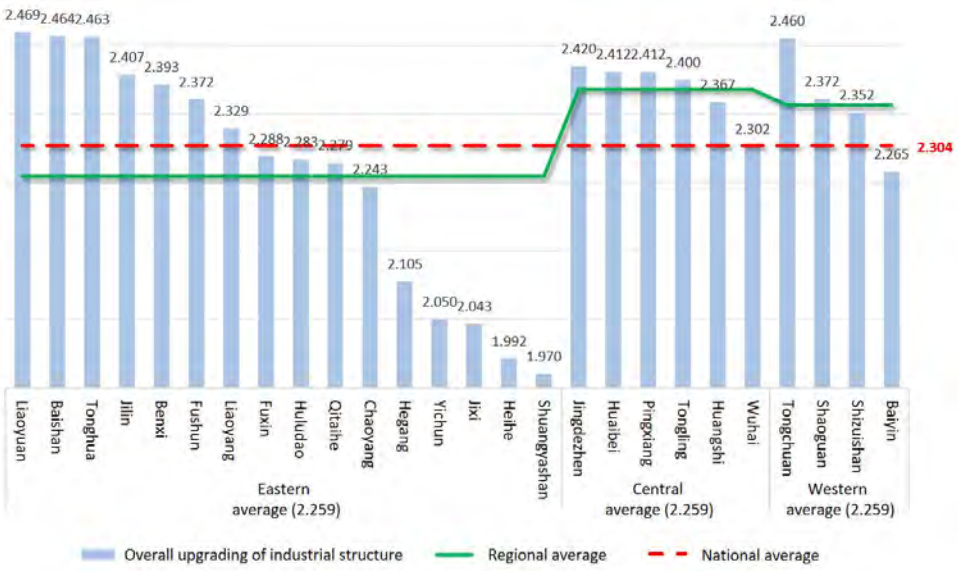


Figure 1. Distribution map of overall upgrading of industrial structure in the eastern, central, and western regions. Source: Author's self-made.

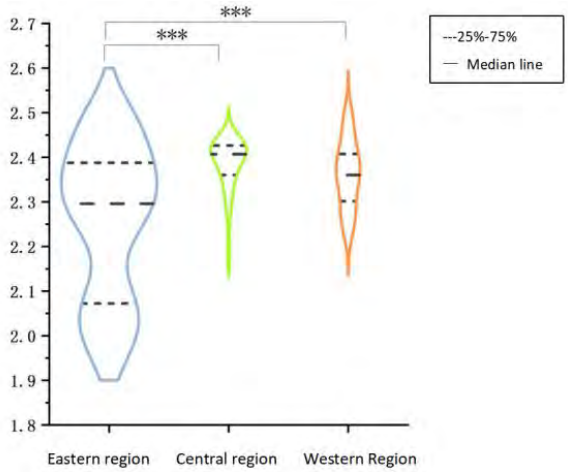


Figure 2. Difference Map of Overall Upgrading of Industrial Structure in Eastern, Central and Western Cities. Source: Author's self-made.

Regarding local government fiscal strength, there are extremely significant differences between the eastern and western regions, while the central region shows a relatively strong average level. In the eastern region, cities in Liaoning Province such as Liaoyang, Benxi, and Fushun show notable performance. Heilongjiang Province overall presents a weaker characteristic. In the central region, cities exhibit relatively smaller differences, whereas no cities in the western region reach the national average level. In the eastern region, Liaoyang, Benxi, and Fushun represent cities where local government fiscal strength displays a water droplet-shaped distribution. This distribution is relatively scattered, with multiple cities in Liaoning Province having relatively high fiscal strength, while cities in Jilin and Heilongjiang Provinces have relatively poor fiscal strength. In the central region, cities such as Wuhai, Tongling, and Huangshi show a leaf-shaped distribution of fiscal strength, with noticeable outliers. These cities exhibit an extremely significant difference compared to the eastern cities. In the western region, the overall local government fiscal strength exhibits a gourd-shaped distribution, which is relatively concentrated and shows a significant difference from the eastern cities(see Figure 3,4).

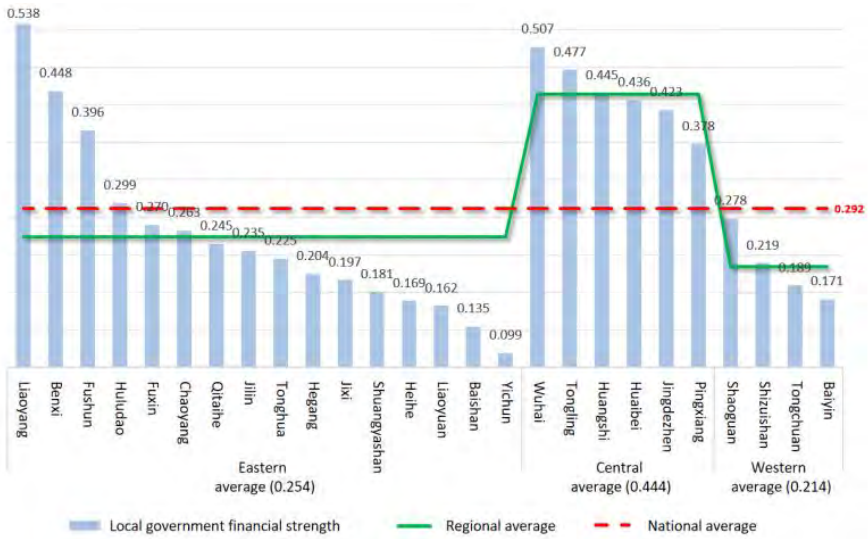


Figure 3. Distribution Map of Financial Strength of Local Governments in the East, Central, and Western Regions.Source: Author's self-made.

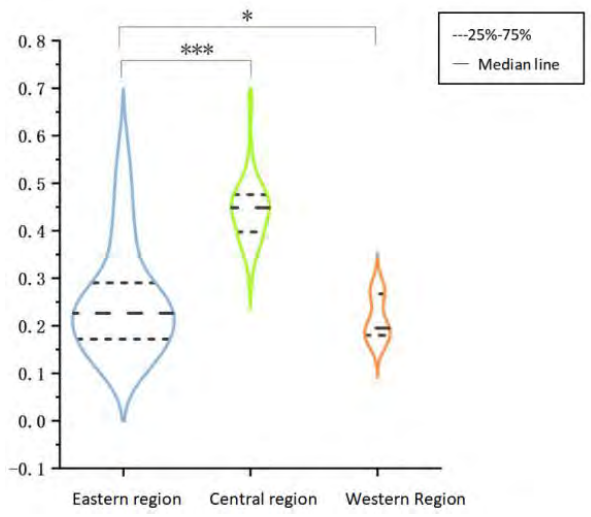


Figure 4. Difference in Financial Strength of Local Governments in the East, Central, and Western Regions.Source: Author's self-made.

Regarding the tertiary sector employment absorption capacity, significant differences are observed between the eastern and central regions. In the eastern region, 62.5% of cities exceed the national level, while Wuhai leads in the central region. In the western region, only Tongchuan and Shaoguan show notable performance. In the eastern region, cities such as Fuxin and Tonghua represent a gourd-shaped distribution of tertiary sector employment absorption capacity. In the central region, Wuhai is prominent, with a noticeable dispersion and significant differences from the eastern cities. In the western region, Tongchuan and Shaoguan fall short of the standard, with an overall linear distribution of tertiary sector employment absorption capacity and noticeable outliers(see Figure 5,6).

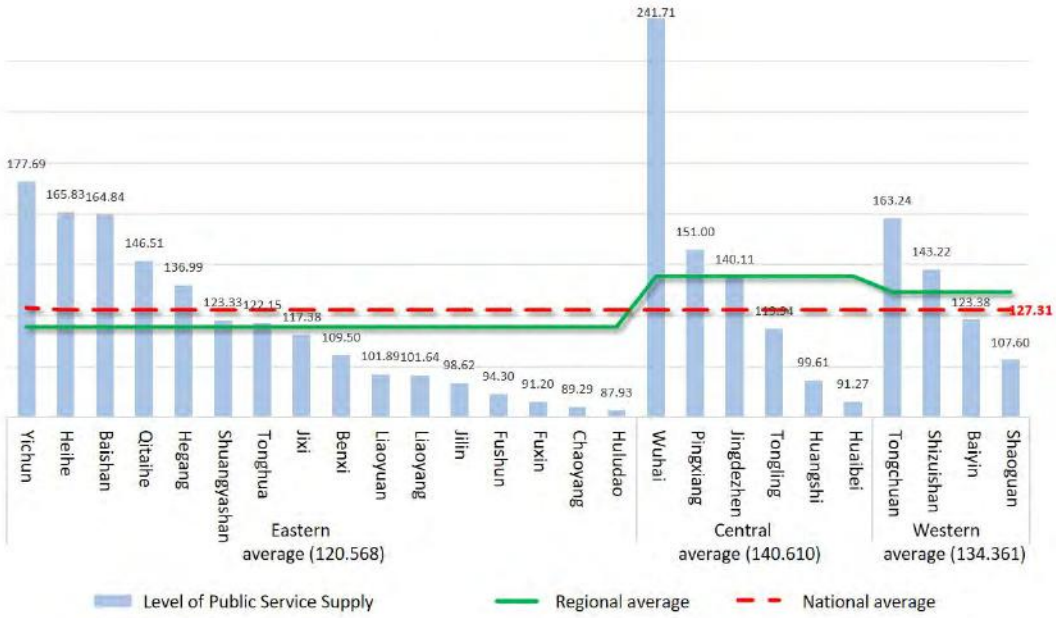


Figure 5. Distribution map of employment absorption capacity in the tertiary industry in the eastern, central, and western regions.Source: Author's self-made.

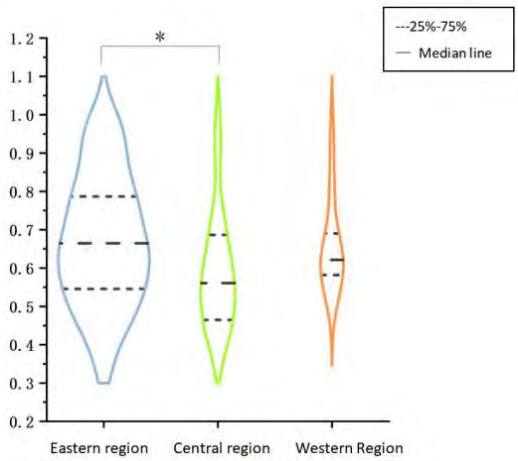


Figure 6. Differences in Employment Absorption Capacity of the Third Industry in the East, Central, and Western Regions.Source: Author's self-made.

In terms of public service provision levels, differences among the eastern, central, and western regions are not significant. The central region, represented by Wuhai, shows a prominent gap. The western region exhibits relatively smaller disparities among cities. In the eastern region, the public service provision level displays an inverted funnel-shaped distribution. In the central region, the public service provision level shows an inverted bat-shaped distribution, with Wuhai standing out with particularly distinct bipolar characteristics. The western region shows a relatively uniform distribution. There are no significant differences in public service provision levels among the eastern, central, and western regions(see Figure 7,8).

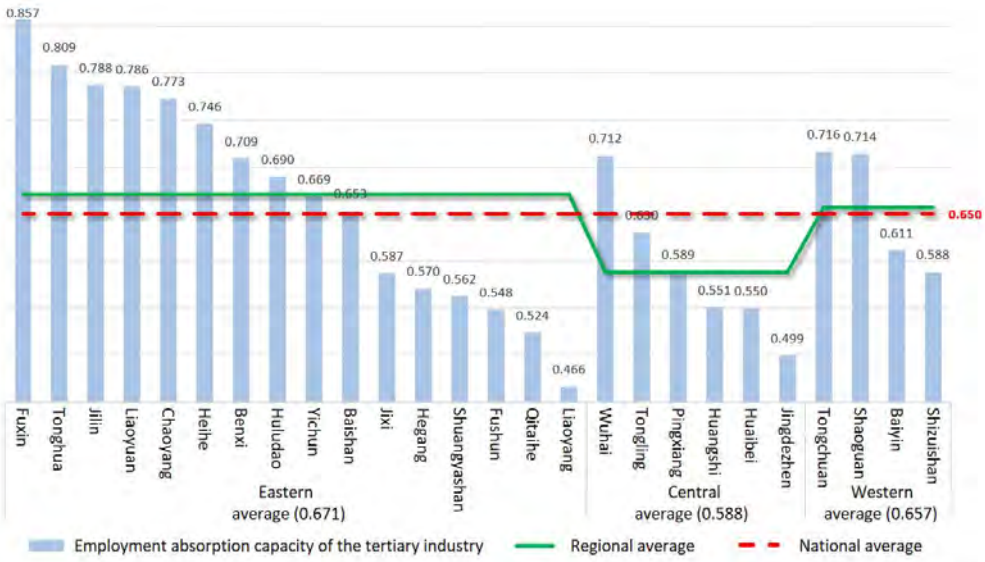


Figure 7. Distribution Map of Public Service Supply Levels in the East, Central, and Western Regions.Source: Author's self-made.

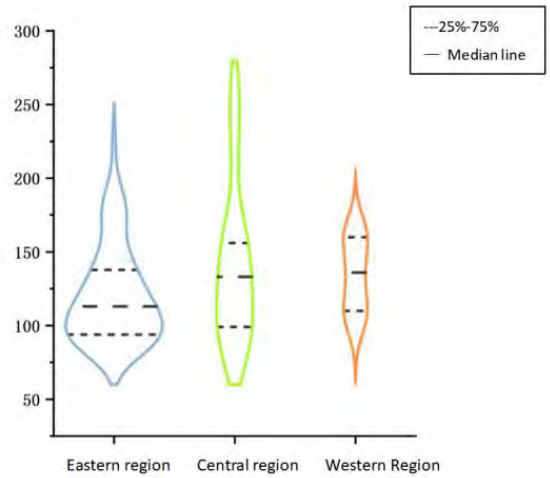


Figure 8. Difference Map of Public Service Supply Levels in the East, Central, and Western Regions.Source: Author's self-made.

In terms of the radiative driving capacity of central cities, significant differences are observed between the eastern and western regions, with the western region showing a stronger average level. Huangshi and Shaoguan lead in performance, while the eastern region, particularly in Heilongjiang Province, generally exhibits weaker characteristics. In the eastern region, cities such as Benxi, Liaoyang, and Fushun represent the area, and the radiative driving capacity of central cities shows an inverted funnel distribution overall. Specifically, several cities in Heilongjiang Province have relatively poor radiative driving capacities. In the central region, Huangshi stands out, with an overall radiative driving capacity of central cities showing a baton-like distribution and notable outliers. In the western region, cities like Shaoguan and Tongchuan represent the area, with an overall distribution of central city radiative driving capacity showing a spindle shape, exhibiting very significant differences from the eastern cities(see Figure 9,10).

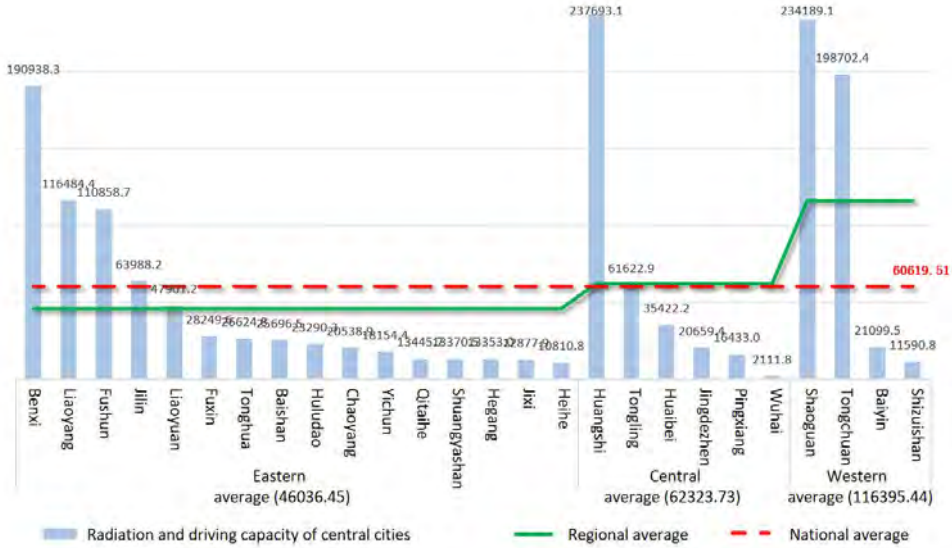


Figure 9. Distribution map of radiation driving capacity of central cities in the eastern, central, and western regions.Source: Author's self-made.

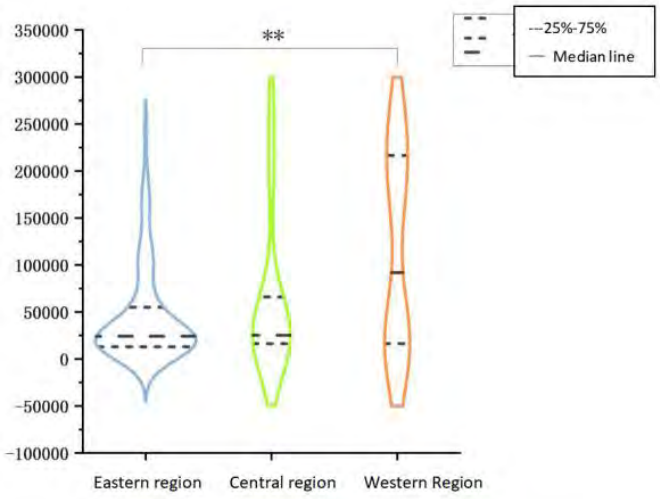


Figure 10. Differences in Radiation and Driving Capacity of Central Cities in the East, Central, and Western Regions.Source: Author's self-made.

Regarding the intensity of environmental regulation, there are no noticeable differences among the eastern, central, and western regions, with all regions close to the national average level. In the eastern region, Yichun stands out, while differences between other cities are relatively small. The eastern region, represented by Yichun, Liaoyuan, and Qitaihe, shows an inverted funnel distribution in environmental regulation intensity, with notable outliers, with Yichun leading. In the central region, cities such as Pingxiang, Wuhai, and Jingdezhen are representative, and the overall distribution of environmental regulation intensity shows a gourd shape, with significant differences from the eastern cities. In the western region, the overall environmental regulation intensity of cities is concentrated in a gourd-like distribution, with cities like Shizuishan, Shaoguan, and Tongchuan representing the area, and the intensity showing a bar-like distribution. There are no significant differences in environmental regulation intensity among the eastern, central, and western cities(see Figure 11,12).

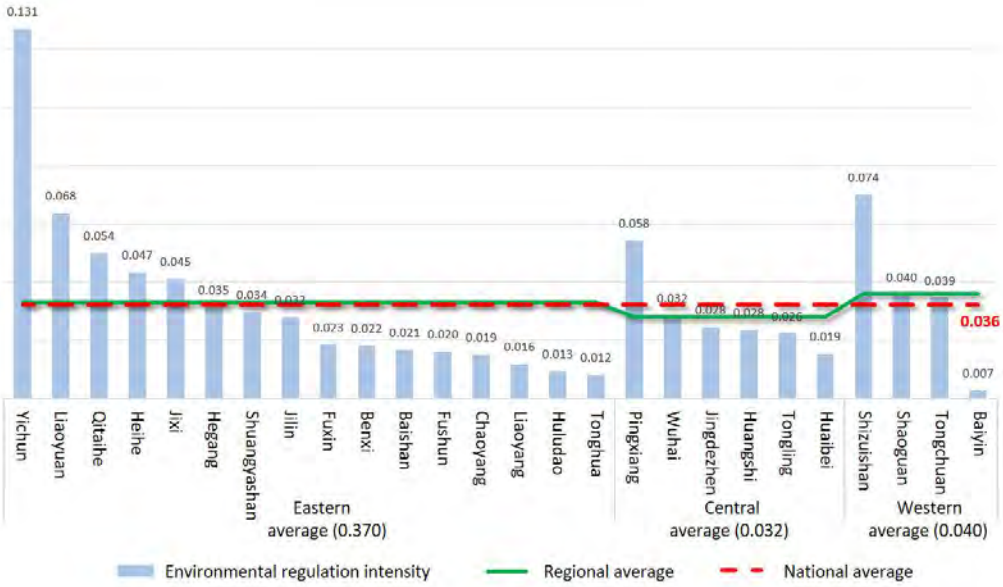


Figure 11. Distribution map of environmental regulation intensity in the eastern, central, and western regions.Source: Author's self-made.

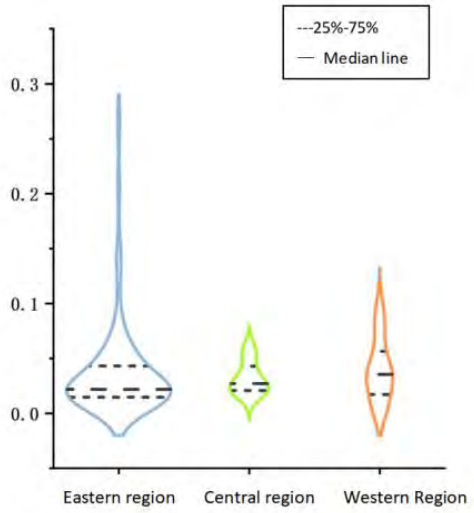


Figure 12.Difference in Environmental Regulation Strength between the East, Central, and Western Regions.Source: Author's self-made.

Regarding the degree of population loss, differences between the eastern, central, and western regions are not significant, with all regions close to the national average level of population loss. In the eastern region, Tonghua and Baishan, and in the central region, Tongling, show severe population loss, with other cities showing relatively small differences in population loss. Tonghua, Baishan, and Tongling experience population loss levels far exceeding those of other resource-depleted shrinking cities, making them regions of extremely severe population loss. Excluding these three cities, the population loss in other eastern cities shows an inverted funnel distribution and is relatively concentrated, while the central region shows a bar-like distribution with noticeable outliers. The western region's distribution is relatively uniform, and there are no significant differences in population loss among the eastern, central, and western regions, with minimal regional differences in population loss levels(see Figure 13,14).

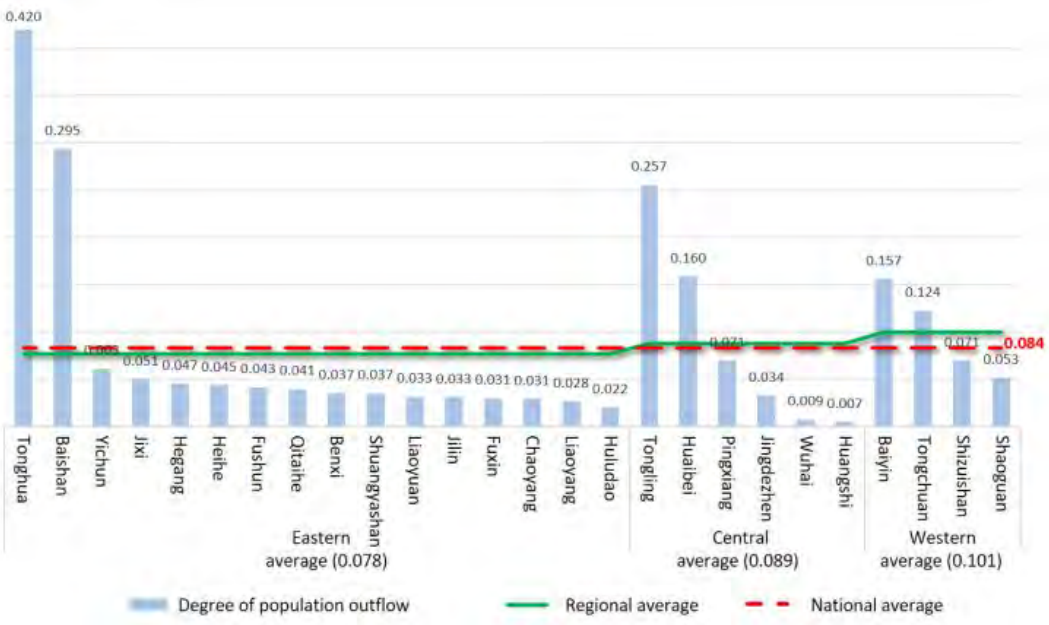


Figure 13. Distribution map of population outflow in the eastern, central, and western regions.Source: Author's self-made.

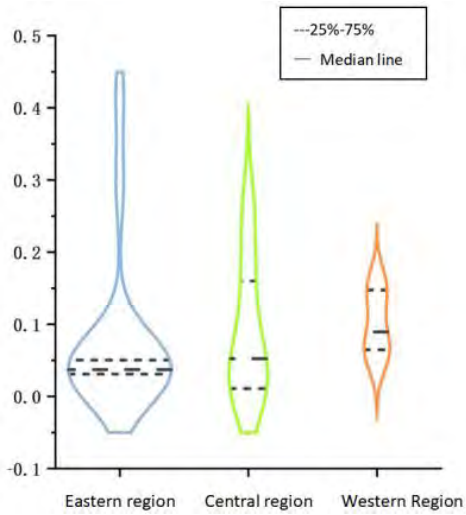


Figure 14.Difference in Population Loss between the East, Central, and Western Regions.Source: Author's self-made.

3.2.Necessity Analysis

Before the configuration analysis using QCA was conducted, QCA was employed to test the necessity of all antecedent variables. It is theoretically required that if an antecedent variable is a necessary condition for the outcome variable, it should be included in all configurations of conditions. In QCA, the assessment of whether a variable is a necessary condition is based on the extent to which the condition is a super set of the outcome. A condition is considered a necessary condition if its consistency level exceeds 0.9 and its coverage exceeds 0.5.

For the outcome variable of high population loss (High PL), it was discovered that none of the influencing factors met the criteria of a consistency level greater than 0.9 and a coverage greater than 0.5. Thus, none of the six specific factors could be individually identified as a necessary condition for high population loss. Therefore, no bottleneck constraints affecting high population loss (High PL) in resource-depleted shrinking cities were found(see Table 2).

Variable	High PL		Not-High PL	
	Consistence	Coverage	Consistence	Coverage
ISU	0.458	0.494	0.631	0.606
~ISU	0.635	0.659	0.473	0.438
GFS	0.411	0.750	0.357	0.580
~GFS	0.770	0.573	0.846	0.561
TEA	0.768	0.633	0.758	0.557
~TEA	0.462	0.682	0.500	0.658
PSL	0.394	0.425	0.698	0.670
~PSL	0.694	0.720	0.401	0.371
CRC	0.542	0.594	0.477	0.465
~CRC	0.512	0.523	0.584	0.532
ERE	0.061	0.872	0.072	0.924
~ERE	0.895	0.546	0.990	0.484

Table 2. FSQCA necessity analysis. Source: Author's self-made.

3.3.Configuration Path Analysis

Based on the research by Fiss et al. (Fiss,P.C., 2011), the original consistency threshold was set at 0.80, the PRI consistency threshold was set at 0.65, and the case frequency threshold was set at 1. By comparing the nested relationships between the intermediate solution and the parsimonious solution , the core conditions of each solution were identified. Conditions that were commonly present in both the intermediate and parsimonious solutions were defined as core conditions, while conditions that appeared only in the intermediate solution were considered as peripheral conditions. The overall consistency for the solutions related to high population loss in resource-depleted shrinking cities reached 0.869. This indicates that among all cases of high population loss that meet the three types of condition configurations, 86.9% of the cities experienced significant population loss. The overall coverage was 0.443, indicating that all condition configurations could explain approximately 44.3% of the cases.

The distribution characteristics of antecedent conditions under the three types of condition configurations were observed. "~Overall industrial structure upgrading" , "~Public service supply level," and "Local government financial strength" were identified as core conditions for high population loss in resource-depleted shrinking cities. Among these, the configuration with "~Overall industrial structure upgrading" and "~Public service supply level" as core conditions had the highest coverage rate, reaching 0.355. The configuration with "Local government financial strength" as a core condition had the highest coverage rate of 0.196. This indicates that the primary source of high population loss lies in the lack of

overall industrial structure upgrading, inadequate public service supply, and that the presence of local government financial strength does not necessarily prevent high population loss. "Tertiary employment absorption capacity," "Central city radiation and driving ability," and "Environmental regulation intensity" were often observed as auxiliary conditions. This suggests that while some cities in resource-depleted shrinking areas have favorable conditions, population loss is partly attributable to tertiary employment absorption capacity, central city radiation and driving ability, and environmental regulation intensity. However, these factors do not have a prominent impact on the population loss process.

The three paths to high population loss in resource-depleted shrinking cities each had an original coverage exceeding the unique coverage. This indicates the presence of supporting cases with multiple causal paths. Based on the core conditions identified, three distinct typical patterns of high population loss were found. The H1 pattern, characterized by "~Overall industrial structure upgrading" and "~Public service supply level" as core conditions, can be termed as the "Industrial Structure and Public Service Deficiency Type." The H2 pattern, characterized by "Local government financial strength" as the core condition, can be referred to as the "Financial Strength Conflict Type." The H3 pattern, with "~Overall industrial structure upgrading," "~Public service supply level," and "Local government financial strength" as core conditions, can be termed as the "Industrial Structure-Public Service-Financial Strength Mixed Advantage and Disadvantage Type."(see Table 3).

Variable	High PL			Not-High PL	
	H1	H2	H3	L1	L2
Overall upgrading of industrial structure（ISU）	⊗	⊗	⊗	●	●
Local government financial strength（GFS）	⊗	●	●	⊗	⊗
Employment absorption capacity of the tertiary industry（TEA）	•	•	⊗		•
Level of Public Service Supply（PSL）	⊗	•	⊗	●	●
Radiation and driving capacity of central cities（CRC）		⊗	•	⊗	
Environmental regulation intensity（ERE）	⊗	⊗	⊗	⊗	⊗
Consistence	0.850	0.897	0.855	0.775	0.849
Original coverage	0.355	0.196	0.140	0.199	0.331
Unique coverage	0.134	0.005	0.083	0.003	0.135
Consistency level of solution	0.869			0.837	
Coverage of solutions	0.443			0.334	

Table 3. FSQCA configuration analysis. Source: Author's self-made.

4. Conclusion

4.1The research outcomes

This study uses 26 resource-based shrinking cities in China as examples to explore the spatial distribution differences of influencing factors by combining variance statistical analysis and fuzzy-set qualitative comparative analysis (fsQCA). From a configurational perspective, the study reveals the path logic of high population loss in resource-depleted shrinking cities and provides an in-depth analysis of the fundamental issues behind population loss in different cities. The conclusions are as follows:

(1) Analysis using single-factor methods reveals significant differences in overall industrial structure upgrading among the eastern, central, and western regions. The eastern region exhibits extremely weak characteristics, with considerable differences among cities within the eastern region. In terms of local government financial strength, significant differences are observed between the eastern and western regions, with no western cities reaching the national average level. Regarding tertiary employment absorption capacity, significant differences are observed between the eastern and central regions. In the western region, only Tongchuan and Shaoguan cities perform well. For central city radiation and driving ability, significant differences exist between the eastern and western regions, with Heilongjiang Province showing weaknesses and considerable differences among cities in the central and western regions. In terms of environmental regulation intensity and public service supply level, differences among the eastern, central, and western regions are not significant, with each region approaching the national average level. Regarding the result variable of population loss, differences among the eastern, central, and western regions are not significant, with each region approaching the national average level of population loss. Within the eastern region, Tonghua, Baishan, and in the central region, Tongling show severe conditions, while other cities exhibit smaller differences in population loss.

The necessary condition analysis reveals that none of the six influencing factors alone constitutes a necessary condition for high population loss. This indicates that there are no bottleneck constraints affecting high population loss in resource-based shrinking cities.

Regarding the combinations formed by the interaction of different influencing factors, three configurational paths are identified. These include the "Industrial Structure and Public Service Deficiency Type," the "Financial Strength Conflict Type," and the "Industrial Structure-Public Service-Financial Strength Mixed Advantage and Disadvantage Type."

4.2 Plans for future investigations

Despite the preliminary findings, further in-depth research is needed. It is recommended that future studies analyze the antecedents and configurations of population loss from the perspective of various types of shrinking cities. Additionally, due to data limitations, this study only selected 26 cities. Future research could increase the number of cases and improve the measurement of variables. The current study primarily relies on objective data and does not encompass subjective factors such as residents' sense of well-being and satisfaction, which may affect the breadth of humanistic concern in the results. Therefore, future research could integrate both subjective and objective data through methods such as surveys, and combine QCA with other approaches to explore the impacts and pathways of population loss from different levels.

5. References

Chen, R. (2021) 'Comprehensive measurement and influencing factors analysis of shrinking cities in China', *Statistics and Decision*, 37(23), pp. 68-71. Availableat: https://doi.org/10.13546/j.cnki.tjyjc.2021.23.015

Chen, S.Y. and Ceng, L. (2016) 'Fiscal autonomy, land finance dependence and the level of public service supply——evidence from the panel date of 286 cities above prefecture level in China', *Journal of Huazhong Normal University (Humanities and Social Sciences)*, 55(4), pp. 42-53.

Chen, Y.B., Wang, S. and Lu, S. (2022) 'Research on the impact of green innovation on carbon emissions and its mechanism driven by the new development concept —empirical evidence based on continuous DID', *Research on Economics and Management*, 43(9), pp. 3-16. Available at: https://doi.org/10.13502/j.cnki.issn1000-7636.2022.09.001

Du, Z.W., Zhang, H.O., Ye, Y.Y., Jin, L.X. and Wang, C.J. (2019) 'Spatiotemporal evolution and influences of urban population shrinkage in Guangdong since 2000', *Tropical Geography*, 39(1), pp. 20-28. Available at: https://doi.org/10.13284/j.cnki.rddl.003105

Fiss,P.C., 2011. " Building Beter Causal Theories: A Fuzy Set Approach to Typologies in Organization Research"， Academy of Management Joural，Vol.54，pp.393~420.

Gu, H.Y., Li, Q.T. and Shen, T.Y. (2020) 'Spatial difference and influencing factors of floating population's settlement intention in the three provinces of Northeast China', *Scientia Geographica Sinica*, 40(2), pp. 261-269. Available at: https://doi.org/10.13249/j.cnki.sgs.2020.02.011

Liu, F.B., Zhu, X.G., Chen, J., Sun, J. and Lin, X.Q. (2018) 'The research on the quantitative identification and cause analysis of urban shrinkage from different dimensions and scales: A case study of Northeast China during transformation period', *Modern Urban Research*, (7), pp. 37-46. Available at: https://doi.org/10.3969/j.issn.1009-6000.2018.07.007

Luo, F.Z. and Dai, X.F. (2021) 'Assessment of shrinking spatial distribution and status of Guanzhong plain urban agglomeration: measurement calculation based on county-level administrative unit data', *Scientific and Technological Management of Land and Resources*, 38(1), pp. 72-85. Available at: https://doi.org/10.3969/j.issn.1009-4210.2021.01.006

Lv, W. and Dan, S. (2009) 'The relationship between government size and public services: evidence from inter-provincial panel data of China', *Finance & Economics*, (3), pp. 106-115.

Ma, Z.P., Li, C.G. and Zhang, P.Y. (2021) 'Characteristics, mechanism and response of urban shrinkage in the three provinces of Northeast China', *Acta Geographica Sinica*, 76(4), pp. 767-780. Available at: https://doi.org/10.11821/dlxb202104001

Qi, Y.D., Liu, C.H. and Ding, S.L. (2020) 'Development of digital economy, optimization of employment structure and improvement of employment quality', *Economic Perspectives*, (11), pp. 17-35.

Ragin, C.C. (1987) *The comparative method: Moving beyond qualitative and quantitative strategies*. Berkeley: University of California Press.

Rihoux, L. and Ragin, C.C. (2017) *QCA Design Principles and Applications: A new approach beyond qualitative and quantitative research*. Du, Y.Z. and Li, Y.F., trans. Beijing: China Machine Press.

Wang, W., Liu, Y.F. and Peng, D.D. (2015) 'Study on upgrading effect of industrial structure of aging population', *China Industrial Economics*, (11), pp. 47-61.

Wiechman, T. (2007) 'Between Spectacular Projects and Pragmatic Deconstruction', *Conference on the Future of Shrinking Cities: Problems, Patterns, and Strategies of Urban Transformation in a Global Context*.

Wu, K., Long, Y. and Yang, Y. (2015) 'Urban Shrinkage in the Beijing-Tianjin-Hebei Region and Yangtze River Delta: Pattern, Trajectory and Factors', *Modern Urban Research*, (9), pp. 26-35. Available at: https://doi.org/10.3969/j.issn.1009-6000.2015.09.004

Yan, G.H., Chen, X. and Zhang, Y. (2021) 'Study on the distribution pattern and influencing factors of shrinking cities in Northeast China based on random forest model', *Scientia Geographica Sinica*, 41(5), pp. 880-889. Available at: https://doi.org/10.13249/j.cnki.sgs.2021.05.016

Zhang, J.B., Duan, L.P., Shi, X.N., Ma, Z.P. and Li, C.G. (2022) 'Differentiation characteristics, causes and co untermeasures of urban growth and contraction in Jilin Province', *Areal Research and Developme nt*, 41(1), pp. 53-59. Available at: https://doi.org/10.3969/j.issn.1003-2363.2022.01.009

Zhang, M.D. and Qu, J.X. (2019) 'Spatial pattern and structural characteristics of urban shrinkage in the middle reaches of the Yangtze River', *Research on Financial and Economic Issues*, (8), pp. 113-121. Available at: https://doi.org/10.19654/j.cnki.cjwtyj.2019.08.014

Zhang, X.D., Han, H.Y. and Jiang, Y.K. (2023) 'Dynamic characteristics and causes of spatial structure of urban population shrinking in China', *South China Population*, 38(1), pp. 59-68. Available at: https://doi.org/10.3969/j.issn.1004-1613.2023.01.006

Zhao, Z., Wang, J.H. and Feng, J. (2017) 'Spatial linkage and influence measurement of core cities in Beijing-Tianjin-Hebei city cluster', *Economic Geography*, 37(6), pp. 60-66,75. Available at: https://doi.org/10.15957/j.cnki.jjdl.2017.06.009

Zheng, J., Wang, T.T. and Chen, H. (2022) 'Identification and influencing factors of shrinking cities in the Yangtze River Economic Belt', *East China Economic Management*, 36(8), pp. 13-25. Available at: https://doi.org/10.19629/j.cnki.34-1014/f.211006003

Research Paper

Urban Green Space Planning Based on the Aniene River Heritage Corridor

Biodiversity Conservation and Sustainable Urban Design

Peiyi FAN, Sapienza University of Rome, Italy

Abstract

With the momentum of urbanization, present places face challenges such as ecosystem degradation, tight geographic tools, and declining environmental quality. By incorporating the cultural and natural heritage of the Aniene River, this research explores a complete industrial green space planning method to advertise biodiversity conservation and sustainable development of places. In an era of rapid industrial expansion, this integration highlights the value of using historical and ecological narratives to enhance urban landscapes.

This paper uses green design principles to produce sustainable and resilient industrial environments in response to the Aniene River Heritage Corridor's recommendations for industrial green space planning. The purpose of the paper is to show how corporate urban planning can promote synergies between urban development and environmental conservation.

By preserving crucial environments and developing ecological corridors, which are essential for maintaining industrial diversity, the study successfully maintained and enhanced wildlife.

Importantly important in nearby communities, widespread and keystone types received special attention. implemented functional green space plans in densely populated areas

industrial ecology is protected while accommodating pleasure needs in densely populated areas. This included designing areas that serve multiple features, such as entertainment, flood mitigation, and biodiversity delivery. In order to improve the state's ability to adapt to climate change, the city should emphasize the importance of managing water resources, green infrastructure, and energy-efficient architectural design. As essential elements of sustainable urban design, innovative solutions like rain gardens, permeable pavements, and natural roofs were highlighted. A useful model for optimizing industrial environments was developed using the Aniene River Heritage Corridor for industrial green space planning, which incorporated biodiversity conservation, green design, and population needs. As a major reference point for global cities, this organizing strategy enhanced both the ecological resilience of places and the people ' quality of life. The project demonstrates how intelligent use of green infrastructure and landscape design can transform urban spaces into attractive, good, and sustainable environments.

Keywords

Biodiversity Conservation, Sustainable Urban Design, Ecological Corridors，Green Infrastructure

1. Introduction

Cities are confronted with numerous environmental and social issues as global urbanization progresses. Urban expansion is required to provide growing groups and more economic activity. But, natural communities are frequently harmed by this expansion. Humanity's endurance is weakened by the loss of biodiversity and the loss of natural communities. Additionally, it lowers the standard of living in urban

places. It is crucial for urban planning to balance development needs with the protection and restoration of natural environments (Piracha & Chaudhary, 2022, Daz et al., 2006, Tzoulas et al., 2007). Problems like air pollution, urban heat islands, and flooding get worse. With its abundant historical past and distinctive natural environment, Rome must balance marketing sustainable urban development with protecting cultural heritage. The Aniene River Heritage Corridor's development as a unit for urban green spaces is the focus of this study. This type of planning may aid in the protection of diversity and enhance city residents ' quality of life.

2. Urban Green Space Planning in Rapid Urbanization

Urbanization has accelerated to a level never before seen in the 21st century. Normal ecosystems are frequently hampered by this rapid industrial growth. It leads to scattered environments, higher levels of pollutants, and the loss of normal areas that are essential for supporting wildlife and ecosystem services. For instance, urban green spaces are crucial for maintaining biodiversity and supporting species diversity (Goddard et al., 2010; Aronson et al., 2014; Beninde et al., 2015). These issues are particularly significant in Rome. Urbanization makes it harder to preserve Rome's historical and cultural heritage in addition to affecting healthy situations.

Rome is currently experiencing quick urbanization. The growth of residential areas and significant infrastructure upgrades contribute to this. This industrial expansion is fueled by population shifts away from the city centre to the suburbs, leading to more residential and commercial development. In order to meet the needs of its expanding community, the town is also upgrading its transport, energy, and communication techniques. Rome's hospitality sector, which contributes significantly to the country's economy, has grown even faster with system projects. This is especially evident in the traditional centre, where there is a lot of industrial development. These urbanization initiatives, but, present challenges, particularly for the preservation of Rome's wealthy historical and natural heritage. As seen with the Metro C range, construction projects frequently experience difficulties caused by historic discoveries. Also, fragmentation and uneven economic policies, which prevent them from addressing issues like waste and habitat loss, make efforts to expand natural spaces difficult. The city must strike a balance between modernization and the preservation of its distinctive historical and ecological resources (DeRobertis & Tira, 2016; Capotorti et al., 2013).

In reducing urbanization's adverse effects, urban green spaces are important. They provide important ecosystem services, like climate rules, temperature regulation, and rainwater control, which are essential for reducing places ' environmental impact. Green spaces also offer recreational and cultural activities for residents, helping to strengthen social bonds and improve public health (Ahern et al., 2014, Haase et al., 2014, Sandifer et al., 2015, Chiesura, 2004).

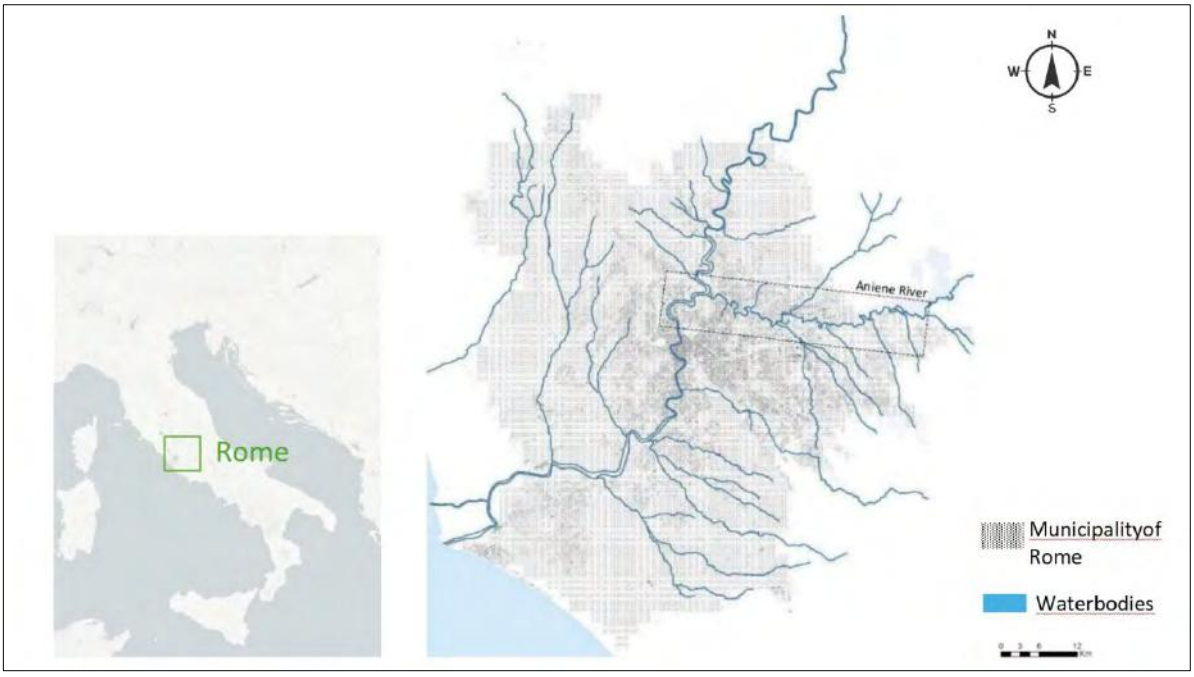


Fig.1 The Aniene River has a very important place in Rome

Source: Own design based on Urban Atlas (EU Copernicus Programme, 2012).

3. The Importance of the Aniene River Heritage Corridor

The more well-known Tiber River has long overshadowed the extra lake in Rome, the Aniene River. The Aniene's healthy ecosystems have experienced increased damage, serious waste, and a lack of effective habitat planning as urbanization has progressed. The Aniene River Heritage Corridor task demonstrates how urban green spaces can help address the challenges posed by swift urbanization. Cities can build systems that support diversity while enhancing the quality of life of people by incorporating natural spaces into the urban environment.

3.1. Historical Significance and Decline

The Aniene River Valley, a significant source of water for the metropolis, was a significant source of water in ancient Rome. The river supported crops, which was crucial to Rome's wealth, as well as providing having water. Some popular aqueducts, such as the Aqua Anio Novus and Aqua Anio Vetus, were constructed to take fluids from the Aniene River to Rome, revealing the engineering skill of the Roman Empire. These aqueducts now serve as historical landmarks, highlighting the significance of the valley in the city's growth and development.

Moreover, Roman nobility favored a retreat at the Aniene River Valley. In the area, numerous aristocrats constructed villas and enjoyed the tranquillity of the natural setting for leisure and recreation (DeRobertis & Tira, 2016).

However, the Aniene River Valley started to suffer carelessness as Rome evolved. Rapid urbanization caused environmental degradation, like water pollution and wildlife separation. The river has been severely impacted by the pressures of urban growth despite after being a significant agricultural and natural area. In an effort to preserve the area's historical and ecological significance, the authorities and

environmental agencies have made efforts to restore it and promote sustainable development in recent years, development that seeks to stabilize the valley's historical value with its natural importance.

3.2. Protecting core ecological habitats

The Aniene River is a significant natural hall that supports a variety of types and ecosystems. Rome's wildlife is greatly increased by the Aniene River Valley's approximately 500 shrub species and more than 100 bird species. A wide range of plants and animals can be found in the Aniene River Valley Nature Reserve. Papyrus, retina, and blackberry are typical vegetation in this stockpile, along with many other water plants that grow in wetland habitats. Brown trout, crabs, frogs, and some invasive species like the American crayfish are also found in the Aniene River (Wikipedia, 2024).

3.3. Social and Cultural Significance of the Aniene River Heritage Corridor

Critical social and cultural significance surrounds the Aniene River Heritage Corridor. Designers can incorporate cultural heritage with natural recovery by protecting and displaying old aqueducts, historic sites, and cultural landmarks along the creek. This strategy helps both Rome's residents and visitors have a richer experience while maintaining its historic significance. A living example of Rome's history can be found in the river hall. Additionally, it opens up fresh opportunities for educational and cultural pursuits.

Fig.2 Population Density（https://www.worldpop.org/methods/populations/）

4. Content formattingPlanning

4.1. Project Focus

The Aniene River Heritage Corridor style aims to bring together industrial planning's historical and natural elements. This strategy promotes a town that is more tenacious, more sustainable, and sustainable. Critical cultural landmarks like old Roman aqueducts and historic ruins, which depict Rome's traditional development, are preserved while also being preserved. The design incorporates cultural heritage into industrial green space planning, providing both economic and historic knowledge and enriching experiences for both residents and visitors.

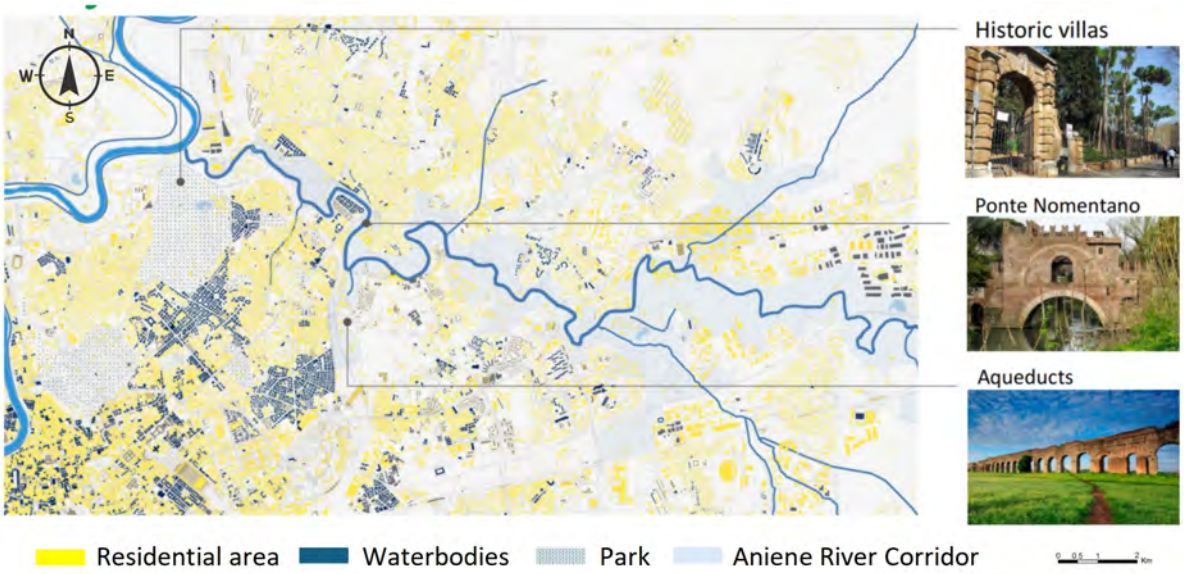


Fig.3 Aniene River Heritage Corridor historic site

Source: Open Street Map database (http://download.geofabrik.de/, accessed on 23 March 2024).

4.2. Identifying key ecological areas and corridors

Land use drawings from OpenMap were used in this investigation to transform land use data into linear pictures using ArcGIS software. A value of 1 was given to areas impacted by human actions, such as farmland, building land, and non-construction area. A benefit of 2 was given to natural resources like forests, grasslands, and water systems. In a linear TIF format, this categorisation created a foreground and background isolation. The review then used GuidosToolbox software to perform MSPA analysis.

Understanding the spatial arrangement of green spaces and their ecological roles can be learned using Morphological Spatial Pattern Analysis (MsPA). In industrial communities, MsPA has played a significant role in identifying critical environments and ecological corridors. These" core areas" and" corridors" are crucial because they promote biodiversity and promote ecosystem health (Prevedello & Vieira, 2010; Hansen & Pauleit, 2014; Opdam & et al., 2006). This approach improves the design of green infrastructure in response to needs (Williams & Winfree, 2013, Forman, 2014).

The Aniene River Heritage Corridor is divided into three main components using the Morphological Spatial Pattern Analysis (MsPA) technique. The population density and historic sites of the area are taken into account in this sector. The MsPA actions are explained in simple terms in this example:

Core Competencies

The core areas are identified as the primary biological areas on both flanks of the Aniene River Heritage Corridor. These locations are crucial for conserving wildlife and sustaining local varieties. Traditional sites, like old Roman aqueducts and cultural landmarks, are also preserved in these core areas. This enables the fusion of biological significance and historic significance.

Edges and Corridors

Hallways and sides are marked to maintain solid natural connections between core areas. These hallways are essential for promoting species activity, particularly in urban environments where movement is frequently constrained. The sides reduce the impact of local industrial actions by serving as buffer areas for core areas and hallways. To prevent conflicts between human actions and biodiversity, population density information is also used to prepare these corridors.

Landscape Fragmentation

Finding and evaluating isolated areas in the Aniene River Heritage Corridor, like as trees and little green islands, is a top priority for landscape separation analysis. This analysis helps to understand how dispersed the place is, as well as develop plans for reconnecting these dispersed regions. Additionally, it makes for a more constant and related wildlife. A particular emphasis is placed on reducing the effects of industrial equipment fragmentation. To join these remote areas, alternative roads or links are suggested.
In order to maintain wildlife, increase wildlife value, and increase accessibility in the Aniene River Heritage Corridor, planners can combine natural, historical, and industrial factors using this approach.

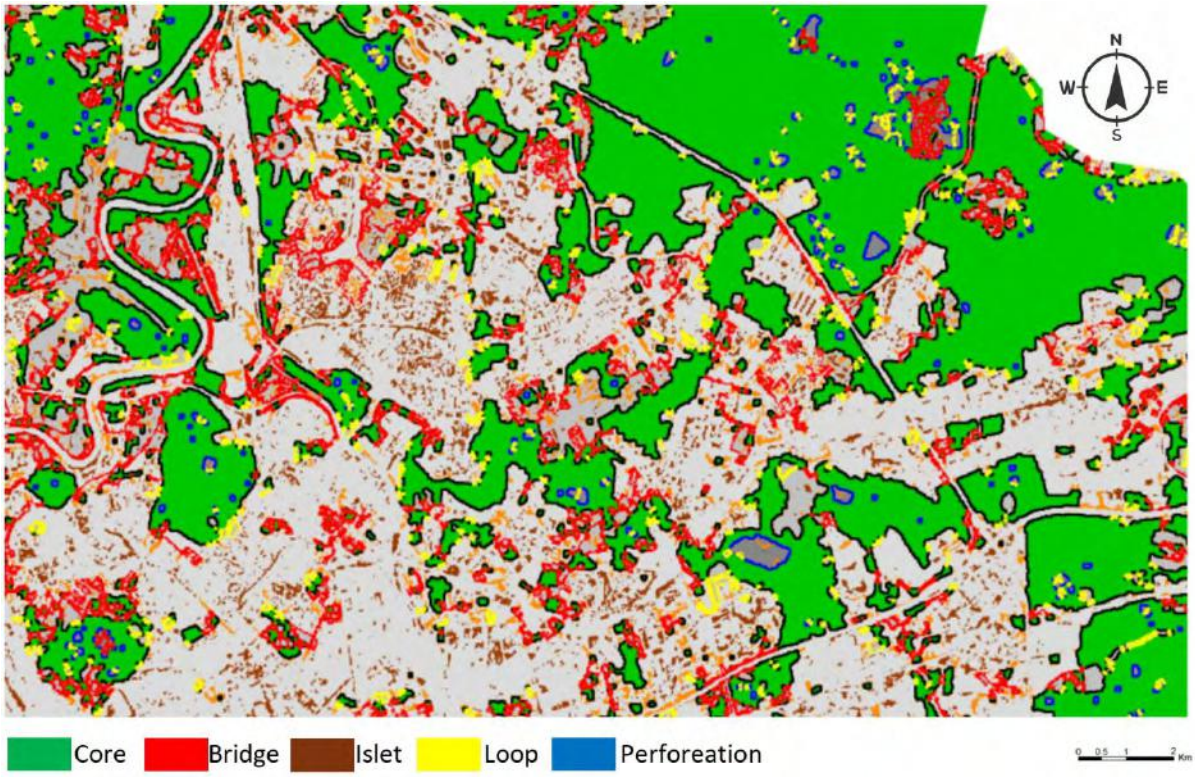


Fig.4 The MSPA landscape classification

Source: Open Street Map database (http://download.geofabrik.de/, accessed on 23 March 2024).

4.3. Strategies for planning and protecting biodiversity

The classification of ecological corridors in the Aniene River Heritage Corridor is following the tiered natural hall system described above, adjusted to fit the town's unique natural and cultural features. We can maintain a healthy balance between natural security, industrial power, and residents ' needs by creating various types and functions of ecological corridors. Below is an analysis of the categorization of ecological

corridors in the Aniene River Heritage Corridor:

Fig.5 The extraction map of network center and Ecological corridor construction

Primary Ecological Corridors: Important channels connect big nature reserves to urban green spaces, known as primary ecological corridors. These interactions aid in the protection of wildlife and the movements of varieties. These corridors enable animals and plants to shift between secluded habitats in order to maintain natural contacts. These hallways connect urban parks and green spaces, stretching from the city's borders to the city's borders. This facilitates the integration of more extensive natural networks between metropolitan areas.

These key corridors improve the conservation of town ecosystems as well as promoting wildlife movement and genetic variety. They offer people important ecosystem services like regulating temperatures, cleansing the air and water, and providing them with recreation areas. These corridors aid in maintaining healthy processes, reducing biodiversity fragmentation, and protecting biodiversity within the city by connecting outer nature reserves with inner-city natural spaces. In order to promote a more harmonious interaction between character and industrial areas, they serve as protective barriers to the stresses of urban development.

Fig.6 Primary Ecological Corridor

Secondary Ecological Corridors: Urban gardens and river systems are connected by secondary ecological corridors, creating entertainment areas that balance human and natural needs. These hallways serve as important links between urban areas and natural settings, which promote biodiversity and enhance residents ' quality of life. These passageways give people a chance to enjoy and enjoy the natural environment without having to travel a long way from home because they give them access to nature within the area.

These corridors serve both natural purposes as well as areas to unwind and unwind. They promote lasting urban growth while allowing people to take advantage of nature's advantages.

Fig.7 Secondary Ecological Corridor

Tertiary Ecological Corridors: Greenways along smaller creeks and roads are used by Tertiary Ecological Corridors to reduce urban natural separation. These passageways facilitate simple access to clean locations for entertainment and exercise and strengthen connections between little ecosystems. These corridors offer crucial outdoor spaces for walking, running, biking, and other exercise activities in densely populated areas where large parks are frequently absent.

These corridors promote the city's natural health as well as promote the real well-being of the residents by blending nature and urban facilities. People have a better chance of connecting with nature and staying engaged yet in highly developed regions.

Fig.8 Tertiary Ecological Corridor

5. Future Development

The Aniene River Corridor's potential growth will concentrate on strengthening natural contacts throughout Rome and expanding its green storage system. In order to increase biodiversity, main efforts will be made to restore damaged habitats, improve water quality, and introduce native plant species (Tzoulas et al., 2007, Sandifer et al., 2015, Hansen & Pauleit, 2014, Alberti, 2005). Modern green infrastructure techniques, such as urban wetlands, rain gardens, and permeable pavements, will also be applied to help minimize flooding and power urban heat island results (MEA, 2005, Haines- Young & Potschin, 2010, Benedict & McMahon, 2006).

For the program's success in the future, community involvement is also crucial. According to research, including local residents in the planning and maintenance of green spaces can promote environmental responsibility and enhance city quality (Haase et al., 2014; Ahern et al., 2014; Dearborn & Kark & Kark, 2010, Ryan, 2005). The Aniene River Corridor project (Colding & Barthel, 2013) aims to foster community involvement by fostering a strong commitment to the long-term preservation and enhancement of urban green spaces (Colding & Barthel, 2013).

6. Conclusion

The Aniene River Heritage Corridor task shows how natural protection, cultural heritage, and green urban planning is all exist together in places. By using Morphological Spatial Pattern Analysis (MsPA), the project found key ecological areas, ecological corridors, and how urban growth affects biodiversity. This data assisted managers in developing a robust, multipurpose clean space system that benefits both Rome's citizens and its natural environment.

The initiative also demonstrates how cultural heritage can be preserved and included in urban development without compromising sustainability, such as traditional villas, aqueducts, and historical sites. The success of these initiatives depends largely on community involvement. The project promotes environmental responsibility and fosters interpersonal relationships by including local residents in the planning, construction, and maintenance of these places.

7. Acknowledgements

This project funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 - Call for tender No. 3138 of 16 December 2021, rectified by Decree n.3175 of 18 December 2021 of Italian Ministry of University and Research funded by the European Union – NextGenerationEU;Award Number: Project code CN_00000033, Concession Decree No. 1034 of 17 June 2022 adopted by the Italian Ministry of University and Research, CUP B83C22002950007, Project title “National Biodiversity Future Center - NBFC” .

8. References

Piracha, A., & Chaudhary, M. T. (2022). Urban Air Pollution, Urban Heat Island and Human Health: A Review of the Literature. *Sustainability,* 14(15), P.9234. https://doi.org/10.3390/su14159234

Díaz, S., Fargione, J., Chapin III, F. S., & Tilman, D. (2006). Biodiversity loss threatens human well-being. *PLoS Biology*, 4(8), p.e277. https://doi.org/10.1371/journal.pbio.0040277

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemelä, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, 81(3), pp.167-178. https://doi.org/10.1016/j.landurbplan.2007.02.001

Goddard, M. A., Dougill, A. J., & Benton, T. G. (2010). Scaling up from gardens: biodiversity conservation in urban environments. *Trends in Ecology & Evolution*, 25(2), pp.90-98. https://doi.org/10.1016/j.tree.2009.07.016

Aronson, M. F. J., La Sorte, F. A., Nilon, C. H., Katti, M., Goddard, M. A., Lepczyk, C. A., ... & Dobbs, C. (2014). A global analysis of the impacts of urbanization on bird and plant diversity reveals key

anthropogenic drivers. *Proceedings of the Royal Society B,* 281(1780), p.20133330. https://doi.org/10.1098/rspb.2013.3330

Beninde, J., Veith, M., & Hochkirch, A. (2015). Biodiversity in cities needs space: A meta-analysis of factors determining intra-urban biodiversity variation. *Ecology Letters,* 18(6), pp.581-592. https://doi.org/10.1111/ele.12427

Capotorti, G., Anzalone, B., Celesti-Grapow, L., & Pignatti, S. (2013). Greening Rome for Human and Ecosystem Health. *Oppla.* Available at: https://oppla.eu

DeRobertis, M. & Tira, M. (2016). An Assessment of the Sustainability of Roman Urban Design. *Engineering Rome.* Available at: https://engineeringrome.org

Ahern, J., Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning,* 125, pp.254-259.

Haase, D., Larondelle, N., Kabisch, N., & Gaston, K.J. (2014). Ecosystem services in urban landscapes: Practical applications and governance implications. *Ecological Economics,* 86, pp.71-83.

Sandifer, P.A., Sutton-Grier, A.E., & Ward, B.P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health. *Ecosystem Services,* 12, pp.1-15.

Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning,* 68(1), pp.129-138.

Wikipedia. (2024). *Aniene River Valley Nature Reserve.* Available at: https://it.wikipedia.org/wiki/Riserva_naturale_Valle_dell%27Aniene [Accessed 19 Oct. 2024].

Prevedello, J.A. & Vieira, M.V., 2010. Does the type of matrix matter? A quantitative review of the evidence. *Biodiversity and Conservation,* 19(5), pp.1205-1223. https://doi.org/10.1007/s10531-009-9750-z

Hansen, R. & Pauleit, S., 2014. From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. *Ambio,* 43(4), pp.516-529. https://doi.org/10.1007/s13280-014-0510-2

Williams, N.M. & Winfree, R., 2013. Local habitat characteristics but not landscape urbanization drive pollinator visitation and native plant pollination in forest remnants. *Biological Conservation,* 160, pp.10-18. https://doi.org/10.1016/j.biocon.2012.12.035

Forman, R.T.T., 2014. *Urban Ecology: Science of Cities.* Cambridge University Press.

Alberti, M., 2005. The effects of urban patterns on ecosystem function. *International Regional Science Review,* 28(2), pp.168-192. https://doi.org/10.1177/0160017605275160

Millennium Ecosystem Assessment (MEA), 2005. *Ecosystems and Human Well-being: Synthesis.* Island Press, Washington, DC. https://www.millenniumassessment.org/en/Synthesis.html

Haines-Young, R. & Potschin, M., 2010. The links between biodiversity, ecosystem services, and human well-being. In *Ecosystem Ecology: A New Synthesis* (pp. 110-139). Cambridge University Press. https://doi.org/10.1017/CBO9780511750458.007

Benedict, M.A. & McMahon, E.T., 2006. *Green Infrastructure: Linking Landscapes and Communities.* Island Press.

Dearborn, D.C. & Kark, S., 2010. Motivations for conserving urban biodiversity. *Conservation Biology,* 24(2), pp.432-440. https://doi.org/10.1111/j.1523-1739.2009.01328.x

Ryan, R.L., 2005. Exploring the effects of environmental experience on attachment to urban natural areas. *Environment and Behavior,* 37(1), pp.3-42. https://doi.org/10.1177/0013916504264147

Colding, J. & Barthel, S., 2013. The potential of ‘Urban Green Commons’ in the resilience building of cities. *Ecological Economics,* 86, pp.156-166. https://doi.org/10.1016/j.ecolecon.2012.10.016

Case Study Report

Jakarta 2045 – Jakarta After IKN: Towards Restorative Urbanism in Jakarta Urban Future

Nur M. Gito WIBOWO, PDW (www,pdw.co.id), Indonesia

Abstract

Indonesia plans to move its capital to Nusantara, East Kalimantan, by 2045, and this has significant implications for Jakarta's future development. Jakarta Metropolitan, as a megacity, faces significant challenges of traffic congestion, sprawl mobility, environmental degradation, and under density in the city center. This pattern is indicative of global urban phenomena, with populations in metropolitan areas estimated to increase to 68% by 2050 (UN, 2018), while sharply decreasing at the center. This profound change allows Jakarta to relate to instead and IKN Nusantara's new city life through restorative urbanism. With the impending dispossession of administrative functions, many of Jakarta's central government buildings will be vacated and will need to be reconverted and retrofitted into useful programs. This shifts future challenges away from Jakarta but also makes for more spaces in the city center. Currently, many workers spend long periods commuting from the suburbs to centralized offices. Transforming these government buildings into mixed-use developments that combine residential, commercial, and cultural facilities can decentralize urban activity and lower the carbon footprints to create more sustainable environments for living. These efforts could enhance accessibility, promote different urban functions, and invigorate neighborhoods.

Jakarta Transformation: The Importance of Transit-Oriented Development (TOD) Redeveloping the areas around transport hubs, TOD can help mitigate urban sprawl and create connected dense neighborhoods with housing, public spaces, and amenities. TOD promotes less dependence on private vehicles, improved mobility, and better air quality. More than its size, TOD can facilitate community interactions, generate economic opportunities, and foster a sustainable urban lifestyle. Next, the strategic retrofitting of underutilized zones into TOD-focused districts will bolster Jakarta's commitment toward reducing carbon emissions and enhancing resilience. The Monas area is one of the major areas in Jakarta for densification and revitalization. This district, as a symbolic and historical center, is performed as the city center and is characterized by high land use and low density. In this sense, the Monas District could develop as a new city center. Through mixed-use development, increased residential density, access to green spaces, and cultural and commercial facilities, the district can remain a sustainable urban metabolic system while simultaneously upholding its historical and cultural value.

Retrofitting existing buildings is a crucial project in Jakarta's sustainability-oriented future development. Instead of demolishing to build from scratch, redeveloping buildings helps to retain heritage, conserve resource use, and reduce emissions associated with construction. Extensively embedded in embodied energy and community history, preserving historical buildings is environmentally and socially valuable. Integrating existing green building standards and resource-efficient retrofitting practices would increase Jakarta's, mostly in the central area. This projects will

recreate development resiliency without erasing the city's identity. While ensuring that the city continues to evolve sustainably, this approach will create a balance between modernization and preservation.

Keywords

Jakarta, Retrofit, Revitalization, Urban Future, Transit Oriented Development

1. Background

In the 21st century, rapid urbanization has led to tectonic changes in the city landscape, the way we manage cities, and our experience of cities themselves. In Indonesia, Jakarta has traditionally served as the nation's administrative and political heartbeat, a megacity with dense populations, extensive infrastructure demands, and persistent environmental pressure. But by 2045, Jakarta will no longer serve in this capacity: the nation's capital will have officially moved to Nusantara, East Kalimantan. This historic move, which will also redistribute development throughout the Indonesian archipelago, poses challenges but also unprecedented opportunities for Jakarta. The capital's relocation has the potential to reshape Jakarta's urban identity and serve as a model for cities transitioning from administrative to multifunctional centers. Numerous studies highlight the interconnectedness of urbanization with change (Elmqvist et al., 2011 | UN 2018 | Garside, Goh, Trinh, Ng, & Kalinowski, 2019), and while cities like Jakarta are particularly vulnerable, they also hold a unique advantage to adjust and lead transformative and restorative urbanism responses as economic, social, and environmental dynamics evolve. Jakarta's transition from being Indonesia's capital represents a turning point in the city's development. Historically the center of the country's political and economic activity, Jakarta's overconcentration on development at the center has long resulted in rampant urban issues, including congestion, environmental decline, and uncontrolled sprawl. The prospect of a government functions and services transfer to Nusantara challenges Jakarta to redefine its role and resuscitates the imperatives of sustainable and/or ecologically-based urban redevelopment, revitalization, and retrofitting. By this article, we analyze Jakarta's post-capital transition in relation to restorative urbanism and suggest that Jakarta's ideological move out from a mere administrative center could act as a catalyst for Jakarta's urban and life quality to be better. Focusing on revitalization and urban redevelopment, this paper considers potential strategies for urban renewal for Jakarta, with emphasis on retrofitting solutions to address the pressures on infrastructure and services, and necessitate the formation of green and open public spaces prioritizing long-term community-driven design and sustainability-oriented solutions. The study establishes an overall concept for Jakarta to metamorphose as a megacity into a diverse and resilient city based on case studies, global urban theories, and Jakarta-appropriate analyses.

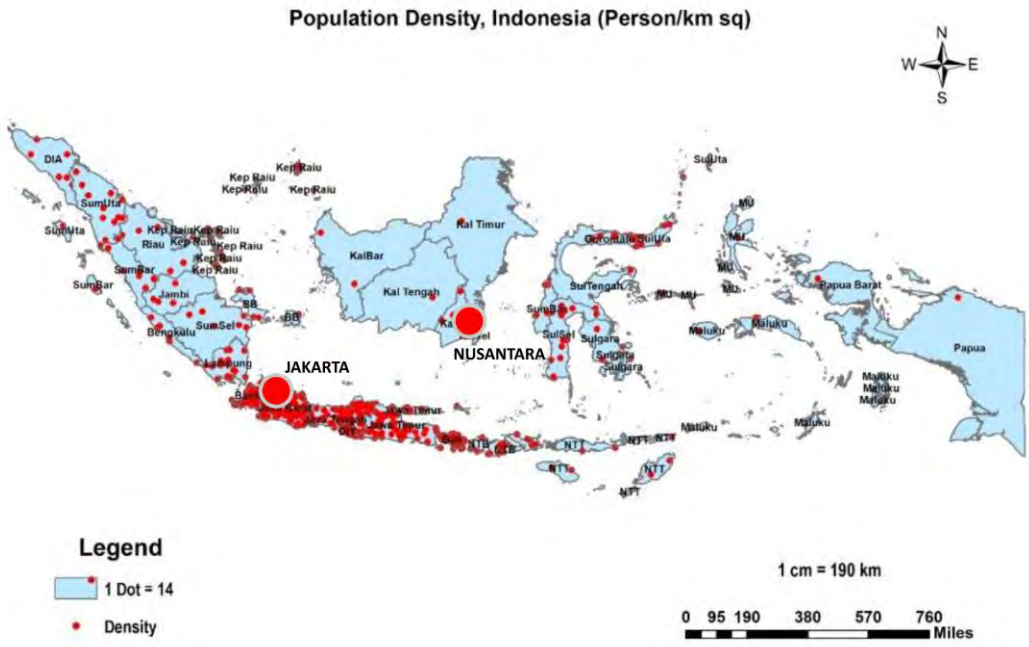


Figure 1. Indonesian cities density. Agus Pitoyo (2017) Urbanization and Economic Development in Indonesia, Demographic Perspectives Analysis.

2. Why Focus in Jakarta

2.1. Challenge

One of the immediate challenges Jakarta faces is the potential for widespread vacancies, which could lead to economic instability in certain districts and disrupt local businesses and services that depend on government workers and their daily activities. In particular, areas densely populated with government buildings may experience a decline in foot traffic, reducing demand for nearby retail, food services, and housing. Without careful planning, these empty spaces risk becoming neglected, leading to blight and contributing to a sense of urban decay, which could further strain the city's already stressed infrastructure. Retrofitting and adapting government buildings to suit new uses will demand substantial investments in upgrading facilities to meet the needs of different sectors, such as residential, commercial, and cultural spaces. The transformation process itself could be challenging, as many government buildings may require extensive renovations to address design and structural limitations, particularly if these buildings were designed with limited flexibility in mind.

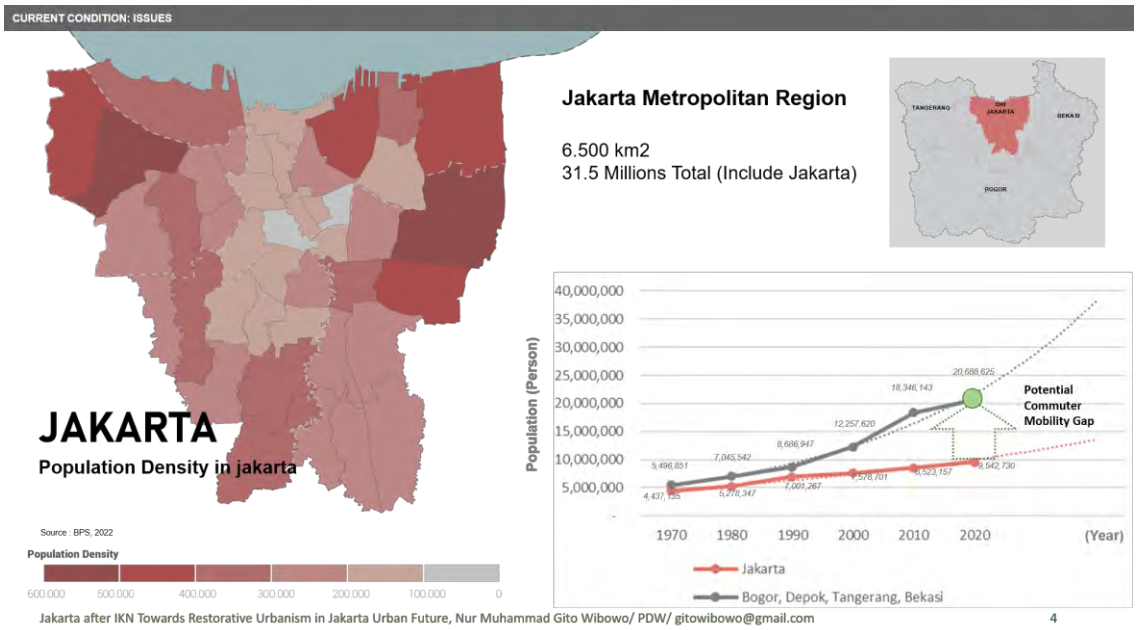


Figure 2. Jakarta Density. Source: PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

2.2. Opportunities

However, the empty government buildings also offer Jakarta a chance to redevelop its urban core and tackle some of the city's most pressing problems the congestion crisis, environmental impact, and lacking public spaces. Changing these buildings into mixed-use developments supplying residential, commercial, and cultural amenities can bring many benefits in line with Jakarta's own aims for urban development.

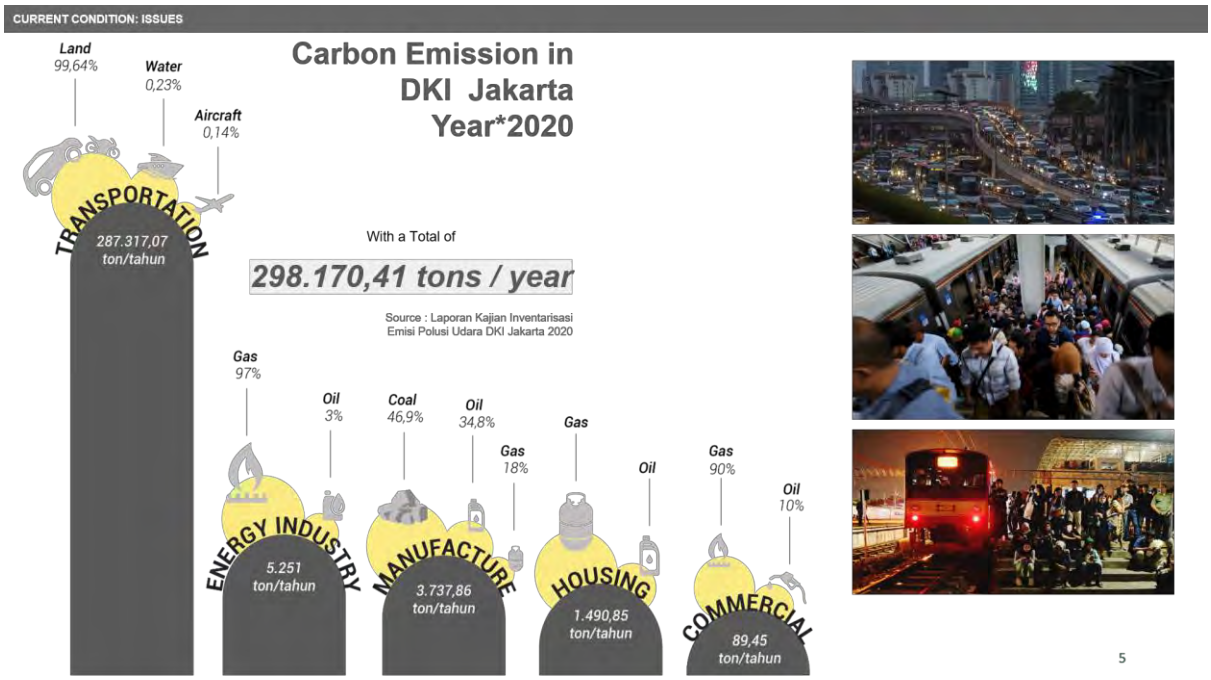


Figure 3. Jakarta Carbon Emission. Source: Laporan Kajian Inventarisasi Emisi Polusi Udara DKI Jakarta 2020

- Reducing Commuting and Carbon Footprint: Repurposing these spaces into residential areas close to central hubs can drastically reduce the need for long-distance commuting from distant suburbs, a significant factor in the city's carbon emissions. By encouraging more people to live

closer to their workplaces and amenities, the city can reduce vehicular congestion and pollution, contributing to improved air quality and lower greenhouse gas emissions.

- Creating Sustainable, Dense Neighborhoods: Mixed-use developments in former government zones can help create vibrant, walkable neighborhoods that foster a sense of community and provide access to essential services, retail, and entertainment within close proximity. Increasing urban density in these areas will support more efficient infrastructure use, as dense developments tend to require fewer resources per capita compared to sprawling suburbs.
- Revitalizing the Urban Core with Cultural Spaces: The repurposing of former government spaces into cultural hubs, museums, art galleries, and event spaces can enrich the city's cultural landscape. This strategy would not only provide Jakarta's residents with more recreational and cultural venues but also attract tourism, supporting the local economy. Additionally, cultural spaces can enhance social inclusivity, providing gathering points that celebrate the city's identity and heritage.
- Strengthening Urban Resilience: Adapting and diversifying the function of these spaces can also contribute to Jakarta's resilience by decentralizing urban amenities and services. Mixed-use neighborhoods are generally more adaptable to changes in population density, economic shifts, and social trends, making them more robust in the face of future uncertainties.
- Creating Green and Public Spaces: The transformation of vacant government buildings offers an opportunity to integrate more green spaces and parks within Jakarta's urban core. Introducing green roofs, community gardens, and public squares in repurposed areas can improve urban biodiversity, reduce urban heat islands, and create recreational spaces that enhance mental well-being and social interaction.

In conclusion, the shift in Jakarta's capital status offers a unique platform for urban experimentation. If managed thoughtfully, the challenges posed by vacant government buildings can be transformed into opportunities that drive Jakarta toward a future of resilience, sustainability, and improved quality of life. Through a combination of mixed-use developments, increased urban density, expanded public spaces, and enriched cultural amenities, Jakarta can leverage this transition to redefine itself as a city that prioritizes livability, inclusivity, and environmental sustainability.

3. Site Selection

The National Monument district, despite its central location and historical significance, currently suffers from a lack of density, with limited residential and commercial activities that could otherwise energize the area and contribute to a dynamic urban core. As a primarily administrative zone, it has traditionally been designed for low-density, single-use purposes, resulting in large, often underutilized spaces that lack the continuous activity seen in more densely populated urban neighborhoods.

This has created a need for a strategic densification plan that not only enhances land use efficiency but also brings vibrancy through a diverse range of activities and residential options. Additionally, the current underutilization of land in the Monas area highlights opportunities for a more efficient and productive urban layout. Many of the government buildings occupy large plots of land yet remain underoccupied or inactive. Repurposing these spaces for mixed-use purposes, including residential, commercial, and public amenities, would enhance land use efficiency, allowing the district to accommodate a greater diversity of functions and attract a wider range of visitors.

The planned strategy for the National Monument district emphasizes enhancing quality of life through increased residential density and an abundance of green spaces, with a focus on sustainable, community-

centered development. By increasing residential options and introducing amenities such as parks, cultural venues, and retail spaces, the district can become a vibrant, self-sustaining community within the city center. This approach to densification not only serves Jakarta's immediate urban needs but also lays the groundwork for a more resilient and adaptable urban core that embodies the principles of restorative urbanism.

3.1. Urban Density

In the heart of the city, the Monument National District still suffers from low density; it lacks both the residential and commercial activity necessary to stimulate it into being a dynamic urban core. Being a predominantly administrative area, its traditional design has been aimed at single-purpose low-density uses, resulting in large spaces that are perhaps somewhat empty next to the teeming life seen in densely populated urban neighborhoods. Thus, a strategic intensification plan is needed for Monas; one which not only improves land use efficiency but also brings life through a variety of activities and housing options. Moreover, the underutilization of land in the Monas area points to opportunities for a more efficient, productive urban form. Many government structures occupy large sites, yet they are half-occupied, deserted areas. By converting these into multi-use spaces that incorporate residential, commercial, and public areas, a denser pattern will emerge and visitors of all kinds may be attracted. In this spirit of strategic densification for the National Monument District: let the city folk live more densely, with additional green areas as a bonus! This plan emphasizes sustainable development that enriches human life through public spaces and community-based social practice, as well as pursuing architectural excellence. By making housing options more widely available and putting in some public facilities like parks, cultural centers, or small businesses, the district would embody the spirit of that self-sufficient community which can be found now right inside city centers. This approach to densification does more than just meet Jakarta's immediate urban needs; it is already laying the basis for a stronger and more supple urban core—one based on restorative urbanism instead of destruction and waste.

But several of these districts, with a high percentage of their populations dependent on government work, may see a decline in foot traffic and a subsequent drop-off in the demand for retail, food options, and housing. The buildings have to be transformed arduously if this situation is not to become rotted, disheveled, and spatially rife with feelings of urban decay—which can only further squeeze the already overburdened infrastructure of our city. Substantial facilities modifications, preparing them to serve different demands for dwelling, commerce, and culture, will inevitably require huge shifts in mentality. Given this, merely changing a government building over—the architectural limitations, structural defects, and format of its evolution just can't help but create an interior design headache!

Changing Monas into an integrally always-on place for living, working, and playing requires adding residential areas to the mix. Putting homes into the area will bring a permanent population and support local enterprises, dramatically increasing foot traffic and generally providing more opportunities for activity all day round. At the same time, making Monas denser in housing means that large numbers of people living nearby need not commute any further at all to work, significantly cutting our city's overall reliance on long-distance commuting and easing both traffic congestion and pollution. It can be done by creatively refitting and reworking the district's vacant, underused buildings to help meet a number of residential, commercial, and cultural needs. Constructing high-density residential communities with shops, restaurants, and recreational facilities all in the same vicinity will breed a more self-supporting neighborhood, in that it not only lets people live there instead of commuting elsewhere, but also makes for a much more lively locality. Not only will this approach raise the population density in the area, but it also greatly complements the variety of roles that the district plays, creating a vibrant, multiuse urban core.

3.2. Transit Oriented Development - The Jakarta Hub

Turning Monas National Monument District into a Transit-Oriented Development (TOD) Hub makes sense, with its accessibility and covered location. The area will provide a densely populated, vibrant urban core. The area is hemmed in on all sides by a multitude of transit systems such as two MRT lines, four Bus Rapid Transit (BRT) corridors, and two commuter rail lines. Monas' high level of connectivity places it as one of Jakarta's major transit nodes, capable of accommodating mixed-use development at greater densities, helping the urban environment to thrive and cut down on car reliance as well.

Monas district as a TOD hub can place living, working, and cultural life together inside precious near transit points. For those who want to follow this type of lifestyle, the MRT, BRT, and commuter lines provide convenience and connectivity. Over time, the TOD-oriented development will promote mobility on foot or two wheels, converting the entire precinct into an environment that interconnects well for people and minimizes emissions into downtown settings.

The TOD structure for Monas will also pave the way for smooth mobility in Jakarta itself, with all links to the district's location from other parts of the city, including business centers, amenities, and public services at large. By massing residential developments around transportation hubs with easy connections, this strategy will result in a thoroughly livable, self-contained neighborhood where people can go to and fro between their homes, places of work, or entertainment sans having to rely on automobiles.

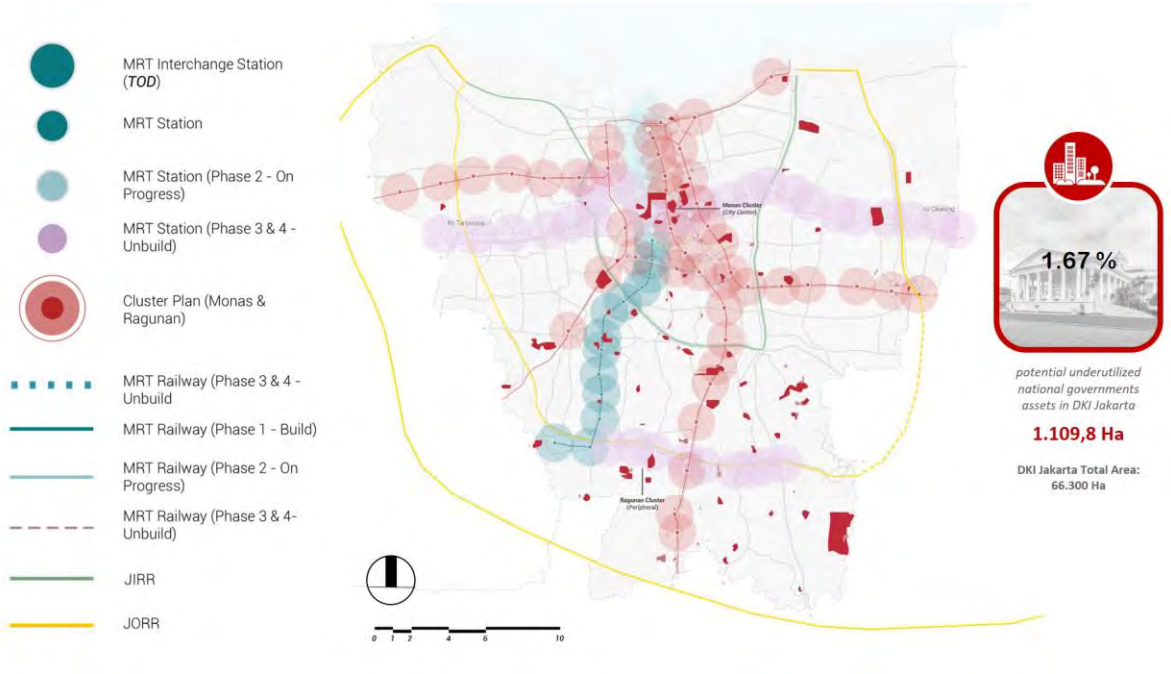


Figure 4. Jakarta Transport Hub and TOD. Source: PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

Additionally, developing Monas as a TOD hub is consistent with Jakarta's broader objectives for urban resilience and sustainable growth. Before we add new buildings, raising density in such a transit-rich area can ensure that the large sums of public transport money spent bear full reward and bring about Tokyo's whole urban shape to become more efficient. The Monas TOD will boost the city's economic and material resources, reducing congestion while offering quality amenities in a well-linked and green urban core accessible to all. This is more than just a growth project in line with Jakarta's future development; it will

transform Monas into a model for future Tokyo, showing how transit-oriented densification can bring new life to old spaces and bring forth dynamic, resilient communities.

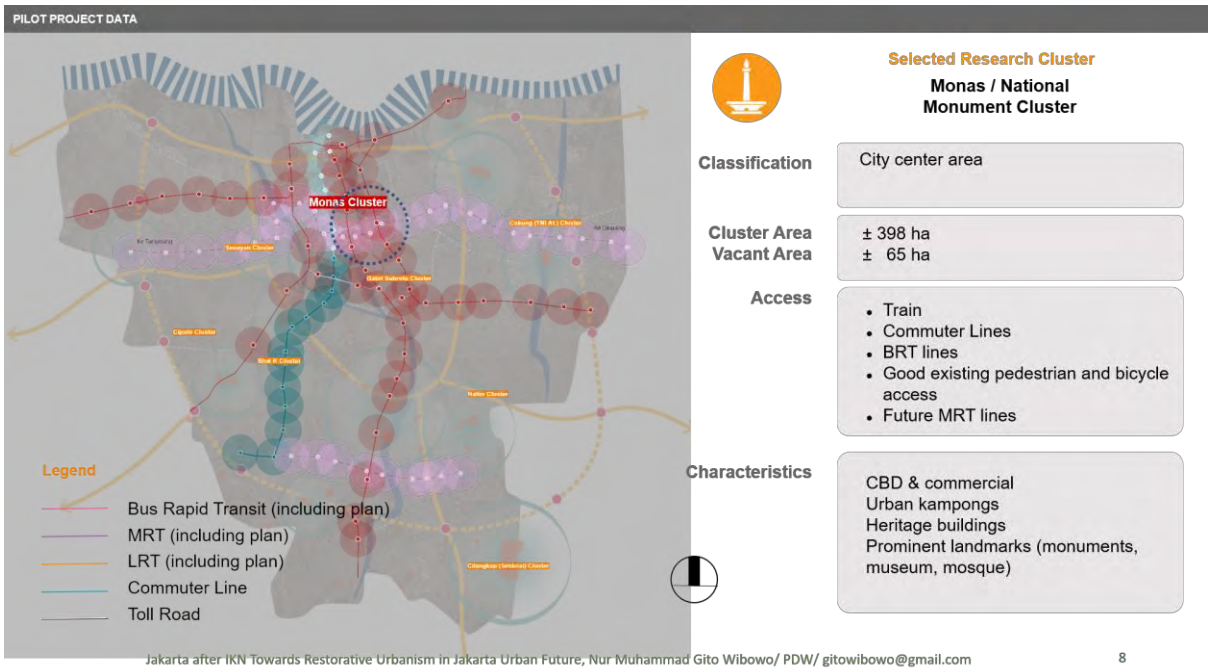


Figure 5. Jakarta Transport Hub and TOD. Source PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

4. Reshaping our centrum - National Monument District

The Monas district is crucial to Jakarta from an ecological and historical overview and is secure for the city. This historical site, still of deep cultural significance, has the heritage to be a futuristic urban core. Few people would argue its credentials for extensive transformation were it taken into account. As the confidential center of Jakarta is moved to Nusantara, Monas can become a pedestrian-priority sector. With more living spaces and public transportation in place as nodal points along the route from one big site to another, it should be possible to shape Monas into a model of sustainable urban living.

4.1. Transforming Monas into Pedestrian Priority Area

Transforming the Monas district into a zone prioritizing pedestrians means redesigning its layout for pedestrians over automobiles. This can be done by creating convenient and safe routes on foot, limiting the number of lanes in favor of local residents. Interconnected sets of pedestrian routes finally lead to rivers, cutting through towns or cities, with their lush green surroundings and attractive scenery. Streets can be redone with pedestrian greenery splitting wide paths, rows of trees along the street, seating spaces shaded by trees with overhead air screens, parks comprising gardens rather than mere trees, and so on. Another way to foster the pedestrian experience is to further restrict the areas that automobiles may enter in Monas. Already such pedestrianization projects are turning this place into a truly flourishing one for commuters and visitors alike. Bike lanes and renting stations would both promote multi-modal travel, in line with the low emission district that Monas pursues to facilitate active mobility, raise its environmental sustainability, and ultimately achieve those goals.

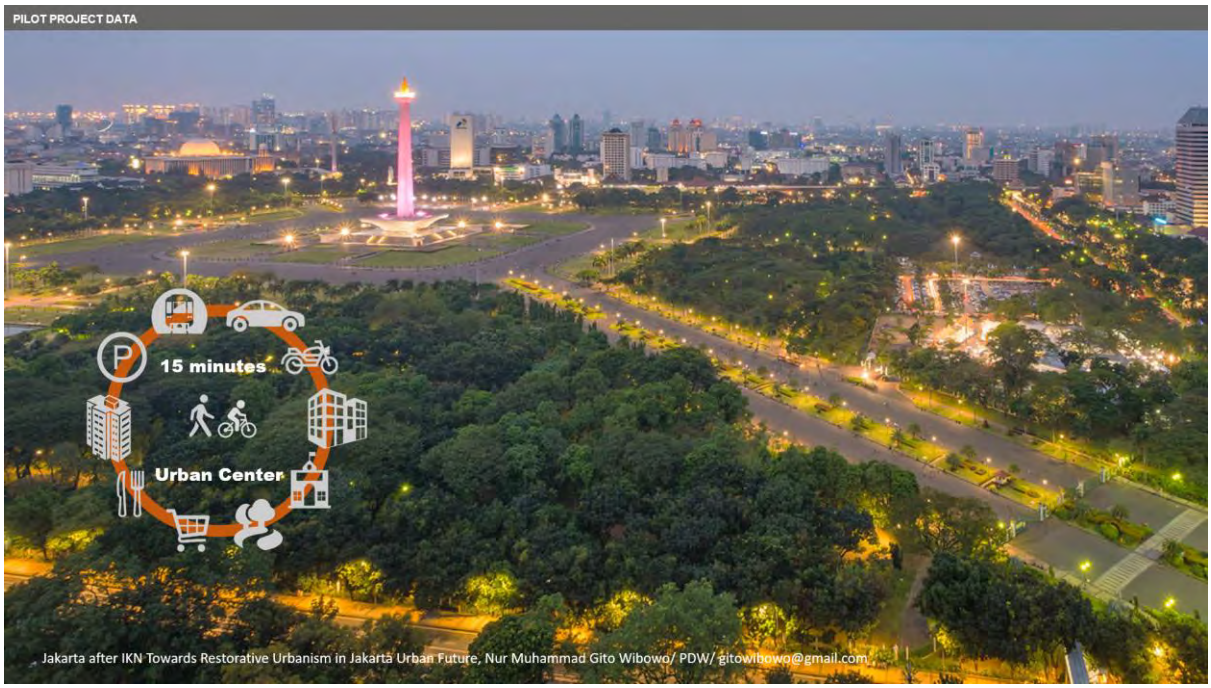


Figure 6. Central Jakarta 15 minutes City. Source: PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

Figure 7. Low Emission District Plan. Source: PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

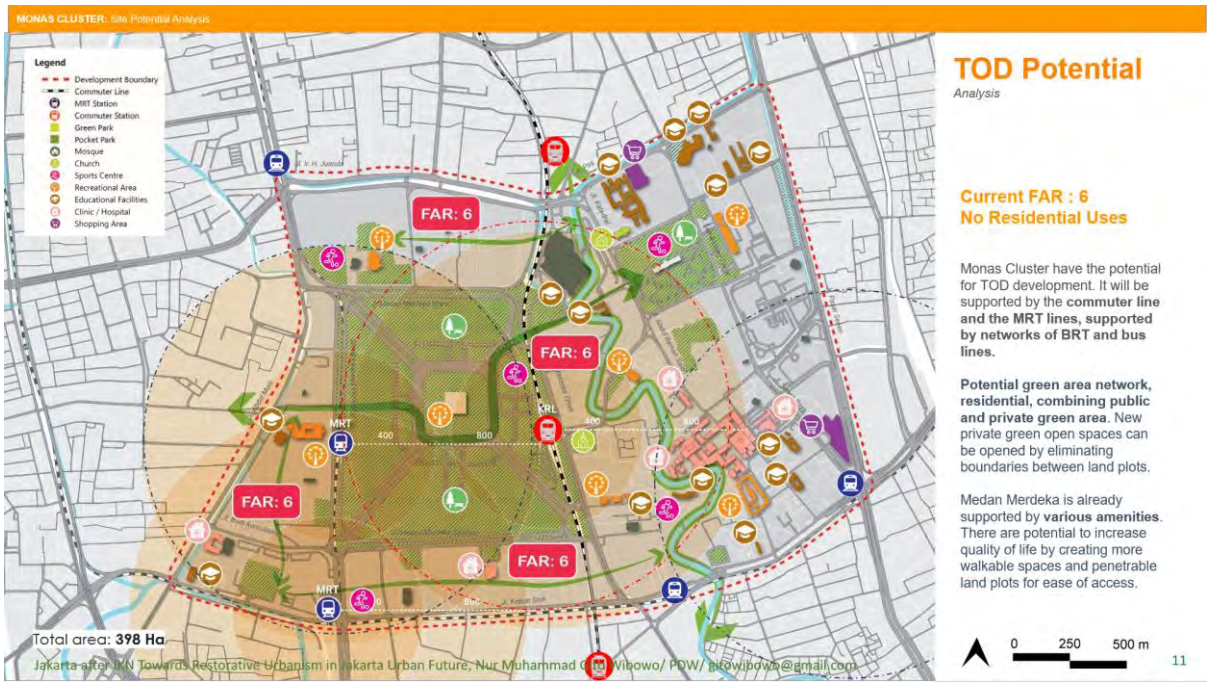


Figure 8. Jakarta Central Transport Hub Plan. Source: PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

4.2. Revitalization with Residential Densification and Adaptive reuse Retrofitting

Currently, having Monas district is characterized by low utilization. City government offices dominate the landscape, and there are but a few residential locations within its borders. With the shift in capital functions, it is natural to think of densification. The area could bring a permanent population into the city heart and thus make possible life therein as a functioning neighborhood. City development programs will focus on high-density residential areas, which will enable people to live, work, and socialize all within sight of each other. Densification like this can also accommodate all kinds of residences, from inexpensive housing for the poor to middle-income flats. The result is a balanced mix of the district's residents.

Adaptive reuse is a major approach to the urban renewal scheme, mainly through converting existing buildings into usage meeting contemporary needs. In Jakarta's transformation of Monas district, adaptive reuse provides the perfect chance to hold on to its historical and cultural heritage. At the same time, it will free up land as well as introduce modern sustainable infrastructure that can return appreciable energy savings. By transforming the Monas region's previous government and administrative structures, Jakarta can save resources, reduce carbon emissions linked to new buildings, and convert neglected spaces into innovative and multi-functional hubs. This approach is consistent with the city's own vision for developing a sustainable way of life, densifying the urban core, and creating a lively, community-minded city center.

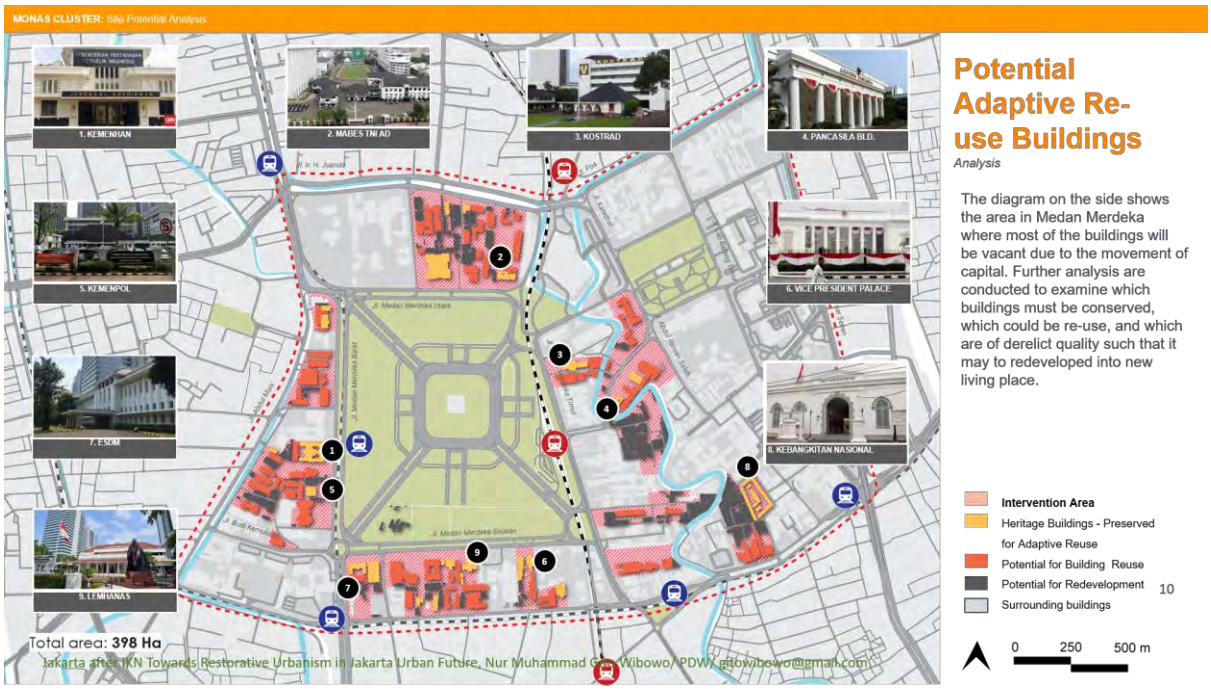


Figure 9. Potential adaptive reuse Building. Source: PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

Figure 10. Jakarta Central Transport Hub Plan. Source: PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

Similarly, we can build new residential areas with strategic points in mind. We can design them based on green building standards, with energy-efficient apartments interspersed throughout large green spaces, and the human-oriented urban environment dovetails with Jakarta's current sustainable tendencies. By bringing more people into the Monas area, the more prosperous residential life there will stimulate a local

economy, support businesses, and encourage public uses. Harried mothers linger on benches across four lanes of traffic while waiting for their children to finish school—in short, this makes around-the-clock operation as developed an urban area can be.

- Conversion of Administrative Buildings to Mixed-Use Developments: Large government buildings, often located in good locations, can be transformed into a mix of residential suites and co-working spaces. By incorporating this method into the community, it will make for a 24-hour place to live that is quite definitely a contrast with single-use spaces and facilitates sustainable lifestyles based on alternative transportation.

- Transformation into Cultural and Recreational Facilities: Smaller government offices or heritage buildings can be turned into venues for the arts such as galleries, museums, or theaters. By placing these cultural facilities in the heart of Monas, Jakarta will be able to better utilize its attraction package offering for visitors and local residents alike; just wait until they are able to experience this lively education that celebrates our city's heritage.

- Incorporation of Green Spaces and Public Facilities: Adaptive reuse can also include the creation of public amenities such as community centers, libraries, and parks. By converting existing buildings into shared spaces, Monas transforms the district from a collection of fragmented districts and ethnic groups struggling for space on the land into one with open public facilities where everyone is welcome. Additionally, rooftop gardens, green walls, and vertical parks can all be added to further increase the urban diversity and improve air quality in Jakarta's environment.

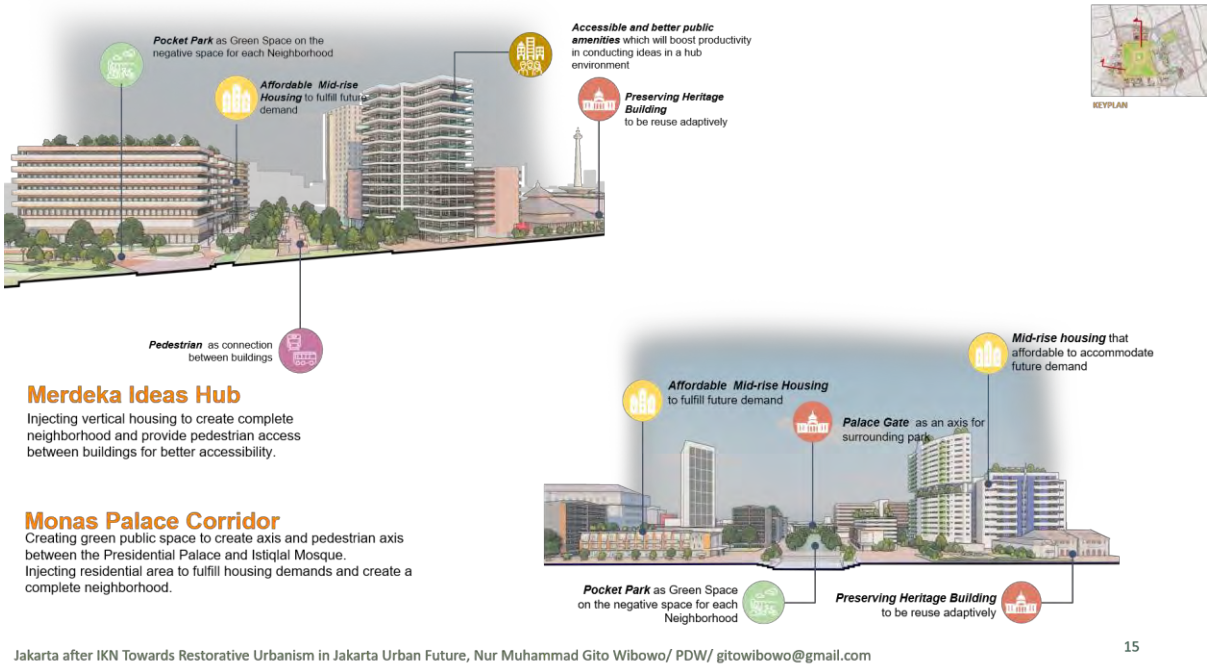


Figure 11. Jakarta Central Transport Hub Plan. Source: PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

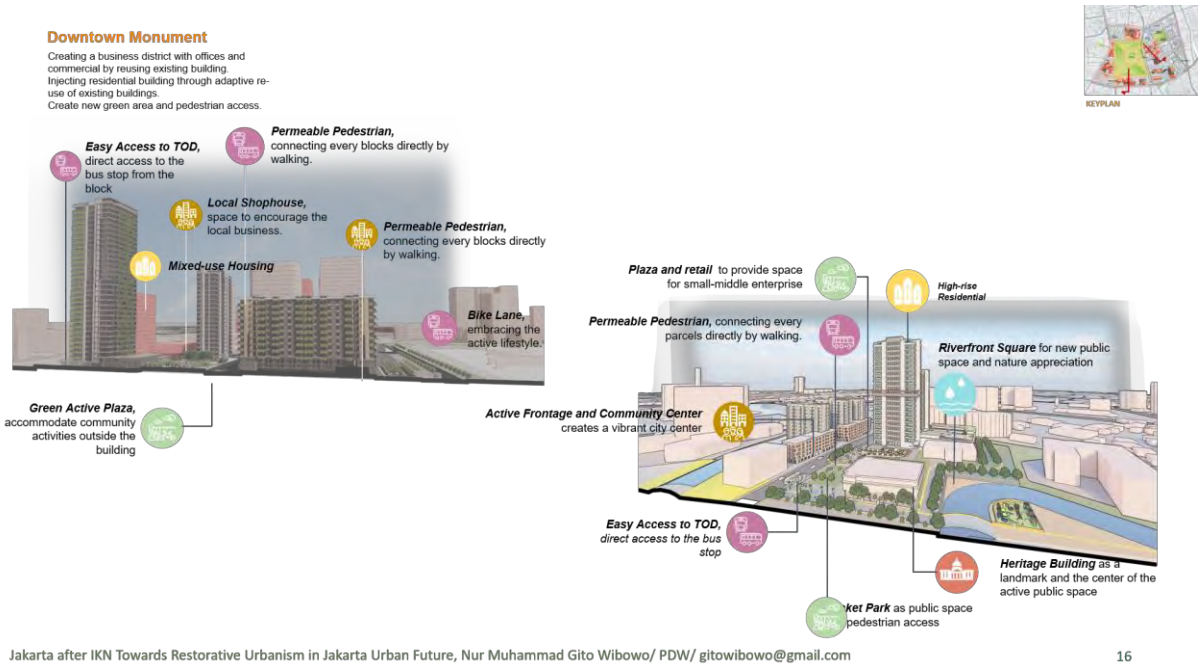


Figure 12. Jakarta Central Transport Hub Plan. Source: PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

Through adaptive reuse, the vision of a sustainable and resilient Monas district can become a reality. By repurposing current buildings, the city can cut its impact on the environment, reduce consumption of resources, and give new life to this area by incorporating many different functions into one place—a bustling urban district that works for residents as well as visitors or businessmen. In Monas, adaptive reuse represents a transformative approach that supports Jakarta's vision for a sustainable city. Through repurposing existing buildings, the environmental load is reduced, and the district's historical and cultural assets are protected; a variety of functions can be introduced into the area to create a hectic urban center catering to residents, businesses, and visitors alike. Through adaptive reuse, Monas has the potential to be a model transformation of how Jakarta can address its past while also meeting modern demands. This way forward gives us hope for future generations in our city and all around the country too—it's both people-oriented and environmentally friendly.

5. References

Roberts, P., Sykes, H., and Granger, R., (2016) Urban Regeneration: A Handbook. 2nd ed. London: SAGE Publications.

Marvin, S. and Bulkeley, H., (2013) Retrofitting Cities: Priorities, Governance and Experimentation. 1st ed. London: Routledge.

Macdonald, D., (2012) Adaptive Reuse: Extending the Lives of Buildings. 1st ed. Kingston, Ontario: Quarry Press.

Knowles, R.D., Ferbrache, F., and Nikitas, A., (2019) Transit Oriented Development and Sustainable Cities: Economics, Community and Methods. 1st ed. Cheltenham: Edward Elgar Publishing.

Guerra, E., and Cervero, R., (2019) Making Transit-Oriented Development Work: Planning, Design, and Policy. 1st ed. Cambridge, MA: MIT Press.

Calthorpe, P., (2021) Calthorpe: An Urban Agenda for the 21st Century. 1st ed. Washington, DC: Island Press.

Bappenas (2021) National Medium-Term Development Plan 2020–2024 (Rencana Pembangunan Jangka Menengah Nasional/RPJMN 2020-2024). Jakarta: Ministry of National Development Planning/National Development Planning Agency (Bappenas).

Dovey, K., Pafka, E., and Ristic, M. (2018) Mapping Urbanities: Morphologies, Flows, Possibilities. New York: Routledge.

Sasana, H., and Prayitno, H. (2021) Transit-Oriented Development (TOD) as an Urban Development Strategy in Jakarta: Opportunities and Challenges. Jakarta: Gramedia Pustaka Utama.

Provinsi DKI Jakarta (2021) Peraturan Gubernur Provinsi DKI Jakarta Nomor 55 Tahun 2021 tentang Pengembangan Kawasan Berorientasi Transit di Wilayah Provinsi DKI Jakarta. Jakarta: Pemerintah Provinsi DKI Jakarta.

Gehl, J., and Svarre, B., (2013) How to Study Public Life. 1st ed. Washington, DC: Island Press

Freeman, L., (2019) Urban Mobility in the 21st Century: Global Perspectives on Sustainable Cities and Pedestrian-Friendly Planning. 1st ed. London: Palgrave Macmillan.

Gehl, J., (2010) Cities for People. 1st ed. Washington, DC: Island Press.

Alfonzo, M., and Sandt, L. (2020) Rethinking Streets for Pedestrians: Tools for Walkable Streets. 1st ed. Eugene, OR: University of Oregon.

PDW, JPI & ENCITY (2023) Jakarta 2045, Jakarta After IKN - Research Project

Agus Pitoyo (2017) Urbanization and Economic Development in Indonesia, Demographic Perspectives Analysis.

OpenAI (2024) Chat GPT : Language model for Generating Textual Responses ver4. Accessed October 2024.

Research Paper

Development beyond the edge

Assessing the externalities of the dual-track urban network at township level in Shanghai Metropolitan Areas

Qimin Xu, College Of Architecture And Urban Planning, Tongji University,China
Chen Chen, College Of Architecture And Urban Planning, Tongji University,China

Abstract

At the township level, rapid development beyond the edge is achieved through a dual network connection of urban functions and urban innovation. The article takes the towns and villages in Shanghai and its hinterland Suzhou, Jiaxing, and Huzhou as the research objects. POI data and patent cooperation data from 2018 and 2022 are used to construct a dual network of urban innovation under the influence of geographical proximity and information topology. The deviation from mean standard deviation multiple method is used to quantitatively evaluate the two types of externalities of the towns. The results show that: (1)The township functional network shows a 'dendritic' development; the spatial distribution of the agglomeration externalities facilitated by this network is inclined to 'circle diffusion', primarily concentrated in the core areas of the metropolitan. (2)The township innovation network shows a 'free-style' development, with resulting network externalities characterized by 'multi-point dispersion', the positive externalities also appear in the peripheral area of the metropolitan. (3) According to the combination of dual network externalities, different towns can be classified into four types: 'integrated, agglomerated, networked, isolated'.When formulating regional development policies, the differential impact of different networks on urban development should be comprehensively considered.

Keywords

Urban network; Agglomeration externalities; Network externalities; Shanghai metropolitan area

1. Introduction

In the wave of globalization and informatization, various production factors cross geographical boundaries through the internet and flow intricately in the global urban regional network. In China, due to the unique administrative division system, resources should have been given priority to higher-level central urban areas. However, in recent years, with the continuous maturity of urban network connections, the population, capital, knowledge and technology of some small towns have begun to actively interact with large cities to varying degrees, and even surpassed their own administrative levels by borrowing their scale. This change is becoming increasingly pronounced in the metropolitan area of Shanghai and its hinterland in China. With the rise of the "integrated development of the Yangtze River Delta" as a major national strategy

and the joint promotion of the regional strategy surrounding the construction of the Shanghai metropolitan area for a long time, the urban network has undergone drastic evolution, bringing about rapid development beyond the edges at the township level.

Scholars have summarized the role of this urban network in urban development as "externalities" (Burger M, 2016). The agglomeration externality brought about by the previously popular reliance on geographically close urban networks cannot fully explain this cross regional urban interaction effect. Therefore, the externality of information association networks that break through spatial limitations has emerged (Capello, 2000). These two externalities are not completely substitutable, but should be combined with each other to perform complex geographical transformations in a dual network, jointly promoting the development of the city. Existing research on network externalities often focuses on analyzing cities or districts as nodes. But in fact, in China, especially around major cities, some townships are large in scale and have even transformed into fully functional new centers. It is urgent to re explore the network externalities that emerge in the metropolitan areas and their hinterland at a more refined township level.

Based on the above analysis, this article takes the towns in Shanghai and its hinterland Suzhou, Jiaxing, and Huzhou as the research object, constructs a dual network of urban innovation under the influence of geographical proximity and information topology, and quantitatively evaluates the externalities from a comprehensive perspective of agglomeration and network integration. The study collected POI data and patent application address data from various towns in 2018 and 2022, and constructed urban functional networks based on industrial connections and geographical distances to study agglomeration externalities; Constructing an urban information network based on the number of patent collaborations to study network externalities. Adopting social network analysis methods to observe the spatial evolution characteristics of dual networks, and using the deviation from mean standard deviation multiple method to quantitatively evaluate the two types of externalities in urban areas from the perspective of borrowing scale. Divide the "agglomeration network" matrix based on the results, classify different towns, and explore the differences in their formation mechanisms.

The aim of this study is to explore the network externalities under finer spatial units, which is of great significance for improving the flow efficiency of elements in metropolitan areas and their hinterland regions from a structural perspective, as well as for small towns to break through edge limitations and seek new development drivers and planning ideas.

2. Research Design

2.1. Research object and data selection

In 2018, the integration of the Yangtze River Delta region became a major national strategy. As the core area of the Yangtze River Delta, the planning and construction work of the Shanghai metropolitan area has made rapid progress in recent years, and it has become the most globally influential region in China. This article selects the towns and villages of the typical metropolis Shanghai and its hinterland Suzhou, Jiaxing, and Huzhou (referred to as the Shanghai Suzhou Jiahu region) as the research objects. The four cities are closely adjacent in space, with developed functions and information networks, and are closely connected in the process of urbanization. According to statistics, there are a total of 453 township administrative units (Figure 1).Please fill in the authors' names as in the example below.

Figure 1. Urban spatial units in the Hu Su Jia Hu area. Source: Author's drawing

This study used three major data sources: (1) Point of Interest (POI) data collected from the Gaode Map Open API platform for Shanghai, Suzhou, Jiaxing, and Huzhou in 2018 and 2022. And by sorting and filtering out POI data related to service functions, we finally obtained 512596 points of interest in 2018 and 995020 points of interest in 2022. (2) Using the Innojoy patent website as the data source, filter based on the number of applicants>2, and crawl patent application data from the research area in 2018 and 2022; And further cleaning will be carried out, retaining only the patent data of pairwise cooperation between cities within the research scope. In the end, a total of 8111 collaborative patents were obtained for the construction of the network in this article in 2018, and 14224 patents were obtained in 2022. (3) The population attribute is derived from the population data of administrative townships in the sixth national census in 2010.

2.2. Analysis Approach

2.2.1 Building a dual network

(1) Constructing urban functional networks under the influence of geographical proximity

Firstly, based on the "Classification of National Economic Industries" (GB/T 4754-2011), this study integrates four major urban service functions, namely circulation, finance and commerce, science, education and culture, and public services, and summarizes and integrates POI data (Table 1).

Table 1. City POI Data and City Function Integration Division. Source: Author's drawing

Town functions	Industry Integration	Industry Division	Contents of POI
Circulation function	Transportation and communications industry	Transportation, warehousing and postal services	Long-distance buses, trains, subways, airplanes, ports, toll booths, post offices, logistics
		Information transmission, software and information technology	Telecommunications Business Hall

		services	
Financial and commercial functions	Financial and commercial industry	Wholesale and retail	Shopping malls, supermarkets, convenience stores, electronics stores, healthcare sales stores, gas stations, gas stations, other energy stations, charging stations, flower, bird, fish, and insect markets, home building materials markets, cultural goods stores, sports goods stores, clothing, shoes, hats, leather goods stores, special buying and selling places, cosmetics stores, car sales, car parts sales
		Accommodation and catering	Chinese restaurant, foreign restaurant, fast food restaurant, coffee shop, tea house, cold drink shop, pastry shop, dessert shop, hotel, hotel guesthouse
		finance	Banks, securities companies, insurance companies, finance companies
		real estate	Buildings and residential areas
		Leasing and commercial services industry	Car rental, travel agencies, advertising companies, law firms, talent markets
Scientific, educational and cultural functions	Science, education and cultural industry	Scientific research, technical services, and geological exploration industry	Research institutions, photography and printing shops
		education	Schools and training institutions
		Culture, sports, and entertainment industries	Science and education cultural venues, museums, exhibition halls, convention centers, art galleries, libraries, science and technology museums, planetariums, cultural palaces, archives, literary and artistic groups, media institutions, sports venues, entertainment venues, vacation resorts, cinemas, lottery sales points
Public service function	Management service industry	Water conservancy, environment and public facilities	Related to scenic spots, parks and squares, scenic spots, public toilets
		Residential services, repair and other services	Beauty salon, bath, car repair, motorcycle repair, repair station, laundry, funeral facilities
		Health and social work	Healthcare service facilities, general hospitals, specialized hospitals, clinics, emergency centers, disease prevention institutions, animal medical facilities
		Public administration, social security and social organizations	Government agencies, foreign institutions, democratic parties, social organizations, public security, procuratorial and judicial institutions, transportation vehicle management, industrial and commercial tax authorities

Referring to Shilin's (2016) method, the location entropy model is used to determine whether a town has outward oriented functions (Equation 1), and the outward oriented function quantity of each town in the study area is calculated (Equation 2). Finally, by combining the gravity model,

the strength of outward functional connections between cities and towns (Equation 3) was obtained. Using this as an edge and the center point of the city as a network node, urban functional networks under geographical proximity in 2018 and 2022 were constructed, and their evolutionary characteristics were compared and observed.

$$L_{qij} = \frac{G_{ij} / G_i}{G_j / G}, \quad (i = 1 \ldots\ldots n; \ j = 1 \ldots\ldots m) \tag{1}$$

G_{ij} represents the total number of POIs for the functions of i town j; G_i represents the total number of POIs in town i; G_j represents the total number of POIs for all functions of town j; G represents the total number of POIs in all towns. If it is greater than 1, it indicates that town i has an outward oriented function; If<1, it indicates that there is no outward function in town i.

$$E_{ij} = G_{ij} - G_i \ (G_i / G) \tag{2}$$

The outward functional quantity of town i in j function is that the number of POIs in town j function exceeds the average number of POIs in j function for all towns within the research scope. The total external energy of city i is obtained by summing up the calculation results of various functions.

$$F_{mn} = \frac{E_m \times E_n}{D_{mn}^2} \tag{3}$$

In the formula of the gravity model, Fmn represents the strength of outward functional connectivity between m cities and n cities, Em and En represent the outward functional quantities of m and n cities, respectively, and Dmn represents the straight-line distance between m and n cities.

(2) Constructing an Urban Innovation Network under Information Topology Connection

Firstly, based on the Baidu Maps API, a Python program is used to geocode each patent application address and place it on the ArcGIS platform. It is then mapped to various towns using the "Spatial Join" tool.

Further statistical research will be conducted on the number of pairwise collaborations between towns within the scope of the study to characterize the strength of connections, and to use this as an edge to represent innovative connections between towns beyond administrative boundaries. Similarly, the centers of each town will be used as network nodes to construct urban innovation networks under information topology connections for 2018 and 2022, respectively, and their evolutionary characteristics will be compared and observed.

2.2.2 Assessment of dual network externalities

Drawing on existing literature, use the method of deviating from the mean standard deviation multiple to analyze the borrowing scale performance level of various towns. When the relative performance of each urban area is positive, there is a borrowing scale effect; When the relative performance of each urban area is negative, there exists a shadow effect of agglomeration (Meijers E, 2015). This study is based on data from 2022, and calculates the regional relative performance level of each town based on the node centrality of the dual network of urban function and innovation (i.e. the degree centrality of each town, as shown in Equation 4), and further evaluates the external effects of the dual network based on the results.

$$DC_i = \frac{k_j}{N-1} \tag{4}$$

Among them, k_j represents the number of edges connected to node i, and N-1 represents the number of edges connected to node i and other nodes. The larger the node degree, the higher the degree centrality of the node, and the more important its position in urban networks.

$$PER_i = (E_i - \sum_i \frac{E_i}{n}) \Big/ \sqrt{\frac{1}{n}\sum_i (E_i - \sum_i \frac{Ei}{n})^2} \quad (5)$$

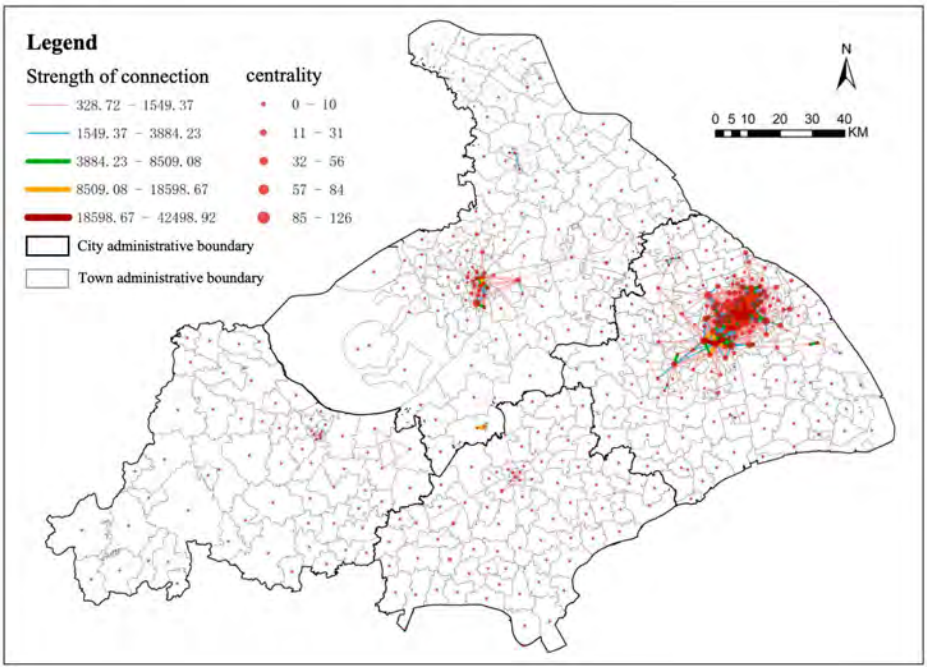
In the formula, PER_i refers to the relative performance of the i town region, E_i refers to the ratio of the centrality of the i town network to the population size of the existing town, and n is the number of towns.

Finally, based on the relative performance values of the dual networks in each town, a scatter plot is drawn. Using 0 as the benchmark, the towns within the research scope can be divided into four types: "comprehensive, clustered, network, and isolated", and their spatial distribution can be observed.

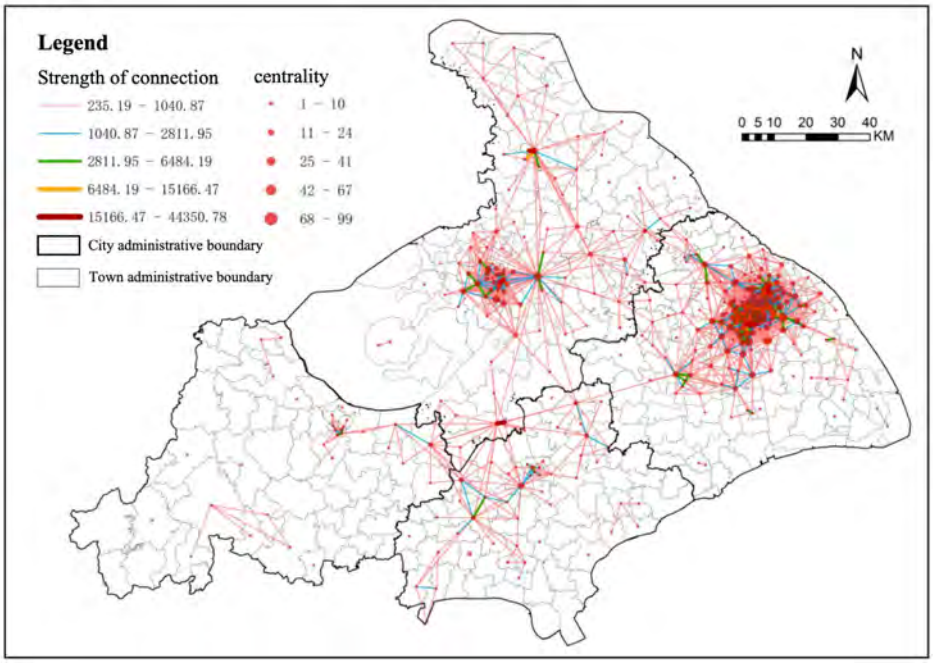
3. Result

3.1. The spatial evolution characteristics of dual networks

Visualize the dual network of urban areas in 2018 and 2022 using the ArcGIS platform. The effect of geographical proximity drives the development of urban functional networks in a "tree like" manner, and network connections become increasingly complex and dense over time (Figure 2). Specifically, the production and market size within the Shanghai Suzhou Jiahu area are mostly dominated by Shanghai, followed by Suzhou. With the continuous maturity of urban networks, smaller network subgroups have also formed in Huzhou and Jiaxing. However, due to the limitation of distance cost, it is difficult to accept the radiation and driving effect of Shanghai's core metropolis.



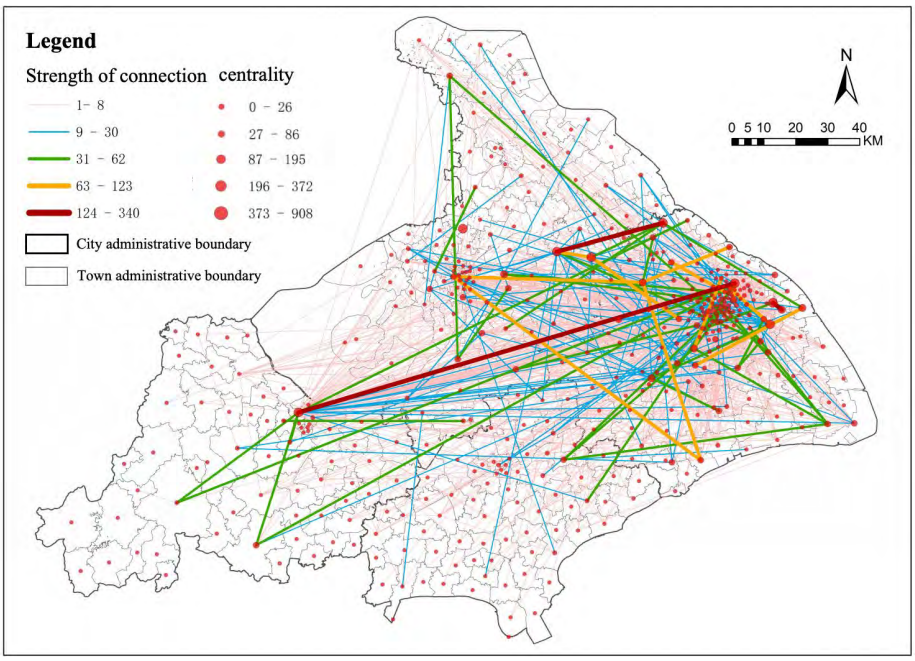
(a) 2018



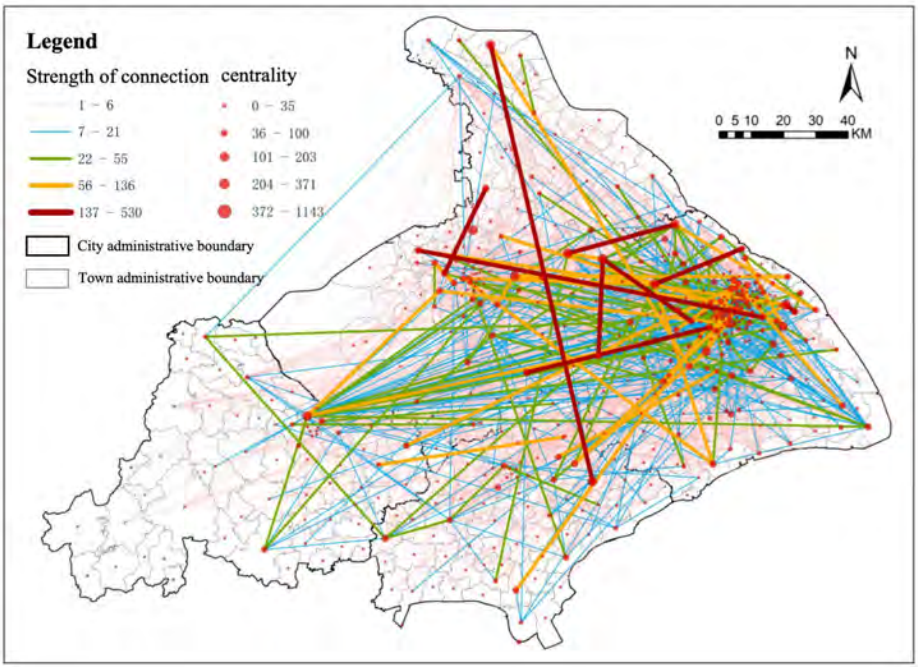
(b) 2022

Figure 2. Regional cooperation of urban functional networks. Source: Author's drawing

The information topology connection is driving the urban innovation network to present a "free-form" feature, and the network structure is developing towards an increasingly complex direction(Figure 3). Specifically, within the scope of the study, the innovation network has broken through the limitations of geographical space, without clear clustering subgroups, and there have been many towns that are far apart but have strong connections between the four cities. Compared to geographical proximity, information connectivity is more conducive to close communication between the urban clusters of Huzhou and Jiaxing and the metropolis of Shanghai.



(a) 2018



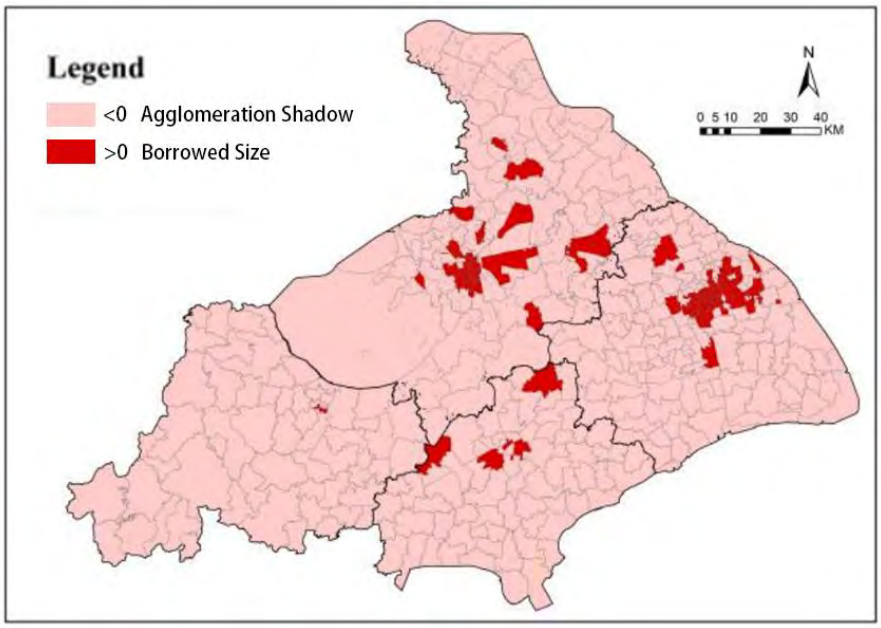
(b) 2022

Figure 3. Regional Cooperation of Urban Innovation Network. Source: Author's drawing

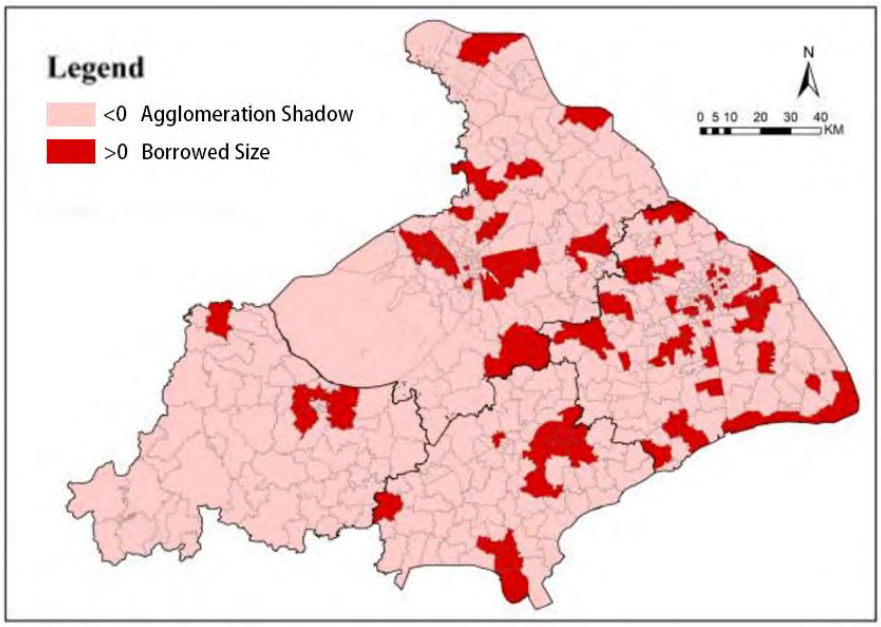
3.2. External effects of dual networks

The agglomeration of dual networks and network externalities at the township scale do not occur synchronously, and the two exhibit differentiated spatial distributions. The spatial distribution of agglomeration externalities based on urban functional networks presents the characteristics of "multi-core" and "circle diffusion". The borrowing scale characteristics of the main urban areas and a few suburban towns in various cities are particularly prominent, such as Wujiaochang Street, Hongqiao Town, Jinqiao Town and other areas in the suburbs of Shanghai's main urban area, as well as Guanqian Street, Shuangta Street and other areas in the suburbs of Suzhou's main urban area. And the towns in the peripheral range show obvious "agglomeration shadow" characteristics, such as Huating Town and Fengcheng Town in the outer suburbs of Shanghai's main urban area. The main urban area of a metropolis usually serves as the center of regional economic development, with concentrated and diverse service functions. It has strong borrowing advantages, such as a larger market and a more diverse workforce. Based on the advantage of geographical proximity, suburban areas prioritize interaction with the main urban area, making it easier to "borrow" its resource elements and profit in the functional network.

Based on the network externalities brought by urban innovation networks, there is a characteristic of "multi-point dispersion" without a clear core, and positive externalities such as "borrowing scale" may also appear in towns in the outskirts of metropolises. For example, Nanhui New Town located in the outer edge of Shanghai and Huangwan Town in Jiaxing. Although these towns are located at the edge of spatial network nodes and have weak geographical connections with metropolitan centers, they can also achieve flexible nesting and scale borrowing of spatial networks within metropolitan areas through innovative cooperation that transcends spatial limitations.



(a) distribution under functional networks



(b) distribution under innovation network

Figure 4. The externalities of urban dual networks. Source: Author's drawing

3.3. Classification analysis of dual network externalities effects

The author categorized the external effects of each township based on the dual network into four types (Figure 5) and visualized them spatially in ArcGIS (Figure 6):

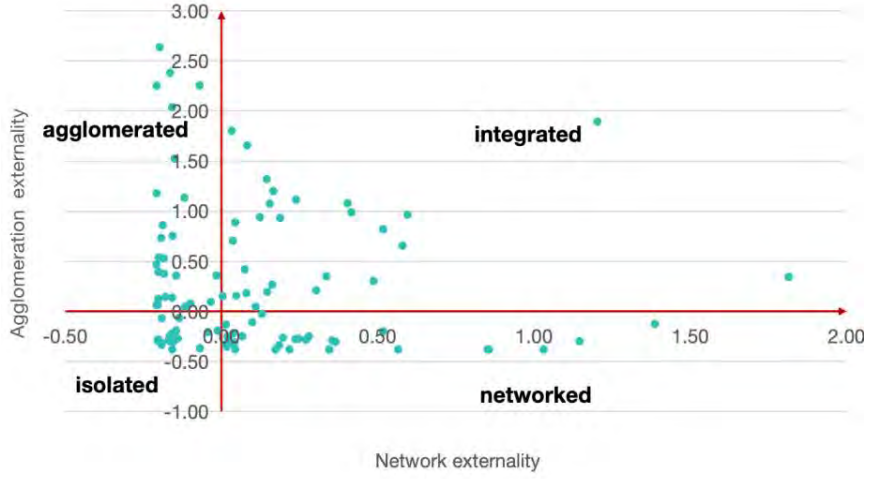


Figure 5. Scatter plot of dual network externalities. Source: Author's drawing

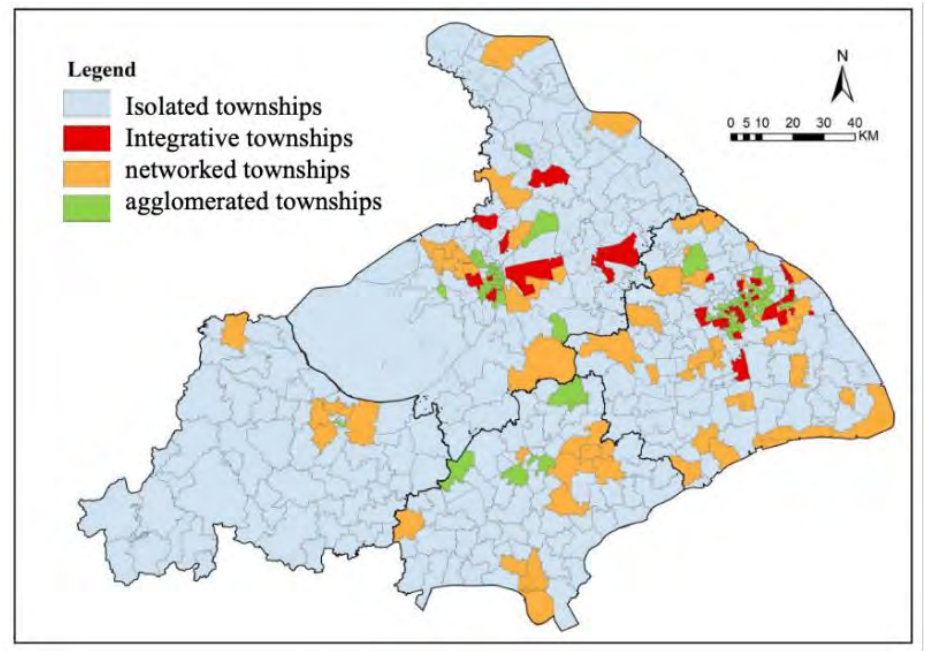


Figure 6. Spatial distribution of urban types. Source: Author's drawing

(1) Comprehensive towns with strong agglomeration externalities and network externalities, such as Jinqiao Town, Hongqiao Town, Wujing Town, etc. These types of towns are often hubs connecting the dual network of the region and surrounding towns, with a good economic foundation, concentrated service functions, and a concentration of innovative resources and more external cooperation. For example, Jinqiao Town, located in Pudong New Area, Shanghai, has a high degree of administrative overlap with Jinqiao Economic and Technological Development Zone. Under the policy of "management town linkage", it has become the first free trade pilot zone in China with innovative high-end manufacturing and productive service industries as its dual core development.

(2) Agglomeration type towns with strong externalities but weak network externalities, such as Xitang Town and Malu Town. These types of towns generally have more functional elements,

relying on geographical distance to interact with surrounding cities, but lack innovative cooperation with cities located further away within the metropolitan area. For example, Xitang Town, located in Jiashan County, Jiaxing City, is committed to building a future water town community that is closely related to the ancient town. It has become a core component of the Yangtze River Delta Ecological Green Integration Development Demonstration Zone and relies more on the integration of the tertiary industry related to culture and tourism into the functional network; Patent cooperation related to technological innovation is relatively weak and not a key direction for its development.

(3) Network type towns with strong network externalities but weak agglomeration externalities, such as Nanhui Xincheng Town and Zhangjiang Town. These types of towns are generally driven by the radiation of innovation cooperation from other towns, with technology innovation industries as their leading industries. Due to geographical limitations, it is difficult to access the development dividends of towns with concentrated functional services. For example, Nanhui New Town in Pudong New Area, Shanghai, is located on the coast and far from the main urban area of the metropolis, with weak agglomeration externalities under its functional network. But as the core carrier area of Shanghai Lingang New Area, a special economic functional zone, it is fully committed to building a high-energy, intelligent, and modern future city. At present, the benefits of its innovative industrial cluster are constantly emerging, becoming an important node in the innovation network of the Shanghai metropolitan area.

(4) The "isolated" townships with weak agglomeration externalities and network externalities, such as Weiting Street, Guangfu Town, and many other townships. These types of towns are often located on the edge of the urban network in metropolitan areas, making it difficult to integrate into the functional network, and their service functions can only serve the local area; At the same time, there is relatively little involvement in the fields of technological innovation and cooperation, and the external effects of innovation networks also need to be developed.

4. Discussion

This article takes the towns and villages in Shanghai and its hinterland Suzhou, Jiaxing, and Huzhou as research objects to explore the external effects brought by urban networks. Based on the concept that the externalities of agglomeration brought by geographically close urban networks and the externalities of information related networks that break through spatial limitations coexist and jointly promote urban development, this study quantifies and evaluates the externalities of urban areas within the research scope from the perspective of functional and innovative dual networks. Towns are classified based on the four dimensions of the "agglomeration network" matrix to describe their differentiated types and spatial distribution, and to guide the formulation of relevant development policies for various towns in the region.

The main conclusions are as follows: (1) Geographical proximity promotes the "tree like" development of urban functional networks; The spatial distribution of agglomeration externalities brought about by it presents the characteristics of "multi-core" and "circle diffusion", mainly concentrated in the core areas of metropolises. (2) The information topology connection promotes the "free" development of urban innovation networks, and the network externality effect it brings is "multi-point dispersion", which can also have positive externalities in the peripheral areas of metropolises. (3) The agglomeration of urban functions and network innovation may not necessarily occur simultaneously, and the externalities of each town can be classified into four types: "comprehensive, agglomeration, network, and island". Each town chooses to embed different types of urban networks based on its own situation, resulting in

spatial spillover differences in externalities. Therefore, when formulating regional development policies, attention should be paid to the externalities of different networks of urban areas in the region; Avoiding islanding risks through effective interaction between cities with different development advantages.

This study explores the network externalities under finer spatial units, but there are still shortcomings: firstly, this study is only a preliminary exploration of the existence of network externalities in metropolises and their hinterlands, and there is still room for exploration on how to guide cities to avoid agglomeration shadow effects and strengthen borrowing scale effects. Secondly, the development stages of urban agglomerations in different regions of China vary. Therefore, the regional network of the Shanghai metropolitan area is only a representative case of developed urban areas in China, and comparative research with other regional urban areas still needs to be carried out, which can be further explored in the future.

5. References

Burger, M.J. & Meijers, E.J., 2016. Agglomerations and the Rise of Urban Network Externalities. Papers in Regional Science, 1, pp. 5-15.

Capello, R., 2000. The City Network Paradigm: Measuring Urban Network Externalities. Urban Studies, 11, pp. 1925-1945.

Ma, H., Fang, C., Pang, B. et al., 2014. The Effect of Geographical Proximity on Scientific Cooperation among Chinese Cities from 1990 to 2010. Plos One, 11, e111705.

Meijers, E. & Burger, M., 2015. Stretching the concept of 'borrowed size'. Urban Studies.

Volgmann, K., Rusche, K. & Weesep, J.V., 2020. The geography of borrowing size: Exploring spatial distributions for German urban regions. Tijdschrift voor Economisch een Sociale Geografie, 111(1), pp. 60-79.

Xu, Y.Q., Zeng, G. & Wang, Q.Y., 2018. The Evolution of Collaborative Innovation Network Patterns in the Yangtze River Delta Urban Agglomeration and Optimization Strategies. Economic Geography, 38(11), pp. 133-140.

Larsson, J.P., 2014. The neighborhood or the region? Reassessing the density-wage relationship using geocoded data. The Annals of Regional Science, 52(2), pp. 367-384.

Sun, Z.Y., Huang, Y. & Yang, L. et al., 2023. A Research Framework for the Externality Effects of Urban Network Evolution and Its Practice in Chongqing. Planner, 3, pp. 73-80.

Rosenthal, S.S. & Strange, W.C., 2004. Evidence on the nature and sources of agglomeration economies. In: Henderson, J.V. & Thisse, J.F., eds. Handbook of regional and urban economics, vol. 4. Amsterdam, Netherlands: Elsevier, pp. 2119-2171.

Castree, N., Amoore, L., Hughes, A. et al., 2020. Boundless Contamination and Progress in Geography. Progress in Human Geography, 3, pp. 411-414.

Lin, B.Q., Gu, R.X. & Wang, J.S. et al., 2018. From Agglomeration Externalities to Network Externalities Across Geographical Boundaries: A Review and Outlook on Agglomeration Economics. Urban Development Studies, 25(12), pp. 82-89.

Chen, J.Y. & Xiao, G.E., 2005. New Developments in Overseas Research on Agglomeration Economics. Jianghan Tribune, 4, pp. 5-12.

Zhao, M.X., Wang, Y.K., Hu, Y.K. et al., 2022. Performance Evaluation of Urban Borrowed Size Externalities in the Guangzhou-Foshan Metropolitan Area. Geographical Research, 41(09), pp. 2367-2384.

Ma, H., Fang, C., Pang, B. et al., 2014. The Effect of Geographical Proximity on Scientific Cooperation among Chinese Cities from 1990 to 2010. Plos One, 11, e111705.

Otsuka, A., 2020. Inter-regional networks and productive efficiency in Japan. Papers in Regional Science, 99(1), pp. 115-133.

Meijers, J.E., Burger, J.M. & Hoogerbrugge, M.M., 2016. Borrowing size in networks of cities: City size, network connectivity and metropolitan functions in Europe. Papers in Regional Science, 95(1), pp. 181-198.

Huang, J.Z., Xu, Y.T. & Hu, G.Y. et al., 2024. Analysis of Borrowed Size Externalities in Metropolitan Areas: A Case Study of the Shanghai Metropolitan Area. Urban Development Studies, 31(03), pp. 16-23.

Shi, L. & Hou, J.X., 2016. The Impact of Urban Export-Oriented Functions on Urban Spatial Connections: A Case Study of Cities in the Yangtze River Economic Belt. Shanghai Economic Research, 7, pp. 10-16+28.

Research Paper

Exploration of Renewal Paths for Modern Sports Architectural Heritage Based on Intelligent Grading

Xianze ZHANG, School of Architecture and Design, Harbin Institute of Technology, Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Ying LIU, School of Architecture and Design, Harbin Institute of Technology, Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Abstract

Modern sports architecture is a witness to the historical development of sports and civilization in human society, and is also an important part of the world's cultural heritage. In the face of the needs of building intelligence, there is not a complete set of intelligent renewal paths that can be combined with the current big data, artificial intelligence and other advanced information technologies in the current research. This study comprehends the development and application status of intelligent renewal technology for sports buildings, analyzes the intelligent grading standards that have been formed in other professional fields, and proposes an intelligent renewal path for modern sports building heritage on this basis. And it explores the hot issue of intelligent renewal, and innovatively applies the grading evaluation standard system to the renewal of sports heritage stock, providing theoretical support for the functional enhancement of modern sports architectural heritage in the context of the era's development with an integrated perspective of hierarchical strategy making. The results of the study can guide the practice of intelligent renewal engineering for modern sports architectural heritage, and then promoting the realization of the goal of creating a high-quality living environment.

Keywords

Modern Sports Architectural Heritage, Renewal Path, Intelligent Grading

1. Research Background

1.1. The demand for intelligent renewal of modern sports architectural heritage

Architectural heritage is a cultural asset bestowed by history and a cultural resource necessary for the future development of humanity. As the connotation and concept of "architectural heritage" continue to expand, the protection and utilization of modern sports architectural heritage have received widespread attention, and its protection value has been continuously explored and recognized. Generally speaking, modern sports architectural heritage is defined as "sports buildings constructed after 1840 that have certain protection and utilization value". Unlike ancient heritage such as the Roman Colosseum, the definition of modern architectural heritage has certain particularities (Figure 1). On the one hand, the existence time of modern sports architectural heritage is broader in definition. For example, the Beijing

Workers' Stadium was included in the "List of 20th Century Architectural Heritage in China" jointly announced by the Chinese Society of Cultural Relics and the Architectural Society of China in 2017, only 56 years after its construction; on the other hand, modern sports architectural heritage often undertakes high-level sports events such as the Olympics and Asian Games, witnessing urban development and having significant era significance; most notably, these sports architectural heritages are generally within their normal use cycle, closely related to the composition of urban space and people's lives. Although most modern sports architectural heritages can be used normally and conduct sports activities such as training and competitions, due to their long construction years, these modern sports architectural heritages gradually cannot meet the increasingly enhanced usage demands of people and urgently need renewal.

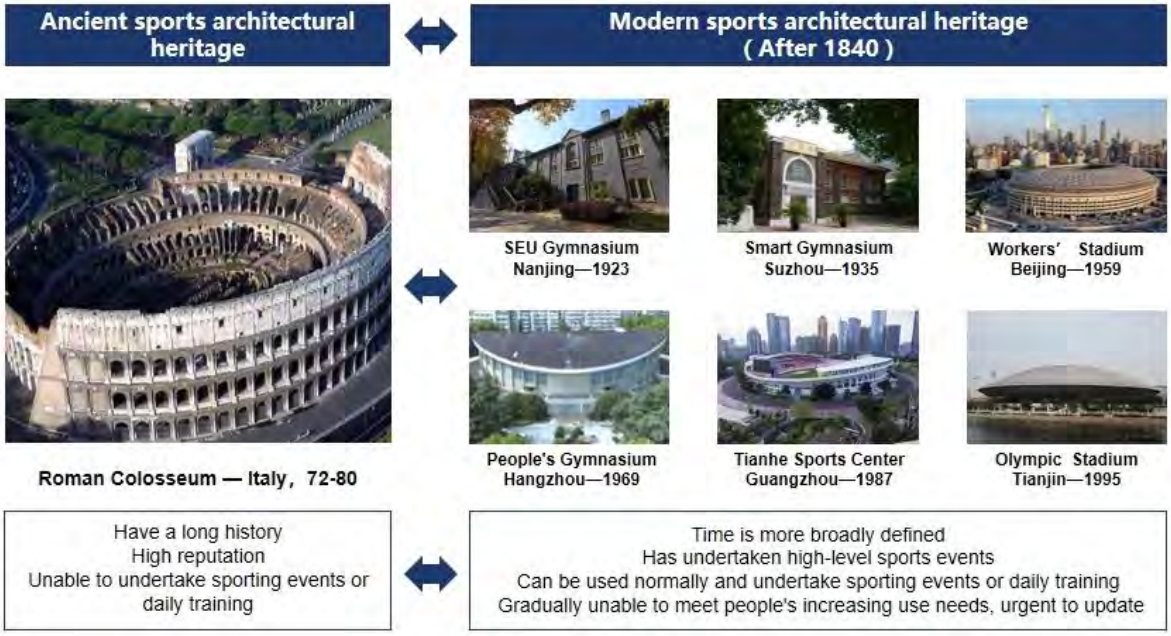


Figure 1. Characteristics of modern sports architectural heritage. Source: Author drawing.

1.2. Application advantages of intelligent renewal technology

With the construction and development of "smart cities," intelligent renewal technology has gradually entered people's vision. By combining technologies such as big data, the Internet of Things, and artificial intelligence for urban construction and stock renewal of existing buildings, the performance of cities and buildings and the quality of public services can be improved. Using smart technology for the intelligent renewal of modern sports architectural heritage can extend the service life of modern sports architectural heritage, endow it with more functions, and better serve humanity.

The intelligent renewal of modern sports architectural heritage is not only a transformation of the building itself but also a comprehensive enhancement of its functions and services. Through the application of intelligent technology, real-time monitoring and regulation of the internal environment of the building can be achieved, ensuring comfort and safety under different usage scenarios. For example, by installing an intelligent temperature control system, the operation of air conditioning and heating can be automatically adjusted according to changes in indoor and outdoor temperatures, maintaining a constant indoor temperature; through an intelligent lighting system, the brightness of indoor lighting can be automatically adjusted according to the intensity of natural light, which is both energy-saving and environmentally friendly. In addition, intelligent technology can also achieve real-time monitoring of the building structure, timely discovering and handling potential safety hazards, and extending the service life of the building. In

the intelligent renewal process of modern sports architectural heritage, data collection and analysis play a crucial role. By collecting and analyzing data on building usage, the operating status of the building under different time periods and usage scenarios can be understood, providing scientific basis for intelligent renewal. For example, by analyzing data on audience flow within sports venues, the entry and exit routes of the audience can be optimized, reducing congestion and improving the audience's viewing experience; by analyzing data on the usage of equipment within sports venues, the maintenance and upkeep of equipment can be reasonably arranged, extending the service life of the equipment and reducing maintenance costs.

In future development, with the continuous advancement of intelligent technology, the intelligent renewal of modern sports architectural heritage will have broader prospects, providing higher quality services and guarantees for human sports activities and urban development.

2. Review of Intelligent Renewal Technologies for Existing Sports Buildings

With the development of building digitization and intelligence, the current intelligent renewal technologies applied to sports buildings are developing rapidly and can be summarized from four aspects: planning, construction, operation and maintenance, and interaction (Figure 2).

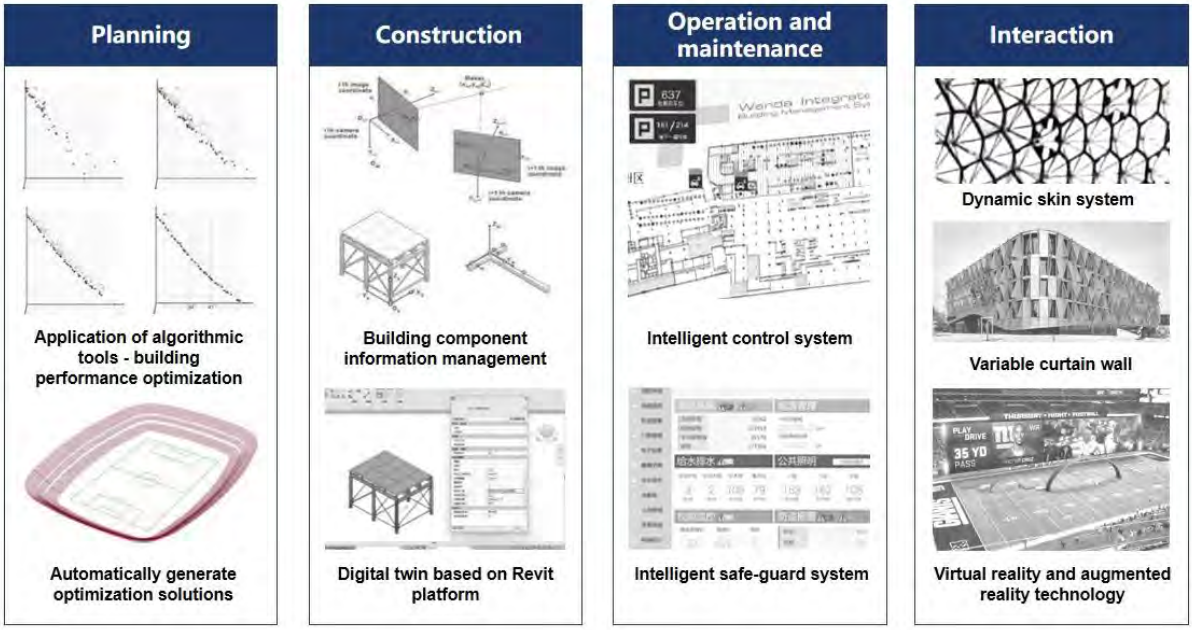


Figure 2. Existing sports building wisdom renewal technology. Source: Author drawing.

The current intelligent planning technology in sports buildings mainly involves the comparison and optimization of renewal plans using algorithm tools. Traditional pre-renewal planning of sports buildings mainly involves manual analysis of the situation of sports buildings and proposing appropriate improvement plans. Algorithm tools are a new type of analysis tool that can intelligently optimize the internal space of sports buildings under goal orientation through the use of algorithm tools, automatically screening out the optimal renewal plan through computer self-learning and analysis. For example, existing research has been able to generate renewal plans for sports venue stands using genetic algorithms with the goal of optimizing audience sightlines, greatly improving the efficiency of pre-renewal planning for sports buildings . This method not only improves the scientific and rational nature of planning but also significantly reduces labor and time costs.

Intelligent construction technology in sports buildings mainly aims to improve efficiency during the construction process by building intelligent information platforms to assist in the construction process. The "Water Cube," which served as a competition venue for the 2008 Beijing Olympics, is the world's first Olympic venue to achieve functional conversion for events. Using BIM as the main data platform during the construction process, each component is assigned a special code and corresponding construction process information is added, ultimately achieving information management for each component during the construction process . The advantage of the intelligent information platform is that it can achieve multi-source data collection and overall analysis, facilitating overall planning and coordination during the construction process, and guiding construction operations through digital twins, reducing the likelihood of errors. This technology not only improves construction efficiency and quality but also effectively controls construction costs and reduces resource waste.

Intelligent operation and maintenance technology in sports buildings mainly involves self-management and automatic adjustment through the installation of intelligent security and environmental control systems, providing high-quality sports activity environments. By installing various sensors within the venue, real-time monitoring of environmental parameters such as temperature, humidity, air quality, and equipment status can be achieved, with real-time data collection and transmission. Using cloud computing platforms to analyze audience flow data can optimize personnel scheduling and resource allocation within the venue, and provide decision support for venue operations by combining big data technology . Through intelligent security systems, real-time monitoring of the safety status within the venue can be achieved, timely discovering and handling potential safety hazards, ensuring the safety of the audience and athletes. These intelligent operation and maintenance technologies not only improve the management efficiency and service level of sports venues but also provide a safer, more convenient, and comfortable experience for the audience.

Intelligent interaction technology in sports buildings mainly involves creating more diverse, high-quality personalized spaces through human-centered interactive design methods. By combining environmental and behavior monitoring technology and component dynamic change technology, sports buildings can be dynamically adjusted for lighting, shading, ventilation, and other environmental issues to meet the needs of athletes and audiences . Through technologies such as movable seats, virtual reality, and augmented reality, viewing interactions can be achieved, creating a viewing environment with atmosphere, aesthetic value, and expressiveness.

3. Content formatting Construction of the Intelligent Grading System for Modern Sports Architectural Heritage

3.1. Interpretation of the Grading Evaluation Standard System

The grading evaluation standard system is a systematic set of evaluation standards and grading methods formulated according to the needs of specific fields, used for systematic evaluation and classification of objects or services. Its purpose is to provide improvement suggestions and enhancement paths through scientific and objective evaluation, helping institutions and organizations in related fields improve service quality and management levels. Currently, the grading evaluation standard system has been applied in various fields such as medical services, education, information technology, and construction.

Clear evaluation standards, multi-level grading methods, and systematic and multi-dimensional evaluation methods are the main characteristics of the grading evaluation standard system (Figure 3). Clear evaluation standards are reflected in the fact that each grading evaluation standard system has a set of clear evaluation standards, which are usually formulated based on best practices and cutting-edge scientific

research in the industry. For example, in the field of medical services, evaluation standards may include multiple aspects such as patient satisfaction, treatment effectiveness, and service efficiency; in the field of education, evaluation standards may cover multiple dimensions such as teaching quality, student performance, and faculty strength. These clear evaluation standards ensure the scientific and objective nature of the evaluation process, making the evaluation results highly credible and operable.

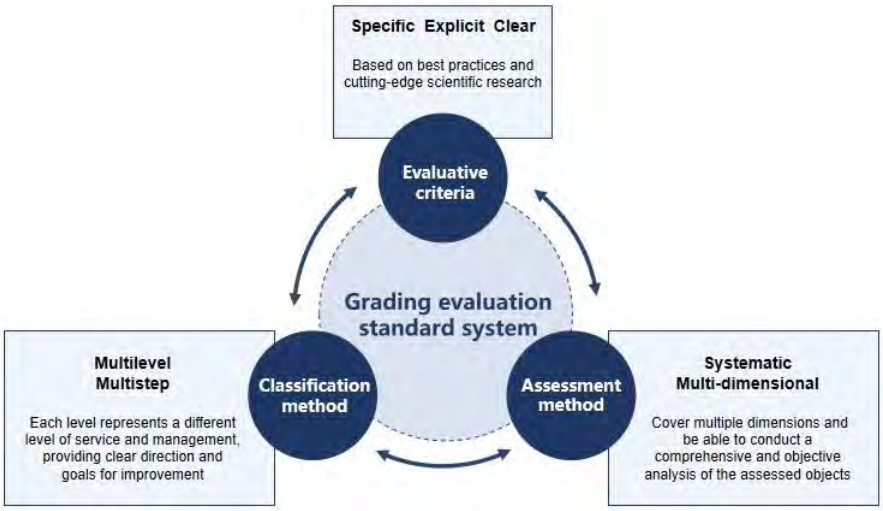


Figure 3. The main characteristics of the grading evaluation standard system. Source: Author drawing.

Multi-level grading methods are reflected in the fact that evaluation results are usually divided into multiple levels, with each level representing different service and management levels. For example, in the field of construction, evaluation results may be divided into four levels: excellent, good, qualified, and unqualified; in the field of information technology, evaluation results may be divided into three levels: advanced, intermediate, and primary. This multi-level grading method not only reflects the actual level of the evaluated object but also provides clear directions and goals for improvement and enhancement.

Systematic and multi-dimensional evaluation methods are reflected in the formulation of evaluation standards, which should cover multiple dimensions and be able to comprehensively and objectively analyze the evaluated object. Systematic evaluation methods are reflected in all aspects of the evaluation process, from the formulation of evaluation standards, collection of evaluation data, analysis of evaluation results to the writing of evaluation reports, all having a set of systematic processes and methods. Multi-dimensional evaluation methods are reflected in the formulation of evaluation standards, which should cover multiple dimensions and be able to comprehensively and objectively analyze the evaluated object.

3.2. Interpretation of the Grading Evaluation Standard System

Currently, representative grading evaluation standard systems in the field of intelligence include the SMART standard formulated by the International Organization for Standardization (ISO) and the SAE J3016 standard formulated by the International Society of Automotive Engineers (SAE).

The SMART standard (Figure 4) is used to evaluate the development degree of machine applicability, readability, and transferability (Standards Machine Applicable, Readable, and Transferable), proposing five evaluation levels based on the nature of content from the real world and virtual world and the different degrees of human-machine interaction. The five evaluation levels of the SMART standard are: L1 Documentation (paper text), L2 Electronization (development data format), L3 Informatization (machine-readable documents), L4 Digitization (machine-readable content), and L5 Intelligence (machine-interactive content).

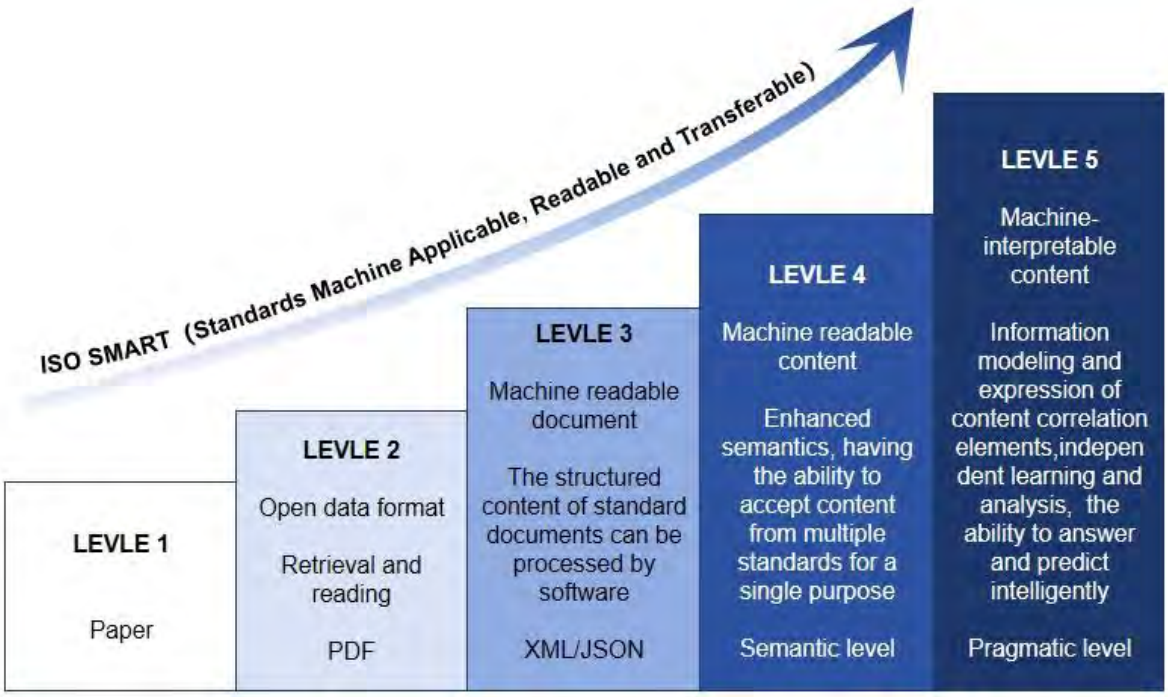


Figure 4. SMART standard and its main contents. Source: Author drawing.

The five evaluation levels of the SMART standard represent different stages of development and technical levels. The L1 Documentation stage mainly refers to the recording and management of paper texts, with a low technical level, mainly relying on manual operations and management. The L2 Electronization stage refers to the electronic management of development data formats, with an improved technical level but still requiring manual intervention. The L3 Informatization stage refers to the management of machine-readable documents, with a further improved technical level, allowing machines to read and process document information. The L4 Digitization stage refers to the management of machine-readable content, with a higher technical level, allowing machines to autonomously read and process content information. The L5 Intelligence stage refers to the management of machine-interactive content, with the highest technical level, allowing machines to autonomously learn, collect information, execute operations, perform automatic Q&A, and make autonomous predictions. When this standard is projected onto the construction industry, there is currently no content in the construction industry that can fully meet the definition of the L5 level or achieve its target effect. The intelligence of buildings is still at the level of converting building information into machine-readable data and solving problems, i.e., L2-L4 levels.

The SAE J3016 standard applies to automotive autonomous driving and is an evaluation standard formulated from an application perspective (Figure 5). Unlike the SMART standard, which judges the degree of technological development, the SAE J3016 standard is formulated from the perspective of practical testing, divided into six evaluation levels from none to full, and provides functional requirements and applicable scopes for each level.

The six evaluation levels of the SAE J3016 standard represent different degrees of automation and technical levels. The higher the degree of driving automation, the higher the evaluation level: L0 level (no automation) refers to a driving system completely operated by a human driver, with the lowest technical level, completely relying on human driver operations. The L1 level (driver assistance) refers to a driving system that can assist in one driving operation, with an improved technical level but still requiring human driver participation. The L2 level (partial automation) refers to a driving system that can assist in multiple driving operations, with a further improved technical level but still requiring human driver monitoring. The L3 level

(conditional automation) refers to a driving system that can complete some driving operations according to people's needs, with a higher technical level, capable of autonomously completing driving operations under certain conditions. The L4 level (high automation) refers to a driving system that can autonomously evaluate road and environmental conditions and automatically respond, with a very high technical level, capable of autonomously completing driving operations in most cases. The L5 level (full automation) refers to a driving system that can be fully operated by an autonomous driving system without human intervention, with the highest technical level, completely relying on the autonomous driving system's operations. When this standard is projected onto the standard formulation of building stock renewal, the renewal results can be used as the judgment standard to grade the degree of building renewal, reflecting the renewal status of buildings through the level of grading. This grading evaluation standard system not only reflects the actual renewal status of buildings but also provides clear directions and goals for building renewal and enhancement.

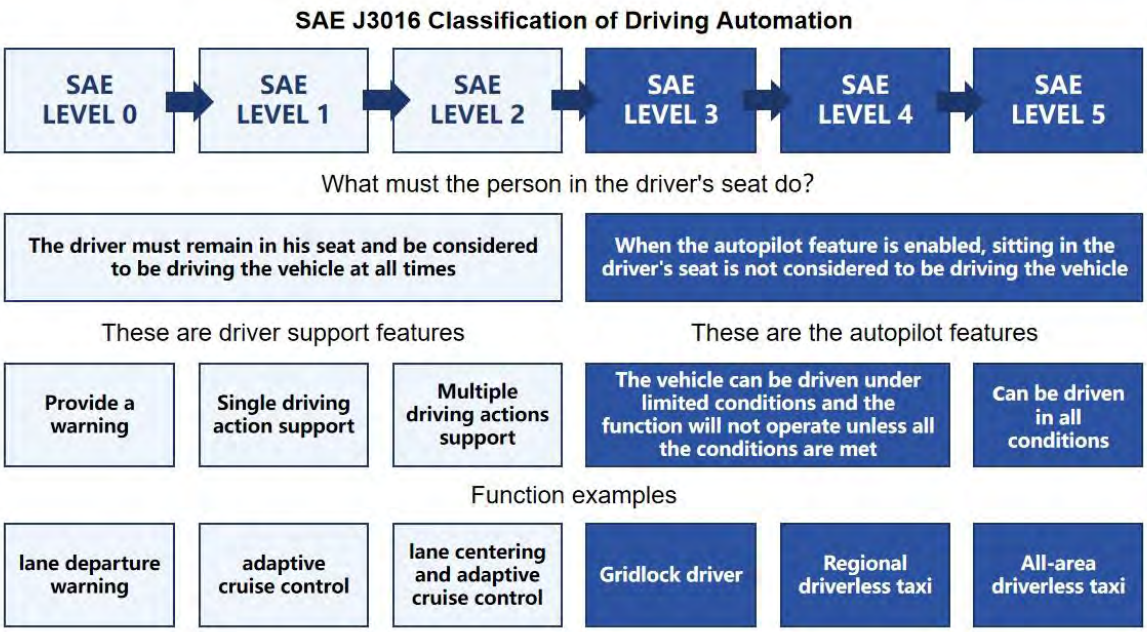


Figure 5. SAE J3016 standard and its main contents. Source: Author drawing.

3.3 Construction of the Intelligent Renewal Grading Evaluation Standard System for Modern Sports Architectural Heritage

Based on the review of intelligent technology and the analysis of existing grading evaluation standard systems, combined with the current status and renewal needs of modern sports architectural heritage, the Modern Sports Architectural Heritage Intelligent Renewal Classification (SAIC) evaluation standard system was established (Figure 6).

The SAIC evaluation criteria mainly involve four aspects: planning, construction, operation and maintenance, and interaction. Planning, construction, and operation and maintenance involve the entire life cycle of the building, while interaction is the enhancement of building performance and space quality brought by intelligent technology. According to the degree of intervention of intelligent renewal technology, SAIC is divided into the following five levels:

SAIC LEVEL 1: Traditional renewal methods for modern sports architectural heritage are still used, without any intelligent renewal technology.

SAIC LEVEL 2: Intelligent renewal technology is used to assist in building planning, with the planning scheme fully formulated or assisted by intelligent technology.

SAIC LEVEL 3: Intelligent renewal technology is used for building planning and construction, further improving the renewal efficiency of modern sports architectural heritage.

SAIC LEVEL 4: Intelligent renewal technology is used for building planning, construction, and operation and maintenance, assisting in the normalized operation of modern sports architectural heritage after renewal.

SAIC LEVEL 5: Intelligent renewal technology is applied to the entire process of planning, construction, operation and maintenance, and interaction of modern sports architectural heritage, enhancing the viewing and performance effects of modern sports architectural heritage through intelligent technology in the normalized operation after renewal.

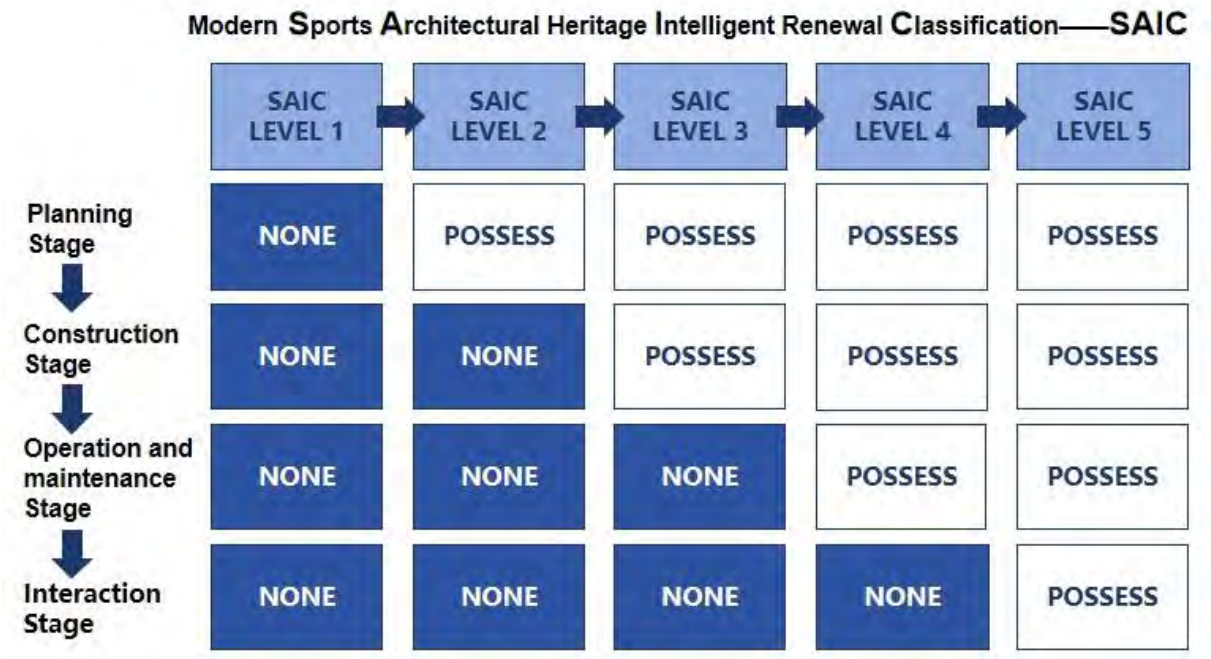


Figure 6. SAIC - Grading and evaluation standard system for intelligent renewal of modern sports architectural heritage. Source: Author drawing.

SAIC is a highly flexible and dynamically changing evaluation standard system (Figure 7). Today, people are in an era of technological explosion. Contrary to the rapid development of technology, the renewal of modern sports architectural heritage is a long process, taking years or even decades to complete. During the process from project initiation to renewal completion, intelligent renewal technology will also develop rapidly. Therefore, the formulation of standards should focus on "whether the technology has been applied and created value" rather than "whether the technology is the most advanced." At the same time, each intelligent renewal process can allow modern sports architectural heritage to be repeatedly evaluated and improve the building's evaluation level. If SAIC is concerned by the construction industry, it will undoubtedly promote the development process of intelligent renewal of modern sports architectural heritage.

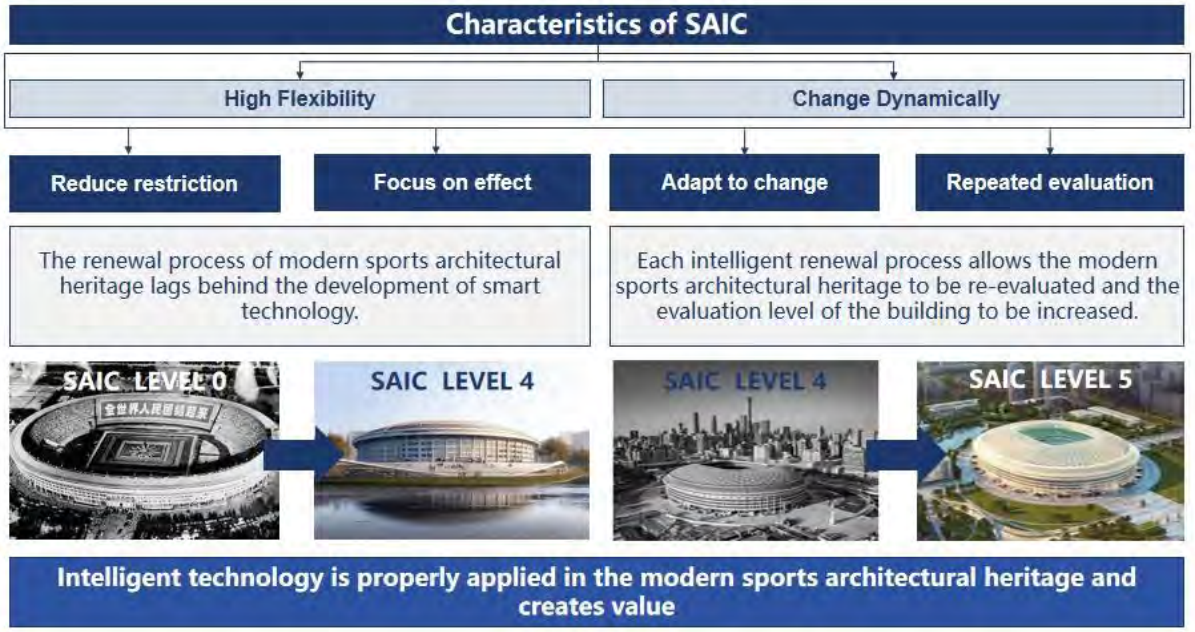


Figure 7. Characteristic interpretation of SAIC. Source: Author drawing.

4. Content formatting Construction of the Intelligent Grading System for Modern Sports Architectural Heritage

By analyzing the formulation process of SAIC, the intelligent renewal path of modern sports architectural heritage can be revealed (Figure 8).

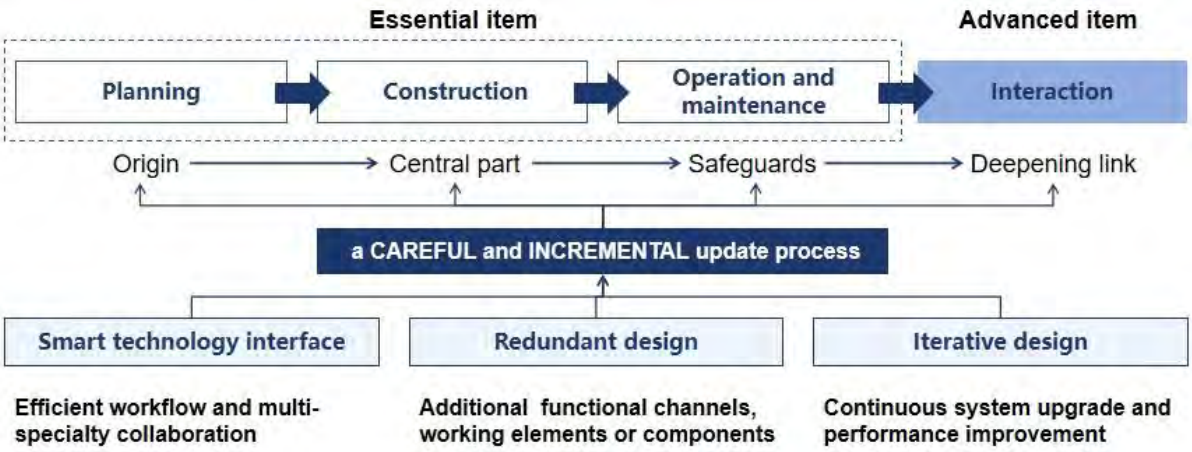


Figure 8. Characteristic interpretation of SAIC. Source: Author drawing.

First, planning, construction, operation and maintenance, and interaction are four essential links in the intelligent renewal of modern sports architectural heritage. Among them, planning, construction, and operation and maintenance are necessary projects in the renewal process, while interaction is further deepened based on the development of the first three contents. The planning stage is the starting point of intelligent renewal. In this stage, architects and related experts need to comprehensively evaluate modern sports architectural heritage, determine its current status and aspects that need improvement, and formulate detailed renewal plans; the construction stage is the core link of intelligent renewal. Architects

and construction teams need to use intelligent technology to update and transform modern sports architectural heritage according to the plans formulated in the planning stage, improving the building's use value and lifespan; the operation and maintenance stage is the guarantee link of intelligent renewal. In this stage, architects and operation and maintenance teams need to continuously monitor and maintain the renewed modern sports architectural heritage, ensuring its normal operation and use, and ensuring the long-term stability and safety of the building; the interaction stage is the deepening link of intelligent renewal. Through the application of intelligent technology, the user experience and satisfaction of modern sports architectural heritage can be improved.

Secondly, although intelligent technology can directly intervene in any link of the renewal process of modern sports architectural heritage, a successful renewal project must be a cautious and gradual process, with good coordination between intelligent technologies throughout the entire renewal workflow. Finally, when architects use intelligent technology to renew modern sports architectural heritage, corresponding safeguard measures need to be formulated, such as adopting redundant design and iterative design. Redundant design refers to adding more than one functional channel, working element, or component that completes the same function in the intelligent systems or intelligent devices that play a key role in modern sports architectural heritage. When this part fails, the system or device can still work normally, reducing the probability of system or device failure and improving the reliability of modern sports architectural heritage after renewal. Iterative design refers to considering the renewal and optimization of intelligent systems and intelligent devices during the renewal process to meet the changing needs of users, continuously upgrading systems and improving performance, ensuring the effective application of intelligent technology in the renewal of modern sports architectural heritage, and improving the quality and use value of the renewed buildings.

5. Summary

The intelligent renewal of modern sports architectural heritage is a complex and multi-faceted process involving multiple aspects such as technology, culture, and environment. Analyzing the intelligent renewal of modern sports architectural heritage from the perspective of smart grading can actively respond to the current intelligent needs of buildings and cities, provide directional renewal paths, and promote the development of related industries towards standardization, normalization, and systematization.

6. References

Chen, L. (2006), Conservation and Restoration Project of the Cultural Heritage Building of Shanghai Jiangwan Stadium, *Times Architecture*, (2), p. 76-81.

Eckelman, M. J., Brown, C., Troup, L. N. , et al. (2018), Life cycle energy and environmental benefits of novel design-for-deconstruction structural systems in steel buildings, *Building and Environment*, 143, p. 421-430.

Feng, S. and Song, M. (2023), 'Research on Interactive Design Strategies of Sports Buildings under Intelligent Operation Mode', *Contemporary Architecture*, (07), p. 129-132

Guo, M., Zheng, Q., Cai, Z., et al. (2010), The Renovation of Guangzhou Tianhe Sports Center, *Architectural Creation*, (11), p. 180-185.

He, J., Guo, W., and Wu, Z. (2006), Design of the State Key Laboratory of Subtropical Building Science, South China University of Technology, *Architectural Journal*, (04), p. 42-45.

Lin, Z. (2011), Nakagin capsule tower: Revisiting the future of the recent past, *Journal of Architectural Education*, 65(1), p. 13-32.

Lu, Y. and Sun, Y. (2021), Research on the Value Connotation and Renewal Mode of Existing Gymnasiums in China, *Architectural Journal*, (S1), p. 165-168.

Lu, Y. and Sun, Y. (2022), Protection and Renewal Design Strategies of Modern Sports Architectural Heritage: A Case Study of the Municipal Sports Center in Turin, Italy, *Journal of Western Human Settlements*, 37(06), p. 101-109.

Ma, G. (2008), *Collection of Large-scale Public Building Designs: National Swimming Center*. Beijing: China Architecture & Building Press.

Mei, H., Fei, T., and Wang, F. (2010), Research on Design Strategies for Large-scale Public Buildings in the Context of a Low-carbon Economy, *Architectural Journal*, (S1), p. 106-109.

Miao, M. and Jin, L. (2013), On the Protection and Utilization of Olympic Architectural Heritage, in *Proceedings of the Protection and Utilization of Architectural and Cultural Heritage*, Tianjin University Press, pp. 62-68.

Meng, Q. (2021), Construction Plan of Intelligent Management Platform for Sports Venues Based on Intelligent Security System, *Intelligent Building*, (03), p. 32-36.

Navarro-Rubio, J., Pineda, P. and Garcia-Martinez, A. (2019), Sustainability, prefabrication, and building optimization under different durability and re-using scenarios: Potential of dry precast structural connections, *Sustainable Cities and Society*, 44, p. 614-628.

Thomson, A., Cuskelly, G., Toohey, K., et al. (2019), Sport Event Legacy: A Systematic Quantitative Review of Literature, *Sport Management Review*, 22(3), p. 295-321.

Tan, Z. and Xu, J. (2020), Design trends of prefabricated buildings from a full life cycle perspective: A study based on disassemblable design, *Residential Science and Technology*, 40(5), p. 33-40.

Wang, C. and Zhao, H. (2011), *Strategies and Practices of Green Building Design*. Beijing: China Architecture & Building Press.

Wang, X., Li, Y., Zhou, Z., et al. (2023), Exploration of Intelligent Construction Technology for Rebuilding: Research on the Digital Design and Construction Strategy of the Ice-Water Conversion Structure of the "Ice Cube", *Architectural Skills*, 29(02), pp. 74-79.

Xu, N. and Xu, X. (2019), Design Strategies for the Renovation and Reuse of Industrial Historic Buildings: Taking the Expansion and Renovation of the University of California, Berkeley Art Museum and Pacific Film Archive as Examples, *New Architecture*, (5), p. 57-61.

Yang, Z. (2013), Considerations of Energy Saving and Environment in Public Building Design, *Urban Architecture*, (14), p. 182.

Yu, H. and Qian, F. (2024), Research and Application of Visual Quality Evaluation System for Sports Building Audience Seats, *Architectural Journal*, (02), pp. 29-35.

Zhang, T. and He, Y. (2011), The Evolution of Thoughts on Building Renewal in China and Its Development Trend, *Urban Development Studies*, 18(1), p. 25-30.

Case Study Report

A study on the digital portrayal of user groups of urban park green spaces in the main urban area of Nanjing based on LBS data

Ying Tan; Jiarui Hu; Yijing Lin

Department of Landscape Architecture, School of Architecture, Southeast University, China

Abstract

From the perspective of humanism, this paper focuses on the issue of different people's preference for the use of urban parks and green spaces. With the deepening process of urbanisation, people's pursuit of urban park green space no longer stays in the simple average number and area, but focuses more finely on the problem of the difference in the use preference between different groups of people. This study collects mobile location-based service (LBS) data on the use of park green space by the resident population in the main urban area of Nanjing in October 2019, and builds a multi-source data platform by combining urban geographic information data and urban house price data. The group adopts the method of stopping point identification and income classification to clean and organize the information of the population, classifies the population into 7 labels from the ontological dimension and behavioural dimension, and carves labels on all the populations to construct the user portrait of the urban parks and green spaces, and generates 493 population types. By comparing and analysing the main crowd labels in different regions and parks, the results reveal different behavioural patterns among different park green space user groups, with short-term visits and low-frequency activities dominating. This study helps us to gain a deeper understanding of the applicable groups of different park green spaces and their actual needs, and also lays the foundation for subsequent behavioural activity preference studies, which can better guide the planning and design of urban park green spaces.

Keywords

urban park green space, digital profiling, LBS data, refined analysis

1. Explanation of context

1.1. Humanistic turn of urban park green space

Initially, urban park green space focused primarily on spatial layout, structure, and functionality, prioritizing aesthetic appeal and practicality (Berleant, 1997). However, the rise of humanistic thought shifted this focus towards human emotions and needs, highlighting the subjective experiences of individuals in urban green spaces (Reyes-Riveros et al., 2021). The integration of urban spatial data enables the analysis of recreational behaviors and psychological perceptions, allowing designers to center

their work on human interactions with these spaces. This shift necessitates a transition from merely designing physical environments to considering human behaviors, experiences, and cultural contexts.

The roots of this humanistic perspective can be traced back to the 19th century, a period marked by significant social transformations and cultural awakenings that emphasized human-centric needs(Bland and Derobertis, 2019; “ Humanistic Approach In Psychology (humanism),” 2023). This ideological shift informed the design of landscapes, architecture, and urban planning, urging designers to incorporate psychological and social factors into their creative processes. Consequently, urban parks evolved beyond mere layout considerations, increasingly focusing on providing spaces for leisure, social interaction, and cultural engagement.

In contemporary urban settings, incorporating humanistic principles into design yields numerous advantages. The concept of humanistic planning and design allows urban planners to create aesthetically pleasing and functional public spaces by paying attention to the different needs of different groups of people. By paying more attention to the behavioural preferences and urban activity habits of different groups, planning and design can be more closely aligned with the needs of community residents, enhancing their sense of belonging and satisfaction. The popularisation of such concepts and the raising of awareness is a sign that urban construction is moving towards a new stage, and accordingly, it also puts forward new requirements on the methods and approaches of urban planners to solve urban problems. This study will use big data to analyse the population in a more refined way.

1.2. Fine construction of urban green space

The rapid pace of urbanization and heightened demand for ecological environments have rendered traditional approaches to urban green space construction inadequate (Zhang et al., 2021). The focus of people's attention on urban development has shifted from the physical to the social level, which has led to the development of all aspects of urban construction, including urban green space, in the direction of refinement (Knobel et al., 2021; Zhang and Qian, 2024). The refined transformation here is reflected in the whole process of urban construction, including urban planning, design, construction and post-construction management, in which data analysis based on digital technology is an important means. Researchers worldwide are actively exploring scenarios and ways of applying digital technologies at many levels of planning, design and management of urban green spaces. For example, tools such as remote sensing technology and geographic information systems (GIS) have enhanced the assessment and monitoring of urban green spaces. In addition, the application of various data analysis methods provides strong support for assessing the needs, costs and benefits of green space construction.

The future of urban green space construction is poised to advance in areas such as digitization, intelligence, and sustainability (Farkas et al., 2023). Intelligent decision support systems will enhance planning accuracy, while the Internet of Things will promote effective management and monitoring (Kaklauskas and Gudauskas, 2016; Soori et al., 2024). Emphasizing sustainable development will ensure the harmonious integration of ecological, economic, and social benefits, fostering collaborative governance and public participation in green space initiatives.

1.3. Research trends in digitalization

With the use of big data, the development in the design of the landscape has been a result of theapplication of digital technologies (Bibri, 2021). "digital design"refers to changing the direction of judgments,which favors the use of data-driven calculations and analysis to inform design procedures, a change ofdesign concept from one to the other. Design design is very different because of the integration of technicaland design features, which increases the specificity and relevancy of planning.

Using big data, the digital population is used to more closely investigate the characteristics, and different groupbehavioral patterns are revealed, which not only increases the amount of resources used in urban service (Rashidand Kausik, 2024).Big data and artificial intelligence are used to the point that it makes possible to use digitaltools in different contexts (Samadhiya et al.， 2022, 4): landscape architecture, where studies concentrate on thedynamic interactions that occur in different places, is aided by the intersection of big data with artificialintelligence (Samadhiya et al.，2014).

With the help of "data-driven" analyses, which are now important in competitive design methods, thetrend of digital transformation is becoming important in landscape architecture. In order to achieveconcrete results in landscape design, future directions will place a strong emphasis on the practicalapplication of digital designs and the use of technologies such as big data and cloud computing platforms.

2. Data

2.1.The spatial and temporal domains of the research object

This study focuses on Nanjing's main urban area, selected for its role as the capital of Jiangsu Province and a strategic hub in East China's development initiatives. With an urbanization rate of 86.9% as of 2021, Nanjing is pivotal in promoting high-quality population growth and establishing a modern socialist city. Understanding the diverse needs and behaviors of its residents is essential for guiding people-oriented urban planning.

Nanjing consists of eleven districts covering 6,587.02 square kilometers, with this research narrowing its focus to approximately 808.70 square kilometers within the central urban area, which includes Xuanwu, Qinhuai, and Gulou Districts, among others. This specific delineation ensures a comprehensive and representative analysis.

Data collection occurred over seven days from October 14 to October 20, 2019, avoiding the National Day holiday to maintain data integrity. The favorable autumn climate promoted outdoor activities, enriching the collected social activity data. This period encompasses both weekdays and weekends, allowing for a detailed examination of behavioral variations across different schedules.

2.2. Data source

To fulfill the research requirements for digital portraits of Nanjing's urban population, this study establishes a multi-dimensional data infrastructure framework. This framework aims to thoroughly characterize the urban population and their geographic associations, incorporating two main data categories: population data and geographic space data, sourced from authoritative channels to ensure accuracy.

(1) Mobile Location-Based Services (LBS) Data: This research utilizes LBS data from a leading mobile information platform in China, comprising 69,436,255 trajectory points from 1,227,724 users. The data, encrypted for privacy, underwent preprocessing for standardization and cleaning, ensuring high integrity.

(2) Population Spatial Data: Age distribution data from Nanjing's seventh population census provides a benchmark for comparative analysis with LBS-derived data, offering macro-level insights into population distribution.

(3) Park Green Space Data: Spatial information of the 299 parks was recorded using Geographic Information System (GIS) and remote sensing technology, including the name of the park, its geographical coordinates, its area and whether it is fee-paying.

(4) Residential Land Data: Crawling residential land information from Baidu map in the main urban area of Nanjing and manually verifying it in the GIS software, the data information of 3992 residential neighbourhoods was finally collected.

(5) House Price Data: The second-hand house price information of 5,048 residential neighbourhoods in Nanjing in 2023 was crawled from Shell.com and converted into coordinates using ArcGIS for residential land price classification.

3. Methodology

In this study, we firstly identified the stay points by introducing the density-based stay point identification method (SPID) (Qiu et al., 2023), and then combined the house price information with the spatial correlation analysis to accurately portray the income level of the resident population, and established a dataset for the analysis of the crowd's portrait. Finally, combined with data calibration, the portrait type of crowd behaviour data is analysed, which provides powerful support for urban planning and public service optimisation.

3.1. Stoppoint Identification Based on Density

Currently, three mainstream method systems have been developed for the research of stop identification: clustering oriented method, probabilistic inference method and distinction recognition method. Among them, the clustering-oriented method focuses on the spatio-temporal aggregation of trajectory data, which is difficult to fully incorporate complex spatial constraints; the probabilistic inference method, such as the use of Bayesian model, Gaussian mixture model and other probabilistic frameworks, often ignores the dynamic changes of the time series of the trajectory data and the differences between them; and the differentiation identification method stresses the clear definition of stopping points and representative points, but its analytical framework fails to fully integrate the temporal and spatial aggregation characteristics embedded in the trajectory points. The differentiated discrimination approach, on the other hand, emphasises the clear definition of stopover points and representative points, but its analytical framework fails to fully integrate the spatio-temporal aggregation characteristics embedded in trajectory points. To address these limitations, SPID (Stay Point Identification based on Density) method was proposed(Jianfeng L.U. et al., 2020), which enhances understanding of spatio-temporal patterns while respecting trajectory continuity. This paper adopts the SPID method to identify stay points within Nanjing's LBS data, as detailed in the following steps.

① Time Series Trajectory Chain. For each user, the cleaned daily trajectory point data are arranged in chronological order to constitute the complete one-day time series trajectory data set of each user, which is denoted as:

$$\text{Track} = \{P_1,\ P_2,\ \cdots,\ P_n\}$$

$$P_i = (x_i,\ y_i,\ t_i)$$

Among them, $Track$ represents the reconstructed user travel chain, P_i indicates the i-th trajectory point of the user, (x_i, y_i) represents the position coordinates of the trajectory point, and t_i represents the corresponding time.

② Forward and Backward Search. Starting from each trajectory point P_i in the time-sequence trajectory dataset, search both forward and backward along the time sequence for all trajectory points within a certain spatial threshold d_{th} in space. Set them as the density interval P_i.interval = [P_{is}, P_{ie}], and calculate

the density P_i density and the time span P_i timespan of the trajectory point P_i within this interval, denoted as:

$$P_i.\text{density} = \text{ie} - \text{is} + 1$$

$$P_i.timespan = t_{ie} - t_{is}$$

Among them, represents the density of the trajectory points, which is represented by the number of trajectory points within this density interval, and P_i.time span represents the time span of the trajectory points.

③ Generation of candidate density intervals. Trajectory points for which P_i.time span exceeds the time threshold t_{th} are set as candidate stay points, and the density intervals in the candidate list are sorted in descending order of density;

④ Stay point identification and candidate update. From the candidate list, the first candidate stay point with the highest density is identified as the stay point sp, and the trajectory points it contains are excluded from the remaining candidate density intervals;

⑤ Trajectory points are updated to recalculate density and time span, identifying candidate stay points for secondary sorting(Huang et al., 2021) . This study employs a spatial threshold of 100 meters and a time threshold of 10 minutes, resulting in 5, 127,510 stay points from 48,702, 144 LBS trajectory data involving 593, 136 individuals.

3.2. Population Screening and Income Classification

According to the 2023 "Statistical Bulletin on National Economic and Social Development of the People's Republic of China," residents were classified into five income groups by quintiles: low-income, lower-middle income, middle income, upper-middle income, and high income. To enhance research applicability, this study combined the bottom 40% of households (original low- and lower-middle-income groups) into a new low-income category. The middle 40% (original middle- and upper-middle-income groups) were classified as middle income, while the top 20% remained as high income.

In this study, the spatial correlation analysis technique was first used to match the residential land use data with the corresponding house price information. Subsequently, based on the above adjusted income class classification criteria, the residential neighbourhoods were accurately classified into the corresponding income class categories(Li et al., 2019; Wang et al., 2017). Based on the identification of basic stopping points, we further focus on the identification of night-time stopping points, and adopt the threshold filtering method to screen out the location where each user stayed for the longest time between 0:00 a.m. and 6:00 a.m. on 14th October 2019 as the user's residency identifier, and ultimately converge into the dataset of the resident population of Nanjing containing 411,283 entries that are closely related to the income class.

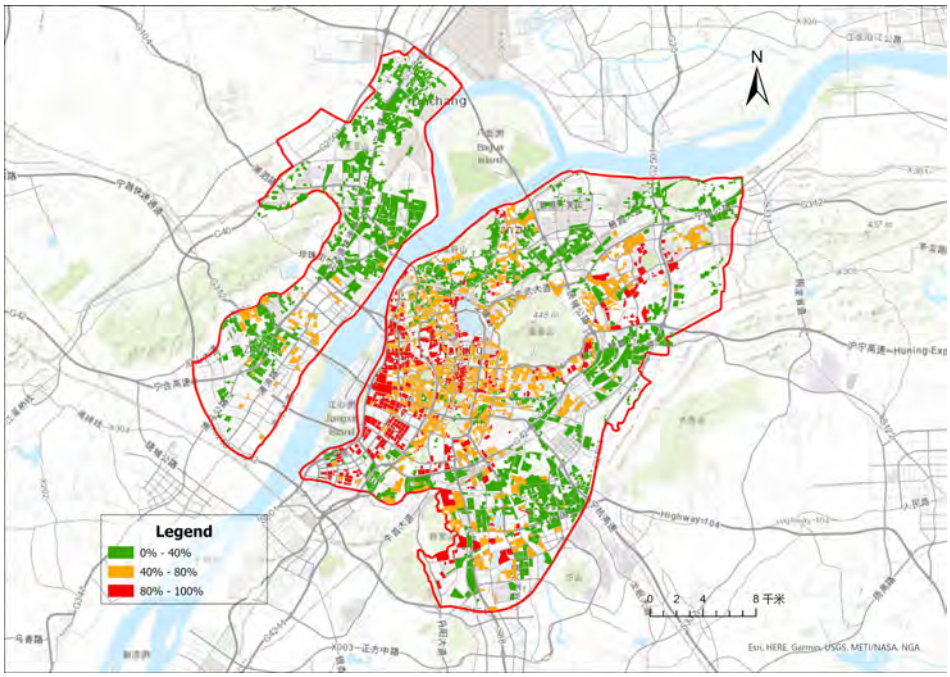


Figure 1. Classification of residential property prices. Source: Self-drawn by the author.

3.3. Effective Behavioural Point Extraction for Park Users

Based on the pre-processing of the research LBS trajectory data, the identified stopping point data is precisely matched with the park green space data, thus realising the statistics on the frequency of activities, the total length of stay and the travel distance of the crowd visiting the park green space.

A combined time threshold method established rules for identifying effective behavioral points related to residential-park interactions. Specifically, trajectory points within 100 meters and with a minimum stay of over 10 minutes were classified as stop points, using the convex hull method to spatially represent these locations. This resulted in 28,350 convex hulls linked to 1,575,609 trajectory points, yielding ID data for residents frequenting Nanjing's parks.

Trajectory points separated by at least 100 meters or with stays under 10 minutes remained as scattered points. Python code was employed to consolidate behaviors occurring within the same park on the same day, while single record trajectory points were retained as isolated entries. The processing methodology applied to seven consecutive days produced a dataset of 43,304 effective behavior records associated with 26, 119 unique IDs, comprising 21,838 recorded stops and 21,466 trajectory entries.

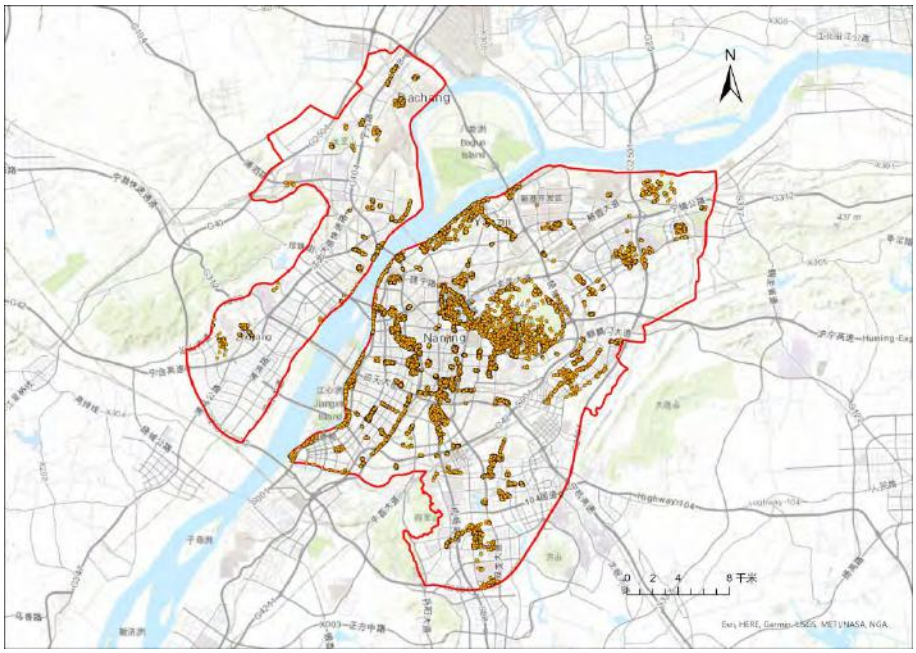


Figure 2. Effective stopping point extraction. Source: Self-drawn by the author.

4. Results

4.1. Feature Extraction of Ontology Dimension

The examination of population characteristics engaged in Nanjing's urban green spaces reveals nuanced trends. Gender distribution is balanced, with males 51.1% and females 48.9%. Age skews towards working-age adults, as 56% are 26-35 years old, while 14% are over 45, indicating the need to cater to diverse user preferences. Income levels are skewed towards lower socioeconomic groups, with 42% low-income and 44% middle-income, underscoring the importance of equitable access and inclusive design. Geographically, a significant proportion reside in Gulou (21.7%) and Jianye (16.9%) districts, suggesting locational influences on visitation patterns. These insights can guide targeted strategies to enhance green space utilization across Nanjing's neighborhoods.

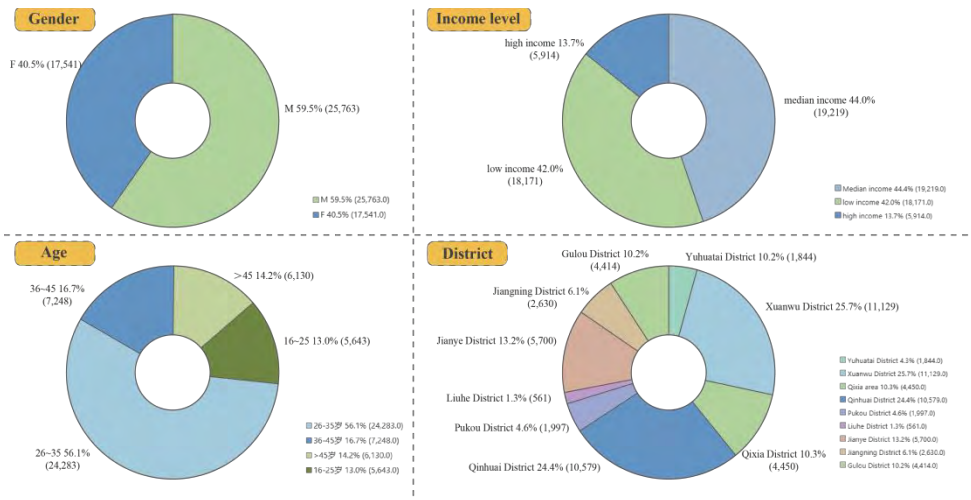


Figure 3. Ontology dimension attribute analysis. Source: Self-drawn by the author.

4.2. Feature Extraction of the Behavior Dimension

The behavioral dimensions of park users were further examined through analyses of travel distance, stay time, and activity frequency. These attributes were categorized into low, medium, and high levels using natural break point methods, resulting in 27 distinct behavioral types.

The analysis reveals that 86% of users exhibit short stay times, with only 3% engaging in longer visits, indicating a preference for brief interactions in urban green spaces. Most users (29,000 trips) traveled 0-5 kilometers, further highlighting this trend. Additionally, the most common activity frequency was 1-2 visits (18,000 occurrences). Collectively, short-distance travel and low-frequency activities account for 67% and 61% of users, respectively, underscoring the need for green space design that aligns with community preferences.

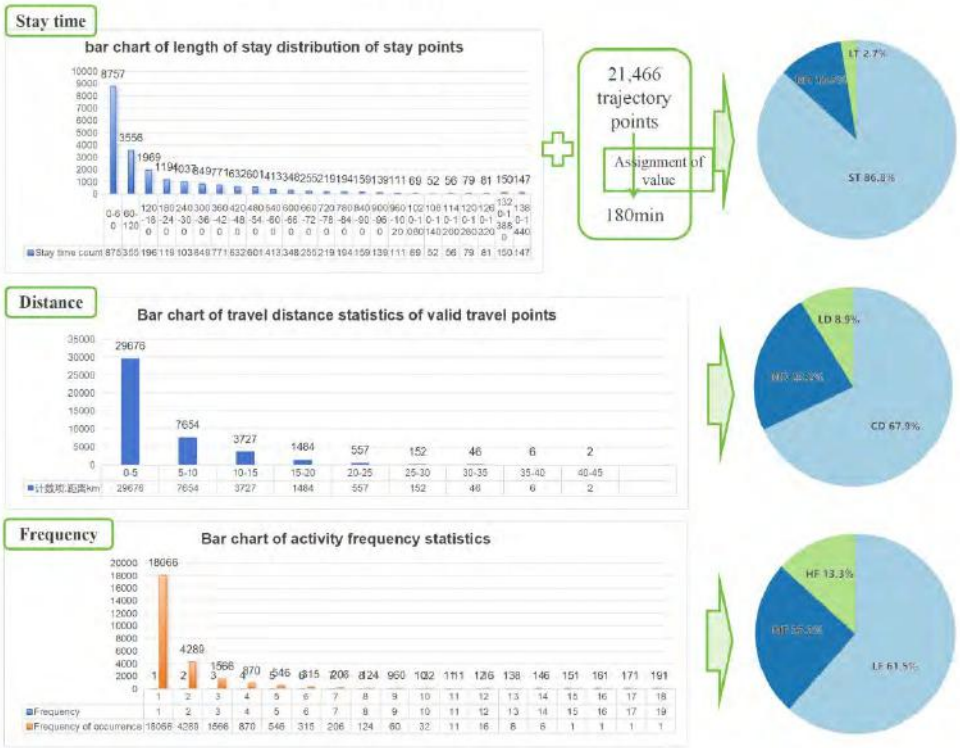


Figure 4. Behavior dimension attribute parsing. Source: Self-drawn by the author.

The analysis of the population composition within the study area reveals a diverse distribution across various demographic profiles. The largest segment is the ST-LD-LF type, accounting for 15.6%, closely followed by the ST-CD-LF category at 9.07%. Overall, short distance travelling (CD) dominates the activities of people visiting parks and green spaces in the main urban areas of Nanjing, accounting for 23.97%. This result reflects that residents in Nanjing main urban areas prefer to choose park green spaces in close proximity for leisure activities, which may be related to the convenience and accessibility of park green spaces as well as residents' daily activity habits. The number of short-distance trips gradually decreases as the frequency of activities increases, but the overall proportion remains high, indicating that low-frequency and medium-frequency short-distance trips are the main modes for residents to visit park green spaces. The proportion of medium distance (MD) trips, whilst lower than short distance trips, remains an important component. However, under long stay (LT) conditions, the number of medium distance trips is relatively small and, in particular, high frequency activities (HF) are almost negligible. Long trip distances (LD) had the lowest share of all trip distances and showed a more significant decreasing trend in numbers with increasing length of stay and frequency of activity.

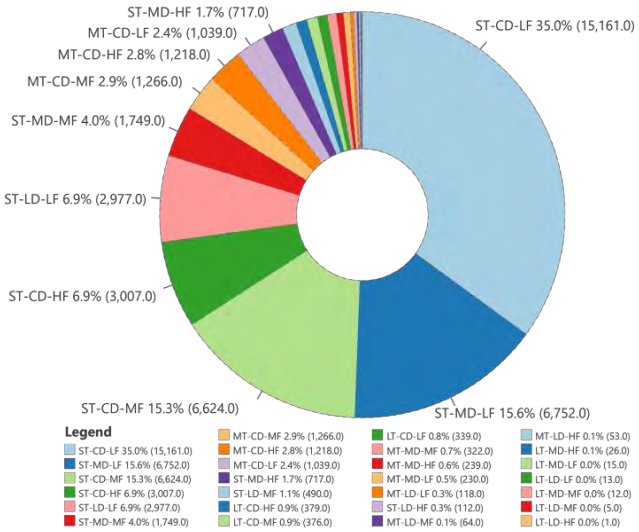


Figure 5. Behavioural dimension label classification and percentage. Source: Self-drawn by the author.

4.3. Area distribution statistics of digital portrait types of urban people in Nanjing

The geographical distribution of the portrait of people using park green space in the main urban area of Nanjing shows obvious differences. For instance, the M-Age-30-Median I-ST-CD-LF type accounted for 4.58% in Gulou District, while it reached 6.75% in Jianye District, a huge difference. In addition, the M-Age-30-Low I-ST-CD-MF type accounted for as much as 16.22 per cent in Luhe District, almost twice as much as in other districts.

These nuanced demographic differences across neighborhoods underscore the need for tailored urban green space strategies to cater to the specific community needs and preferences. The data provides valuable insights for developing nuanced approaches that account for the diverse demographic characteristics within Nanjing's main urban area (“ Urban green space disparities: Implications of environmental injustice for public health - ScienceDirect,” n.d.; Yang et al., 2022). By leveraging these insights, urban planners and policymakers can optimize the distribution and design of green spaces to better serve the varying preferences and needs of different neighborhoods in Nanjing (“ Residents’ Preferences and Perceptions toward Green Open Spaces in an Urban Area,” n.d.).

Type	Gulou District	Jianye District	Jiangning District	Liuhe District	Pukou District	Qixia area	Qinhuai District	Xuanwu District	Yuhuatai District	Total
M-Age-30-Median_I-ST-CD-LF	4.58%	6.75%	3.35%	0.18%	0.50%	2.52%	7.00%	5.34%	5.69%	5.17%
M-Age-30-Low_I-ST-CD-LF	3.29%	1.75%	15.13%	15.86%	14.87%	9.51%	1.48%	2.42%	3.52%	4.49%
F-Age-30-Median_I-ST-CD-LF	3.38%	4.23%	1.86%	0.00%	0.30%	1.46%	5.75%	3.32%	4.07%	3.61%
F-Age-30-Low_I-ST-CD-LF	2.63%	1.67%	8.78%	16.22%	12.17%	7.17%	1.33%	1.76%	1.90%	3.39%
M-Age-30-Low_I-ST-MD-LF	2.42%	1.82%	2.17%	1.78%	2.05%	2.97%	2.23%	4.22%	3.85%	2.84%
M-Age-30-Median_I-ST-CD-MF	1.84%	4.00%	0.84%	0.00%	0.10%	0.94%	4.34%	2.39%	3.80%	2.70%
F-Age-30-Low_I-ST-MD-LF	1.50%	1.46%	1.52%	0.71%	1.50%	1.98%	1.85%	3.06%	1.74%	2.03%
M-Age-40-Median_I-ST-CD-LF	2.04%	2.37%	0.57%	0.00%	0.15%	0.70%	2.40%	1.91%	2.22%	1.81%
F-Age-30-Median_I-ST-CD-MF	1.36%	2.11%	0.61%	0.00%	0.05%	0.54%	2.64%	1.84%	3.15%	1.76%
M-above45-Median_I-ST-CD-LF	1.93%	2.30%	1.03%	0.00%	0.00%	0.65%	2.45%	1.80%	1.57%	1.76%
M-Age-30-Low_I-ST-LD-LF	1.40%	2.18%	1.41%	0.89%	1.60%	1.75%	1.34%	2.12%	2.39%	1.76%
M-Age-30-Median_I-ST-MD-LF	1.29%	1.88%	1.29%	0.00%	0.55%	1.44%	1.21%	2.67%	2.28%	1.71%
M-Age-30-High_I-ST-CD-LF	3.67%	3.33%	0.49%	0.00%	0.00%	0.67%	1.56%	1.12%	1.46%	1.64%
M-Age-30-Low_I-ST-CD-MF	1.20%	0.88%	3.99%	4.81%	4.46%	3.62%	0.67%	0.87%	0.70%	1.54%
M-Age-30-Median_I-ST-CD-HF	1.25%	1.88%	0.38%	0.00%	0.00%	0.67%	2.52%	1.03%	0.76%	1.38%
F-Age-30-Low_I-ST-CD-MF	1.52%	0.88%	2.89%	4.81%	3.15%	2.31%	0.65%	0.73%	0.33%	1.25%
F-Age-40-Median_I-ST-CD-LF	1.52%	1.39%	0.42%	0.00%	0.00%	0.61%	1.72%	1.27%	1.57%	1.24%
F-Age-30-Median_I-ST-MD-LF	0.93%	1.26%	0.53%	0.00%	0.55%	1.01%	0.97%	1.94%	1.30%	1.21%
F-Age-30-Low_I-ST-LD-LF	0.59%	1.28%	0.61%	0.36%	0.65%	1.21%	1.13%	1.59%	1.63%	1.18%
M-Age-40-Low_I-ST-CD-LF	1.04%	0.21%	3.65%	3.92%	4.01%	2.34%	0.35%	0.76%	0.92%	1.15%
M-Age-40-Median_I-ST-CD-MF	1.02%	1.18%	0.87%	0.00%	0.20%	0.40%	1.18%	1.10%	1.74%	1.01%
M-Age-20-Median_I-ST-CD-LF	0.82%	1.12%	0.68%	0.00%	0.10%	0.47%	1.55%	0.99%	1.08%	1.00%
F-Age-30-High_I-ST-CD-LF	2.58%	1.95%	0.42%	0.00%	0.05%	0.27%	0.80%	0.78%	0.70%	1.00%

Figure 6. Area distribution statistics of digital portrait types of urban people in Nanjing. Source: Self-drawn by the author.

5. Broader Project Impact

This research project has significant implications for advancing equitable spatial policies. By integrating the aforementioned data with an analysis of demographic characteristics, we are able to conduct a more detailed examination of behavioral preferences within the population, encompassing both behavioral and efficiency indicators (Xie et al., 2023).

Using the above data in combination with crowd profiling, we can further analyse the behavioural preference characteristics of the crowd, including the behavioural index and efficiency index. The Behavioural Index mainly measures the use and satisfaction of the public towards the green space, reflecting the social value and humanistic care of the green space; while the Efficiency Index focuses on the operational efficiency and resource allocation of the green space, reflecting the economic benefits and sustainability of the green space. Combining the above indicators, the study can construct this performance model system to achieve a comprehensive and scientific evaluation of the overall performance of urban green space, analyse the difference between the supply and demand of low-income people in the use of urban green space, and reveal the imbalance in the distribution of resources, and push the government and the community to take measures to achieve a fair distribution, which will help to promote the fair distribution of urban green space.

In addition, based on the case of Nanjing, the results of typical correlation analyses can provide researchers with an in-depth understanding of the complex relationship between different socio-economic groups and park green space use and social relations in the process of green gentrification, and provide a scientific basis for urban planning and green space management. In concrete practice, researchers need to give full consideration to factors such as the layout, size and form of the park green space, as well as its location in relation to low-income neighbourhoods, traffic, and the condition of the surrounding land. For example, in the planning process, attention should be paid to the accessibility of parks and green spaces to ensure that low-income groups can easily enjoy green space resources, or to the cultural value of green spaces to provide low-income groups with more opportunities for cultural experience and leisure activities.

6. References

Berleant, A., 1997. Living in the Landscape: Toward an Aesthetics of Environment. University Press of Kansas.

Bibri, S.E., 2021. Data-driven smart sustainable cities of the future: urban computing and intelligence for strategic, short-term, and joined-up planning. Comput. Urban Sci. 1, 8.

https://doi.org/10.1007/s43762-021-00008-9

Bland, A., Derobertis, E., 2019. Humanistic Perspective.

Farkas, J.Z., Hoyk, E., de Morais, M.B., Csomós, G., 2023. A systematic review of urban green space research over the last 30 years: A bibliometric analysis. Heliyon 9, e13406. https://doi.org/10.1016/j.heliyon.2023.e13406

Huang, H., Yao, X.A., Krisp, J.M., Jiang, B., 2021. Analytics of location-based big data for smart cities: Opportunities, challenges, and future directions. Computers, Environment and Urban Systems 90,

101712. https://doi.org/ 10.1016/j. compenvurbsys.2021.101712

Humanistic Approach In Psychology (humanism): Definition & Examples, 2023. URL

https://www.simplypsychology.org/humanistic.html (accessed 10.30.24).

Kaklauskas, A., Gudauskas, R., 2016. 17 - Intelligent decision-support systems and the Internet of Things for the smart built environment, in: Pacheco-Torgal, F., Rasmussen, E., Granqvist, C.-G., Ivanov, V., Kaklauskas, Arturas, Makonin, S. (Eds.), Start-Up Creation. Woodhead Publishing, pp. 413 – 449. https://doi.org/10.1016/B978-0-08-100546-0.00017-0

Knobel, P., Dadvand, P., Alonso, L., Costa, L., Español, M., Maneja, R., 2021. Development of the urban green space quality assessment tool (RECITAL). Urban For. Urban Gree. 57, 126895. https://doi.org/10.1016/j.ufug.2020.126895

Li, H., Wei, Y.D., Wu, Y., Tian, G., 2019. Analyzing housing prices in Shanghai with open data: Amenity, accessibility and urban structure. Cities 91, 165–179. https://doi.org/10.1016/j.cities.2018.11.016

Qiu, S., Pi, D., Wang, Y., Liu, Y., 2023. Novel trajectory privacy protection method against prediction attacks. Expert Systems with Applications 213, 118870. https://doi.org/10.1016/j.eswa.2022.118870

Rashid, A.B., Kausik, M.A.K., 2024. AI revolutionizing industries worldwide: A comprehensive overview of its diverse applications. Hybrid Advances 7, 100277. https://doi.org/10.1016/j.hybadv.2024.100277

Residents' Preferences and Perceptions toward Green Open Spaces in an Urban Area [WWW Document], n.d. URL https://www.mdpi.com/2071-1050/ 13/3/ 1558 (accessed 10.30.24).

Reyes-Riveros, R., Altamirano, A., De La Barrera, F., Rozas-Vásquez, D., Vieli, L., Meli, P., 2021. Linking public urban green spaces and human well-being: A systematic review. Urban For. Urban Gree. 61, 127105. https://doi.org/ 10.1016/j.ufug.2021.127105

Samadhiya, A., Agrawal, R., Kumar, A., Luthra, S., 2024. Bridging realities into organizations through innovation and productivity: Exploring the intersection of artificial intelligence, internet of things, and big data analytics in the metaverse environment using a multi-method approach. Decision Support Systems 185, 114290. https://doi.org/ 10.1016/j.dss.2024.114290

Soori, M., Jough, F.K.G., Dastres, R., Arezoo, B., 2024. AI-Based Decision Support Systems in Industry 4.0, A Review. Journal of Economy and Technology. https://doi.org/ 10.1016/j.ject.2024.08.005

Urban green space disparities: Implications of environmental injustice for public health - ScienceDirect [WWW Document], n.d. URL https://www.sciencedirect.com/science/article/pii/S1618866724002395 (accessed 10.30.24).

Wang, Y., Wang, S., Li, G., Zhang, H., Jin, L., Su, Y., Wu, K., 2017. Identifying the determinants of housing prices in China using spatial regression and the geographical detector technique. Applied Geography 79, 26–36. https://doi.org/ 10.1016/j.apgeog.2016.12.003

Xie, X., Zhou, H., Gou, Z., 2023. Dynamic real-time individual green space exposure indices and the relationship with static green space exposure indices: A study in Shenzhen. Ecological Indicators 154, 110557. https://doi.org/ 10.1016/j.ecolind.2023.110557

Yang, W., Yang, R., Zhou, S., 2022. The spatial heterogeneity of urban green space inequity from a perspective of the vulnerable: A case study of Guangzhou, China. Cities 130, 103855. https://doi.org/10.1016/j.cities.2022.103855

Yang, Y., Cai, J., Yang, H., Zhang, J., Zhao, X., 2020. TAD: A trajectory clustering algorithm based on spatial-temporal density analysis. Expert Syst. Appl. 139, 112846. https://doi.org/10.1016/j.eswa.2019.112846

Zhang, F., Qian, H., 2024. A comprehensive review of the environmental benefits of urban green spaces. Environ. Res. 252, 118837. https://doi.org/ 10.1016/j.envres.2024.118837

Zhang, Y., Zhang, T., Zeng, Y., Yu, C., Zheng, S., 2021. The rising and heterogeneous demand for urban green space by Chinese urban residents: Evidence from Beijing. Journal of Cleaner Production 313, 127781. https://doi.org/ 10.1016/j.jclepro.2021.127781

Jianfeng L.U., Maozu G.U.O., Yu Z., Lingling Z., 2020. Stay point recognition method based on spatio-temporal constraint density clustering [WWW Document]. https://doi.org/10.11992/tis.201910026

Case Study Report

Traditional Industrial Parks Renewal Practices from the Perspective of Circular Economy

Take the Yangtze River Delta Demonstration Zone as an example

Liang HE, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, CHINA
Peikui FENG, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, CHINA
Xuanyuan Gu, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, CHINA

Abstract

Based on the concept of circular economy, a waste steel circular economy industrial chain covering the Yangtze River Delta region is constructed to explore the renewal path of traditional industrial parks. Through strategies such as aggregating inefficient spaces, upgrading the waste steel industrial chain, and transforming and upgrading traditional industrial spaces, the demonstration area helps to achieve the ecological and green development goals, promotes the landing of more new types of industrial products, and has a relatively good demonstration and reference significance for the renewal of traditional industrial parks in China.

Keywords

waste steel, circular economy, traditional industrial spaces, renewal path

1. How to develop traditional industrial parks in ecologically sensitive areas?

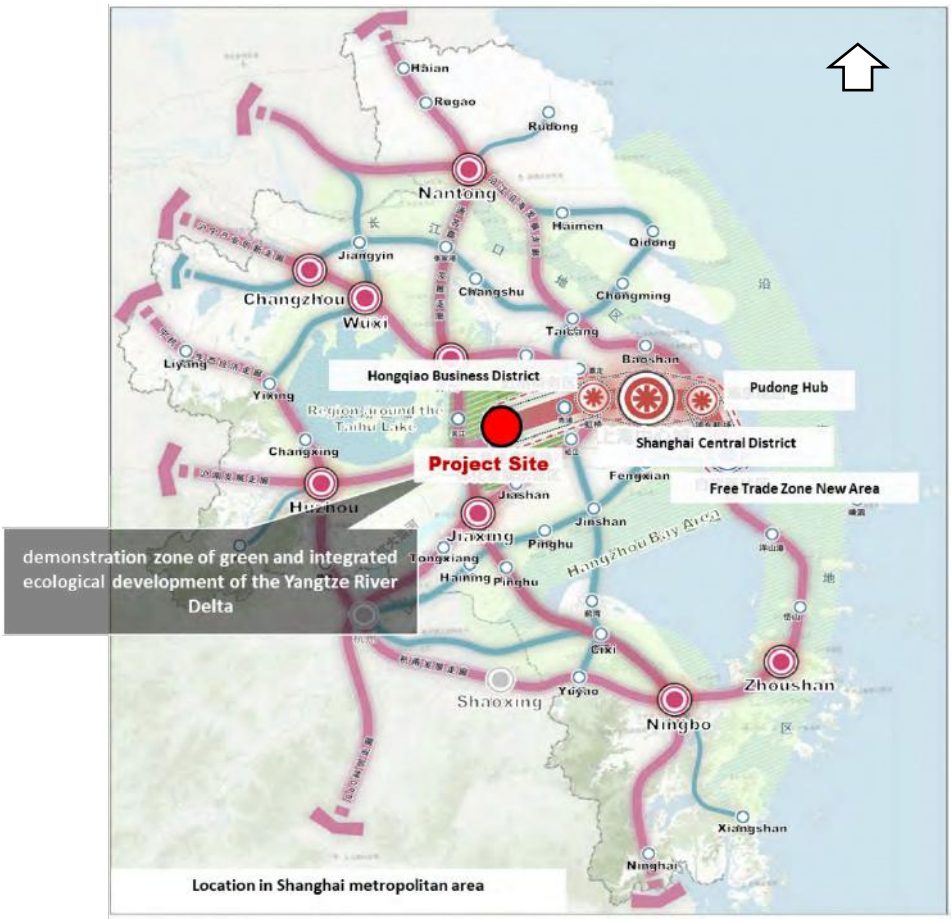
Taozhuang Town is located in the core area of the Demonstration zone of green and integrated ecological development of the Yangtze River Delta(hereinafter referred to as the Demonstration Zone), with dense lakes and excellent ecological environment. The development of the scrap steel industry in Taozhuang Town has a long history, dating back more than 40 years since the end of the 1970s. Currently, it has become the largest and only Chinese scrap steel processing and distribution base in Zhejiang Province. It is worth considering and researching how Taozhuang Town, located in an ecologically sensitive area with highly developed traditional industries, can embark on a path of industrial renewal and upgrading.

2 The context of the project

2.1 The demonstration zone has been elevated to a national strategy in China

The Demonstration Zone is located in the border area of Shanghai, Jiangsu Province, and Zhejiang Province, with an area of 2413 square kilometers and a water area accounting for 20.3%. Promoting the construction of integrated demonstration zones is the first move and breakthrough of the Yangtze River Delta regional integration development strategy implemented by the Chinese government. It is conducive to highlighting the innovative policies, systems, and methods of implementing new development concepts and promoting

high-quality development in the Yangtze River Delta region, taking the lead in achieving quality, efficiency, and driving force changes, and better leading the development of the Yangtze River Economic Belt; Beneficial for taking the lead in transforming ecological advantages into economic and social development advantages, and exploring eco-friendly development models; It is conducive to taking the lead in exploring institutional innovation from regional project collaboration to regional integration, without breaking administrative subordination or boundaries, achieving consultation, co-construction, co-management, sharing, and win-win.



Graph 1: Location in Shanghai metropolitan area

2.2 Upgrading the scrap steel industry drives urban development

Taozhuang Town is located at the junction of Jiangsu, Zhejiang and Shanghai provinces and one city. Shanghai, Suzhou, Hangzhou, Ningbo and Huzhou are included in the surrounding 200 km scrap trading radius, radiating the whole Yangtze River Delta region. At present, the annual processing and trading volume of scrap steel and related materials products reaches about 3 million tons, and the annual trading volume exceeds 10 billion yuan, driving 12,000 employees. The scrap steel industry in Taozhuang Town has become an indispensable upstream raw material source and downstream product distribution center for major iron and steel enterprises in the Yangtze River Delta region, and it is mainly delivered to major iron and steel enterprises by water transportation, among which the annual supply of Baosteel Group reaches 250,000-300,000 tons, accounting for 40-45% of its annual demand for outsourced scrap steel. Taozhuang Town has formed a spatial pattern of "one core and three plates", including urban service core, circular economy park industry plate, Fenhu leisure tourism plate and Fennan rural tourism plate. With the completion of the inter-city railway from Tongsu to Jiayong and the construction of Jiaxing North Station,

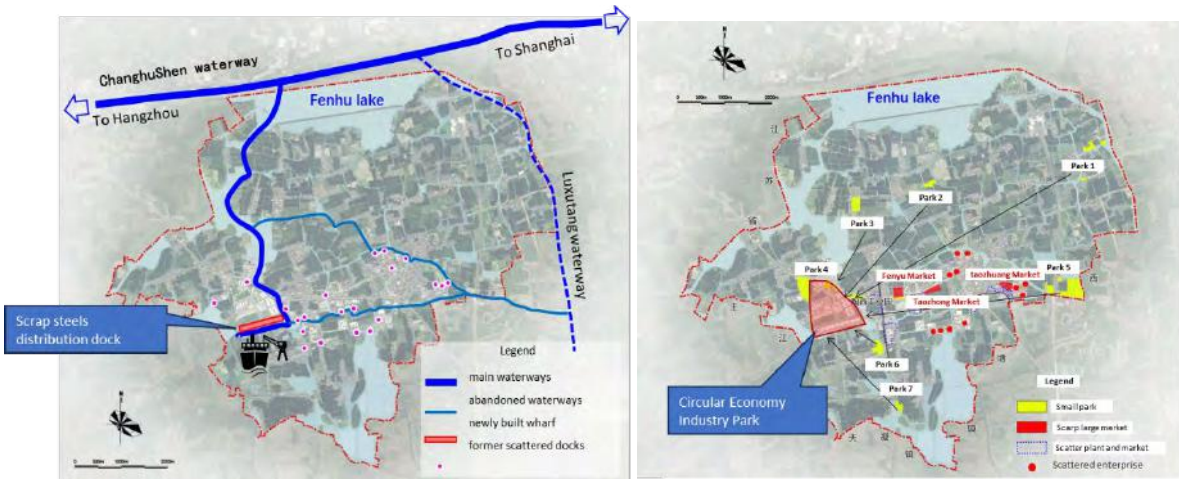
the comprehensive energy level of Taozhuang Town will be greatly improved with the improvement of traffic conditions in the future.

Image 1: The Development History of Scrap Steel Industry in Taozhuang Town

3 The project approach

3.1 Ecological Strategy

Under the requirements of the Yangtze River Delta Ecological Green Integration Development Demonstration Zone, Taozhuang Town focuses on addressing the challenges brought by traditional industries in terms of land resources, low-carbon transportation, and shoreline improvement. In terms of land resources, by vacating and renovating low and small polluting enterprises in the entire town, returning farmland, and concentrating on the construction of circular economy parks, the efficiency of land use has been improved and land indicators have been saved. In terms of low-carbon transportation, 17 storage and transportation terminals have been built in a centralized manner, making full use of water and land transportation conditions, reducing dependence on ground transportation from the raw material end to the distribution end, achieving energy conservation, reducing transportation costs for enterprises, and contributing to reducing carbon emissions. In terms of shoreline remediation, by clearing more than 300 scattered docks in the town and restoring the shoreline to nature, noise pollution and water pollution have been effectively reduced, creating a blue-green space with clear water and green shoreline.

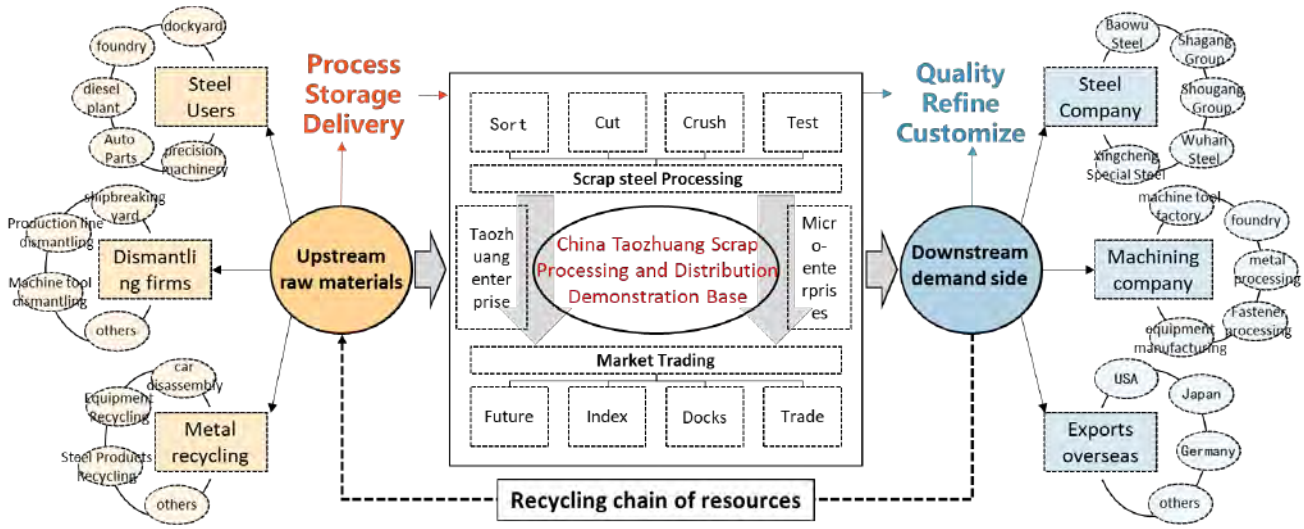


Graph 1: Clustering of low-small and scattered enterprises Distribution of fairways and wharves

3.2 Industrial Strategy

Taozhuang scrap steel and related industries should break through the original scattered and inefficient organizational model, upgrade the Taozhuang scrap steel processing and distribution market in combination with the future development trend of the scrap steel industry and market, build a circular economy hub for the steel industry in the Yangtze River Delta region, improve the recycling efficiency of

scrap steel resources for upstream industries, support leading steel enterprises in downstream industries to reduce carbon emissions, and promote the construction of a local scrap steel resource recycling industry cluster led by circular economy. On the one hand, it provides high-quality scrap steel products for large steel enterprises in the Yangtze River Delta, meets the gradually growing demand for scrap steel, and improves the scrap steel ratio of steel production in steel enterprises. On the other hand, based on the scrap steel industry, cultivate local equipment manufacturing and precision machinery related industries, achieve the utilization rate of renewable resources within the park, and improve independent innovation and research and development capabilities.



Graph 2: Schematic diagram of industry chain based on Taizhuang scrap base

3.3 Space strategy

Overall, reshaping the ecological, production, and living organic spaces of the entire town provides strong support for optimizing and reconstructing spatial resources, reshaping the traditional industrial park space, supporting the rational layout of the scrap steel industry cluster, reshaping the industrial workshop building space, and supporting the integrated functional integration of small and medium-sized enterprises. Among them, town space: By updating and renovating the industrial space in the town, the reduction of construction land is achieved, forming the future spatial pattern of Taozhuang industry. Park space: Plan circular economy industrial parks to meet the needs of different entities such as small and micro enterprises, large and medium-sized enterprises in production, trading, storage, supporting facilities, and public services, and reasonably layout various functions. Optimize the transportation flow of the dock and achieve intelligent control. Based on the characteristics of small and micro enterprises, optimize the building space of the plot, and create production and co creation spaces through vertical layout, two-story corridors, property rights division, and other methods.

Graph 3: Industrial Space Map of Taozhuang Circular Economy Industrial Park

4 The results of the project

4.1 Building a scrap steel recycling industry system

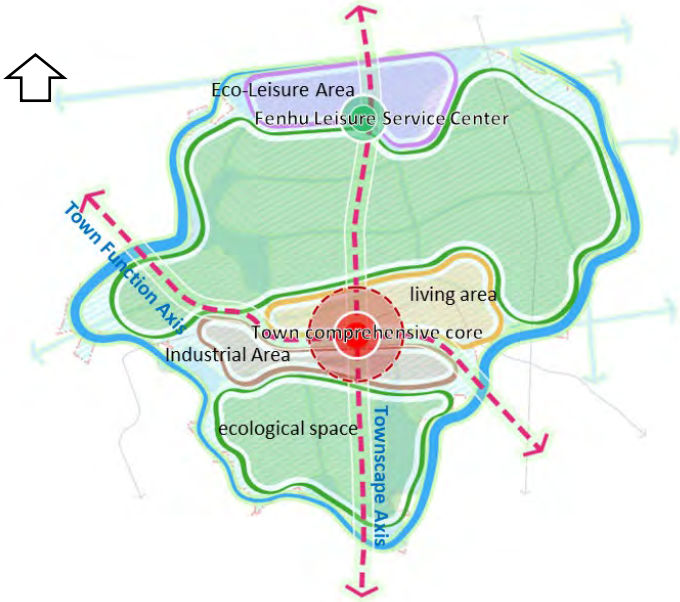
The scrap steel and related industries in Taozhuang Town should break through the original scattered and inefficient organizational model, and combine with the future development trend of the scrap steel industry and market. On the one hand, it should provide high-quality scrap steel products for large steel enterprises in the Yangtze River Delta, meet the gradually growing demand for scrap steel, and improve the scrap steel ratio of steel production in steel enterprises. On the other hand, based on the scrap steel industry, cultivate local equipment manufacturing and precision machinery related industries, achieve the utilization rate of renewable resources within the park, and improve independent innovation and research and development capabilities.

From the perspective of the demonstration zone, build Taozhuang Town into a specialized and characteristic industrial park with high-quality development; From the perspective of Jiashan County, establish the Taozhuang model of the "park within a park" development model for Jiashan's industries, and become a circular economy park dominated by precision machinery, new materials, and equipment manufacturing; From the perspective of Taozhuang Town, it aims to become an empowering center for small towns and build a comprehensive industrial park that integrates functions such as high-end manufacturing, production and processing, warehousing and display, scientific research incubation, and industrial supporting facilities.

4.2 Form reasonable spatial layout

Through the following four spatial strategies, achieve a reasonable layout of industrial space. One is iterative upgrading: based on the existing precision machinery and scrap steel processing industries in Taozhuang, the goal of upgrading and optimizing the park construction is achieved through continuous

industrial updates and spatial iteration. The second is road network reconstruction: The park is located at the end of the regional transportation in Jiashan County, with multiple regional main roads crossing. The plan will reorganize multiple roads and optimize and improve passenger and freight traffic as well as road entrances and exits. The third is smart ecology: planning to guide the high-quality development of the park through the creation of ecological water systems and green spaces, fully reserving high-quality ecological open spaces along the water and road, and guiding the future digital construction of the park. The fourth is the combination of near and far: considering the feasibility of industrial renewal in the industrial transformation zone and the complexity of property rights, the focus in the near future will be on renovating and building standard factories, while in the long term, the focus will be on innovating industrial space and supporting public services.



Graph 4: Spatial structure of the town

From Taozhuang Master Plan 2019

4.3 Guide the design of the land parcel

Implement various functions of the industrial park in stages according to the planning scheme, guide various enterprises to move into corresponding plots in an orderly manner, and achieve a green ecological spatial organization model. Propose specific strategies for the architectural design of standard factories on industrial land in the early stage of construction, and provide guidance requirements for the design of factories for self built enterprises on purchased land. Guide and standardize the spatial design of office areas in the park, and comprehensively design the site, landscape, and architecture of public activity spaces in the park.

Image 2: Design rendering of industrial park

From Detailed Design of Taozhuang Circular Economy Industrial Park 2021

5 Broader project impact

5.1 Leading steel companies reduce carbon emissions

After the upgrading of the scrap steel industry, the supply of scrap steel products has increased. Leading steel companies have reduced carbon emissions by increasing the utilization rate of scrap steel in the steelmaking process. For example, Baosteel Group has gradually increased its utilization rate of scrap steel in recent years, ranking among the top in carbon reduction among similar enterprises.

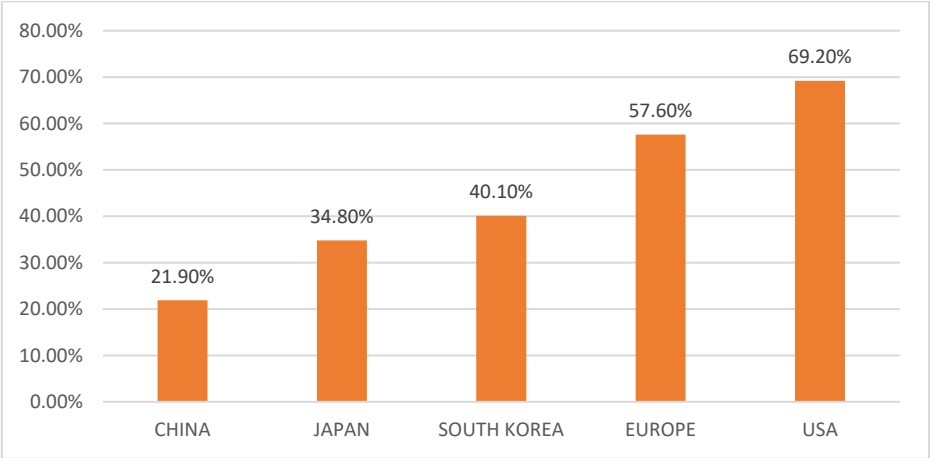


Figure 1: Main Country Scrap ratio（2021）

From Chinese Journal of Scrap Steel

5.2 Improvement of air and water environment governance

With the continuous upgrading of the scrap steel industry, the urban spatial structure has been optimized, and scattered enterprises and docks have gathered, significantly improving the water environment and air quality of the town. Taozhuang Town's air quality ranks among the top in the county, and the PM2.5 concentration has been greatly reduced.

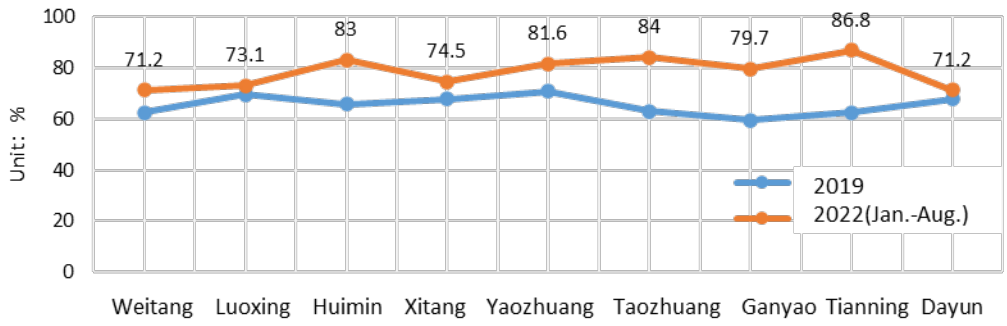


Figure 2: Change in AQI good rate

From Data provided by the local environmental protection department

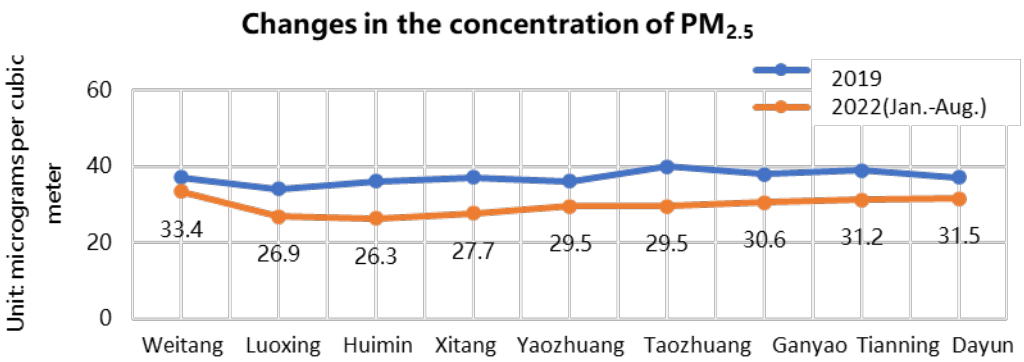


Figure 3: Changes in the concentration of PM2.5

From Data provided by the local environmental protection department

5.3 Provided a demonstration model for upgrading traditional industries

The upgrading of traditional industries in Taozhuang Town is achieved in ecologically highly sensitive areas, with greater difficulty and higher requirements. It provides a demonstration case for reducing carbon emissions in the upgrading of traditional industries nationwide.

Indicator name	the Demonstration Zone indicators（2035）	target value of Taozhuang（2035）
Blue-green space ratio（%）	≥66%	≥70%
Percentage of living/ecological shoreline（%）	≥80%	≥90%
Proportion of trips by green transport（%）	≥85%	≥90%

Percentage decrease in carbon emissions（%）	≥45%	≥50%
Water quality compliance rate for functional areas of water bodies（%）	100%	100%
Percentage of land used for manufacturing and R&D（%）	≥22%	≥30%
Water consumption of 10,000 Yuan GDP（m^3/10,000 yuan）	≤20%	≤20%

Table 1 the Demonstration Zone development indicators(partial)

6. References

Tao X.D. 'Cross-border regional coordination: content, mechanism and policy research: a case study of three interprovincial metropolitan areas', *Shanghai economic research 2010*(1), p56-64.

National Development and Reform Commission (2019) 'The State Council on Tuesday approved a plan for building a demonstration area in the Yangtze River Delta on ecologically friendly development', *https://www.gov.cn/xinwen/2019-11/19/5453512/files/1ea2d01619194ceeadbd0160215ffb66.pdf.*(Accessed: 19 November 2019)

Ning G.L. 'Discussion on Industrial Parks and the Development of Circular Economy', *Theory and Practice of Circular Economy 2006*.

Rapporteurs:
- ***Guido Cimadomo**, Universidad de Málaga, Spain*
- ***Luisa Bravo**, City Space Architecture, Italy*
- ***Hope Magidimisha-Chipungu**, University of KwaZulu-Natal, South Africa*

1. Introduction

The "Urban Memories and Inclusive Regeneration" theme explored innovative approaches to preserving intangible urban memories while promoting inclusive regeneration practices that empower communities and foster social inclusion. This report synthesizes insights from Track 3, identifying key challenges, findings, and recommendations for integrating heritage preservation with contemporary urban needs. Presented abstracts, based on research contributions and real countrywide experiences, provide a comprehensive outlook on fostering urban identity, cultural continuity, and social resilience, addressing issues of inclusivity, well-being, and community engagement while highlighting future opportunities for investigation and research.

2. Core Objectives

Track 3 focused on four primary objectives that are crucial to the future evolution of urban spaces:

1. **Community-Driven Preservation**: Engage local communities in documenting and preserving their intangible cultural heritage, ensuring their stories and traditions are honored in urban regeneration projects.
2. **Inclusive Public Spaces:** Design and revitalize public spaces that reflect the diverse cultural histories and memories of all community members, promoting social cohesion.
3. **Participatory Planning:** Involve residents in the planning and decision-making processes, ensuring regeneration efforts meet the needs and aspirations of all groups, particularly marginalized populations.
4. **Cultural Programs and Events:** Develop programs and events that celebrate and revive local traditions, enhancing community pride and connection to place.

3. Sub-Themes

To better manage these objectives and contextualise concepts and case-studies, five sub-themes have been defined:

1. **Heritage, Culture and Spatial Development**
   This sub-theme explored the integration of urban and industrial heritage into contemporary spatial planning, emphasizing community involvement, cultural continuity, and innovative approaches to conserving and revitalizing historic urban and industrial landscapes while addressing socio-economic and cultural challenges.
2. **Publicness, Well-being and Inclusivity**
   Putting the focus on the relationship between street spaces, social dynamics, and community well-being, highlighting creative practices and inclusive approaches to urban planning. It explored diverse themes such as accessible public spaces, sustainable streetscapes, urban biodiversity, and cultural centers, emphasizing the role of design in fostering health, social equity, and environmental justice while addressing the evolving needs of communities.
3. **Methodologies and Tools for Historical Regeneration**
   It explored innovative approaches to revitalizing historical and rural areas, emphasizing participatory frameworks, community empowerment, and cultural preservation. It highlighted diverse strategies, including gamification for empathy-building, temporary cultural use, and youth-driven planning, to address spatial injustices, foster sense-of-place, and promote inclusive and sustainable urban and rural regeneration practices.
4. **Urban Identity through Planning**
   This sub-theme delved into the interplay of cultural, spatial, and socio-economic factors shaping urban identity. It addressed themes like historical and cultural preservation, inclusivity in public spaces, governance in urban regeneration, and the dynamics of urban transitions, offering comparative insights and innovative strategies for fostering community attachment, cultural continuity, and sustainable urban growth.
5. **Enhancing Memory and Health through Planning**
   The last sub-theme explored the intricate connections between urban environments, cultural memory, and community well-being. Key themes included the preservation and revitalization of collective and cultural memories, the impact of the built environment on social and physical health, and participatory strategies for creating inclusive and sustainable public spaces. Case studies from diverse geographic and cultural contexts provided insights into balancing historical narratives with modern urban needs, fostering community identity, and addressing health and social challenges through thoughtful urban planning.

4. Data Summary

From 105 abstracts submitted, 103 were accepted, including 15 as posters. They were evenly distributed through the five sub-tracks. Finally 68 participants registered, covering twelve sessions for more than 120 hours, some conducted in a hybrid format. Research contributions represented 24 countries across five continents, with Asia being the highest represented region. Authors came

from Australia, Austria, Brazil, China, Cyprus, Egypt, Germany, India, Indonesia, Iran, Italy, Jordan, Lebanon, Nigeria, Poland, Portugal, Romania, Saudi Arabia, Somalia, South Africa, Turkey, United Arab Emirates, United States, and Vietnam.

5. Key Findings

- **Living labs for transformative knowledge and impact on daily life**
  Living labs foster innovation by integrating real-life experimentation with community engagement, facilitating the co-creation of solutions that directly address local needs. This approach not only drives transformative knowledge but also has tangible impacts on improving daily life, enhancing sustainability, and encouraging active citizen participation in shaping their environments.
- **Interconnection between past and future for urban identity development**
  The interplay between historical context and future aspirations is essential in shaping a city's urban identity. By respecting and incorporating the past into modern planning, cities can create a sense of continuity, cultural heritage, and place-making, ensuring that future developments resonate with the values and memories of the community.
- **Community gardens as an opportunity to enhance social welfare and healthy environments**
  They provide an opportunity to improve social welfare by promoting local food production, fostering social cohesion, and improving mental and physical health. These spaces serve as green sanctuaries, enhancing urban biodiversity and offering accessible, sustainable solutions to environmental and health challenges.
- **Relevance and impact of infrastructure design for just urban design**
  The design and implementation of infrastructure play a crucial role in creating equitable urban environments. Thoughtful, inclusive infrastructure ensures that all urban residents, regardless of socio-economic status, have access to essential services and opportunities, contributing to a fairer, more just city for everyone.
- **Interdisciplinary approach to planning to ensure sustainable development**
  Sustainable urban development requires the collaboration of diverse disciplines—urban planning, architecture, engineering, ecology, and social sciences. By adopting an interdisciplinary approach, cities can address complex challenges holistically, balancing environmental, economic, and social factors to create sustainable, resilient urban spaces.

6. Identified Challenges

- **Missing proper policies to enhance well-being, inclusivity, and cultural identity:**
  The lack of comprehensive policies limits efforts to foster well-being, inclusivity, and the preservation of cultural identity in urban development.
- **Short-sighted governance on identification, implementation and management of urban infrastructures, public spaces and cultural policies:**
  Governance often overlooks long-term planning, leading to poorly managed infrastructures, public spaces, and cultural policies that fail to meet future needs.
- **Inclusive regeneration is not properly addressing memory preservation:**
  Inclusive regeneration efforts often ne-

glect the preservation of historical and cultural memory, risking the erasure of a community's identity and heritage.

- **Blue infrastructures don't receive enough consideration**
  Research on Blue Infrastructures is still limited. Their benefits need more recognition, being a relevant tool for urban improvements.

7. Recommendations

- **More alternative visions from across the globe are needed to balance and enrich outcomes related with the implementation of urban memories.**
- **Always consider the whole lifespan of projects. Keep them alive (i.e. through living labs)**
- **Greenery is not only a solution for environmental problems but also for social and health care and development**

8. Conclusion

The "Urban Memories and Inclusive Regeneration" track has underscored the importance of integrating cultural heritage with urban regeneration to foster inclusive, sustainable communities. The findings highlight the need for participatory approaches, such as living labs and community-driven initiatives, which not only enhance urban sustainability but also strengthen social cohesion and well-being. By addressing challenges like the lack of policies for inclusivity and memory preservation, and the short-sightedness in governance, the track emphasizes the necessity of long-term planning that incorporates both historical context and future aspirations to create vibrant, equitable cities.

Moving forward, it is clear that interdisciplinary collaboration and the holistic integration of cultural, social, and environmental considerations are essential for the success of urban regeneration efforts. The recommendations stress the importance of creating policies that prioritize cultural identity, memory preservation, and inclusivity, while also recognizing the transformative potential of green spaces and community engagement. By focusing on these key areas, cities can build resilient, inclusive environments that honour their past while fostering a sustainable future for all residents.

Research Paper

Socio-Economic Contributions of Living Industrial Heritage

A Correspondence Analysis of the Industrial Community in West Bengal, India

Abantika MUKHERJEE, Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur, Kharagpur, India

Haimanti BANERJI, Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur, Kharagpur, India

Abstract

Living industrial heritage emphasizes the continuity of function, community engagement, and evolving cultural practices, making it a suitable framework for studying operating industrial heritage sites. Taking the case example of jute mills in West Bengal, India as living industrial heritage, this paper explores the impacts of five social and economic attributes. The paper uses correspondence analysis to evaluate the disparities in perception amongst the different occupational groups within the industrial community, including industrial workers, non-industrial employees, self-employed individuals, students, and retired or unemployed individuals. Data was collected from surveys conducted in six jute mill neighbourhoods along the Hooghly River. The study highlights the dual role of jute mills as both living industrial heritage and contemporary economic assets, using five socio-economic factors, which are, employability, community pride, willingness to pay, accessibility and tourism potential. The key findings include the level of agreement amongst the occupation groups and the inter-relationship of the socio-economic attributes with the occupation groups. The results indicate a higher level of agreement amongst the industrial workers for their willingness to pay for industrial skills development. Whilst the non-industrial works and self-employed individuals have higher agreement towards accessibility and tourism in living industrial heritage sites, indicating their interest in developing social infrastructure. With a focus on inclusivity, the study concludes with recommendations for future management of jute mill as living industrial heritage.

Keywords

Living industrial heritage, Jute mill, Socio-economic contribution, Industrial community, Correspondence analysis

1. Introduction

Living heritage sites comprise a distinct resident community that actively engages with the site and contributes to the local socio-economic landscape (Pham, 2015; Haselberger and Krist, 2022a; Raevskikh, Di Mauro and Jaffré, 2024). Historically significant industrial sites that are partially or fully operating, with complex layers of actively engaged stakeholders, require management as living heritage sites. However, most of the recognized industrial heritage sites, often reflect post-industrial or brownfield contexts. 4% of the total UNESCO World Heritage sites constitute industrial heritage, majority of which are post-industrial

landscapes (Falser and Yang, 2001). In India, however, their socio-economic value of UNESCO World Heritage Sites such as the Chhatrapati Shivaji Maharaj Terminus (formerly Victoria Terminus) and the Darjeeling Himalayan Railway is largely impacted by their continuous utility and ability to support local livelihoods. The jute industry in India, particularly along the Hooghly River in West Bengal, serves as one such example of how industrial heritage can be both a symbol of historical significance and a driver of contemporary economic growth (Rai, 1978; Stewart, 2017). The jute industry of West Bengal grew significantly in the early 20th century, employing over 300,000 workers, allowing migrants to settle and creating a cosmopolitan industrial society. (Palit and Kajaria, 2007; Bharadwaj and Fenske, 2012; Stewart, 2017). The social and economic fabric of this industrial landscape has been shaped by both the direct employment within the mills and the ancillary industries that developed around them, including transportation, trade, and services. Despite a decline in the global demand for jute products, most of these mills continue to operate (Rai, 1978), evolving into a form of living industrial heritage, functioning as historical landmarks and significant economic contributors. This research investigates how these dual roles impact the socio-economic well-being of the communities that continue to depend on the jute industry.

The paper commences with a literature review to establish the theoretical frameworks of living industrial heritage, from which the socio-economic components were determined. The subsequent section presents an overview of the topic area and delineates the research methodology. The results and debates are developed based on the methodology, followed by conclusions and recommendations for future research.

2. Literature review

2.1. Industrial heritage as living heritage

Living heritage is often characterized by active community engagement, and involves continuous evolution of cultural practices (Pham, 2015; Nugroho, Yuliastuti and Rukayah, 2021) which contributes to its dynamic nature (Haselberger and Krist, 2022b; Raevskikh, Di Mauro and Jaffré, 2024). The community participation for economic and social sustainability is further emphasized in studies referring to intangible cultural heritage as living heritage (Abdul Aziz *et al.*, 2023). In the context of industrial heritage, most studies have traditionally focused on post-industrial landscapes or brownfield sites, often addressing the challenges of conservation in abandoned or underutilized industrial spaces (Navratil *et al.*, 2018; Mostadi and Biara, 2019; Konior and Pokojska, 2020; Jóźwiak and Sieg, 2021; Kuzior *et al.*, 2021). These studies primarily investigate the repurposing of deindustrialized sites, with a focus on regeneration, adaptive reuse, and cultural heritage tourism. However, there is a notable gap in research on continuing industrial sites that maintain active production while simultaneously serving as heritage assets. These sites, hereby referred to as living industrial heritage, still function within their original industrial purpose but are increasingly recognized for their cultural and historical significance. While significant research has been devoted to post-industrial sites, there is a gap in the study of living industrial heritage and its association towards the engaged community.

2.2. Industrial community and socio-economic attributes

An industrial community is a socio-economic entity who are directly or indirectly involved in industrial operations, sharing a common culture related to industrialization (Hornborg, 2015; Zhang, Xu and Aoki, 2023). Studies examining how these sites serve both as heritage assets and active economic contributors have drawn attention to the socio-economic impacts on the community (Xu and Aoki, 2018; Claver, García-Domínguez and Sebastián, 2020; Zhang *et al.*, 2021; Yang, 2023; Mousavinia, 2024). Study of these literature led to the identification of the key socio-economic attributes which have been elaborated in this section.

Sense of pride, often linked to the collective memory, is a critical attribute in reinforcing social cohesion of industrial communities constituting the workers, residents, and other stakeholders (Coscia, Lazzari and Rubino, 2018; Rek-Wozniak and Wozniak, 2020). The willingness to pay for the ongoing usage, accessibility, and maintenance of live industrial historic sites reflects users' perceptions as significant economic contributors (Somoza-Medina and Monteserín-Abella, 2021; Kuzior *et al.*, 2022). Tourism as a regeneration strategy for declining industrial heritage is a well-researched area (Pawlikowska-Piechotka, 2010; Andrade-Suárez and Caamaño-Franco, 2020; Zhao and Liu, 2021; Berkenbosch, Groote and Stoffelen, 2022) and aims to identify if tourism is also perceived as a potential for living industrial heritage. Employability is crucial for economic sustainability (Canevaro *et al.*, 2019; Pardo Abad, 2020), whilst accessibility to the industrial landscapes may provide opportunity for enhancing social infrastructure (Heesche, Braae and Jørgensen, 2022). Studies discuss how living industrial heritage sites maintain local employment opportunities, while accessibility to these sites ensures inclusivity, promoting economic diversification and social engagement (Loures, 2015; Štrbíková, Vdolečková and Vitková, 2020). This study examines the impact of the five socio-economic attributes, which are, sense of pride, willingness to pay, tourism potential, employability, and accessibility, through a survey on the perceptions of the industrial communities.

3. Research methodology

The research aims to evaluate how different occupational groups within the industrial community perceive the socio-economic contributions of living industrial heritage. The study is conducted in four stages. The first stage involved a literature review for living industrial heritage studies which led to the establishment of the connection between the industrial neighbourhood and identification of the industrial community groups. Next, five socio-economic attributes were identified. Following this, the study area and demographic composition was identified, based on which the questionnaire was designed. Finally, the data was analysed using appropriate statistical technique for the collected data type.

3.1. Study area

The jute mills situated along the Hooghly River in West Bengal, India, founded in the mid-19th century, were instrumental in converting the region into an industrial centre. By the 1920s, more than 50 mills flanked both riverbanks, forming a continuous industrial landscape (Ali, 2012; Dey, 2018). This development stimulated urbanization and significant in-migration, leading to the formation of cohesive worker communities (Palit and Kajaria, 2007; Bharadwaj and Fenske, 2012; Ghosh, 2016). The forward and backward linkages of the jute mills influenced livelihoods through practices of cultivation, transport, and marketing (Sethia, 1996). Despite setbacks in the industrial growth due to partition of Bengal after independence, the mills remain key to the historic industrial identity of the region (Bharadwaj and Fenske, 2012), thus serving as an appropriate case example of living industrial heritage. The study identified six of the operating jute mills (refer Figure 1) located along the Hooghly River: Hukumchand Jute Mill, Gondalpara Jute Mill, India Jute Mill, Hastings Jute Mill, Hooghly Jute Mill, and Bauria Jute Mill, with existing industrial community in the respective neighbourhoods.

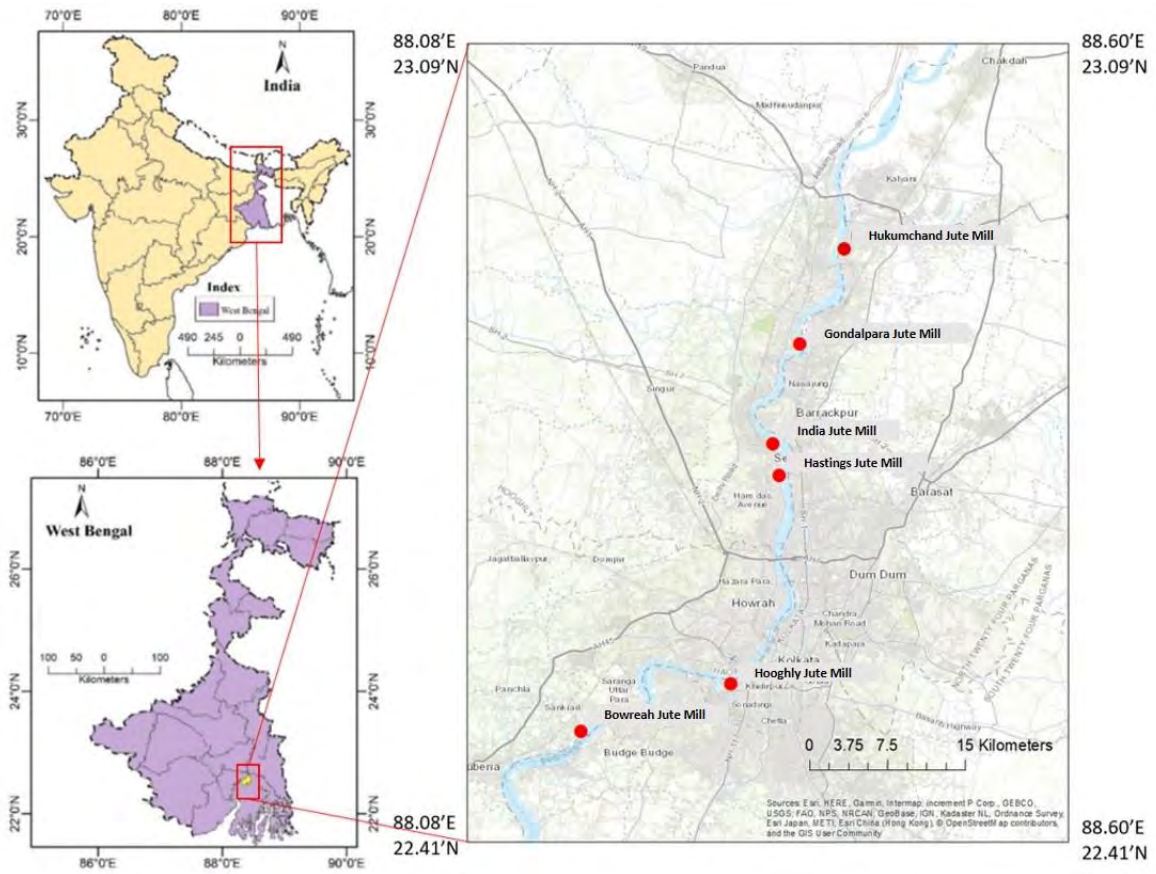


Figure 1 Map of study area showing location of six jute mills in West Bengal, India. Source: Author.

The mills have been identified based on their historic significance, present operation status, availability of secondary data and accessibility for survey of the industrial community. For identifying the industrial community, the neighbourhood for each of the jute mills (refer Figure 2) were delineated having a 15 minutes walking distance from the mills.

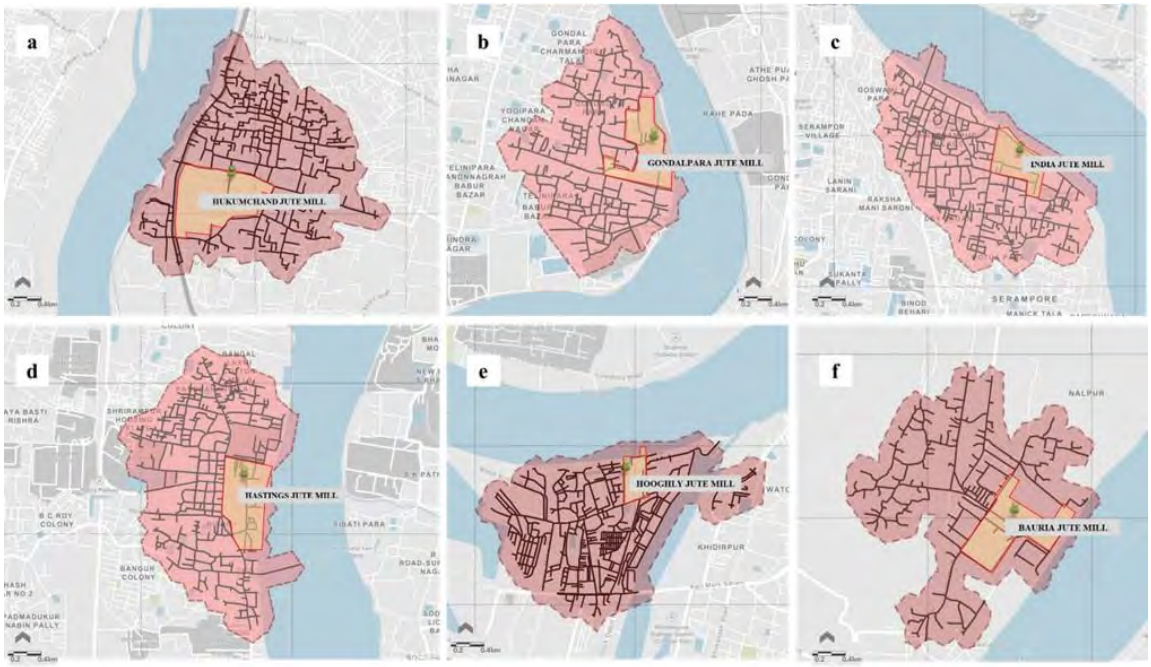


Figure 2 Neighbourhood delineation of six jute mills along Hooghly River in West Bengal, India. a. Hukumchand Jute Mill, b. Gondalpara Jute Mill, c. India Jute Mill, d. Hastings Jute Mill, e. Hooghly Jute Mill, f. Bauria Jute Mill. Source: Author.

After a reconnaissance survey of the delineated neighbourhood, the industrial community was identified, having appropriate acquaintance with respective jute mills.

3.2. Questionnaire survey

The questionnaire survey aimed to identify how the community perceives the socio-economic contributions of the jute mills in terms of employability, community pride, tourism potential, accessibility, and willingness to pay for industrial training programs or continuing industrial activities. For each of the six delineated neighbourhoods, the required sample size was calculated by assuming a finite population size, using the population density as the unit. A stratified purposive sampling approach was adopted to identify samples across the five occupational groups. This stratified sampling helps ensure a broad representation without requiring a larger overall sample size. After removing the missing data, a total of 273 responses were used across five occupational groups: industrial workers, non-industrial employees, self-employed individuals, students, and retired/unemployed individuals (refer Table 1).

Table 1 Table showing demographic profile of sample. Source: Author.

Demographic parameters	Description	N	Percentage
Gender	Male	219	80.2
	Female	54	19.8
Occupation	Employed-industrial	48	17.6
	Employed-others	38	13.9
	Self-employed	81	29.7

	Student	48	17.6
	Retired/ unemployed/ others	58	21.2

Although the proportions of different occupation groups have been attempted to be similar, the ratio of female to male respondents are skewed, which is considered as one of the limitations of this study.

3.3. Data analysis

Correspondence analysis is a multivariate statistical technique applied on categorical variables (Iwasaki and Pederzoli, 2023). In heritage studies, it has been often used to identify patterns and correlations between heritage attributes or indicators (refer Table 2).

Table 2 Literature review of correspondence analysis in heritage studies. Source: Author.

Source	Subject area	Data Type	Findings
(Iwasaki and Pederzoli, 2023)	Heritage collections	Survey questionnaire	Levels of impacts in different regions and age-groups
(Patru-Stupariu, Pascu and Bürgi, 2019)	Resilience of cultural landscapes	Structured and semi-structured interviews	Resilience levels of tangible and intangible heritage in cultural landscape
(Pujol-Tost, 2017)	Virtual archaeology	Survey questionnaire	Associations between topics and experimental conditions
(Tureckova *et al.*, 2019)	Brownfield regeneration	Observation data from case study	factors impacting decision-making on brownfield regeneration

This study employs correspondence analysis (CA) to evaluate the relationship between the variables, which are the occupational groups and the socio-economic attributes related to the six jute mills.

4. Results and discussion

The results of this study highlight the varied socio-economic contributions attributed to jute mills as living industrial heritage. The Likert-scale data, the respective median scores for the five attributes, and the correspondence graphs helped identify the strength of agreement amongst the industrial communities.

4.1. Agreement to socio-economic attributes

The varying levels of agreement (refer Figure 3) for socio-economic attributes reflect different expectations based on occupational responsibilities.

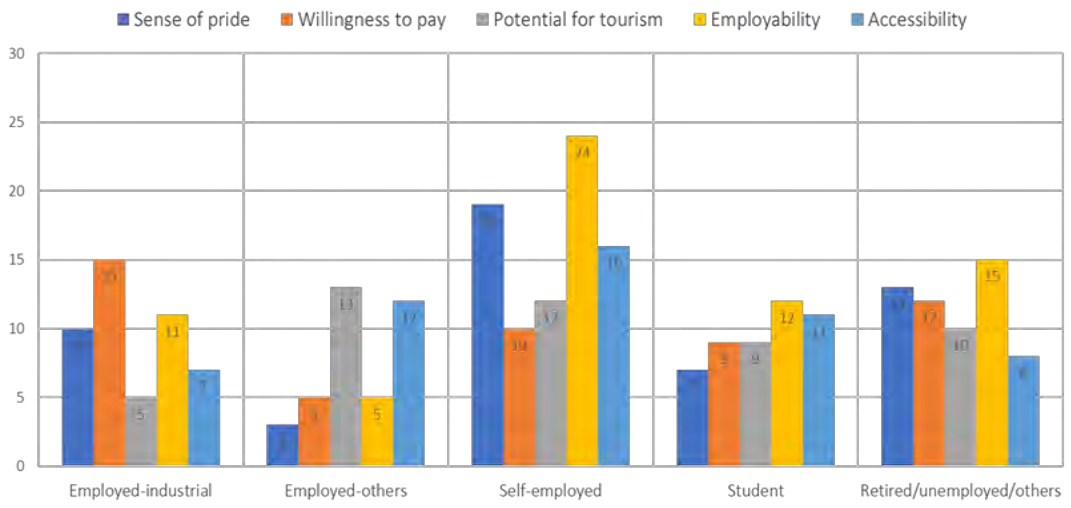


Figure 3 Bar diagram showing level of agreement to the various socio-economic contributions. Source: Author.

Industrial workers exhibited a high level of agreement on the *willingness to pay* for the learning of industrial skills linked to jute mills, suggesting that these skills hold both cultural and economic significance for this group. The workers, thus, are more interested in continued usage of the jute industry. In contrast, the median scores on *potential for tourism* and *accessibility* are higher as given by the employees of other sectors. This corresponds to their necessity of social infrastructure or blue-green infrastructure, especially in the high-density areas around the jute mills in West Bengal. Among self-employed individuals, whose businesses rely on the forward and backward linkages of jute production, there is a higher appreciation for the roles of jute mills in providing *employability* and promoting a *sense of pride* for the community. Additionally, the students and employees of other sectors rated the *sense of pride* attribute as a relatively low, potentially due to limited exposure to these heritage sites and a regular access to with other institutional spaces outside the neighbourhood. The highest agreement on *employability* attribute came from self-employed and retired individuals. The differences in agreement on the contributions the of jute mills as living industrial heritage underscores the need for community participation for interventions in these living heritage sites. Employability and physical accessibility of the riverine jute mills landscapes are identified as the main requirements, especially in the context of West Bengal, which should be utilised in future adaptive reuse strategies. A comparison with similar studies in other industrial landscapes would help identify the region-specific requirements of industrial communities.

4.2. Inter-relation of socio-economic attributes

The dimensions of the correspondence analysis, for analysing the closely linked attributes to the occupation groups, were limited to two, with a cumulative percentage explained exceeding 60%. The dominance of the first dimension indicates that major divergences among occupational groups or attributes might be understood by examining the factors associated with this dimension.

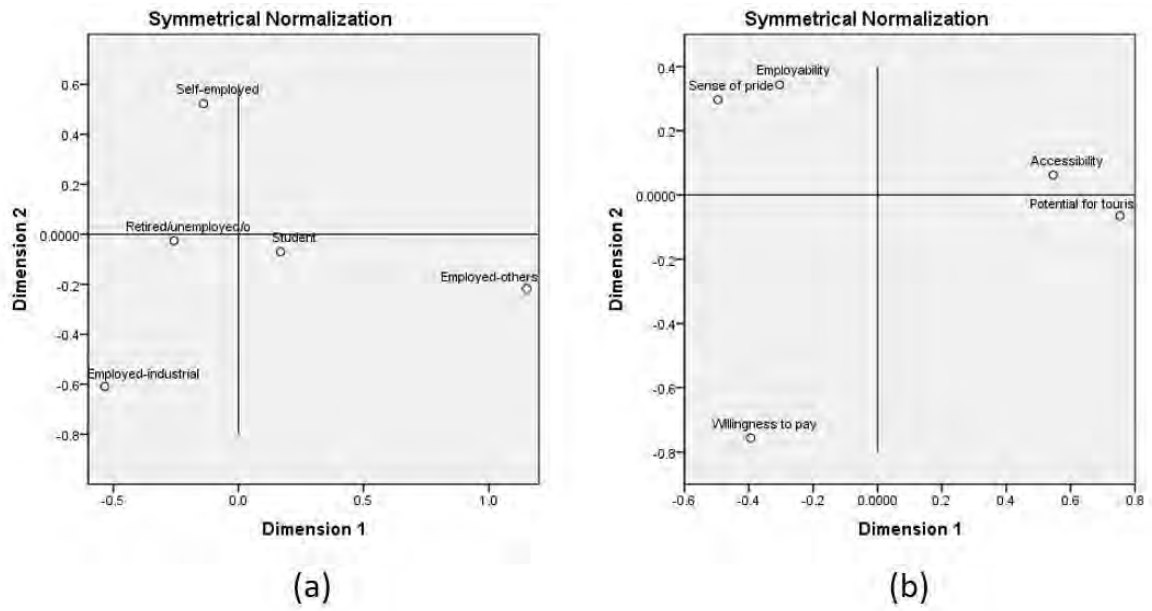


Figure 4 Correspondence analysis (a) Row profile for occupation and (b) column profile for socio-economic attributes. Source: Author.

The row profiles analysis shows how the respondents from the different occupation groups vary in their opinion. On the Dimension 1 of the row profile analysis (refer Figure 4a), *employed-industrial* workers are positioned on the negative side of the axis, whereas *student* and *employed-others* groups occupy the positive side. On the Dimension 2 of the row profile analysis (refer Figure 4a), the *self-employed* are positioned on the positive side, while all other occupation groups are positioned on the negative side. Thus, it may be observed that the opinions of the industrial workers and the self-employed individuals has the largest variation in opinion. The row profile analysis seems to differentiate between those who see industrial heritage primarily as a source of entrepreneurial opportunity (self-employed) and those who view it through the lens of direct employment (industrial workers). The column profiles analysis (refer Figure 4b) shows how the opinions about the socio-economic attributes are correlated. Attributes like *employability* and *sense of pride* cluster closely together in the upper quadrant of the correspondence map. This proximity suggests that these attributes are highly valued across the community and may be viewed as interconnected. On the other hand, *willingness to pay* is positioned in the second quadrant, and not clustered with any of the other four attributes, indicating that the opinions about the industrial continuity is largely varying amongst the industrial community.

In the total correspondence analysis (refer Table 3), Dimension 1 accounts for 70.8% of the total inertia, with a singular value of 0.259, while Dimension 2 explains an additional 24.9% with a singular value of 0.154.

Table 3 Summary table of correspondence analysis

Dimension	Singular Value	Inertia	Proportion of Inertia		Confidence Singular Value	
			Accounted for	Cumulative	Standard Deviation	Correlation 2
1	.259	.067	.708	.708	.060	.042

2	.154	.024	.249	.957	.061
3	.058	.003	.036	.992	
4	.027	.001	.008	1.000	
Total		.095	1.000	1.000	

Together, these two dimensions capture over 95% of the variance, justifying their importance in explaining the relationships between occupational groups and the socio-economic attributes of the jute mills.

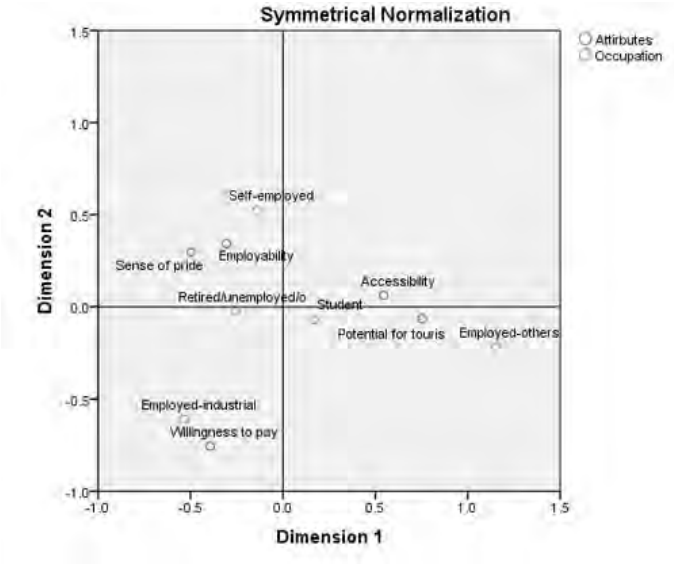


Figure 5 Summary chart of correspondence analysis. Source: Author.

The attributes of *employability* and *sense of pride* were closely linked in the upper quadrant of the correspondence map (refer Figure 5), indicating a similarity in perception across the entire industrial community. *Self-employed* individuals displayed a strong association with *employability* and *sense of pride*, indicating that they perceive the jute mills as both historical landmarks and sources of entrepreneurial opportunities. Though positioned on the negative quadrant, the opinions of the *retired/unemployed* group are also closely clustered with *employability* and *sense of pride*. Figure 5 clearly depicts that only the *employed-industrial* group has a strong and unified opinion about the *willingness to pay* for continued usage of the jute mills. Despite limited direct interaction, the *employed-others*, i.e., the non-industrial employees and the *students* were closely associated with the *potential for tourism* and *accessibility*, demonstrating their acknowledgement of the cultural and economic contributions of the jute mills. Overall, *accessibility* is the only attribute positioned in the fourth quadrant, whose opinion in this case may be biased as the industrial workers are the only group having physical accessibility to the jute mills. Similarly, there might be a bias on opinions towards *willingness to pay*, which is positioned furthest with respect to all occupation groups except the industrial workers. These findings reveal that accessibility is a key determining factor for altering the perceptions about a living industrial heritage. Future scope should involve surveying of occupation groups having direct or indirect accessibility to living industrial heritage sites. The findings also indicate that community pride is closely associated with the functioning status or economic opportunities provided by the industrial heritage sites. Finally, the students and the retired or unemployed groups within the industrial community have some similarity in opinion about a living

industrial heritage, especially in the case of jute mills. Whilst, the industrial workers, the employees from non-industrial sectors and the self-employed groups widely differ in their opinions about a living industrial heritage.

5. Conclusions and recommendations

The disparities in perceptions across occupational groups of the industrial community highlight the importance of inclusive approaches for management of living industrial heritage.

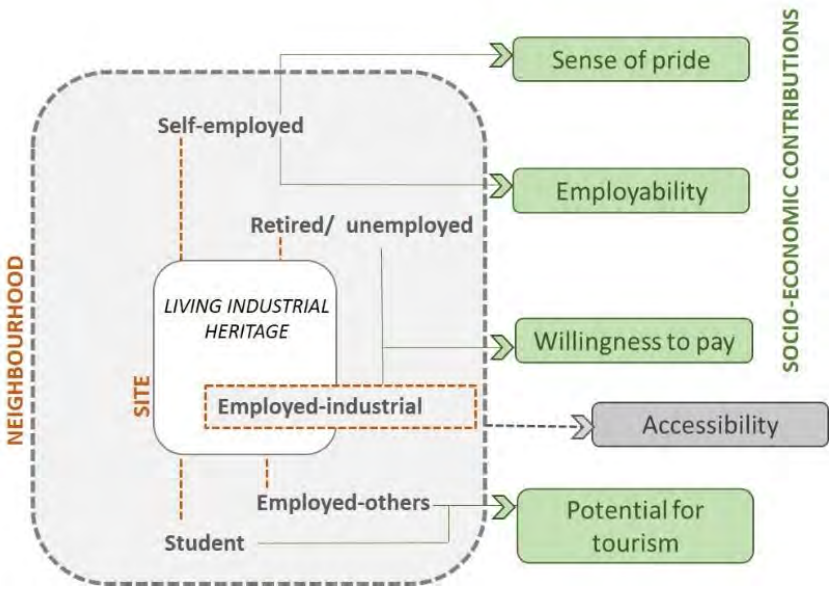


Figure 6 Socio-economic contributions according to industrial community

The study takes forward the argument of how the different stakeholders, based on their level of connection, perceive the contributions of a living industrial heritage. For the case of jute mills in West Bengal, India, the industrial workers are the only group having both inside access and outside perspective, who have expressed a strong opinion in continuing the "livingness" of the sites. Figure 6 summarises the findings from the correspondence analysis, emphasizing that the industrial workers are the most significant occupation group while accessibility serves as the principal socio-economic attribute that influences overall perception of industrial heritage. Future scope may analyse the region-specific mediating factors for each of the five attributes.

5.1. Recommendations for future prospect of jute mills as living industrial heritage

Jute industry in west Bengal had a major economic impact, which employed over 300,000 workers during the earliest stage of industrial revolution in India (Palit and Kajaria, 2007). Heritage management policies for jute mills should focus on offering skill development programs and entrepreneurship support for the jute industrial community. Similar approaches have been employed in former industrial regions of European and Asian countries where heritage sites have been linked to job creation through adaptive reuse and skill training programs (Rizzo *et al.*, 2015; Lu, Liu and Wang, 2020; Chen, 2021; Somoza-Medina and Monteserín-Abella, 2021). The continued presence of industrial communities along the heritage jute mills, create a potential to serve as hubs for community-based tourism. Studies have shown that industrial heritage tourism not only contributes to local economies but also promotes a sense of ownership within communities (Pawlikowska-Piechotka, 2010; Đurkin and Perić, 2017). This approach of participatory

planning is advocated for intangible cultural heritage (UNESCO, 2003; Petronela, 2016). Further, policies should prioritize both physical accessibility and inclusivity, making the sites interpretable for a wide demographic.

5.2. Way forward

This study underlines the extent to which the jute mills as living industrial heritage contribute to community pride, employment, and tourism for their respective industrial community. This research may be taken forward to analyse the differences in this contribution for a larger community, outside the demarcated industrial neighbourhoods. This, added with a proximity analysis of the social infrastructure facilities around the site, will lead to the understanding of the regional impact of the sites. Overall, the study highlights the multiplicity of stakeholders constituting an industrial community and proposes a way forward for perceptions study on living industrial heritage.

6. Acknowledgements

The authors acknowledge the Department of Architecture and Regional Planning, Indian Institute of Technology Kharagpur for supporting this research as part of an ongoing PhD. The authors also acknowledge all the anonymous respondents of West Bengal, India, who participated in the survey.

7. References

Abdul Aziz, N.A. *et al.* (2023) 'Community Participation in the Importance of Living Heritage Conservation and Its Relationships with the Community-Based Education Model towards Creating a Sustainable Community in Melaka UNESCO World Heritage Site', *Sustainability (Switzerland)*, 15(3). Available at: https://doi.org/10.3390/su15031935.

Ali, T.O. (2012) *The Envelope of Global Trade : The Political Economy and Intellectual History of Jute in the Bengal Delta, 1850s to 1950s*. Harvard University. Available at: https://dash.harvard.edu/bitstream/handle/1/10364584/Ali_gsas.harvard_0084L_10545.pdf?sequence=1.

Andrade-Suárez, M. and Caamaño-Franco, I. (2020) 'The relationship between industrial heritage, wine tourism, and sustainability: A case of local community perspective', *Sustainability (Switzerland)*, 12(18). Available at: https://doi.org/10.3390/SU12187453.

Berkenbosch, K., Groote, P. and Stoffelen, A. (2022) 'Industrial heritage in tourism marketing: legitimizing post-industrial development strategies of the Ruhr Region, Germany', *Journal of Heritage Tourism*, 17(3), pp. 327–341. Available at: https://doi.org/10.1080/1743873X.2022.2026364.

Bharadwaj, P. and Fenske, J. (2012) 'Partition, Migration, and Jute Cultivation in India', *Journal of Development Studies*, 48(8), pp. 1084–1107. Available at: https://doi.org/10.1080/00220388.2011.579114.

Canevaro, E. *et al.* (2019) 'Strategies for the Sustainable Reindustrialization of Brownfields', *IOP Conference Series: Earth and Environmental Science*, 296(1). Available at: https://doi.org/10.1088/1755-1315/296/1/012010.

Chen, W. (2021) 'Coworking spaces in China: Developing a new strategy of reusing industrial heritage properties under sharing economy', *International Archives of the Photogrammetry, Remote Sensing and*

Spatial Information Sciences - ISPRS Archives, 46(M-1–2021), pp. 117–123. Available at: https://doi.org/10.5194/isprs-Archives-XLVI-M-1-2021-117-2021.

Claver, J., García-Domínguez, A. and Sebastián, M.A. (2020) 'Multicriteria decision tool for sustainable reuse of industrial heritage into its urban and social environment. Case studies', *Sustainability (Switzerland)*, 12(18). Available at: https://doi.org/10.3390/SU12187430.

Coscia, C., Lazzari, G. and Rubino, I. (2018) 'Values, memory, and the role of exploratory methods for policy-design processes and the sustainable redevelopment of waterfront contexts: The case of Officine Piaggio (Italy)', *Sustainability (Switzerland)*, 10(9).

Dey, T. (2018) 'Jute Industry and Its Labour: Analysis the Trend of Change in Context of West Bengal', *Journal of Emerging Technologies and Innovative Research*, 5(5), pp. 510–514. Available at: www.jetir.org510.

Đurkin, J. and Perić, M. (2017) 'Organising for community-based tourism: Comparing attitudes of local residents and local tourism entrepreneurs in Ravna Gora, Croatia', *Local Economy*, 32(7), pp. 678–691. Available at: https://doi.org/10.1177/0269094217734811.

Falser, M. and Yang, M. (2001) *Industrial Heritage Analysis*. Available at: http://whc.unesco.org/archive/.

Ghosh, R. (2016) 'A study of Birla Jute Mill of West Bengal', 2(10), pp. 603–606.

Haselberger, M. and Krist, G. (2022a) 'Applied Conservation Practice Within a Living Heritage Site', *Studies in Conservation*, 67(S1), pp. 96–104. Available at: https://doi.org/10.1080/00393630.2022.2076778.

Haselberger, M. and Krist, G. (2022b) 'Applied Conservation Practice Within a Living Heritage Site', *Studies in Conservation*, 67(S1), pp. 96–104. Available at: https://doi.org/10.1080/00393630.2022.2076778.

Heesche, J., Braae, E.M. and Jørgensen, G. (2022) 'Landscape-Based Transformation of Young Industrial Landscapes', *Land*, 11(6). Available at: https://doi.org/10.3390/land11060908.

Hornborg, A. (2015) 'Industrial Societies', in J.D.B.T.-I.E. of the S.& B.S. (Second E. Wright (ed.) *International Encyclopedia of the Social & Behavioral Sciences*. Oxford: Elsevier, pp. 863–867. Available at: https://doi.org/https://doi.org/10.1016/B978-0-08-097086-8.12200-7.

Iwasaki, A. and Pederzoli, J.L. (2023) 'Why collections matter: impacts of cultural heritage collections on people's lives', *International Journal of Heritage Studies*, 29(11), pp. 1229–1249. Available at: https://doi.org/10.1080/13527258.2023.2243481.

Jóźwiak, M. and Sieg, P. (2021) 'Tourism development in post-industrial facilities as a regional business model', *Sustainability (Switzerland)*, 13(4), pp. 1–16. Available at: https://doi.org/10.3390/su13042028.

Konior, A. and Pokojska, W. (2020) 'Management of postindustrial heritage in urban revitalization processes', *Sustainability (Switzerland)*, 12(12). Available at: https://doi.org/10.3390/SU12125034.

Kuzior, A. *et al.* (2021) 'Post-industrial tourism as a driver of sustainable development', *Sustainability*, 13(15), p. 8145. Available at: https://www.mdpi.com/2071-1050/13/15/8145/htm (Accessed: 2 September 2021).

Kuzior, A. *et al.* (2022) 'Revitalization of Post-Industrial Facilities in Economic and Socio-Cultural Perspectives—A Comparative Study between Poland and the USA', *Sustainability (Switzerland)*, 14(17). Available at: https://doi.org/10.3390/su141711011.

Loures, L. (2015) 'Post-industrial landscapes as drivers for urban redevelopment: Public versus expert perspectives towards the benefits and barriers of the reuse of post-industrial sites in urban areas', *Habitat International*, 45(P2), pp. 72–81. Available at: https://doi.org/10.1016/j.habitatint.2014.06.028.

Lu, N., Liu, M. and Wang, R. (2020) 'Reproducing the discourse on industrial heritage in China: reflections on the evolution of values, policies and practices', *International Journal of Heritage Studies*, 26(5), pp. 498–518. Available at: https://doi.org/10.1080/13527258.2019.1666293.

Mostadi, A. and Biara, R.W. (2019) 'Brownfield in the entrance of the town of Kenadsa: An industrial heritage, difficult to assume', *Arquiteturarevista*, 15(2), pp. 388–407. Available at: https://doi.org/10.4013/arq.2019.152.10.

Mousavinia, S.F. (2024) 'Changes in Social Impacts of Industrial Heritage Adaptive Reuse in High-Density Residential Environment: Reciprocal Relations Between Social Cohesion and Perceived Safety', *Social Indicators Research*, 172(1), pp. 59–80. Available at: https://doi.org/10.1007/s11205-024-03308-9.

Navratil, J. *et al.* (2018) 'Brownfields do not "only live twice": The possibilities for heritage preservation and the enlargement of leisure time activities in Brno, the Czech Republic', *Cities*, 74(November 2017), pp. 52–63. Available at: https://doi.org/10.1016/j.cities.2017.11.003.

Niti Aayog, G. of I. (2018) *SDG INDIA INDEX BASELINE REPORT, 2018*.

Nugroho, P.S., Yuliastuti, N. and Rukayah, S. (2021) 'Cultural Aspects and the Sustainability of the Tasikmadu Sugar Factory as an Industrial Living Heritage in Java', *IOP Conference Series: Earth and Environmental Science*, 830(1). Available at: https://doi.org/10.1088/1755-1315/830/1/012064.

Palit, S. and Kajaria, S. (2007) *Jute Industry: A Historical Perspective*. Firma KLM. Available at: https://books.google.co.in/books?id=jWDtAAAAMAAJ.

Pardo Abad, C.J. (2020) 'Valuation of industrial heritage in terms of sustainability: Some cases of tourist reference in Spain', *Sustainability (Switzerland)*, 12(21), pp. 1–23. Available at: https://doi.org/10.3390/SU12219216.

Patru-Stupariu, I., Pascu, M. and Bürgi, M. (2019) 'Exploring tangible and intangible heritage and its resilience as a basis to understand the cultural landscapes of Saxon communities in southern Transylvania (Romania)', *Sustainability (Switzerland)*, 11(11). Available at: https://doi.org/10.3390/su11113102.

Pawlikowska-Piechotka, A. (2010) 'Industrial Heritage Tourism: a Regional Perspective (Warsaw)', *Physical Culture and Sport. Studies and Research*, 46(1), pp. 276–287. Available at: https://doi.org/10.2478/v10141-009-0025-x.

Petronela, T. (2016) 'The Importance of the Intangible Cultural Heritage in the Economy', *Procedia Economics and Finance*, 39, pp. 731–736. Available at: https://doi.org/10.1016/s2212-5671(16)30271-4.

Pham, H. (2015) 'Living heritage, community participation and sustainability: Redefining development strategies in the Hoi An Ancient Town World Heritage property, Vietnam in Logan, W. and Labadi, S. 2015 'Urban Heritage, Development and Sustainability International Frame', in.

Pujol-Tost, L. (2017) '"3D·CoD": A New Methodology for the Design of Virtual Reality-Mediated Experiences in Digital Archaeology', *Frontiers in Digital Humanities*, 4. Available at: https://doi.org/10.3389/fdigh.2017.00016.

Raevskikh, E., Di Mauro, G. and Jaffré, M. (2024) 'From living heritage values to value-based policymaking: exploring new indicators for Abu Dhabi's sustainable development', *Humanities and Social Sciences Communications*, 11(1). Available at: https://doi.org/10.1057/s41599-024-03841-5.

Rai, A. (1978) 'Trends in the Jute Industry since Independence', *Social Scientist*, 6(6/7), p. 83. Available at: https://doi.org/10.2307/3516545.

Rek-Wozniak, M. and Wozniak, W. (2020) 'Working-class and Memory Policy in Post-Industrial Cities: Łodz, Poland, and Tampere, Finland, Compared', *International Labor and Working-Class History*, 98, pp. 5–21. Available at: https://doi.org/10.1017/S0147547920000125.

Rizzo, E. *et al.* (2015) 'Brownfield regeneration in Europe: Identifying stakeholder perceptions, concerns, attitudes and information needs', *Land Use Policy*, 48, pp. 437–453. Available at: https://doi.org/10.1016/J.LANDUSEPOL.2015.06.012.

Sethia, T. (1996) 'The Rise of the Jute Manufacturing Industry in Colonial India: A Global Perspective', *Journal of World History*, 7(1), pp. 71–99. Available at: http://www.jstor.org/stable/20078659.

Somoza-Medina, X. and Monteserín-Abella, O. (2021) 'The sustainability of industrial heritage tourism far from the axes of economic development in Europe: Two case studies', *Sustainability (Switzerland)*, 13(3), pp. 1–27. Available at: https://doi.org/10.3390/SU13031077.

Stewart, G.T. (2017) *Jute and empire: The Calcutta Jute Wallahs and the landscapes of empire*, *Jute and Empire: The Calcutta Jute Wallahs and the Landscapes of Empire*.

Štrbíková, D., Vdolečková, E. and Vitková, Ľ. (2020) 'Industry as a determining factor of sustainable development of settlements by the Danube', *IOP Conference Series: Materials Science and Engineering*, 960(3). Available at: https://doi.org/10.1088/1757-899X/960/3/032053.

Tureckova, K. *et al.* (2019) 'Categorization of impact of the selected variables for potential brownfield regeneration in the Czech Republic by means of correspondence analysis', *Geographia Technica*, 14(2), pp. 120–130. Available at: https://doi.org/10.21163/GT_2019.142.11.

UNESCO (2003) *Convention for the safeguarding of intangible cultural heritage (2003)*, *The Impact of Uniform Laws on the Protection of Cultural Heritage and the Preservation of Cultural Heritage in the 21st Century*. Available at: https://doi.org/10.1163/ej.9789004180444.I-786.6.

Xu, S. and Aoki, N. (2018) 'Introduction to a Major Project of the National Social Science Fund: Research on China's Industrial Heritage Conservation System', *Built Heritage*, 2(1), pp. 3–18. Available at: https://doi.org/10.1186/bf03545699.

Yang, Q. (2023) 'The Social Production of Industrial Heritage Spaces in the Background of Cultural Governance: A Comparative Study Based on Cases from Taipei and Hong Kong', *Buildings*, 13(7). Available at: https://doi.org/10.3390/buildings13071579.

Zhang, J., Xu, S. and Aoki, N. (2023) 'Contradictions of indigenous cognition and heritage evaluation under political transformations in a working-class community in Tianjin, China', *Cities*, 132(February 2021), p. 104031. Available at: https://doi.org/10.1016/j.cities.2022.104031.

Zhang, P. *et al.* (2021) 'Study on Comprehensive Value of Industrial Heritage in Yuejin Road Historic District Based on GIS Technology', *Open Journal of Social Sciences*, 9(5), pp. 440–454. Available at: https://doi.org/10.4236/JSS.2021.95024.

Zhao, Z. and Liu, Z. (2021) 'Development path of industrial heritage tourism: A case study of Kitakyushu (Japan)', *Sustainability (Switzerland)*, 13(21). Available at: https://doi.org/10.3390/su132112099.

Research Paper

Reviving Heritage and Empowering Communities:
Inclusive Regeneration Practices in the Temple Towns of Bishnupur and Kalna, India

Nandini MUKHOPADHYAY, Indian Institute of Technology Kharagpur, India
Shreyas P BHARULE, Indian Institute of Technology Kharagpur, India
Joy SEN, Indian Institute of Technology Kharagpur, India

Abstract

Temple towns in West Bengal, such as Bishnupur and Kalna, comprise a rich cultural heritage, including terracotta-ornamented temples and intangible artisan craftsmanship and the town's economy thrives on the temple-related activities. The traditional knowledge of temple building and Sthapatis is on the verge of getting lost. Still, the craftsmanship associated with the ornamentation in these temple towns continues, with changed uses and traditional ones in the memories of the elderly. This research aims to preserve these traditions while encouraging community empowerment and social inclusion through innovative regeneration practices. The research uses a qualitative methodology, including a review of existing literature on the domain area, site visits including visual surveys, interviews with artisans and photographic documentation, and analysis of existing terracotta craftworks and saree weaving designs. The research focuses on inclusive practices, including training and resources for the artisan and craftspersons, while recommending community participation. It suggests that this method can enhance community ties and social harmony, and develop policy in heritage conservation and regeneration of temple towns. Integrating traditional crafts into the modern creative economy can be a sustainable strategy for preserving urban memories and reinventing invisible cities.

Keywords

Heritage revival, regeneration, craftsmanship, temple town, community

1. Introduction

1.1. Temple Towns and its Economy

The planning and development of a historic town/city is from within and temples are placed at the center or multiple nuclei of temples and termed temple towns. The system of temple towns revolves around the temple precincts, the associated local community and their rituals and cultural practices, and the intangible cultural heritage. The town's economy thrives on the temple-related activities(Ayyar, 1916). A creative economy is still a developing concept that resorts to creative resources to drive economic growth and development. It encompasses economic, cultural, social, technological, intellectual property, and tourism objectives, with a diverse impact on the economy of the town(Gibson and Kong, 2005), (Nations United, 2024). The creative clusters in historic towns focus on intangible practices, rituals beliefs, and traditions. The case of terracotta artisans' village Panchmura near the temple town of Bishnupur, the Raghurajpur village near the temple town of Puri, pottery communities near Sukhothai World Heritage site in Thailand (Arkarapotiwong & Chindapo, 2023) are a few examples. The knowledge of the local community in historic

towns holds considerable value in driving the economy of the region. In terms of income generation, employment creation, and revenue from exports, the creative economy is one of the rapidly rising sectors of the global economy. The main driving force of these businesses is artisans' unique skillset and creativity, both on an individual and group level. Such an economic system is firmly embedded in the environment in which it develops and thrives and the communities in which it engages. (Saha & Sen, 2016). It serves a key function in the context of these towns, the core creative field comes in the centre, followed by the cultural practices which include the mass production of items that are required for the functioning of the temple, then the people and the cultural practices. All these functions come together for the growth and economic development of these towns.

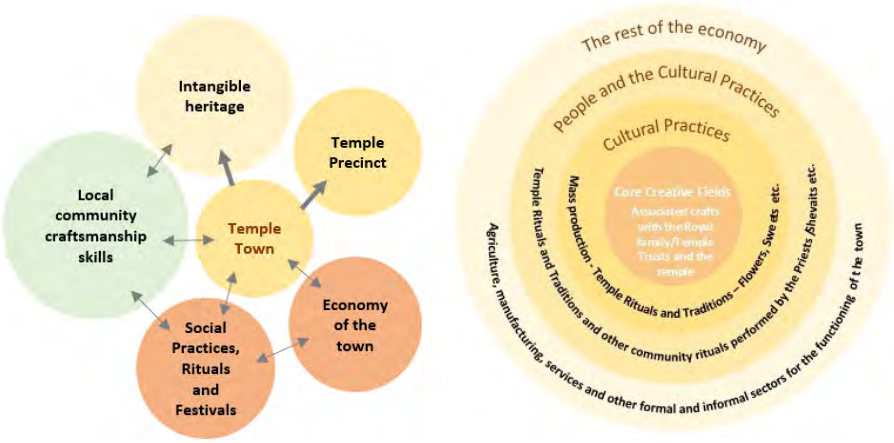


Figure 1. System of Temple Towns and its Creative Economy; Source - Author

1.2. Overview of existing research and background

India has a rich cultural heritage, architecture, historic past, traditional knowledge systems, and practices that highlight the civilization that lived in this geographic entity and which is unique in every state. *'Built heritage within a larger framework of Indian civilizational studies. It confines itself to historical architecture and cities as cultural resources. This approach, which I shall refer to as the Architectural Knowledge Systems approach, is based on the premise that problems with our heritage today can be solved if we understand traditional knowledge systems'* (Thakur, 2002). The temple towns of India are unique, suitable measures should be taken for the conservation and protection of these entities from the glorious past and take them to future generations. These city centres now face issues of congestion, and loss of identity/ character due to the pressure of urbanization and population explosion (Shastri and Subrahmanian, 2021), (Singh and Rana, 2021), (Kaur and Bhandari, 2022). There is the absence of national, state, or local recognition or protection for specific categories, such as cultural landscapes, routes, and historic cities, along with their associated intangibles, although they are included in both the World Heritage List and the Tentative List of India (DRONAH and Niti Ayog, 2021), (Kiruthiga and Thirumaran, 2019), (Kumar Paul, Roy and Kr Paul, 2021). Because of the less organized Craft sector, the implementation of integrated programs for strengthening artisan cooperatives, and organizations becomes difficult while market exploitation continues to marginalize artisans(Bhattacharya and Sen, 2018). The development and protection of identified context-specific cultural heritage values in various historic urban systems are the complex goals of development projects and studies that are looking for a new methodological approach to research, planning, and implementation of sustainable urban development in historic towns. In this framework, sustainable urban economics, preservation of the urban environment, social context, and good governance procedures are viewed as significant parts of the growth of historic towns (Božić, Dumbović Bilušić, & Kranjčević, 2019). There is a lack of adequate cultural resource information and hence policy framework

for conserving the Living Heritage of India needs to be framed in different contexts to ensure the "historic living city" adapts and evolves(Swensen, 2012), (Ragheb, Aly and Ahmed, 2021), (Yawer, Bakr and Fathi, 2022).

The review of the existing literature identifies the need to study the unprotected historic temple towns of India and their associated craft-making communities. The paper is divided into sections comprising the methodology of research, followed by the case studies of the two temple towns of Bishnupur and Kalna in West Bengal, India, and then the research outcomes. It comprises the comparison of survey results between the two temple towns followed by the broader impact of the project and ends with the future development strategies and conclusions.

2. Methodology

Heritage protection initiatives in India frequently concentrate on heritage assets as separate entities, overlooking interdependent areas and communities. Not abiding by the UNESCO's initiatives on Culture 2030 indicators, countries struggle with integrating cultural conservation into conventional development planning(Sridharan, Sharma and ShivaJi, 2023). The loss of traditional knowledge systems can result in environmental deterioration, biodiversity reduction, cultural heritage diminishment, and resource depletion, compromising the sustainability of religious tourism and the preservation of cultural heritage(Tater *et al.*, 2023).

Temple building community is gradually disappearing. And the associated traditional crafts face a lot of hardships. Due to inadequate income to sustain the household, the new generations are migrating to other jobs (Bhattacharya and Sen, 2018). Hence the crafts and the skill set, the intangible cultural heritage are on the verge of getting lost. Therefore, the research is based on establishing a link between traditional craftsmanship and the contemporary needs of society to ensure its continuity and revival of creative economies. The central question is " How can the preservation of cultural heritage and inclusive regeneration practices promote economic empowerment and social inclusion in these towns?".

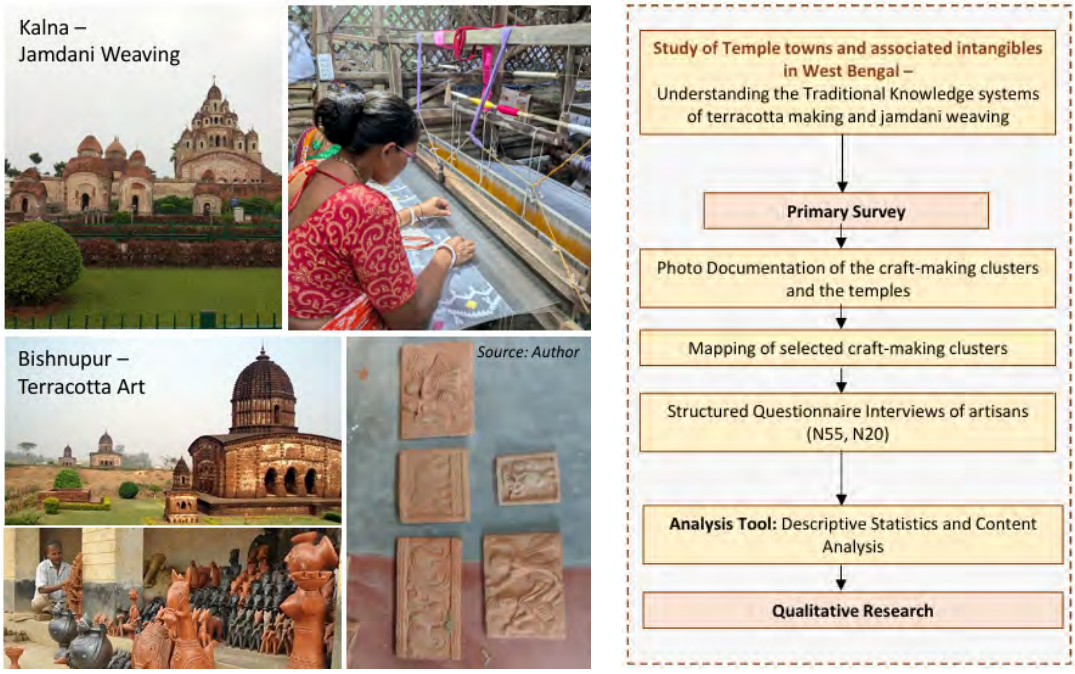


Figure 2. Pictures of Case Studies; Research Method Diagram

A qualitative research study on the temple towns of Bishnupur and Kalna in West Bengal seeks to investigate traditional knowledge systems related to terracotta-making and Jamdani weaving. Qualitative research intentionally selects participants or sites to understand the problem and research question, rather than random sampling. The setting, actors, events, and process of the research are considered, along with the actors' evolving nature within the setting(Creswell and Creswell, 2023).

This research integrates field surveys and observations, photographic documentation, and interviews to examine the intangible cultural history of these crafts and their connection to local temple architecture and rituals. The primary survey involves mapping designated craft-making clusters inside these communities, and photographic documentation of the creative processes of terracotta and Jamdani craftspeople. The study used structured questionnaires to directly engage artisans, with sample sizes of N=20 in Bishnupur and N=55 in Kalna, to collate their reflections, skills, and perceptions regarding the continuity of these crafts. The interviews revealed first-person inquiries of the difficulties and benefits of preserving old craft techniques in a contemporary setting, providing insight into how craftspersons integrate traditional knowledge systems with changing design requirements. Descriptive statistics and content analysis use a systematic method to identify the data patterns and different themes, explaining the cyclic relationship between the temple architecture – the tangible cultural heritage, and the craftsmanship of artisans – the intangible cultural heritage. This research stresses on socio-cultural significance of craft traditions in temple towns and their role in defining the identity of the artisan community and preserving the unique artisan history during the present challenges of modernization and globalization.

3. Case Studies

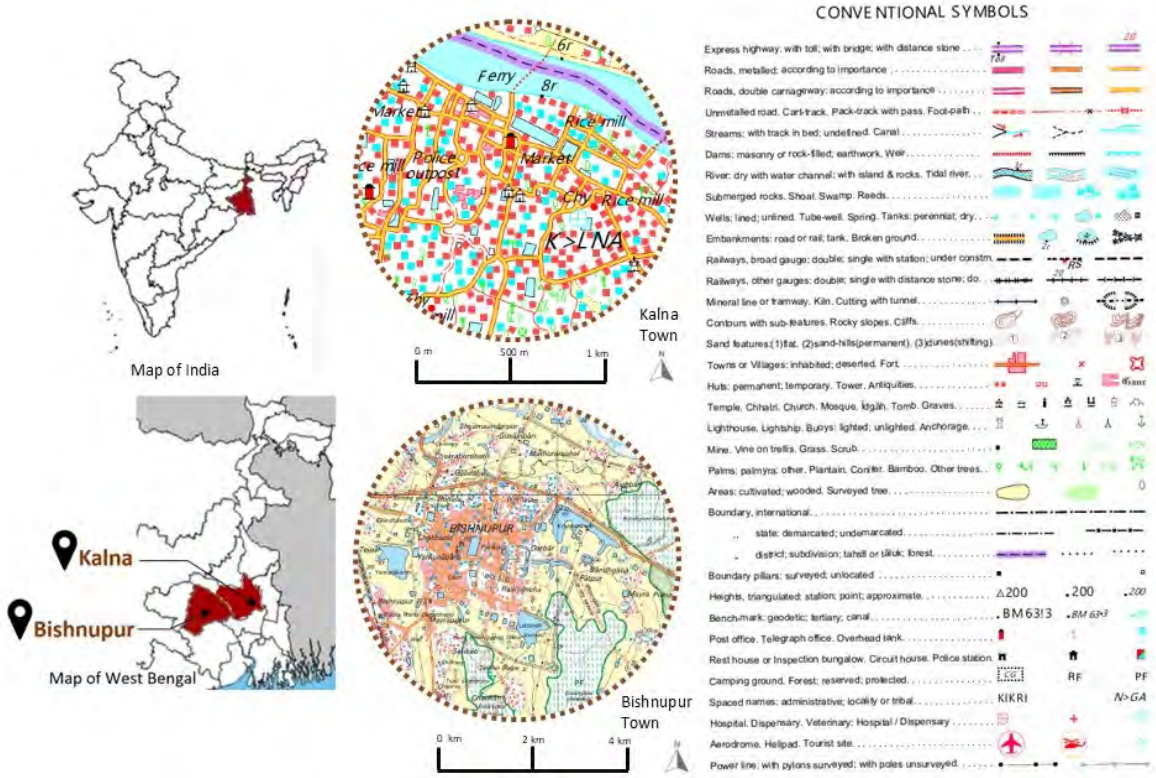


Figure 3. Location of Bishnupur and Kalna in the map of India and the Bankura and Purba Bardhaman district of the state of West Bengal; Survey of India Toposheet 1967

3.1. Case Study 1 – Kalna, West Bengal, India

Kalna is a temple town near the Hooghly River in the Purba Bardhaman district of West Bengal in India with a population of 56,722(Government of India, 2011) and a town size of 4.7 square kilometers renowned for its unique terracotta temple complex in Bengal and Jamdani sarees. Kalna town has several unprotected temples dedicated to Chaitanya Mahaprabhu, the torch bearer of Vaishnavite culture. The Kalna Rajbari complex has 108 Shiv temples arranged in two concentric circles and 12 more living temples under the protection of the Archaeological Survey of India. The Kalna Rajbari/ Place needs urgent conservation and is under the ownership of the descendants of the Bardhaman Kings. The Jamdani saree artisans and their clusters are present in and around the town(Sarkar, 2017). Samudragarh is a Jamdani saree weavers village located at 17 kilometres from the Kalna town. Photographic documentation and mapping of one unit settlement of artisans after understanding the Jamdani saree weaving process as a part of the Primary survey.

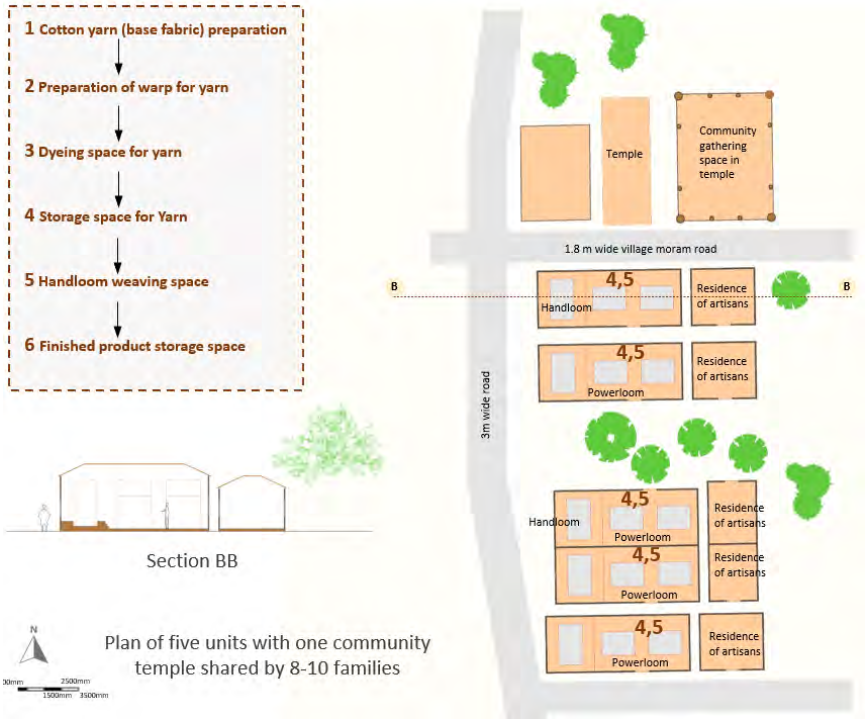


Figure 4. Mapping of one unit in a Saree Weaving Cluster in Samudragarh Village near Temple town of Kalna

The Jamdani saree weaving process is sequential and embodies both craftsmanship and tradition(Yasmin and Agrawal, 2023). The first step is the preparation of cotton yarn of good quality, which acts as the base fabric on which the ornamented design patterns are crafted with detail. Subsequently, the warp, or the longitudinal threads on the loom, is prepared, a crucial step that guarantees the strength of the fabric. In the Dyeing Space, weavers tint the yarn with natural dyes that provide the saree its distinguishing and variety of colors. In contemporary times the dying is done by a separate group of artisans who specialize in it and others purchase from them. After dyeing, the yarn is stored in a dedicated place to be readily used for weaving. The weaving process is carried out in the Handloom Weaving Space, where weavers use handlooms to interlace yarns, producing ornamented patterns and motifs that make each saree unique. Presently each family has one handloom and the rest are power-looms for increasing the quantity of production to meet the market demands. The finished Jamdani sarees are housed in a designated Finished Product Storage Area, prepared for market distribution. Every phase of this technique, from yarn preparation to the finished product, depicts the traditional Jamdani saree weaving. The cluster has

residences and workspaces nearby with a community temple and gathering space for rituals and practices (Figure 4).

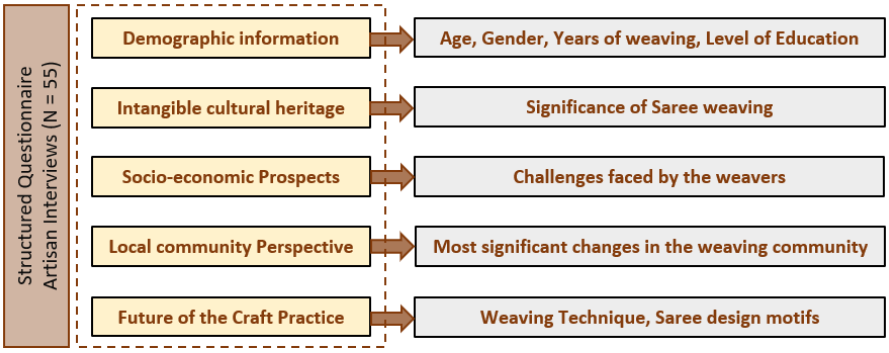


Figure 5. Sections of the Structured Interview Questionnaire for weavers in Kalna

Fifty-five Jamdani weavers from Samudragarh village are surveyed with a structured questionnaire (Figure 5) divided into five sections comprising demographic information, intangible cultural heritage, socio-economic prospects, local community perspective, and the future of the craft practice. The observations from the survey results are mentioned. From the demographic information (Figure 6), it can be noted that the formal education of most weavers is till the fifth standard, the female artisans are 44% of the respondents and they are involved in the handloom sarees due to lower wages and the age group (<5) with years of craft is 15% due to migration to other occupation.

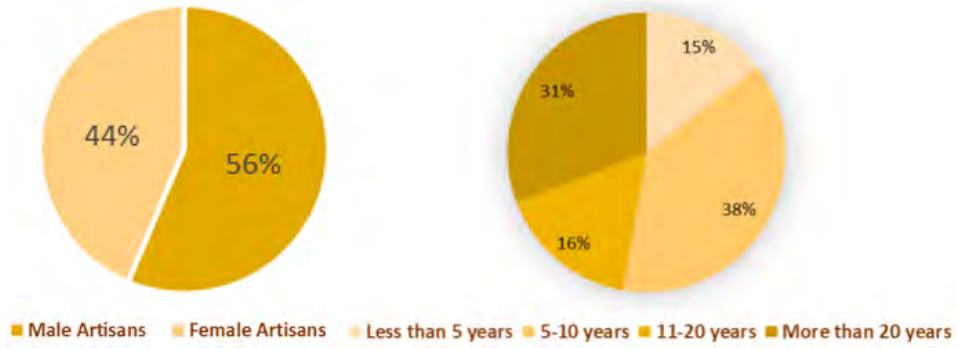


Figure 6. Survey Results Depicting Demographic Information in Kalna

The intangible cultural heritage (Figure 7) of Jamdani weaving and its significance, it can be noted that 40% of the total respondents learned the craft as a part of family tradition and 60% of them feel that the tradition is not being passed on, as the younger generation is not ready to take it up as their primary occupation. 55% of the respondents feel that more support from the government is required for the preservation of the craft as post-covid due to the financial crisis artisans have shifted to powerlooms.

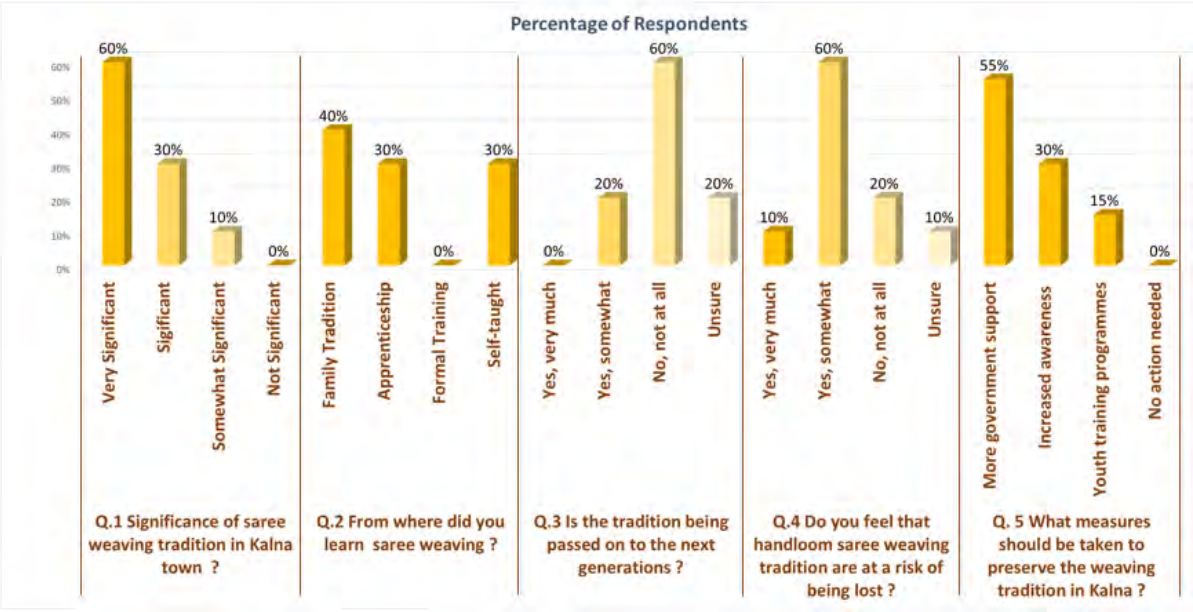


Figure 7. Survey Results Depicting the significance of intangible cultural heritage in Kalna

The challenges faced by weavers (Figure 8) is the comparison with power loom sarees as mentioned by 38% of respondents, as they are cheaper and in high demand. The most significant changes in the weaving community were a shift in Demand and Market Preferences as mentioned by 33% of respondents. Saree Design Motifs – Stories from Ancient Texts (Ramayana and Mahabharata) in the memories of the elderly and not practiced now as mentioned by 5% of respondents.

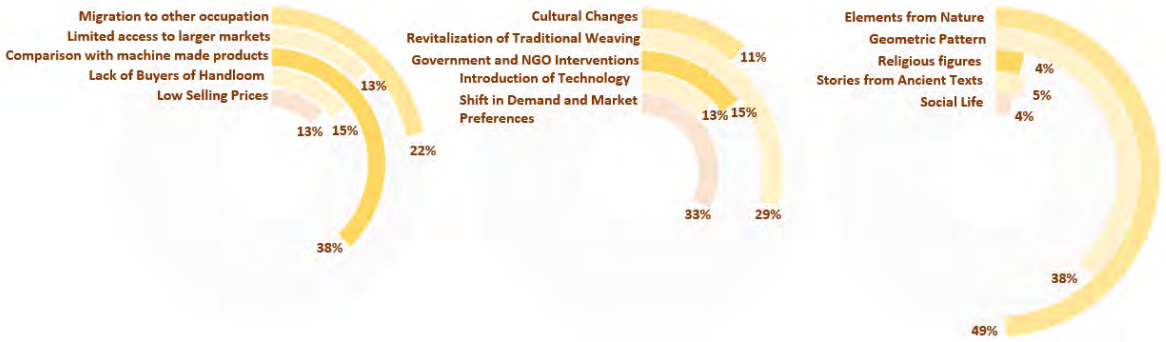


Figure 8. Survey results depicted through 3 charts - Challenges faced by weavers; Significant changes in the weaver's community; Saree Design Motifs in Kalna

3.2. Case Study 2 - Bishnupur, West Bengal, India

Bishnupur is a fortified temple town near Dwarkeshwar river in the Bankura district of West Bengal in India with a population of 67,783 (Government of India, 2011) and a town size of 22 square kilometers renowned for its unique terracotta temple architecture in Bengal and Baluchari sarees. Bishnupur has seven man-made water embankments/ bandhs a source of water supply to the town constructed by the Malla Kings of Bengal(Kumar Bain, 2016). The fortification walls are in remains while the gateways still stand bearing the testimony of time. The town has 20 temples and structures protected under Archaeological Survey of India. The terracotta artisans and their clusters are present in and around the town(Mangaonkar, 2011), (Basu, 2021). Panchmura is a terracotta artisan village located at 24 kilometres from the Bishnupur town.

Photographic documentation and mapping of one unit settlement of terracotta artisans after understanding the terracotta artifact-making process as a part of the Primary survey.

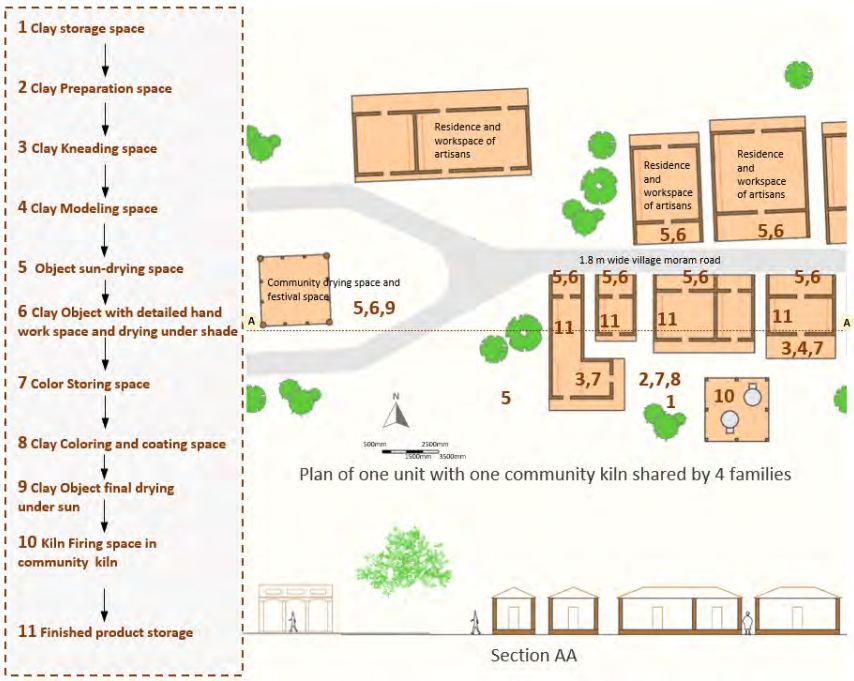


Figure 9. Mapping of one unit in a Terracotta Craft Making Cluster in Panchmura Village

The making of terracotta artifacts comprises multiple steps, each designated to certain locations in the cluster unit(Dutta, 2013). In the first step, clay is preserved in a Clay Storage Space near the artisan's residence to maintain its purity. In the Clay Preparation Space, artisans eliminate impurities from the clay to a refined consistency suitable for clay modeling. Then the clay was kneaded in the Clay Kneading Space, an essential process to improve its texture. Then artisans meticulously mould the clay in the Clay Modelling Space, handcrafting each item. The newly formed objects are then sun-dried in an open area common space shared by artisan families of the village. Artisans do meticulous handwork on delicate pieces, ensuring they are dried in the shade to prevent cracking. Color pigments are housed in a designated location (Colour Storing Space), where female artisans carry out the Clay Colouring and Coating using natural. Subsequently, the objects are positioned outdoors for a final sun-drying procedure. After complete drying, they are transported to the Kiln Firing Space, usually a communal kiln, where high temperatures consolidate the clay. The completed products are stored in a designated Finished Product Storage area, prepared for distribution (Figure 9) . The sharing of spaces for the terracotta artifact-making process instils a sense of belongingness in the community both for the peers and the craft practice.

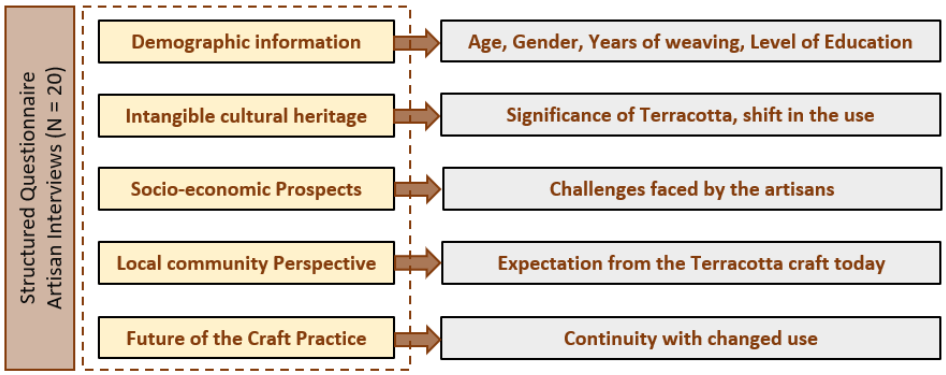


Figure 10. Sections of the Structured Interview Questionnaire for Terracotta Artisans in Bishnupur

Twenty terracotta artisans from Panchmura village are surveyed with a structured questionnaire (Figure 10) divided into five sections comprising demographic information, intangible cultural heritage, socio-economic prospects, local community perspective, and the future of the craft practice. The observations from the survey results are mentioned. From the demographic information (Figure 11), it can be noted that the formal education of the majority of artisans is till fifth standard, only 10% of the total respondents are the young artisan's group and the female artisans are 40% of the total respondents and they are mainly involved in the coloring of terracotta, the designs, and intricate details are done by males.

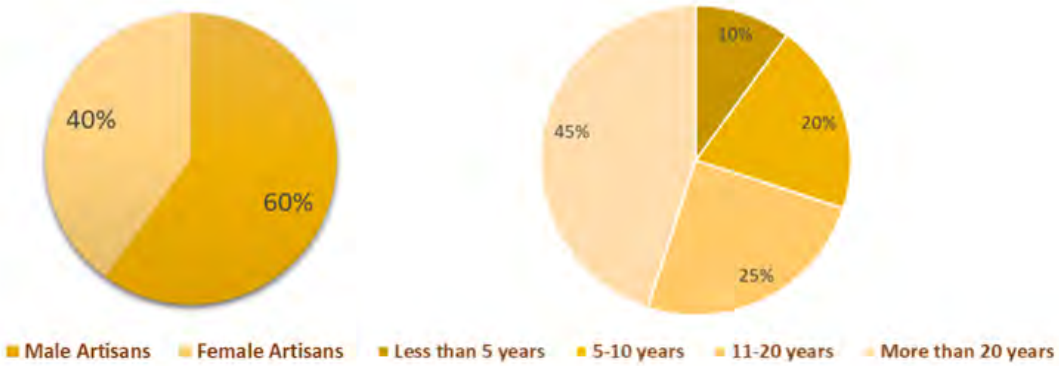


Figure 11. Survey Results Depicting Demographic Information in Bishnupur

The intangible cultural heritage (Figure 12) of terracotta artifact-making and its significance, it can be noted that 75% of the total respondents learned the craft as a part of family tradition and 40% consider the shift in materials of construction as the reason for the shift in the use of terracotta from a building material used in temple ornamentation to present day uses. And 75% of them feel that the tradition is not being passed on, as the younger generation is not ready to take it up as their primary occupation. The temple-building community – Sutradhars and Sthapatis are in the memories of the elderly.

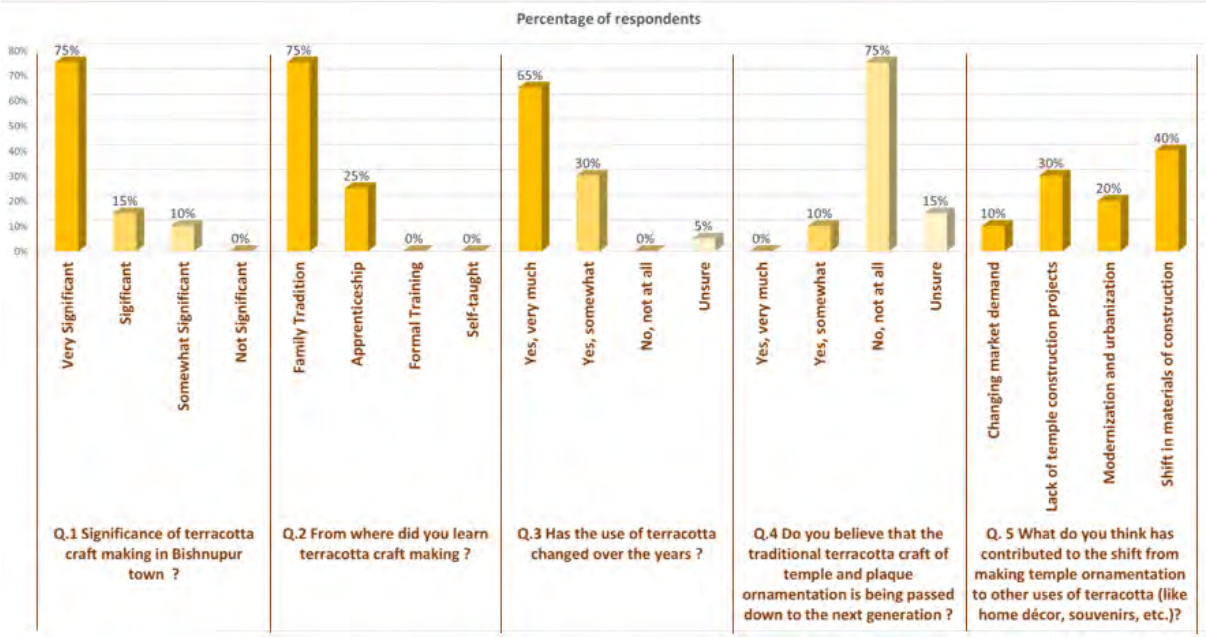


Figure 12. Survey Results Depicting the significance of intangible cultural heritage in Bishnupur

The Challenges faced by most artisans (Figure 13) —40% of total respondents—are the changing cultural relevance of terracotta from temple ornamentation plaques depicting social life to plaques used for interior decoration. The Expectations from the Terracotta craft today (Figure 13) stated by 50% of respondents the changing use, balancing traditional art, and meeting modern requirements. The continuity with changed use (Figure 13); can be noted that the making of terracotta plaques for temple ornamentation is not practiced anymore by the artisan community.

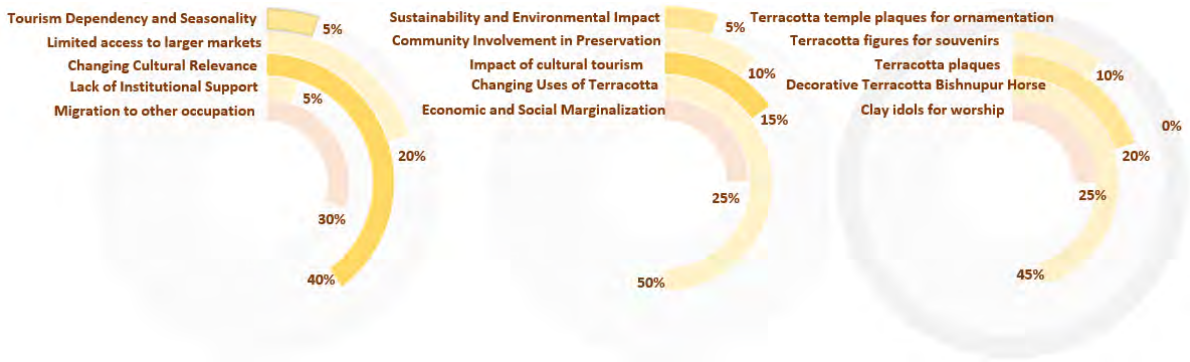


Figure 13. Survey results depicted through 3 charts - Challenges faced by artisans; Expectations from the Terracotta craft today; Continuity with changed use in Bishnupur

4. Research Outcomes

4.1. Comparison between two temple towns

The comparison of the two Case Studies (Table 1) of Kalna and Bishnupur is based on several factors like demographic information, significance of intangible cultural heritage, socio-economic prospects, local community perspective, and future of crafts practice from the primary survey results. It can be noted that terracotta exemplifies architectural craftsmanship, whilst Jamdani Saree fuses tradition with contemporary

fashion. The larger market adaptability of Jamdani promotes economic sustainability whereas the distinctive cultural character of terracotta necessitates a tourism-driven revival for economic advancement.

Table 1. Comparison between Survey results of two temple towns

Factors	Kalna	Bishnupur
Demographic Information	Due to lack of formal education, the artisans could not adapt to the modern technology. The designs once done by the artisans are now done by designers in power loom.	The use of terracotta has evolved from a building material, idol worship to a decorative element with new design forms preserving the craft techniques.
Intangible cultural heritage	The traditional handloom technique is on the verge of getting lost, very few artisans practice it now.	The temple-building community of sutradhars are losing its identity but the kumbharkars the terracotta artisans are practicing the traditional craft.
Socio-economic Prospects	The artisans receive a meagre amount on the finished product, as the larger market is mainly accessed through middlemen.	The creative economy of the temple town from the terracotta crafts and the Baluchari saree weaving can be revived with the use of modern technology.
Local community Perspective	The steps of making a saree are now divided into several groups, yarn making by one group, dyeing by one, likewise.	Every year, Cultural fairs and festivals celebrate the artisans and make global outreach and promotion.
Future of the Craft Practice	The artisans have a positive attitude that the demand for handloom sarees will return, as the power loom saree has very little longevity. The traditional design motifs to be revived.	The artisans are trying to balance the traditional craft and modern aesthetic designs and needs of society.

Therefore, the survey in temple towns depicts several factors impacting craft traditions: first, market demand and commercial feasibility ensure craft making, and second, the transmission of skills to younger generations guarantees the continuation of the tradition. Blending technology in traditional craft-making modernizes the process, while sustainable practices and access to raw materials maintain environmental balance. Additionally, the preservation of craftsmanship, along with global recognition and promotion, collectively sustains these traditions and practices.

4.2. Broader Project Impact

In temple towns, the temple precinct serves as the town's spiritual and cultural centre. Situated in a natural setting near a river, the temple's unique terracotta architecture complements nature, its aesthetic and spiritual importance. A craft cluster flourishes around the temple, where craftsmen practice traditional crafts, the intangible heritage; becomes the spirit of the place. The local community cultivates a sense of belongingness and collective bond(Kato, 2006). Hence the conservation of skill, the conservation of craft,

and the continuity of rituals are significant in these towns (UNESCO, 2022).The skills are acquired orally or in hands-on sessions from a person who shares the knowledge. The traditional knowledge systems have to be passed on. The craft is the practical implementation of skills through any method. For the conservation of craft, continuity is significant. The conservation of skill can be achieved through digital documentation(Isa *et al.*, 2018), use of technology, and a cultural heritage status. The conservation of craft is done through the organization of apprenticeships and workshops, site-based workshops, and the generation of funding opportunities. The continuity of temple rituals can be maintained through digital documentation, community participation in temple activities, and monetary support from government and religious institutions. This can make the craftspersons relevant in contemporary times with future generations genuinely interested in learning this skill set making it their primary occupation and reviving the creative economy.

4.3. Future Development and Conclusion

This research answers the central question and delves into the identification of techniques for the preservation of cultural heritage and inclusive regeneration practices to promote economic empowerment and social inclusion in the temple towns of Bishnupur and Kalna. It can be noted that the craftsmanship associated with the ornamentation in the temple is continuing, but the use has changed in Bishnupur. Similarly in Kalna, the design motifs have evolved, but the craftsmanship of saree weaving is continuing. Therefore it highlights the importance of the conservation of the skill of craftsmanship, the craft itself as evidence, and the continuity of the rituals in these temples, which are long-standing evidence of the traditional knowledge. This explains a cyclic relationship between the craftsperson and the cultural heritage of temple towns which ensures its sustainability while reviving the creative economies. Hence the measures mentioned can instill collective bonds and social harmony in the community and implementation of the policies related to the conservation of cultural heritage including the tangible and the intangible are crucial for the continuity of these temple towns in the twenty-first century

5. References

Ayyar, V.C.P. (1916) *Town Planning in Ancient Dekkan* . 1st edn. Madras: Law Printing House.

Basu, A. (2021) 'Contexts and concerns for sustainability of cultural heritage sites of Bishnupur | Contextele și preocupările pentru sustenabilitatea siturilor patrimoniului cultural din Bishnupur', *Plural. History. Culture. Society*, 8(2), pp. 120–130. Available at: https://doi.org/10.37710/PLURAL.V8I2_11.

Bhattacharya, R. and Sen, S. (2018) *Pride and Prejudice: The Condition of Handloom Weavers in West Bengal*. Available at: www.twitter.com/working_indiawww.facebook.com/centreforsustainableemployment/.

Creswell, J.W. and Creswell, J.D. (2023) *Research Design Qualitative, Quantitative, and Mixed Methods Approaches* . 6th edn. Thousand Oaks: Sage.

DRONAH and Niti Ayog (2021) *Challenges faced in Heritage Management in India and Policy Imperatives*. Available at: https://www.niti.gov.in/sites/default/files/2023-03/Challenges%20Faced%20in%20Heritage%20management%20in%20india%20%26%20policy%20imperatives.pdf (Accessed: 25 February 2024).

Dutta, A. (2013) *The Cultural Significance of Early Historic Terracotta Art ofWest Bengal: An Ethnoarchaeological Approach*. Deccan College Post-Graduate and Research Institute.

Gibson, C. and Kong, L. (2005) 'Cultural economy: a critical review', *Progress in Human Geography*, 29(5), pp. 541–561.

Government of India (2011) *West Bengal Census*. Kolkata.

Isa, W.M.W. *et al.* (2018) 'Digital preservation of intangible cultural heritage', *Indonesian Journal of Electrical Engineering and Computer Science*, 12(3), pp. 1373–1379. Available at: https://doi.org/10.11591/ijeecs.v12.i3.pp1373-1379.

Kato, K. (2006) 'Community, connection and conservation: Intangible cultural values in natural heritagethe case of Shirakami-sanchi world heritage area', *International Journal of Heritage Studies*, 12(5), pp. 458–473. Available at: https://doi.org/10.1080/13527250600821670.

Kaur, P. and Bhandari, H. (2022) 'Transforming Traditional Cities to Smart Cities: An Overview of Hriday Scheme, India', *ECS Transactions*, 107(1), pp. 8521–8530. Available at: https://doi.org/10.1149/10701.8521ecst.

Kiruthiga, K. and Thirumaran, K. (2019) 'Effects of urbanization on historical heritage buildings in Kumbakonam, Tamilnadu, India', *Frontiers of Architectural Research*, 8(1), pp. 94–105. Available at: https://doi.org/10.1016/j.foar.2018.09.002.

Kumar Bain, W. (2016) 'Bishnupur: A Town of Cultural Excellence', *Journal of the Anthropological Survey of India*, 65(1), pp. 89–105. Available at: https://journals.sagepub.com/doi/pdf/10.1177/2277436X20160107 (Accessed: 12 February 2024).

Kumar Paul, S., Roy, S. and Kr Paul, S. (2021) 'Urban dynamics and contested built-heritage: study of a historic town in India', in *Conference: Asian University Network Forum on Advances in Research (AUNFAIR) 2016At: Aichi Gakuin University, Japan*. Available at: https://www.researchgate.net/publication/357254729.

Mangaonkar, P. (2011) 'Terracotta Temples of Bishnupur: Transformation through Time and Technology', *Chitrolekha International Magazine on Art and Design*. Available at: www.chitrolekha.com/V1/n2/04_terracotta_Architecture_of_Bankura_technology.pdf.

Nations United (2024) *UNITED NATIONS Creative Economy Outlook 2024*. New York. Available at: https://shop.un.org/.

Ragheb, A., Aly, R. and Ahmed, G. (2021) 'Toward sustainable urban development of historical cities: Case study of Fouh City, Egypt'. Available at: https://doi.org/10.1016/j.asej.2021.06.006.

Sarkar, S. (2017) 'A Detailed Analysis of Cotton Textile Industry at Bardhaman Cluster of West Bengal', *The International Journal of Engineering and Science*, 6(01), pp. 33–39. Available at: https://doi.org/10.9790/1813-0601023339.

Shastri, A. and Subrahmanian, R.R. (2021) 'Historic cities in karnataka: Policies for conservation, growth and sustenance, the case of badami and kampli', in *Advances in Science, Technology and Innovation*. Springer Nature, pp. 311–324. Available at: https://doi.org/10.1007/978-3-030-51961-2_24.

Singh, R.P.B. and Rana, P.S. (2021) *Cultural Diplomacy in India: Dispersal, Heritage Representation, Contestation, and Development*, *Transcultural Diplomacy and International Law in Heritage Conservation: A Dialogue between Ethics, Law, and Culture*. Available at: https://doi.org/10.1007/978-981-16-0309-9_15.

Sridharan, K., Sharma, A. and ShivaJi (2023) 'Cultural Heritage Conservation Through the Framework of UNSDG', in A. Chakrabarti and V. Singh (eds) *Design in the Era of Industry 4.0 , Proceedings of ICoRD 2023*. Springer, pp. 1129–1145. Available at: https://doi.org/https://doi.org/10.1007/978-981-99-0264-4.

Swensen, G. (2012) 'Integration of historic fabric in new urban development-A Norwegian case-study', *Landscape and Urban Planning*, 107(4), pp. 380–388. Available at: https://doi.org/10.1016/j.landurbplan.2012.07.006.

Tater, N.G. *et al.* (2023) 'The Role of Sacred Eco Heritage Places in Conserving Traditional Knowledge Systems: The Case of the Braj Region in India', *ISVS e-journal*, 10(5), pp. 113–134. Available at: https://www.researchgate.net/publication/372077636_The_Role_of_Sacred_Eco_Heritage_Places_in_Conserving_Traditional_Knowledge_Systems_The_Case_of_the_Braj_Region_in_India (Accessed: 27 November 2023).

Thakur, N. (2002) *The Architectural Knowledge Systems Approach*, *Architexturez Imprints*.

UNESCO (2022) *Basic Texts of the 2003 Convention for the Safeguarding of the Intangible Cultural Heritage 2022 Edition*. Paris.

Yasmin, Z. and Agrawal, N. (2023) 'Design Intervention in Jamdani Motif Development', *International Journal for Multidisciplinary Research (IJFMR*, 5(4), pp. 2–8. Available at: www.ijfmr.com.

Yawer, A.S., Bakr, A.F. and Fathi, A.A. (2022) 'Sustainable urban development of historical cities: Historical Mosul City, Iraq'. Available at: https://doi.org/10.1016/j.aej.2022.12.042.

Research Paper

Clarifying Existing Land Use Rights in China

Foundation for Urban Redevelopment

Zhangna SU, South China University of Technology, China
Jianyun ZHOU, South China University of Technology, China

Abstract

After 3 decades of rapid urbanization spurred by reform and opening-up, China is currently entering a downturn in the real estate sector. The previous development model was based on the publicly-owned land system and leasehold system. However, top-down planning has established visible buildings and properties but has failed to clearly define the invisible newly established land use rights. Widespread privatization of land use rights has led to the stock development model. Empowering private landowners is necessary to mobilizing urban renewal initiatives and facilitate urban regeneration. Existing use rights need to be clarified. This paper examines the concepts of "existing use", reviewing legal definitions of "existing" as the time node that defines rights and "use" as the essence of rights under different land systems. Using Guangzhou and Shenzhen as examples, it analyzes the practical implications of "existing use" in national and local urban planning laws and regulations. It reveals that provisions related to "existing use" are scattered across planning technical standards and local urban renewal policy. However, local renewal policies cannot substitute legal provisions of "existing use." Moreover, the fact that policies substitute laws in interpreting "existing use" indicates current urban redevelopment are restricted to the single approach of land acquisition. This reality leads to the rigidity of land use , the suppression of private urban renewal initiatives, and the lack of legal basis for compensation in land acquisitions.

Keywords

Existing Use, Land Redevelopment, Land Use Right, Development Right

1. Introduction

After 3 decades of rapid urbanization spurred by reform and opening-up, China is now entering a downturn in the real estate sector. The previous development model was based on public land ownership, including state-owned urban land and collectively-owned rural land, on the one hand, and the land lease system borrowed from Hong Kong, on the other. By statutory detailed plan and land lease contracts, the government converted collectively-owned rural land to state-owned urban land and then granted state-owned land to private individuals for a certain number of years, usually 40 or 70 years. In this system, the government, as both landlord and planning authority (Booth, 1996; Lai, 1998), has played a dominant role in the process of marketization of land use rights. However, this system has established tangible buildings and properties but failed to clearly define the intangible land use rights. Widespread privatization of land use rights has led to a shift from incremental expansion based on land grants to stock development based on urban renewal. This problem has been highlighted in urban renewal where the lack of clear definitions of land use rights increases transaction costs, and emerging demands for self-renovation highlight the limitations on private rights. With the real estate downturn and local debt problems, local

governments find it challenging to continue their dominant role in urban development. Empowering private landowners is necessary to mobilize urban renewal initiatives and facilitate urban regeneration. Existing use rights need to be clarified as they form the basis of the redevelopment system.

Since “existing use” is not presented as a formal concept in the domestic legal documents, most of the relevant studies in China have introduced this concept in overseas planning, such as “non-conforming use” of existing use in New York’s zoning (Li, X., 2007; Li, S., 2020) and “existing use” in Hong Kong’s Town Planning Ordinance(Guo, 2022). In addition to urban and rural planning, other fields in territorial spatial planning in China also face similar existing use issues(Wu, 2018), which provides some reference perspectives. In contrast, as some other regions have already established the concept of existing use in their laws and practices, the relevant international studies present different research depths and orientations. The studies span a variety of fields such as planning, law, and land, with legal scholars contributing most of the research. They also span different land systems, with different regions focusing on different areas of concern. Scholars in the United States have explored the defining factors of the generation and acquisition of existing uses(Scott, 1956), the constitutionality of regulating existing uses (O'Connell, 1961) and the justification for special protection of existing uses (Serkin, 2009). Australia Scholars have explored the impact of amendments to planning regulations on existing uses (Nguyen, 2006) and the balance of planning ideologies in existing use rights cases (Schatz, 2015). British scholars have explored the impact of planning permissions on existing use rights (Fairest, 1971; Duxbury,1984). In general, Chinese scholars have not widely recognized the significance of the concept of “existing use”, and have not extended their research from a simple introduction to a systematic and applied study of “existing use” in China's land system.

This paper examines the concepts of "existing use", reviewing legal definitions of “existing” as the time node that defines rights and “use” as the essence of rights under different land systems. Taking Guangzhou and Shenzhen as examples, it analyzes the practical implications of "existing use" in national and local urban planning laws and regulations. It finds that national laws do not explicitly define the concept of "existing use" or specify "existing use rights." Provisions relating to "existing use" are scattered throughout planning technical standards and local urban renewal policy documents. The fact that policies substitute laws in interpreting "existing use" indicates that current urban renewal is restricted to the single approach of land acquisition. This reality leads to the rigidity of land use , the suppression of private urban renewal initiatives, and the lack of legal basis for compensation in land acquisition.

2. The concept of “existing use”

It is clear that “existing use” is a technical term, one which has a separate and distinct meaning from actual physical utilization or alteration of realty (Scott, 1956). In many national and regional planning systems, “existing use” or “existing use right” is presented as a legal term (see Table 1). In general, existing use refers to a land use that existed prior to the effective date of certain plans, zoning or regulations, and is protected as a property right to varying degrees in different systems.

Table 1. Relevant concepts and definitions of existing use

Provenance	Concept	Definition
Building Zone Resolution 1916, City of New York	Existing building and premises	Any use existing in any building or premises at the time of the passage of this resolution and not conforming to the regulations of the use district in which it is maintained
Zoning Maps and Resolution 1961, city of New York	Existing uses	In all districts, after the effective date of this resolution, the use of any existing building or other structure; any existing tract of land
	Non-conforming	Any lawful use, whether of a building or other structure or of a tract of land. Which does not conform to any one or more of the applicable use

	use	regulations of the district in which is located, either on the effective date of this resolution or as a result of any subsequent amendment thereto.
Town Planing Act 1990, UK	Existing buildings and uses	Buildings or works constructed or carried out, or a use of land instituted, before the date of the application
	Established use	(a) it was begun before the beginning of 1964 without planning permission and has continued since the end of 1963; (b) it was begun before the beginning of 1964 under a planning permission granted subject to conditions or limitations, which either have never been complied with or have not been complied with since the end of 1963; or (c) it was begun after the end of 1963 as the result of a change of use not requiring planning permission and there has been, since the end of 1963, no change of use requiring planning permission.
Environmental Planning and Assessment Act 1979, New South Wales	Existing use	(a) the use of a building, work or land for a lawful purpose immediately before the coming into force of an environmental planning instrument which would, but for this Division, have the effect of prohibiting that use, and (b) the use of a building, work or land— (i) for which development consent was granted before the commencement of a provision of an environmental planning instrument having the effect of prohibiting the use, and (ii) that has been carried out, within one year after the date on which that provision commenced, in accordance with the terms of the consent and to such an extent as to ensure (apart from that provision) that the development consent would not lapse.
Planning Act 2016, Queensland	Existing lawful uses	A lawful use of premises immediately before a planning instrument change
Town Planning Ordinance, Hong Kong	Existing use	in relation to a development permission area means a use of a building or land that was in existence immediately before the publication in the Gazette of notice of the draft plan of the development permission area
Standard Master Schedule of Notes to Statutory Plans for urban area, Hong Kong		(i) before the publication in the Gazette of the notice of the first statutory plan covering the land or building, ● a use in existence before the publication of the first plan which has continued since it came into existence; or ● a use or a change of use approved under the Buildings Ordinance which relates to an existing building; and (ii) after the publication of the first plan, ● a use permitted under a plan which was effected during the effective period of that plan and has continued since it was effected; or ● a use or a change of use approved under the Buildings Ordinance which relates to an existing building and permitted under a plan prevailing at the time when the use or change of use was approved.
Standard Master Schedule of Notes to Statutory Plans for rural area, Hong Kong		the use of any land or building which was in existence immediately before the first publication in the Gazette of the notice of the (interim development permission area plan/draft development permission area plan) conform to this Plan

2.1. The concept of "status quo use" in planning survey

"Status quo use" in the context of planning survey, based on Geddes' rational process planning method of "survey-analysis-planning", is the purpose and result of the act of "survey". The "status quo" refers to a wider time frame, referring to the state of the land at the present time, usually before the final planning action. In rational process planning, planning is seen as a scientific process rather than a political process

(Taylor, 1998), and the status quo use is seen as an object of the planning action, an object to be interfered with, rather than an vested right that needs to be treated equally. Therefore, "Status quo use" in the context of planning surveys is presented more as a material and functional base map of the status quo for planning and less as a rights-based aspect.

2.2. The concept of "existing use" in planning intervention

"Existing use" is presented in the context of planning powers interfering with private property rights. In the public interest, planning in the broad sense of planning regulations, planning instruments, and zoning almost always intervenes in land, either by imposing on an area a vision of the future that differs from the present situation (planning control) or by directly interfering with the right to use and develop the land (development control). when these interventions are imposed on built-up areas, established land uses may become non-compliant, even if they were previously legally acquired. If the land is privately owned, a paradox arises: land use is protected as a private property under the property laws of most countries, while planning authorities have the power to intervene, whether this power comes from the police power in private ownership or from the government's inherent power to control the land in public ownership. And, as a dynamic set of documents, plans and regulations change over time, so land use and property rights may face some uncertainty from time to time. Essentially, this is a conflict between private property rights and planning powers: for existing uses, the property law wants to protect them, while the administration wants to interfere with them, and "the public interest nature of planning encounters the traditional tendency of courts to protect private property rights."(Schatz, 2015)

At this point, the concept of "existing use" is introduced, identified as a pre-existing right prior to planning intervention, as distinguished from a future use designated by the plan (Booth,2002). Planning only intervenes in the future and cannot retroactively apply to property rights that existed prior to planning. Existing use rights protect private land users to some extent from changes in planning law and allow landowners to continue to use their property for lawful purposes. By separating existing uses from planned future uses, the conflict that needs to be addressed shifts from the conflict between private rights versus planning power to the relationship between existing use versus future use (see Figure 1).

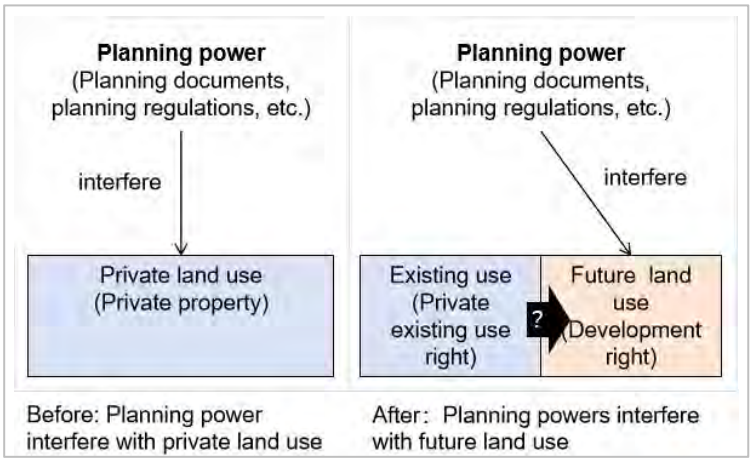


Figure 1. The establishment of existing uses: separation of existing and future uses

In summary, there are two prerequisites and one trigger for existing use. First, private property right in land is a prerequisite; if ownership and use are public, then housing and land use is simply just a "status quo use" that serves as a base map for planning, and intervention in it is subject only to the costs of construction and not to the transaction costs associated with property rights. Second, it is "existing" and precedes the plan or regulation that intervenes. Finally, planning or regulatory intervention on private property triggers the need to define existing use. Existing uses and existing use rights, as well as their

counterparts future uses and development rights, do not arise from planning interventions, which "merely bring the issue to light" (Li,F.,2015) .

3. Definition of "existing" (the time node that defines rights) and "use" (content of rights) in the context of existing use

3.1. Definition of "existing": when are existing rights defined under different land systems?

In different land systems, there are differences in the way land use is generated. As a result, the relationship between land use and planning powers and development rights varies, as does the generation of existing uses and the timing at which "existing" is defined.

3.1.1 Private land ownership, regulated private development rights: the zoning model of New York

In some private land ownership system, existing uses arise from the inherent tenure of the land long before the birth of planning intervention, and before the birth of planning land use was primarily subject only to the common law of ex post remedies for nuisances, and it was only after the birth of planning law and planning that ex ante interventions in future land use and the constraints on the development right arose. New York is an example, where zoning began to impose extensive interventions in land use with the passage of the first zoning resolution in 1916. Zoning provided for the continuation of "any use existing in any building or premises at the time of the passage of this resolution," but the future land use and development rights were regulated, with future uses and development rights that conformed to zoning remaining private, or being granted to private persons in advance by zoning, but those that did not conform to the zoning being physically restricted. For a factory zoned R1 Residential, it can continue industrial use under its existing use rights (this part of the existing use rights is entirely private), or it can follow the zoning rules and develop on its own without a permit to convert to a conforming use (this part of the development rights is pre-granted to a private party by the zoning), but to convert to any other use that does not conform to the R1 rules, it may require a permit or simply be prohibited (this part of the development rights is actually controlled by the police power).

Although both existing uses and a large proportion of development rights are private under zoning, a clear distinction needs to be made between existing use rights and development rights. Development rights that comply with zoning rules are theoretically private, but they are potential and unfulfilled rights that depend on the recognition of the zoning, and this part of the development rights can change when the zoning changes. This is why in some cases there are disputes about whether development rights have been acquired under zoning. For example, if someone was in the process of developing the land as of right under previous zoning, and a new zoning ordinance was enacted, the court need to determine whether the development rights have been acquired on the half-built lot, and whether the new "existing use" has been realized (Scott, 1956). In the Court's opinion, a certain amount of physical construction can be considered to have acquired development rights and to have fixed the development rights to the existing use, essentially recognizing the realization of the property right to the existing use by recognizing this physical input.

3.1.2 Private land, nationalized development right: the development control model of the UK

Also under a private land ownership system, "existing use" was introduced in the UK not through planning or zoning intervention in future use, but through the nationalization of development rights under the Planning Act. Despite the enactment of the first Town and Country Planning Act as early as 1909, the lack of central support for local government made it difficult for planning schemes to intervene in private land use and development under the huge expropriation compensation costs (Cullingworth & Nadin, 2014). Following the passage of the new Town and Country Planning Act in 1947, development

rights were nationalized once and for all, with private individuals retaining only the existing (1947) use rights and values in their land, and any development required a permit. It separated the right to existing use from the right to the further development of land (Booth, 1996). The withdrawal of development rights through legislation represented the nationalization of all future land use possibilities. The difference with the zoning model is that "existing use" in the UK is not because the plan depicts a future use that is different from the current one, but because all future land use and development rights no longer belong to private individuals and have to be determined and allocated by the state. There is a clear distinction between existing use rights and development rights, which belong to the private sector and the state respectively. Due to the excessive administrative control of the nationalization of development rights, development rules were subsequently introduced to grant a portion of the development rights that comply with the rules to private individuals in advance.

3.1.3 State-owned land，private land use right: the hybrid model of Hong Kong

In the case of Hong Kong, under the public land ownership and leasehold system, the existing land uses are basically separated from the publicly owned land and granted by the government to private individuals. The formation of the land system in the history of Hong Kong is divided into several parts. On Hong Kong Island, after it was ceded to the British in 1842, the Letters Patent in the following year declared that the colonial land belonged to the British Crown, and thereafter, all land was to be held under leases granted by the Crown. In the New Territories, after the British imposed a lease in 1898, some of the land was resumed as Crown land and the land originally recognized by land leases as having full private property rights was restricted from future development rights, while another portion of the rural land was exchanged for Crown leases, converting the private land ownership into tenancy rights (Guo,Z., 2020). The current land system in Hong Kong is a combination of state-owned land and leasehold system. The land use was intervened in since its inception, and prior to the advent of planning, this intervention was mainly from the control of land contracts, which represented private property rights to land. Before Hong Kong was colonized by the British, the right in the land contracts (granted by the Qing government) was still freehold. But later on, when Hong Kong was colonized, the freehold gradually change to leasehold. And the emergence of statutory plans imposed further control over the future land use. There are different plans that intervene in the future land use in different areas: for example, in areas covered by the Outline Zoning Plans for the urban areas, the existing use is determined by the date of "the publication in the Gazette of the notice of the first statutory plan covering the land or building" .

3.1.4 The point in time when the delineation of an existing use: the moment when the right is interfered with

The cases above show that there is often a point in time at which the delineation of an existing use occurs and that this is the point at which the right is interfered with. Although the system varies from place to place, the delineation of existing use is triggered whenever there is a legal intervention in land use through plans or regulations. In most areas, the point in time is before the passage or coming into force of a legally binding plan or zoning, such as New York's 1916 and 1961 zoning resolutions and Hong Kong's statutory plans. Not all plans will be the point in time. Only plans that directly affect rights, rather than policy-oriented plans, will trigger the definition of existing uses. In the UK, the time node is more specific, being the date of enactment of the planning legislation, with the withdrawal of development rights being a direct intervention in rights. In summary, existing uses are delineated when future rights are interfered with. Earlier plans, zoning, and regulations provided an initial definition of existing uses, and all subsequent land uses must be converted to new existing uses based on existing uses and in compliance with current plans, regulations, and permits. Later, new plans, zoning, and regulations become the new criteria and time nodes for delineating existing uses. The time node of "existing" reflects the actual legally binding planning tools in the planning systems of different places. "Existing" also reaffirms the difference

between “status quo use” and “existing use”: “existing” is a legal concept, referring to the moment when the law intervenes; it is not an arbitrary point in time, but a point in time when public and private rights are divided.

3.2. Definition of “use”: what is the content of existing use rights?

Once the time node for defining existing uses has been determined, how should the content of existing use right be defined? For example, should the existing use of a coffee shop be recognized as “coffee shop”, “restaurant” or “store”? On the surface, this seems to be a matter of classification or accuracy of language, but in reality, it is a matter of initial allocation and establishment of rights. Defining the use of a coffee shop as a “store” gives it a greater right than defining it as a “coffee shop” or “restaurant”. In defining the existing use, the definition of “use” will determine the range of the right. An overly broad use may result in a nuisance with excessive land use rights, while an overly subdivided use may result in too narrow a right and make it difficult to fully utilize the land.

Some regions have developed a set of use classes to standardize the expression of existing uses and to define existing use rights, such as the Use Classes Order (UCO) in the United Kingdom, which was developed as a companion piece of legislation to the 1947 reform of the nationalization of development rights, and which is a typical tool for defining uses and rights. In the context of the nationalization of development rights, land use would have been very rigid if owners had only the pre-1947 status as their existing use rights while the rest of the land use possibilities could only be obtained by applying for permits. Therefore, the first UCO of 1948 divided the uses into 22 classes, with one class being a bundle of rights for an existing use, thus transforming the pre-1947 land use status into a set of rights. Under the UCO, the existing use of a coffee shop was a “shop,” and all uses within the “shop” class fell within its existing use bundle, within which the owner could change uses at will. Over the next half-century, the UCO has been revised and the number of classes has been simplified from the original 22 to 10, and the bundle of existing use rights has gradually been merged and expanded (Su, Zhou and Pang, 2024). For example, a coffee shop was initially entitled as a “shop”, which was adjusted to “class A3. food and drink” in the 1987 revision, and then to a larger class of “class E. Commercial, business and service” in the 2020 revision. In the process, even if the physical form and activity of the pre-1947 existing use remains the same, the existing use rights may change as the UCO is revised.

There are similar tools including broad use in Hong Kong, in which a use is identified as a certain type of broad use, and all activities under that broad use are covered by the land use right. For example, the existing use of a canteen is “eating place”, then the “cooked food centre” and “restaurant” under “eating place” will also fall within the range of its existing use right. To summarize, under different land system, there are different “existing” time node and “use” rights (see Table 2).

Table 2. Summary of definitions of "existing" and "use" of existing uses under each land system

Region	Land system and property	Time node of “existing”	Definition of "use"
New York	Private land, private development right	after the **effective date of the resolution**	Use groups
New South Wales		before the coming into force of an **environmental planning instrument** which would **have the effect of prohibiting that use**	-
Queensland		before the commencement of the Act; before the **commencement/an amendment of a planning instrument**	-
UK	Private land, nationalized development right	before the **appointed** day	Use classes

Hong Kong	State-owned land，private leasehold	before **the publication in the Gazette of n otice of the draft plan of the DPA**	Broad use

4. Existing uses in China : case study of Guangzhou and Shenzhen

So what about existing uses in China? To briefly review the formation of China's land system, starting with the prevailing private property rights over land before 1949, China nationalized urban land and collectivized rural land through a series of land reforms in the 1950s and 1960s, and marketed and privatized land use rights through the land grant system in the 1970s and 1980s, which is a “a legal reversion to private property rights”. Today, China's land-use system consists mainly of a public land system with state ownership of urban land, collective ownership of rural land, and a system of land-use rights grants, an “equivalent of the Hong Kong leasehold system”(Lai, 1995). Existing uses are established by detailed plan as the statutory plan and land grant contracts , on which land use classification explain the content of rights. However, the land grant-oriented land use classification established in the era of incremental development gives only the types of buildings that can be developed without interpreting the land-use activities contained therein. It serves as a technical tool for the planning preparation and implementation that translate planning objectives into construction projects, rather than a set of rules as a statutory tool for land empowerment. The resulting existing use is a single activity and physical form of land use, rather than a set of adaptive land use rights and rules.

Examining the laws and regulations relating to existing uses (see Table 3, table 4), China has not put forward the concept of existing use or defined the right of existing use at the legal level. The Civil Code and the Planning Act only set out the general principles of protecting of lawful private property and owners enjoying rights in accordance with the law, but fail to answer the question of what happens to existing uses when statutory planning conflicts with lawful land use. They only clarify the path of expropriation of existing use where the public interest requires it , while ignoring other dispositions of existing uses in redevelopment. Provisions for the continuation of existing uses and the right of the owner to change the use on his own or to adapt the existing use to a conforming use are missing. In practice, due to legal restrictions in China, except for qualified developers, it was almost difficult for private individuals holding property rights to acquire development rights to develop on their own (Zhou & Qi, 2008). The expropriation of housing and the recovery of land use rights have almost become a mandatory stage of redevelopment (Shan, 2017).

Table 3. National laws, regulations and policies relating to existing uses

laws	Urban and Rural Planning Law
	Property Law
	Land Administration Law
Regulations	Regulations of Housing Acquisition and Compensation on the state-owned land

Table 4. Local regulations and policies relating to existing uses in Shenzhen and Guangzhou

Shenzhen	Urban renewal Regulations, Shenzhen SEZ
	Measures for the implementation of housing Acquisition and compensation, Shenzhen
	Provisions on handling illegal private houses left over from history, Shenzhen SEZ
	Several provisions on handling illegal production and business buildings left over from history, Shenzhen SEZ
	Decision on the disposal of illegal buildings left over from the history of rural urbanization, She nzhen

Guangzhou	Measures for compensation of expropriation of collectively owned land of farmers, Guangzhou
	Measures for the implementation of the expropriation and compensation of houses on state-owned land in Guangzhou
	Measures for Cost Accounting of Comprehensive Renovation of Old Villages in Guangzhou

Provisions related to existing use are scattered in planning technical standards and local urban renewal policy documents, especially in expropriation compensation policies. At present, the compensation standards issued by different regions are complicated. In Guangzhou and Shenzhen, for example, for the expropriation of residential houses alone, there have already been two types of compensation standards : commercial houses and rural houses. Compensation for commercial housing is based on the market value and floor area of the house being expropriated, and monetary compensation and property right exchange are not lower than these two types of benchmarks. Compensation for rural houses is based on the maximum residential floor area permitted to farmers under the policies (Guangzhou's standard is 280 square meters for one people and one house and Shenzhen's is 480 square meters). In the case of non-commercial residences of indigenous villagers in Shenzhen, for example, a house with a floor area of less than 480 square meters can be subject to monetary compensation or property rights exchange at the standard of 480 square meters, while a house with a floor area of more than 480 square meters, in the case of property rights replacement , can only be exchanged at 480 square meters, with the excess part being compensated in monetary terms (see Figure 2). Compensation rates for expropriation are decentralized and vary according to the city, land use, owner and other factors.

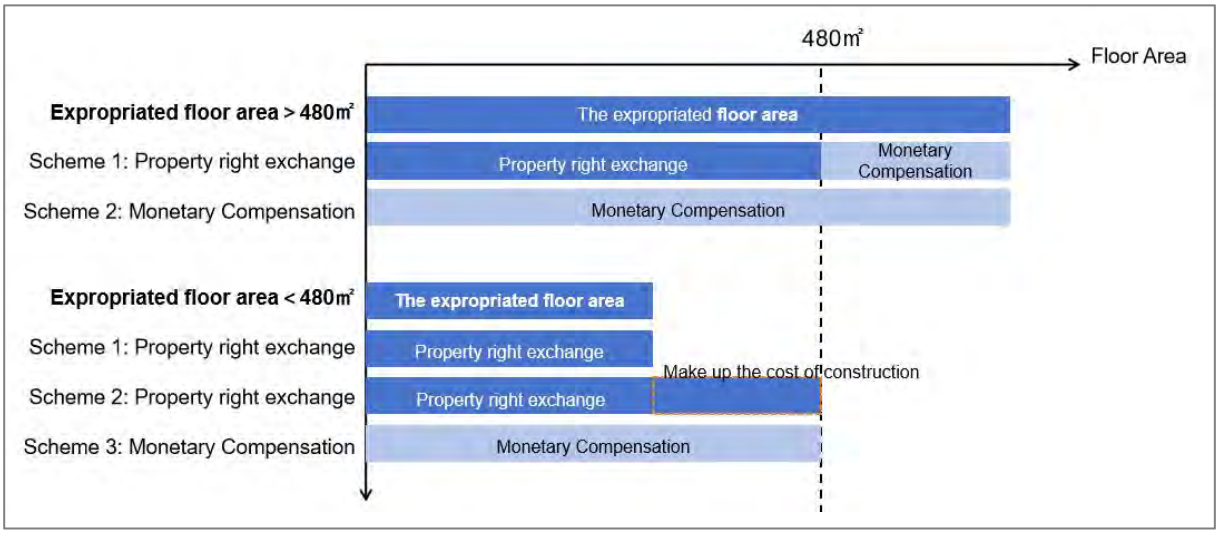


Figure 2. Expropriation compensation scheme of non-commercial housing of indigenous villagers in Shenzhen

In fact, the lack of a clear definition of existing use rights makes compensation for expropriation without a legal basis. Most of the local renewal compensation policies use the "market price of real estate" as the basis for actually recognizing the existing right to use, and to some extent, existing use seems to be recognized more through these local policy documents than through the law. However, the compensation standards only state the rights that can be redeemed in the single case of expropriation, but not the legal recognition of existing use rights. "What rights are included" and "what compensation can be obtained" are actually two different issues. The compensation standard in these policy documents is actually the result of the existing use right superimposed on a number of practical factors, including other urban renewal policies and the games and bargaining between the government and private parties

in the renewal practice. “The Takings Clause is the most likely source of protection, but it cannot fully account for courts' treatment of existing uses.”(Serkin, 2009)

To summarize, there is a lack of a rights perspective in the definition of existing uses in land use regulation. Existing use in the built environment is not without legal rights; if an existing use can be put into use in the process of planning implementation and land grant, then it must have been granted rights. However, the detailed plan and land use classification established for the purpose of land grant have failed to establish a clear and appropriate scope of land use and rights, and have only provided a vague and fragmented interpretation of the use and rights based on technical standards. What emerges is that the land use rights acquired by private individuals are more in the form of “status quo use” of a single activity and material form than in the form of clearly defined “existing use” and existing use rights.

5. Conclusion

This paper identifies the nature of existing use as a legal concept by recognizing the difference between “status quo use” and “existing use”. It refers to the land use that has existed before the effective date of certain plans, zoning or regulations and arises from planning intervention in Property Rights and is protected as a property right. The time node that defines “existing” relate to those planning tools with legal force. The “use” that explain the range of rights is usually defined by planning or development control tools like use classes or use groups. Existing use is distinguished from future use in planning or regulatory interventions on private land use, and existing use rights are distinguished from development rights. It draws the line between public power and private rights in land use, gives the basic rules for land use in the functioning of the built environment, and serves as a benchmark and starting point for planning and urban renewal.

A review of existing use-related national laws and local regulations reveals that the concept “existing use” or “existing use right” are not introduced in laws at the national level. Provisions related to "existing use" are scattered across planning technical standards and local urban renewal policy documents. especially expropriation compensation policies. Existing use rights are confined to a single current land use or land cover defined by the current imperfect Land Use Classification standards. And current urban redevelopment are restricted to the single approach of land acquisition, which means the suppression of private urban renewal initiatives. The absence of definition of “existing use” leads to the lack of legal basis for compensation in land expropriation.

Future studies could focus on Establishing the general concepts of "existing use" in laws at the national level under China's land system. What is now needed is to reaffirm detailed plan as a statutory planning tool that explains land use rights. In defining “existing use”, reference can be made to Hong Kong to Hong Kong, whose land system and regulation model are similar to China’s. More broadly, research is also needed to formalize rules regarding existing use right by use groups or use classes tools.

6. Reference

Booth, P. (2002) 'Nationalising Development Rights:The Feudal Origins of the British Planning System', *Planning and Design*, 29, pp. 129-139.

Booth, P. (2003) *Planning by Consent*, London: Routledge press.

Cullingworth, B. and Nadin, V. (2014) *Town and Country Planning in the UK*, London: Routledge.

Duxbury, R. M. C. (1984) 'Planning Permission: Effect on Existing Rights', Trent Law Journal, 8, pp. 33.

Fairest, P. B. (1971) 'Planning Permission and Existing Uses—Enforcement Notices', *The Cambridge Law Journal*, 29(2), pp. 201-203.

Guo, Z. (2020) 'A Comparative Study of Hong Kong's Dingh House Policy and Mainland's Rural Homestead System', [Online] Available at: https://www.cityu.edu.hk/slw/lib/doc/RCCL/RCCL_work_paper_Guo_Zhijing.pdf (Accessed: 15 September 2023).

Guo, J. (2022) Research on Use Regulation in Town Planning and Development Administration in Hong Kong, PhD thesis, South China University of Technology, Guangzhou.

Home, R. (1992) 'The Evolution of the Use Classes Order', *The Town Planning Review*, pp. 187-201.

Li, Y. (2007) A Study on American Land Use Cases, PhD thesis, Tsinghua University, Beijing.

Li, F. (2015) 'Issues on Protecting the Development Right to Land and Defining of Its Owners', *Journal of Social Sciences*, (4), pp. 105-113.

Li, S. (2020) Regulatory Scale and Technical Instruments of the City of New York Zoning Maps and Resolutions 1961, PhD thesis, South China University of Technology, Guangzhou.

Nguyen, T. (2006) 'Less Protection for Existing Use Rights', *Law Society Journal*, 44(4), pp. 34.

O'Connell, J. (1961) 'Iowa's New Water Statute--The Constitutionality of Regulating Existing Uses of Water', *Iowa Law Review*, 47, pp. 549.

Schatz, L. (2015) 'The Balance of Planning Ideologies in Existing Use Rights Cases at the New South Wales Land and Environment Court', in 7th State of Australian Cities Conference, Gold Coast.

Scott, M. (1956) 'Zoning--When Has One an Existing Use?', *Kentucky Law Journal*, 45(1), pp. 14.

Serkin, C. (2009) 'Existing Uses and the Limits of Land Use Regulations', *New York University Law Review*, 84(5), pp. 1222-1291.

Shan, H. (2017) 'From Administrating Land Allocation and Construction to the Control of Land Use Change: Diverging Planning Control Concepts in the City of Shenzhen's Recent Land Governance Reform', *Urban Development Studies*, 24(2), pp. 104-112.

Su, Z., Zhou, J. and Pang, X. (2024) 'Use Classes as a Tool to Define Land Use Rights-- Establishment, Evolution and Reference of Use Classes Order in the UK', *City Planning Review*, 1-12. [Online] Available at: http://kns.cnki.net/kcms/detail/11.2378.TU.20240124.1702.002.html (Accessed: 23 February 2024).

Taylor, N. (1998) *Urban Planning Theory since 1945*, London: SAGE Publications.

Wu, Q. (2018) Coordination of Existing Use and Potential Use of Transboundary Watercourses, PhD thesis, Wuhan University, Wuhan.

Zhou, J. and Qi, D. (2008) 'Relationship among Urban Planning, Development Right and Development Activities', *City Planning Review*, 2008(01), pp. 74-80.

Zhou, J., Li, S., Qi, D., et al. (2019) 'Establishing Building Use Management System in China Based on the Regulation Framework of New York's Certificate of Occupancy', *China Soft Science*, 2019(12), pp. 1-16.

Research Paper

Conservation and revitalization of port industrial heritage under the historic urban landscape framework

A case study of Great Harbor in Qingdao, China

Dawei WANG, Southeast University, China

Wenzhu ZHOU, Southeast University, China

Abstract

Ports are foundational to port cities, initiating urban development. However, as the city grows economically and spatially, industrial land uses shift, and the transportation role of ports diminishes. This change necessitates finding new purposes for former port areas and reinterpreting the significance of port industrial heritage. This paper explores how to treat the port industrial heritage in Qingdao's Great Harbor area, initially established by the colonizers but later advanced through local autonomous research, using the framework of historic urban landscape (HUL). We counted 121 heritage elements, identified typical heritage elements with both isochroneity and diachroneity, and prioritized their preservation and utilization on the basis of heritage value and vulnerability. For typical heritage elements, we examined their spatial status and evolution, and discussed their regeneration concepts and strategies. The findings indicate that the typical elements of port industrial heritage include docks, coastlines and railways, etc., which were built throughout various developmental phases and spread throughout the port area, reflecting the advanced planning and design concepts and technologies, and should be preserved intact and prioritized. Other heritage elements, such as warehouses, tide gauging stations and bridge cranes, mainly located on docks and along the coastlines or railways, should be selectively preserved and flexibly utilized. This is because, although they are numerically dominant, they are mostly post-1990s (late stage of port life cycle) in terms of time. Moreover, with the goal of awakening the collective memory of the city, we propose strategies for regeneration of port industrial heritage and port space, which are based on the concepts of "productization of development, publicization of use, and ecologization of landscape". Therefore, the HUL framework effectively guides the protection and utilization of these heritage elements, and these results will help planners and policy makers to better develop action plans for the preservation and reuse of the port's industrial heritage.

Keywords

Port industrial heritage, HUL, layering, Uniqueness, Integrity

1. Introduction

In the process of contemporary industrial development and urban transformation, industrial upgrading and transfer, urban renewal and expansion have resulted in a large number of industrial sites facing functional adjustment and a large number of industrial heritage facing demolition. For port cities, ports are the origin of urban construction, and they have greatly driven urban development, but in the process of urban transformation, they have encountered an existential crisis (Hein, 2021; De Rosa, 2013). With the transfer

of port industrial land, the original role of port transportation is gradually reduced, the original land needs to find a new use, and the port industrial heritage needs to be re-conceptualized, re-positioned, re-interpreted and re-translated (Alemany, 2019). In China, due to historical reasons, many port cities (e.g. Qingdao, Dalian, etc.) were initially built as ports of trade for colonizers. Research on the topic of "how to deal with the industrial heritage of ports that were initially built by colonizers and then automated through independent research and development" is important for correctly recognizing the value of this type of heritage, dealing with the relationship with colonizers and building cultural self-confidence.

Generally speaking, the port consists of port waters, quay shoreline and land facilities, including five major functional systems, such as ship navigation, loading and unloading, storage, marshalling, information and commerce (Hein, 2019). Port industrial heritage is the industrial heritage with the function of sea-land intermodal transportation hub after the industrial revolution, which takes the wharf as the material main body and includes two kinds of field space of sea and land (Hettema, 2020). It not only has a wide variety of elements, but also often has a construction history of hundreds of years, so its full recognition should be based on both ephemeral and time-penetrating, and should comprehensively consider both tangible and intangible cultural values, as well as highlighting the industrial characteristics and its role in urban development. Therefore, we introduce a research theory and method that is holistic, dynamic and sustainable, i.e., Historic Urban Landscape (HUL).

2. The HUL framework

The HUL framework is a template for integrating heritage into development. In the 2016 UNESCO's The HUL Guidebook, the HUL is the urban area understood as the result of a historic layering of cultural and natural values and attributes, extending beyond the notion of "historic centre" or "ensemble" to include the broader urban context and its geographical setting (UNESCO,2015; UNESCO2016). In the document, the term "layering" is used five times, and its meaning is both conceptual and practical (Deng, 2018).The conceptualization is reflected in the fact that the urban historic landscape is the material entity of the urban area, and the various values and characteristics are the result of the continuous superposition and accumulation of historical remains in different periods on a specific spatial scope or spatial object (Zhang, 2017). The practicality is reflected in the presentation of history and tradition. Researching, documenting, understanding and presenting the lamination is a process of lamination that responds to the value by spatial analysis in different time slices (Grazuleviciute-Vileniske, 2021; Jiang, 2022).

According to the HUL methodology, a conceptual framework on the port industrial heritage was formed (Figure 1). Firstly, the main stakeholders to be considered are the employees of the port, the enterprises of Qingdao Port and the local government, especially the Natural Resources and Planning Bureau. Then, the port's industrial heritage should be recognized and evaluated from the perspectives of dynamic (layering), wholeness and uniqueness, and conservation plans and sustainable development strategies should be formulated (Liu, 2015; Liu, 2014). Layerinng is the unveiling of the history of port's development in layers from the perspective of time, and the presentation of the layers of continuous, superimposed history in a material form to form a sustainable, life-improving space (Xu, 2023). Currently, the process of dynamism encompasses the entire history of the industrial development of the port area and the transition from industry to services. Uniqueness is an important expression of heritage value, and attention should be paid to the linkages between tangible and intangible, natural and cultural, local and international values (Pereira, 2019). The origin, value and continuing significance of tangible cultural expressions come from intangible cultural practices, and it is important to see the value of practices and spiritual heritage in the economic, social and cultural spheres. Integration is a spatial approach to realize the protection of the integrity of heritage elements and the synergistic development of the port area and the city. Heritage

elements should be protected as a whole according to the production and transportation flow lines. In addition, port-driven city development and city-driven port upgrading often exist in different stages of port city development, and the understanding of the relationship between port and city affects the judgment of heritage value, and is also of decisive significance for future heritage revitalization.

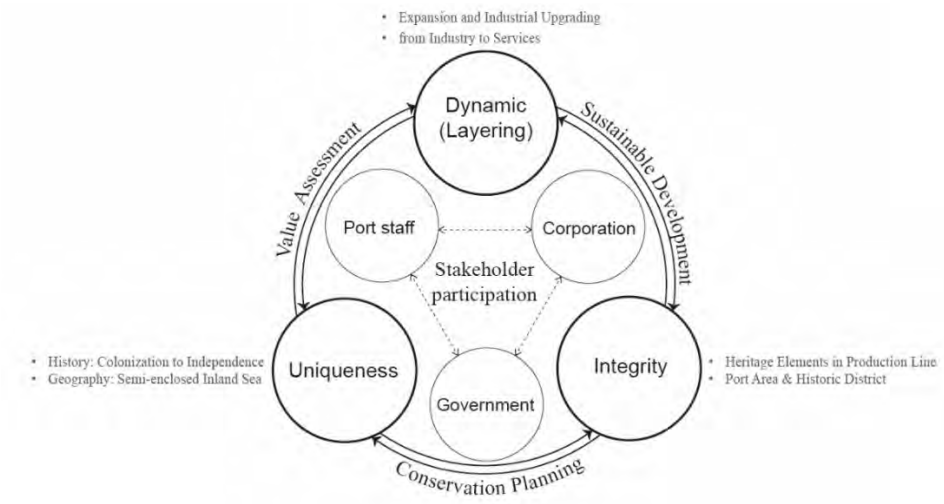


Figure 1. Conceptual framework (based on HUL).

3. Object of study

In this paper, the Great Harbor in Qingdao, China, which is the starting point of urban construction and facing transformation, is selected as the research object to explore the preservation and revitalization of its heritage.

3.1. History and overview of Great Harbour in Qingdao

Qingdao is a typical colonial port city in China, which now has a population of 10 million inhabitants. It was founded in 1891 and built by the Germans after the signing of *the Sino-German Treaty of Jiaoao* in 1897, which laid down the basic framework for the industrial development of Qingdao. The Great Harbor is located on the northwest side of the old city, close to the Guantao Road historic district, but separated by an elevated highway (Figure 2). It was originally (1890s) planned and built by German colonists as a military and commercial port, and was later (1980s) deep-watered and automated by the Chinese themselves. It was at one time the second largest port in the country, ranking eighth in the world in terms of container throughput (Anonymous, 2006). At present, Qingdao Port has realized the transfer of its focus, and the Great Harbour is facing the problems of industrial heritage renovation and spatial regeneration of the waterfront dock area, which need to be planned in a comprehensive manner with the development trend of the times, the characteristics of the population's demand and the city's industrial layout (Figure 3).

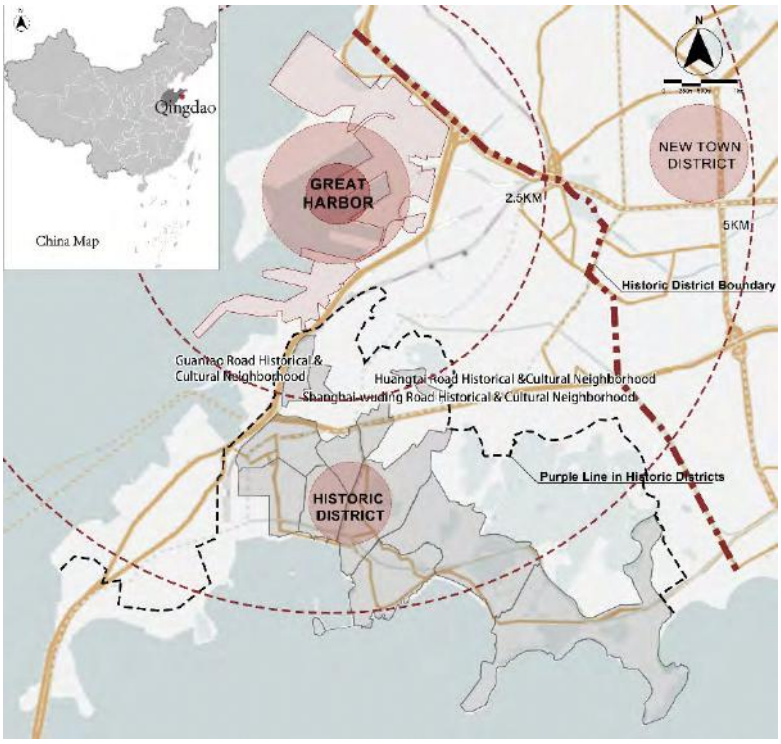


Figure 2. Location of the study area.

Figure 3. 100 years of changes in the whole landscape of Qingdao's large harbor - from the beginning of the 20th century to the beginning of the 21st century. Source: Qingdao Port 120 Years Picture Album. (2012).

According to the process of the construction of the big port and the development of shipping, the development of Qingdao port industry is roughly divided into five stages (Wang, 2022). During the beginning stage (1891-1914), Germany began to build a port in Qingdao as well as a railroad connecting the mainland with the seaport, a large harbor on the east side of Jiaozhou Bay in the low granite hills, railroads along the east coast of Jiaozhou Bay, and industries along the railroads. The stage of rapid development (1915-1949), including the periods of the Japanese Occupation, the rule of the Nationalist Government (Nanjing and Beijing), and the second Japanese Occupation, port was further expanded on the basis of the original construction, and continued to develop and improve. After nearly 30 years of slow development, there was the maturity stage (1980-2010). In the 1980s, deep water and automation were carried out by the Chinese themselves. In 1985, the port construction command was moved from Dagang District to Huangdao, and the reconstruction of Dagang District was carried out. With the gradual substitution of the shipping function by new port areas, the Great Harbour had been entering the transition stage (2011-present). In 2014, Qingdao Municipality put forward the transformation of the Great Harbour

into “Qingdao Future Port”, which integrates tourism, vacation, and international business with the cruise industry as the leading one. (Figure 4)

Figure 4. Analysis of historical evolution. Source: Evaluation, conservation and reuse of port industrial heritage under the background of stock renewal: A case study of Qingdao Port. (2022).

3.2. Census and mapping of the current state of the heritage

Located on the east coast of Jiaozhou Bay, the Great Harbour in Qingdao consists of eight protruding wharves, carrying the memories of Qingdao's port industrial development and city construction. Throughout the century's history, the fusion of Qingdao's coastal spatial environment and colonial history and culture with the unique shipping industry culture of the Great Harbour has formed the unique, richly typed, and massive industrial heritage of the Great Harbour (Wang, 2023). Most of them is distributed in single point, line, group and network forms, and the combination of point and line is its main morphological feature. According to the census results, the total number of port industrial heritage is 121, distributed as shown in Figure 5.

Figure 5. Distribution diagram of Great Harbour industrial heritage elements.

From the perspective of industrial function, the Great Harbour industrial heritage includes transportation, warehousing, processing and living auxiliary, etc. Among them, the transportation category can best reflect the characteristics of the port and the city, such as wharves and dams, coastline, railroad line, etc., which is characterized by the dominance of the industrial status, the cross-border spatial distribution, the continuity of the historical evolution, the typicality of the value of the heritage, and the diversity of the cultural connotation. It is the core and foundation of the Great Harbour industrial heritage preservation, as well as the focus and difficulty of regeneration. There are about 30 transportation industrial heritages, accounting for about a quarter of the total industrial heritages of the Great Harbour, and most of them are located on top of the wharf dams and distributed along the shoreline or railroad lines.

4. Results

4.1. "Layering" of Heritage Elements

4.1.1. Evolution of dock dams

A wharf is a hydraulic building for ships to dock, load and unload cargo, and pick up and drop off passengers, and it is the main component (material entity) of a port. After a century of history, there are 8 wharves and 52 berths in the port. Pier 1 to 4 were built in the period of German occupation, pier 6 is the only one constructed in the period of the Republic of China, pier 7 is a mechanized wharf independently designed and constructed by Chinese after the founding of the country, and pier 8 was constructed after the reform and opening up and transformed into a containerized wharf. They are the witnesses of the whole production and development of the Great Harbour since the colonial period, from which a large amount of our country's materials have been plundered out of the country while a large number of foreign goods have flowed into the Chinese market.

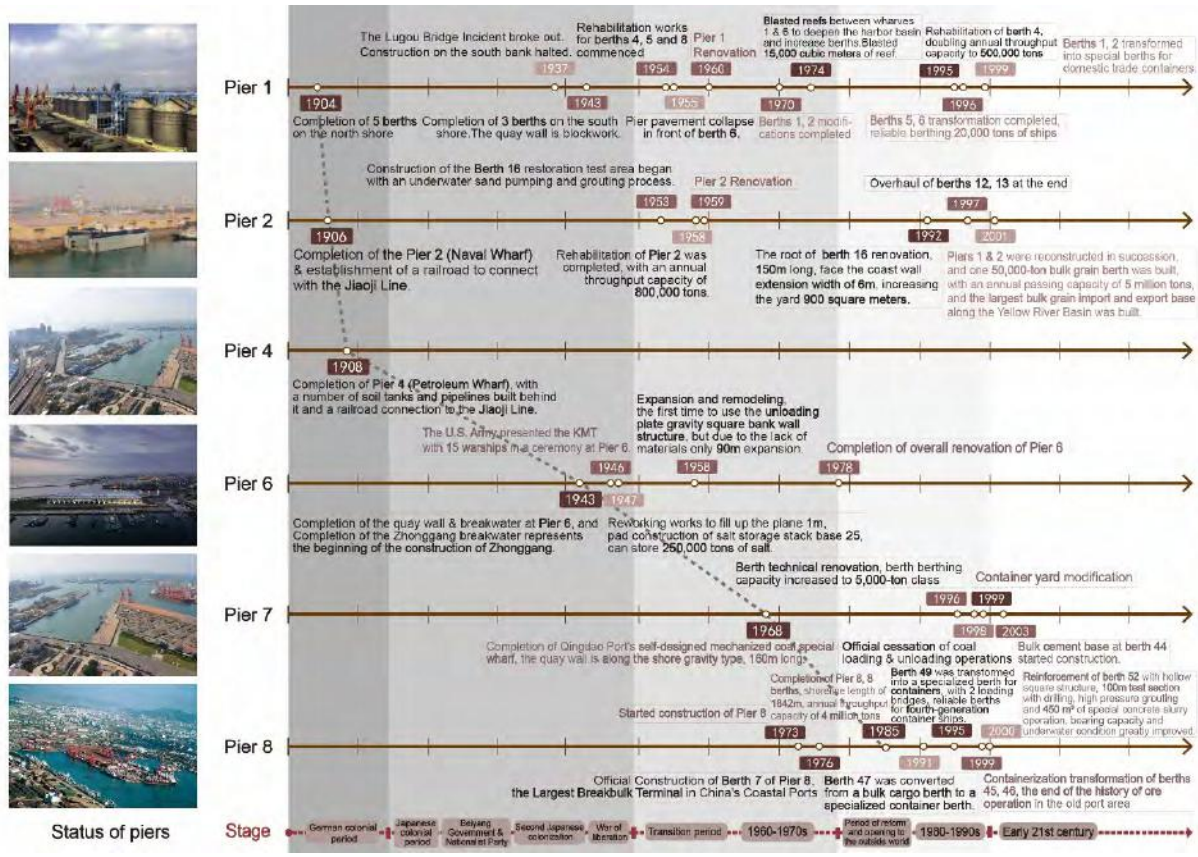


Figure 6. Evolution and current status of the terminals in the Great Harbour. Source: Evaluation, conservation and reuse of port industrial heritage under the background of stock renewal: A case study of Qingdao Port. (2022).

From the perspective of port hydraulics and port planning, we analyze the main processes of site investigation and selection, planning and design, construction, restoration and expansion, etc., extracting the scientific concepts and technologies, recognizing the scientific, technological and engineering values. In addition, the industrial characteristics are explored from the spatial and functional relationship, and the social and cultural connotations are explored from intangible heritage(Ron, 2012). The specific contents of which are shown in Table 1.

Table 1. Characteristic value analysis of dock dams

Aspect	Details	Value
construction	Different masonry techniques were used for different dams at different times: wood pile concrete bearing type in the early period (Pier 1, 2, 4) and concrete gravity type in the later period (Pier 6, 7, 8).	Reflecting the representative port construction technology and construction level at home and abroad in various periods, reflecting the difference in scientific and technological level between countries.
Space & Function	Terminals that transport different goods (grain, oil, containers, etc.) vary in carrying capacity, berth	The relationship between land & sea maps the industrial layout, reflects the industry features and the port development, and is the basis for

	scales, and transportation & storage equipment.	the construction of the industrial chain, as well as the key to maintaining industrial operations.
Social & cultural	People carried goods, commanded management, and lift operations on the wharf, where labor and life coexisted, forming a collective memory of production and life, solidarity and collaboration.	Dock dams are not only the material carriers and basic platforms for production, but also carry the prosperous modern industrial scene from the exploitation of hard labor of many people to mechanized transportation.

4.1.2. Evolution of dockside

The length of the quay shoreline of the port is one of the important symbols of the scale of the port, indicating the number of ships it can accommodate and carry out loading and unloading operations at the same time, which is the embodiment of the transportation capacity. The 17.57km shoreline of the Great Harbour has three main uses, namely operation(5.6km), docking(5.4km) and protection(4.4km). The quay shoreline is a linear industrial heritage, a cross-section of the quay wall, an artificial interface between land and sea, contrasting and complementing with the gentle and changing nature of the beach shoreline along Qingdao's south coast. The existing coastline is of different ages, with the import and export coastline of the harbour constructed earlier, during the period of German occupation, and the internal reclamation, mostly after the founding of the PRC. The overall shape of the shoreline is circular. With the continuous construction of the wharf, the degree of curvature gradually increases. Until the wharf is saturated, the shoreline has the longest length and the greatest degree of curvature, which is utilized to the fullest extent and can berth most ships (Figure 7).

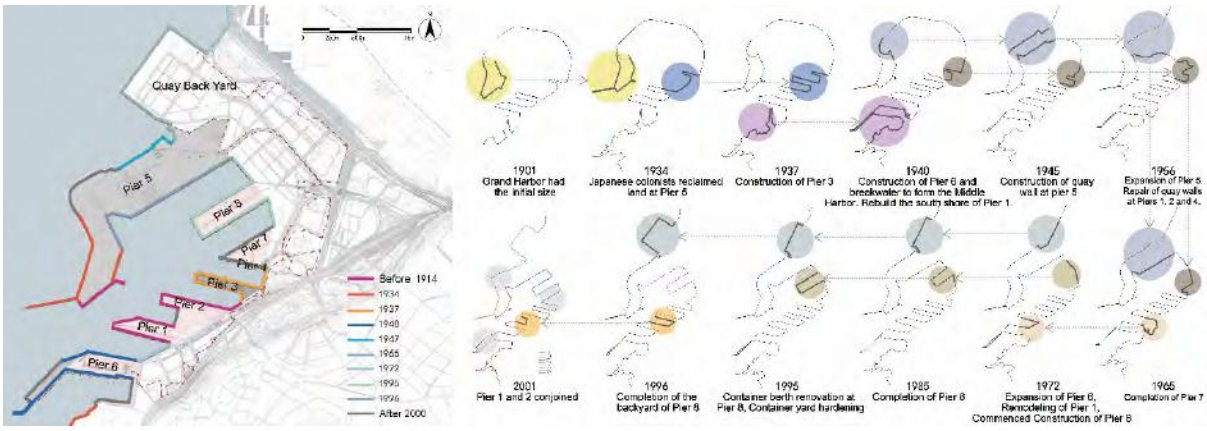


Figure 7. Diagram analyzing the completion age and evolution of dockside in the Great Harbour. Source: Evaluation, conservation and reuse of port industrial heritage under the background of stock renewal: A case study of Qingdao Port. (2022).

For the excavation of the shoreline's special value, it is mainly analyzed from the perspectives of history, space, landscape, relationship with transportation industry and sustainable development. First of all, the artificial shoreline recorded in various periods of construction, the south side of the import and export place is mostly the shoreline before the founding of the country, and the north side of the harbour is mostly constructed after the founding of the country, which has become a "corridor" to show the history of the development of the port. Secondly, the shoreline formed by the protruding dam, so that the sea and land interlacing, in keeping with Qingdao "Trestle Bridge" landscape characteristics. This creates favorable conditions for subsequent multi-dimensional landscape modifications. In addition, the berth is set according to the shoreline's length, the gate machine, bollards are also set along the shoreline, so the

shoreline is the basis for berthing and a reflection of the level of transportation. Finally, the setting up of wharves and breakwaters in the early stage leaves room for later construction, which is forward-looking and an example of practicing the concept of sustainable development planning.

4.1.3. Evolution of port railway lines

The railroad line in Dagang area started with the first port construction during the German occupation period, and is a part of Jiaoji Railway. The Dagang railroad line has been continuously expanded to all the wharves with the increase and decrease of wharves in each period, and it is an important historical witness to the development of Qingdao port, while its railroad construction technology also shows high scientific and technological values. The construction of Jiaoji Railway started in 1899, and the section from Qingdao to Jinan (394.05km) was opened to traffic in 1904, and the special lines in the harbor have increased from the initial 6 strands to the current 12 strands, and the intersection nodes in the harbor have been changed from one to two, and have been preserved until now, which is a structural material element with the highest value of the heritage in the harbor area. The increasing number of branch lines feeding into the main Jiaoji Railway reflects the increase in freight traffic and a more complete railroad network pattern (Figure 8).

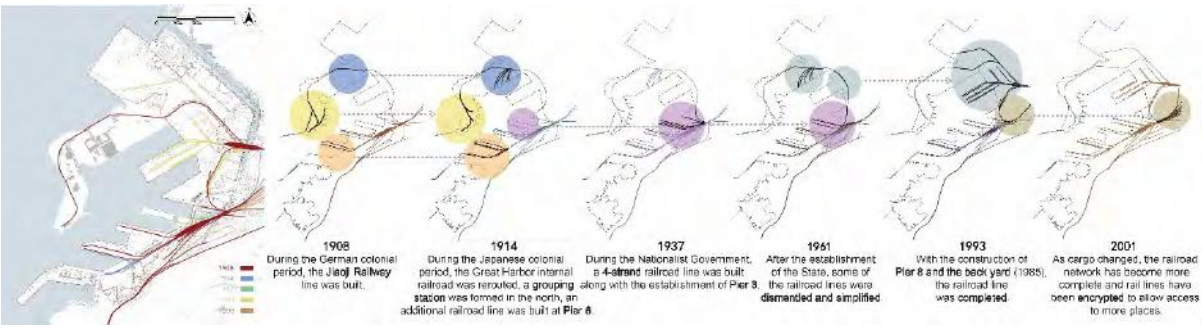


Figure 8. Diagram analyzing the completion age and evolution of railroad lines in the Great Harbour. Source: Evaluation, conservation and reuse of port industrial heritage under the background of stock renewal: A case study of Qingdao Port. (2022).

For the excavation of the characteristic value of the railroad line, it is mainly analyzed from the perspectives of historical status, mode of transportation, relationship with the storage industry, structure and material technology, spatial morphology, and standardization. Undoubtedly, Jiaoji Railway is one of the earliest railroads in China, the first electrified railroad in Shandong, an important record of Shandong's modern economic and social development, and is listed in the first batch of China's industrial heritage protection list [14]. The Dagang railway, in turn, is the origin of the Jiao-Ji Railway, the first railroad in China with the initial intention of contacting the port, which has lasted for a hundred years and is basically well-preserved to this day, and is an important witness to the plundering of resources by foreign invasion. What's more noteworthy is that the ship transportation is closely integrated with Jiaoji Railway, which is an example of the transportation industry layout of sea-railway intermodal transportation, reflecting the more advanced transportation mode and concept in the world at that time. The layout of the railroad line is closely related to the wharf warehousing, and the main warehouses and silos are arranged with a railroad line on one side, which facilitates the unloading of goods or loading of trucks for transportation directly. In addition, Dagang railroad line is a unique record of railroad line construction in different periods. The evolution of sleepers materials from "iron" to "wooden" to "reinforced concrete" reflects the railroad technological progress. In the Great Harbour industrial heritage, the railroad line is one of the most unique types of heritage, which is an independent and complete system spreading all over the port area. The railroad line and the shoreline act as the tandem line of the landscape of the land area and the shore area respectively, and the two lines

have their own characteristics, and they run in parallel and interweave with each other, which can constitute the two characteristic landscape belts of the Dagang area.

4.2. Holistic framework

4.2.1. Holistic conservation of heritage elements

The holistic conservation of port industrial heritage involves industrial production and transportation flows, which can reflect the technical conditions of production and the technical characteristics of the products, and are also an important part of the intangible cultural heritage of the industrial heritage. The holistic conservation of heritage elements based on industrial production and transportation flow lines is a tangible demonstration of intangible technology and culture, which will profoundly explain the significance of heritage conservation.

In this study, six production and transportation flows were identified. First of all, the transportation function is embodied in the international container sea-rail intermodal line & container transportation EDI system (Pier 8, 1989). The combination of the wharf and the railroad line is the material embodiment of “sea-rail intermodal transportation” , an intangible concept and technology, which fully demonstrates the concept that “the origin, value, and continued significance of tangible cultural expressions come from intangible cultural practices,” and therefore needs to be conserved in a holistic manner. Secondly, on the wharf, the ship unloader unloading operation process, bulk grain receiving and unloading system (Pier 1, 2001) and coal wharf mechanization system (Pire 4, 1966) play the role of temporary storage and transhipment; in the hinterland at the back of the port area, the role of production and processing is played by the mechanical processing production line of the port machinery factory and the production line of processing soybeans in the port (2005). In the port, the transportation function is the first priority, and the construction of the storage area is earlier than the processing area, so the protection priority of the storage area located on the wharf is higher than the production and processing area in the hinterland.

4.2.2. Holistic regeneration of the port area and the old town

Initially, Qingdao was born because of the port and prospered towards the sea, and the port drove the development of the city. Later on, urban & port expansion, the port changed from a suburb of the city to the central area of the city. With the technological change and the shortage of land, the port partially relocated outward to Huangdao, and with the internal industrial upgrading, it is still a pillar industry in the city. With the appreciation of the land in the city and the shortage of the scale of the old port area, the port relocated as a whole, and the urban renewal pushed the renewal of the port area. In the future, the preservation of the port's industrial heritage to the city's memory will make it an engine for the development of the port area and even the whole city space, transforming the port into a new functional center in the existing urban structure (Vries, 2014).

Since the port area is a relatively independent industrial area in the city, its production and living system is obviously separated from other areas around the city, so the development link between the port area and the city is also concerned. In Dagang, the Jiaoji Railway and the viaduct cut off the port area from the old city (Gantao Road Historic District) on the southeast side and form an intermediary space with dynamic and ephemeral characteristics. The utilization of the intermediary space is the key to integrating the port area with the historic district, which is a comprehensive and dynamic process aimed at building a network of urban resources. Restoring usable space through transient uses in response to intense socio-economic changes is a way to diversify the economy, making it more adaptable to change and creating attractions, even as a source of long-term financing (María, 2024). In terms of the overall urban spatial pattern, the core elements, natural landscape, and humanistic environment that constitute the series of heritage of

port industry and history and culture should be integrated, highlighting the important heritage units, organizing the excursion routes around specific themes, and organically combine the protection of port industrial heritage with the protection of historical and cultural heritage (Whitehand, 2010). As far as possible, the continuity of the landscape and the connectivity between the port area and the urban area should be guaranteed.

5. Discussion and conclusions

This paper examines the conservation and revitalization of port industrial heritage in Qingdao, China, using the framework of urban historic landscape as an example. Typical heritage elements with both historical and co-temporal characteristics were identified from the 121 elements surveyed. Then, we analyzed "layered" characteristics of three typical heritage elements, including wharves and dams, coastlines and railroad lines. From the perspectives of continuity and wholeness, we discussed the renewal strategy of port industrial heritage, established the connection between intangible values and tangible heritage elements, and established the connection between port areas and the old town, in order to realize the regeneration of port industrial heritage and the living, publicizing and landscaping of port space.

Through the history of the construction of the Grand Harbor and the evolution of typical heritage elements, we can learn about its iterative construction techniques, and the spatial landscape features. Although the site was originally chosen and planned by German colonizers, the construction process was carried out by the local working people - a history of exploitation through hard work, but also a history of solidarity, collaboration, sweat and lives of the local underclass. In the 1980s, Chinese scientists automated machinery through their own research and development, and the legacy of the local people's thinking and technology is embedded in the heritage - a process that is imbued with national pride, from oppression to independence. Nowadays, with China's development and rising international status, the people's pride has replaced the feeling of suffering from the colonial past, but the contribution of our ancestors should not be forgotten, and this collective memory should be preserved and displayed in a tangible way. The complete preservation and revitalization of the industrial heritage of Dagang is not only a record of the colonial history of the past 50 years, but also a historical witness to the autonomous development and anti-colonialism of the following 70 years.

In theory, by applying the HUL methodology to the study of port industrial heritage, the concepts and principles of heritage conservation are emphasized, while the methodology is applied to a wider range of areas and objects. In addition, the hierarchical dissection of specific objects has led to a deeper understanding of the value and development dynamics of heritage, and the holistic regeneration of the port area and the historic city center has strengthened the continuity of urban space. In practice, the project "Conservation and Planning of the Industrial Heritage of Qingdao Dagang" has pointed out the direction and provided a reference for similar heritage conservation and revitalization projects.

This project has been more fully studied in terms of preliminary research and value evaluation, and detailed planning has been adjusted according to conservation. The next step will be in the implementation of the protection of the port's industrial heritage and the execution of the overall renewal of the port area, including the display of heritage elements, renovation, investment and operation.

References

Anonymous. (2006) *Qingdao Port Records*. Qingdao: Qingdao Port (Group) Co. Ltd.

Alemany, J. (2019) 'Preservation and Reuse of Port Heritage', *Portus*, 37.

De Rosa, F., Di Palma, M. (2013) 'Historic urban landscape approach and port cities regeneration: Naples between identity and outlook', *Sustainability*, 5(10), p4268-4287.

Deng, K., Song, F., Shi, Y. (2018) 'Historical urban landscape from the perspective of cultural landscape', *Landscape Architecture*, 25, 4. (in Chinese)

Grazuleviciute-Vileniske, I., Seduikyte, L., Daugelaite, A., et al. (2021) 'Links between heritage building, historic urban landscape and sustainable development: Systematic approach', *Landsc. Archit. Art*, 17, p30-38.

Hein, C. (2019) 'The port cityscape: spatial and institutional approaches to port city relationships', Portus-Plus 8.

Hein, C. (2021) 'Port city porosity: boundaries, flows, and territories', *Urban Planning*, 6(3), p1-9.

Hettema, J., Egberts, L. (2020) 'Designing with maritime heritage: adaptive re-use of small-scale shipyards in northwest Europe', *J. Cult. Herit. Manag. Sustain Dev.*, 10 (2), p130-143.

Ron, V.O, Han, F. Wang, X. (2012) 'The concept of historic urban landscape and its relation to cultural landscape', *Chinese Landscape Architecture*, 28(5), p16-18.

Jiang, J., Zhou, T.C., Han, Y.R., et al. (2022) 'Urban heritage conservation and modern urban development from the perspective of the historic urban landscape approach: A case study of Suzhou', *Land*, 11(8), 1251.

Liu, Y.H. (2014) 'A preliminary study on the anchor-layer theory for recognizing and protecting historic urban landscapes', Tsinghua University.

Liu, F.Y. (2015) 'Research on the classification system of modern industrial heritage in China', *Urban Development Research*, 22(11), p64-71. (in Chinese)

María, J. A., Eduardo, J.M., Rachel, R.R., Pablo, M.R. (2024) 'Reuse of port industrial heritage in tourist *cities: Shipyards as case studies', Frontiers of Architectural Research, 13 (1), p164-183.*

UNESCO. (2015). *World Heritage and Sustainable Development* (Document WHC-15/39.COM/5D). Retrieved from https://whc.unesco.org/en/documents/

UNESCO. (2016). *The HUL Guidebook: Managing Heritage in Dynamic and Constantly Changing Urban Environments*. Paris: UNESCO.

Vries, I.M.J. (2014) 'From Shipyard to Brainyard: the redevelopment of RDM as an example of a contemporary port-city relationship', in Y. Alix, B. Delsalle & C. Comtois (eds) *Port-City Governance*. EMS, Cormelles-en-Royal.

Whitehand, J.W.R. (2010) 'Urban morphological regionalization and historical urban landscapes', *Chinese Landscape Architecture*, 26(9), p53-58.

Wang, D.W. (2022) 'Evaluation, conservation and reuse of port industrial heritage under the background of stock renewal: A case study of Qingdao Port', Qingdao University of Technology.

Wang, R.S., Wang, D.W., Liu, M., et al. (2023) 'The value evaluation of Qingdao Great Harbour industrial heritage', Industrial Construction, 53(02), p79-86.

Xu, M., Li, J.J. (2023) 'Historic urban landscape evolution of the port city area from the perspective of historic layering: A case study of Qingdao', *Modern Urban Research*, 9, p29-36. (in Chinese)

Zhang, W.Z., Han, F. (2017) 'A review of the theoretical and practical research on historic urban landscape', *Landsc. Archit.*, 24, p22–28. (in Chinese)

Pereira, R. (2019) 'The historic urban landscape approach in action: eight years later', in A. Pereira Roders & F. Bandarin (eds) *Reshaping Urban Conservation: Creativity, Heritage and the City*, 2nd edn. Springer, Singapore.

Research Paper

Heritage, Heart, and Home — A Socio-Cultural and Emotional Approach to Urban Tree Trail Planning

Shutao LIAO, Central Academy of Fine Arts, China

Abstract

Shichahai Subdistrict in Beijing, a historic area rich in cultural, commercial, residential, and tourism elements, is home to 55 cultural heritage sites and 403 ancient trees. Despite their significance, these trees have been largely overlooked, leading to diminished ecological heritage value and weakened community identity. This study investigates local residents' attitudes and willingness to participate in planning ancient tree trails, aiming to integrate these trails with daily activities and tourism routes.

Through literature analysis and GIS technology, the study assessed the distribution and health of ancient trees in Shichahai. A community participation survey yielded 264 responses and 25 interviews, revealing that residents recognize the ecological and cultural value of the trees and express strong support for their protection. However, they highlighted the need for education on sustainable practices.

The findings suggest four strategies for enhancing cultural heritage integration in urban planning: utilizing GIS for spatial optimization, considering diverse user needs, promoting community participation, and addressing cultural factors in design. This approach not only fosters a deeper connection between residents and their environment but also enhances community involvement in preserving their cultural heritage.

Keywords

Ancient Tree Protection, Community Participation, Cultural Heritage,Emotional Identification,Urban Planning

1. Introduction

As globalization sweeps across the globe, the significance of cultural heritage has become increasingly prominent (Francioni, 2015). Cultural heritage serves not only as a testament to history but also as a symbol of national identity and cultural diversity. However, the protection of cultural heritage faces unprecedented challenges worldwide (Sesana et al., 2021). From climate change to urbanization, and from natural disasters to human destruction, these precious historical legacies are under various degrees of threat. Protecting cultural heritage is not only a respect for the past but also a responsibility for the future (Macmillan et al., 2013).

Cultural heritage protection has been widely placed on the agenda, yet there remains a category of cultural heritage that is often overlooked: ancient trees (Townsend et al., 2018). These spot-like historical resources are not only material entities but also carriers of emotion and memory. They constitute unique historical and cultural landscapes in urban spaces, representing irreplaceable cultural heritage. However, they often lack the necessary attention and protection (Parikka, 2019). While the ecological importance of

dispersed trees in natural landscapes is well-recognized, their value in human-altered environments is frequently neglected (Manning et al., 2006).

2. Background and Literature Review

2.1. Current Status and Issues of Ancient Tree Protection

Ancient trees are a critical part of nature's web and a valuable cultural and social asset. These trees are vital homes for various animals, and they strengthen air purity. These enduring beings are strongly linked to local legacy, customs, and community identity, and they represent cultural heritage. In society, ancient trees offer shared spots for rest and social unity, although also encouraging environmental care and belonging.

The city is evolving rapidly and finance is also progressing, but the main issue is how to find a balance between the two, especially when it comes to protecting ancient trees. Urban expansion drives economic development but often threatens precious cultural heritage. Studies have demonstrated that many ancient trees are declining and at risk of removal because of urban development, pollution, and poor management (Zapponi et al., 2017). This means that cities need to be planned carefully to promote financial goals although preserving these cultural landmarks. Which include ancient tree protection into city renewal, travel, and community projects is vital. This aims to make answers that guard ancient trees and encourage community advancement and cultural travel. Innovative urban planning and community participation can help us superior understand and preserve the social and cultural value of ancient trees, which is very helpful for the sustainable development of cities.

Although several cities and communities have begun stressing the protection of ancient trees, many ideas and examples guide practice. For example, cities such as London, Tokyo, and Hangzhou have implemented ancient tree surveys and database construction, systematically managing and protecting ancient trees (Figure 1). These planning practices significantly preserve the ecological value of ancient trees. However, the socio-cultural value of ancient trees is often overlooked in urban planning (Blicharska et al., 2014), leading to neglect and destruction of the social and cultural significance of these "living relics." A lack of public participation and awareness is also a critical issue in ancient tree protection. Currently, the public's understanding of ancient tree protection is insufficient, resulting in low participation rates. Designing and implementing educational programs to raise public awareness and foster a sense of responsibility and initiative towards ancient tree protection through community engagement and interactive activities is vital for effective conservation.

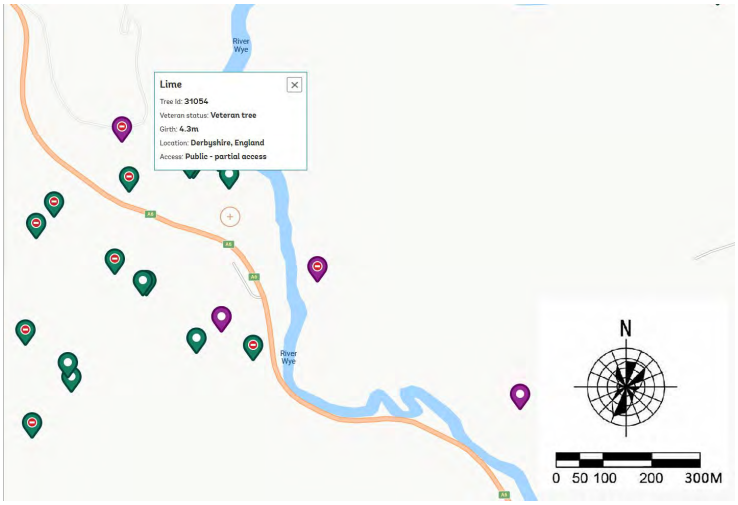


Figure 1.The ancient tree map of the UK marks the location of ancient trees, whether they are located in public areas, and supports individuals to upload unmarked ancient trees. Source: https://ati.woodlandtrust.org.uk/tree-search/?v=2729286&ml=map&z=13&nwLat=53.43607917273829&nwLng=-1.6566809167480834&seLat=53.32610782303615&seLng=-1.2834890832519896.

Another reason for ignoring ancient tree protection in city planning is the clash between economic advancement and cultural preservation, which links to the relationship between ancient trees and city growth. City growth is often fueled by economic advancement, but, this progress can come at the cost of ancient trees, which are invaluable cultural legacy (Butler et al., 2001). Ancient trees hold local historical and cultural worth and symbolize community identity and unity. Thus, city planning and building must find a way to encourage continued economic advancement although also protecting and respecting these precious cultural icons. This needs adding the protection and sensible use of ancient trees into city renewal, tourism advancement, and community building. The goal is a win-win plan that keeps ancient trees and drives community advancement and cultural tourism. Via creative city planning and community involvement, we can secure the socio-cultural worth of ancient trees is recognized, although adding to lasting city advancement.

Simply put, protecting ancient trees in modern cities is not only an ecological issue, but also involves challenges in social, cultural and economic development. In future research and practice, we need to pay more attention to these related aspects in order to develop a comprehensive protection strategy.

2.2. Theoretical Framework

Because there is no comprehensive theoretical framework to evaluate the socio-cultural value of ancient trees in urban ecosystems, this study constructed a framework that includes ecosystem services, long-term use, community participation, and cultural heritage. This structure highlights the importance of ancient trees in community assist, like cultural sharing, learning significance and visual value, and the critical role that groups play in preserving cultural heritage. Its goal is to offer a scientific basis for how to protect and utilize ancient trees in urban planning, so as to achieve a balance between protection and development.

2.2.1. Ecosystem Services

Natural services are the various direct and indirect benefits and functions that natural habitats bring to us humans. These perks fall into four main types: providing perks, which cover food and water supplies; controlling perks, such as weather control and water cleaning; cultural perks, which contain fun and

spiritual meanings; and supporting perks, involving soil creation and biodiversity upkeep (Holmgren et al., 2017). The nature services framework forms a scientific base for handling and saving natural supplies by judging perks systematically.

The framework is a total tool for assessing and planning the various values of ancient trees within urban areas. It mentions the main ecological roles of ancient trees, like absorbing carbon dioxide and producing oxygen, as well as providing broader socio-cultural benefits, like cultural sharing, educational significance and aesthetic value (Holmgren et al., 2017). Numerical checking of these perks' aids grasps ancient trees' impact on city habitats and community well-being, thus guiding fair saving and use plans in city planning.

Using the nature services framework needs an emphasis on the community-level perks of ancient trees. The value of these places lies not only in providing entertainment, learning opportunities and environmental beautification, but also in improving the quality of life and cultural identity of local people. These concrete data on benefits offer urban planners with a factual basis for finding a balance between urban expansion and preserving ancient trees.

2.2.2. Sustainable Utilization

Lasting frameworks help keep ancient trees by balancing current needs and future supply saving. In this framework, ancient trees are a total treasure of urban ecology, culture and economy, and they are very critical to the city's biodiversity and cultural history. The lasting use idea highlights the need to balance saving with social perks and future responsibilities (Guzmán et al., 2014).

The concept of sustainable use is to find a suitable balance between current needs and future savings. Ancient trees have great ecological, cultural and economic value and are an critical part of keeping urban biodiversity and cultural history (Pereira Roders and Van Oers, 2012). Non-use activities like nature travel and environmental learning can drive local economic growth and make people appreciate their value, thus rising people's awareness of savings.

Handling plans, such as visitor number limits and learning events, secure the long-term strength and survival of ancient trees, helping lasting supply use (Nocca et al., 2017). This combined method meets the needs of current society although protecting these precious natural and cultural treasures for future generations.

2.2.3. Community Participation and Cultural Heritage

The involvement of the community and the cultural historical framework highlight the importance of the community in preserving history (Guzmán et al., 2017). This idea suggests that cultural history maintaining goes beyond government and expert tasks, showing a shared community duty (Diego et al., 2020). Active community involvement raises the success of cultural history maintaining and sharing, especially for living landmarks such as ancient trees.

Ancient trees, as living signs of cultural and natural history, need full community joining for their maintaining. Via efforts to learn and share projects, we can help everyone superior understand the cultural importance of ancient trees and inspire community-led conservation actions (Bonnett et al., 2013).

2.2.4. Summary

Community forums, talks, and public presentations work well to boost resident involvement and responsibility. Use local knowledge and traditional approach to find new ways to protect ancient trees.

For instance, the 'Tree Exchange and Imprint' project in Jian'ge County shows how traditional cultural elements can successfully meet modern preservation needs. In this study, we elaborated a complete conceptual model specifically designed to address the various barriers to preserving old growth trees during urban development and economic advancement. This model combines three main concepts: ecosystem services, long-term use and public participation, and cultural heritage, to explain the protection of ancient trees from multiple perspectives. The concept of ecosystem services highlights the ecological, cultural and aesthetic value of ancient trees, making them particularly critical in urban planning. We have always adhered to the concept of sustainable development, make sure the rational growth of resources and protecting ancient trees to promote in conclusion advancement. At the same time, the idea of group participation emphasizes the importance of residents in protection and promotes everyone's sense of responsibility. Using this model, we can protect and pass on the valuable heritage of ancient trees, and also promote sustained community advancement so that people and nature can live in harmony (Roslan et al., 2021).

2.3. Context of the Project

In summary, this study focuses on Shichahai Subdistrict in Beijing, a historic place located in the northeastern part of Xicheng District, close to the imperial palace. This district is particularly notable because it combines cultural, commercial, residential and tourist elements. It has 55 cultural heritage sites and 403 ancient trees (see Figure 2), making it the largest and best-preserved historical district in Beijing's old city. The ancient trees, which are interspersed throughout the area's streets, alleys, communities, and landmarks, are emblematic of the collective identity of Beijing residents and serve as living repositories of the city’s historical and cultural narratives.

Figure 2. Ancient trees in Shichahai, Beijing. Source: Author’s own work.

While these ancient trees are critical, compared with famous cultural relics like Prince Gong’s Mansion and Yinding Bridge, basically no one pays attention to them. Problems like missing records, outdated information or damaged identifying signs mean that even less is known about its ecological and cultural value. Therefore, if we do not pay attention to these trees, the result will be that they will be neglected, their value will be reduced, and the emotional connection between people will be weakened, which will threaten the inheritance of cultural heritage.

The study sought to understand how local residents feel about participating in the planning of ancient tree trails and their readiness to integrate these trees into daily activities, tourist routes and historical sites. The study aims to enhance community cohesion and actively participate in the protection of cultural heritage by stimulating everyone's interest in caring for trees and helping the public superior understand ecological knowledge. The results highlight the importance of combining scientific research and community engagement to protect the unique cultural landscape of Shichahai.

3. Research Methods

3.1. Research Design

This study used a mixed approach method to study the layout. First, we conducted a literature review and collected details from policy documents and planning texts related to ancient tree protection. Critical documents examined involve the "Control Detailed Planning of the Core Functional Area of the Capital," the "Beijing Land Use Master Plan 2006-2020," and the "Archives of Ancient Trees in Xicheng District, Beijing." Then, Geographic Information System (GIS) tech gathers and studies quantitative info, which include green space planning charts and remote sensing pictures of Shichahai Subdistrict, to grasp the spatial spread and health status of ancient trees. Semi-structured chats were used to collect several qualitative information, which helped us to gain a deeper understanding of local people's views and feelings on the protection of ancient trees. Merging both quantitative and qualitative studies, this research aims to explore thoroughly the emotional connection of Shichahai Subdistrict folks with ancient trees and its effect on cultural legacy protection.

3.2. Data Collection

This study began with an in-depth analysis of essential documents, which include the "Control Detailed Planning of the Core Functional Area of the Capital," the "Beijing Land Use Master Plan 2006-2020," and the "Archives of Ancient Trees in Xicheng District, Beijing." This analysis provides useful details on green space planning and the location of ancient trees in the Shichahai area. By examining the distribution and actual growing conditions of these trees, supplemented by information from on-site observations, we can gain a clearer picture of their current condition. To conduct a more in-depth study, we conducted a community engagement survey to understand local residents' thoughts and readiness for participating in the planning of ancient tree trails. Eight on-site surveys were done in Shichahai Subdistrict from November 2023 to March 2024. The research subjects are the people in Shichahai Subdistrict, especially those who have lived there for a long time and have deep feelings for the ancient trees. The selection criteria are based on how long people have stayed in the area and their knowledge of the ancient trees. We sent out a overall of 271 questionnaires and finally collected 264 valid ones. Based on the readiness shown in the surveys, 25 semi-structured chats were held in familiar places, such as streets or community spots, to ease open and honest talk. You can ask several leading questions during the conversation so that everyone can talk about their memories and experiences with ancient trees.

3.3. Data Analysis

3.3.1. Literature Analysis

The research performed a thorough examination of the critical papers mentioned above, uncovering the safeguarding status and planning needs for ancient trees within the existing policy setup. The information extracted from these documents mainly talks about the critical points of protection measures, planning objectives and development restrictions, especially those related to the ancient trees in Shichahai Subdistrict. This information gives the necessary background understanding and basic data to grasp the present condition and hurdles of ancient tree safeguarding at the policy level.

3.3.2. GIS Analysis

This study used geographic information system (GIS) technology to map and record the distribution of ancient trees in Shichahai Subdistrict. The study identified both tree groups and individual tree samples,

which helps us understand the density and distribution of ancient trees. Scientists utilized field evaluations and satellite pictures to evaluate ancient tree wellness by inspecting growth aspects and environmental hurdles. This method can thoroughly identify which examples require higher protection. This study is about the relationship between ancient trees and the plants around them. It looks at how the layout of green space affects the growth environment of trees. By linking the location of ancient trees to the spread of green space, scientists are learning about the influence of plant life on tree life. This geographical research assists urban gardening projects by making superior use of ancient trees and enhancing their aesthetic value in urban environments (Ye et al., 2019).

3.3.3. Questionnaire Data Processing

This study used SPSS statistical software to process and analyze the survey results. Preliminary data cleaning removed invalid answers and statistical outliers to maintain the integrity and reliability of the data. Descriptive statistics were used to understand residents' feelings about ancient trees, their awareness of protection, and their willingness to participate. Cross-tabulation and chi-square analysis were used to investigate the differences in attitudes toward protecting ancient trees among different demographic groups (such as age, gender, and length of residence). The study showed that cutting-edge multivariate techniques such as factor analysis and regression analysis can identify key factors that affect residents' participation in ancient tree protection activities (Bonnett et al., 2013).

3.3.4. Thematic Analysis

Qualitative analysis software (like NVivo) was used to transcribe and code the data from the semi-structured interviews. Reviewing transcript codes from the outset can help identify and categorize major ideas and trends. The scientists then used axial coding to show the relationships between the identified ideas, forming greater theoretical groups and connections. The final step used selective coding to refine core themes and patterns in the study. This method deepened the understanding of the emotional connection between residents and ancient trees, enhanced their awareness of protection and willingness to participate, and also revealed how these factors affect their views and actions on tree protection (Anau et al., 2019). Qualitative analysis uncovered residents' underlying views and emotional connections to veteran tree preservation, offering valuable perception for evolving effective conservation plans.

4. Findings and Discussion

4.1. Policy Framework and Current Status of Ancient Tree Protection

0Literature analysis shows that within the policy papers for Shichahai Subdistrict, ancient trees, as part of cultural heritage, get a certain level of focus, with matching protective steps and planning aims suggested.However, the promotion and attention to ancient trees are relatively weak compared to other cultural heritage elements (Figure 3), resulting in a lack of prominent position in public awareness. Results from field surveys and resident interviews further reveal that many visitors are even unaware of the existence of ancient trees, reflecting the need to strengthen the implementation of ancient tree protection. This situation aligns with ecosystem services theory, which emphasizes the importance of ancient trees in providing ecological, cultural, and social services. The current lack of effective policy implementation may lead to the loss of these service values (Wu et al., 2022), thus necessitating urgent improvements in policy execution and raising public awareness of the importance of ancient tree protection through education and outreach (Figure 4) to achieve a harmonious balance between ancient tree protection and urban development.

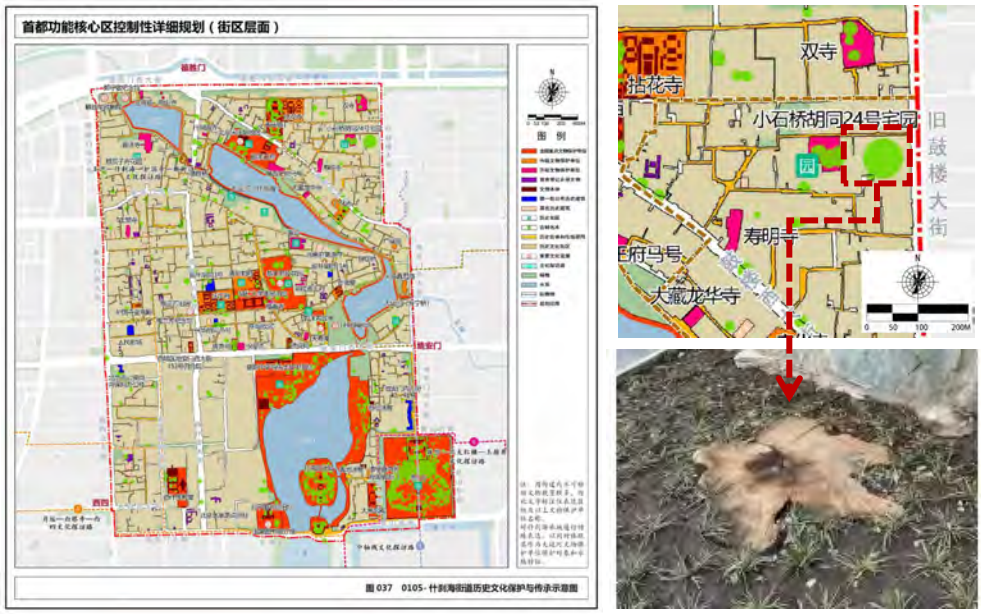


Figure 3. Inaccurate records of ancient tree related documents. Source: Controlled Detailed Planning of the Capital Functional Core Area (Block Level).Author's own work.

"There used to be a 300-year-ancient tree here, but it was unfortunately cut down last year due to some reasons." (The security guard, BANBOO GARDEN HOTEL)

Figure 4. The living environment of ancient trees has been damaged due to human activities.Source: Author's own work.

"In the absence of space for drying clothes in the alleyways, it's quite common to string a wire between the big trees for hanging clothes and bedding to dry." (Resident, 75-year-old)

4.2. Spatial Distribution and Health Status of Ancient Trees

GIS analysis results indicate that the distribution of ancient trees in Shichahai Subdistrict is uneven, with some trees concentrated in areas rich in historical and cultural heritage, such as the Wangfu Rear Courtyard. This distribution fosters an organic connection between ancient trees and other cultural heritage, enhancing the cultural continuity and historical depth of the area. However, the health status of some ancient trees is threatened, potentially linked to historical development patterns, urban planning

decisions, and inadequate green space protection (Figure 5). The study found that some ancient trees are located within private courtyards or government offices, where they often lack public access and may not receive adequate protection and management. Specific environmental pressures faced by these trees, such as nearby construction activities and human interference, further exacerbate their health risks. As a means to connect these point-like historical resources, the ancient tree trail enhances both the accessibility and aesthetic value of ancient trees, while also providing new ideas for urban greening and cultural heritage protection. These measures resonate with the theory of sustainable utilization, highlighting the need to balance current demands with the protection of future resources while ensuring that these cultural heritages are effectively protected and reasonably utilized.

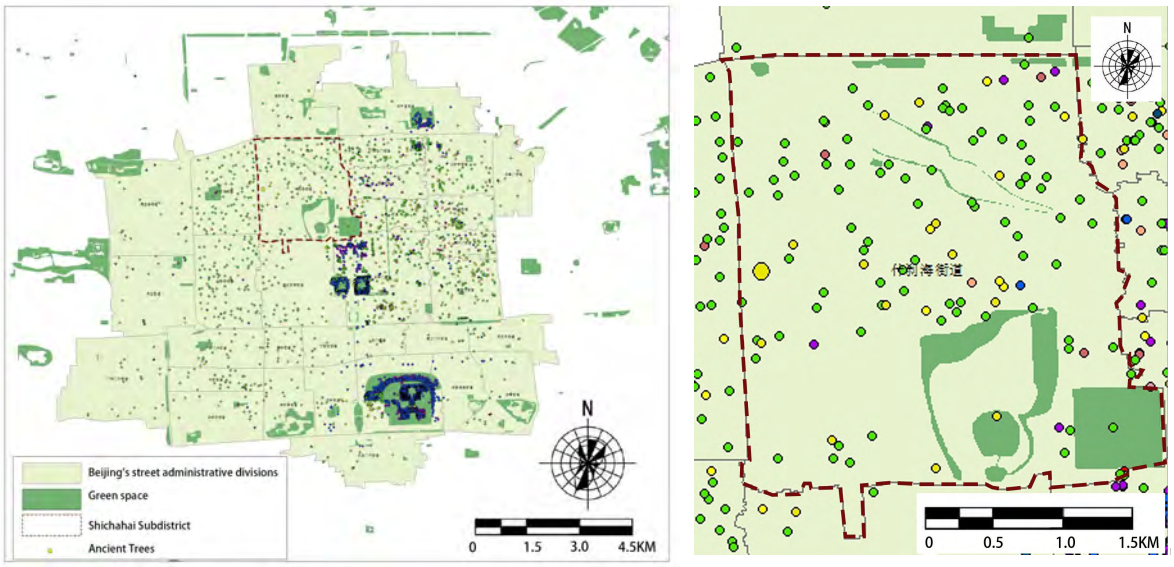


Figure 5. The distribution of ancient trees does not match that of green spaces.Source: Author's own work.

4.3. Residents' Emotional Identification and Participation in Protection

Survey and interview results reveal the extent of residents' emotional identification with ancient trees and their willingness to participate in protection activities (Figure 6). While most residents exhibit some emotional attachment to ancient trees, this feeling does not always translate into active protective actions. This may be related to residents' insufficient understanding of protective measures, personal resource limitations, or skepticism regarding the effectiveness of protection efforts. The theories of community participation and cultural heritage transmission emphasize the importance of enhancing public awareness and community involvement, indicating the need for educational and participatory projects to strengthen the community's recognition of the cultural value of ancient trees, thereby promoting the implementation of protective actions.

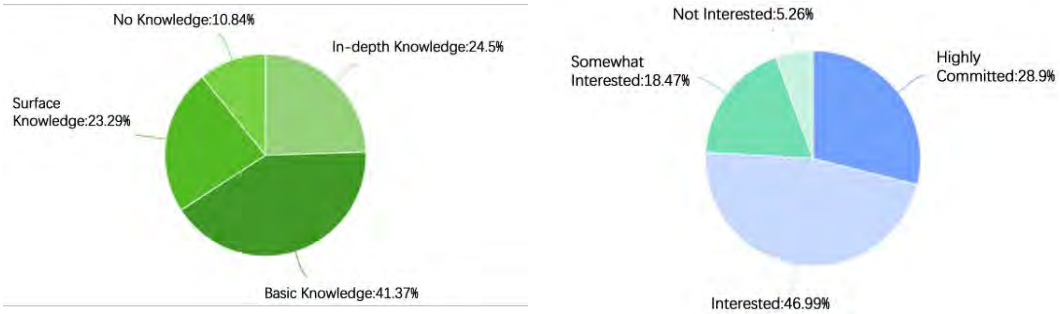


Figure 6. The willingness of Shichahai residents to participate in planning activities related to ancient tree protection and their degree of understanding of ancient trees. Author's own work.

5. Recommendations for Planning

5.1. Strengthen Policy Implementation and Supervision Mechanisms

Given that the literature analysis indicates insufficient enforcement of ancient tree protection policies, it is recommended to strengthen policy implementation and supervision mechanisms to ensure that protective measures are effectively implemented. This includes regularly reviewing and updating relevant policy documents and ensuring that sufficient resources and personnel are available to monitor the execution of protective measures.

5.2. Optimize Ancient Tree Archive Management

Due to the absence or lack of timeliness in some ancient tree records, it is recommended to establish a comprehensive archive management system for ancient trees, regularly updating their growth conditions and protection needs. This will enhance the targeted and effective protection of ancient trees.

5.3. Improve Spatial Distribution of Ancient Trees and Their Relationship with Green Spaces

GIS analysis results reveal a mismatch between the distribution of ancient trees and green spaces. It is suggested that urban planners consider the locations and needs of ancient trees when planning new green spaces or improving existing ones, in order to enhance the accessibility and aesthetic value of ancient trees and to provide a healthier growth environment.

5.4. Raise Residents' Awareness and Participation in Ancient Tree Protection

Survey and interview results indicate that while residents have some emotional identification with ancient trees, their willingness to participate in protection activities varies. It is recommended to enhance residents' awareness of protection through community education and outreach activities while also encouraging them to participate in volunteer activities for ancient tree.

6. References

Francioni, F. (2017) 'Beyond state sovereignty: the protection of cultural heritage as a shared interest of humanity',*In Globalization and Common Responsibilities of States* (pp. 375-394). Routledge.

Sesana, E. Gagnon, A.S., Ciantelli, C., Cassar, J.A. and Hughes, J.J.(2021) 'Climate change impacts on cultural heritage: a literature review',*Wiley Interdiscip Rev Clim Chang*, 12, pp. 1–29.

Macmillan, F.(2013) 'The Protection of Cultural Heritage: Common Heritage of Humankind, National Cultural'Patrimony'or Private Property?' ,*N. Ir. Legal Q.*, 64, p.351.

Townsend, J.B. and Barton, S. (2018) 'The impact of ancient tree form on modern landscape preferences', *Urban forestry & urban greening*, 34, pp.205-216.

Parikka, J.(2019) 'Remain (s) scattered'.

Manning, A.D., Fischer, J. and Lindenmayer, D.B. (2006) 'Scattered trees are keystone structures–implications for conservation', *Biological conservation*, 132(3), pp.311-321.

Zapponi, L., Mazza, G., Farina, A., Fedrigoli, L., Mazzocchi, F., Roversi, P.F., Peverieri, G.S. and Mason, F. (2017) 'The role of monumental trees for the preservation of saproxylic biodiversity: re-thinking their management in cultural landscapes', *Nature Conservation*, 19, pp.231-243.

Butler, J.E., Rose, F.R.A.N.C.I.S. and Green, E.E. (2001) 'Ancient trees, icons of our most important wooded landscapes in Europe', *Textbook*, 2, pp.20-26.

Holmgren, M. and Scheffer, M. (2017) 'To tree or not to tree: cultural views from ancient Romans to modern ecologists'. *Ecosystems*, 20, pp.62-68.

Guzmán, P.C., Pereira Roders, A.R. and Colenbrander, B.J.F. (2014) 'April. Bridging the gap between urban development and cultural heritage protection', *In IAIA14 Conference Proceedings*.

Bandarin, F. and Van Oers, R. (2012) 'The Historic Urban Landscape: managing heritage in an urban century', *John Wiley and Sons*.

Nocca, F. (2017) 'The role of cultural heritage in sustainable development: Multidimensional indicators as decision-making tool', *Sustainability*, 9(10), p.1882.

Diego, R. (2020) 'Heritage storytelling, community empowerment and sustainable development', *Правоведение*, 64(1), pp.57-67.

Guzmán, P.C., Roders, A.P. and Colenbrander, B.J.F. (2017) 'Measuring links between cultural heritage management and sustainable urban development: An overview of global monitoring tools', *Cities*, 60, pp.192-201.

Bonnett, A. and Alexander, C. (2013) 'Mobile nostalgias: connecting visions of the urban past, present and future amongst ex-residents', T*ransactions of the Institute of British Geographers,* 38(3), pp.391-402.

Roslan, Z.B., Ramli, Z., Razman, M.R., Asyraf, M.R.M., Ishak, M.R., Ilyas, R.A. and Nurazzi, N.M. (2021) 'Reflections on local community identity by evaluating heritage sustainability protection in Jugra, Selangor, Malaysia', *Sustainability*, 13(16), p.8705.

Ye, Y., Richards, D., Lu, Y., Song, X., Zhuang, Y., Zeng, W. and Zhong, T. (2019) 'Measuring daily accessed street greenery: A human-scale approach for informing better urban planning practices', *Landscape and Urban Planning*, 191, p.103434.

Bonnett, A. and Alexander, C. (2013) 'Mobile nostalgias: connecting visions of the urban past, present and future amongst ex-residents', *Transactions of the Institute of British Geographers*, 38(3), pp.391-402.

Anau, M., Andrade, A.D. and Waizenegger, L. (2019) 'Digital technology for preserving cultural heritage in Tonga', *IFIP Adv Inf Commun Technol*.

Wu, J., Lu, Y., Gao, H. and Wang, M. (2022) 'Cultivating historical heritage area vitality using urban morphology approach based on big data and machine learning', *Computers, environment and urban systems*, 91, p.101716.

Research Paper

INT-ACT Intangible Cultural Heritage, bridging the past, present, and future

A position paper on INT-ACT project progress

Inkeri AULA, Aalto University, Finland

Andrada-Ioana LUPULESCU, Urbasofia, Bucharest, Romania

Pietro Elisei, Urbasofia, Bucharest, Romania

Saturnino LUZ, University of Edinburgh, UK

Masood MASOODIAN, Aalto University, Finland

Áurea RODRIGUES, CIDEHUS, University of Évora, Portugal[1]

Antti RUOTOISTENMÄKI, Aalto University, Finland

Ilektra SIMITSI, ITML, Greece

Elpida TZIKA, ITML, Greece

Renata VIEIRA, CIDEHUS, University of Évora, Portugal[2]

Abstract

The INT-ACT project explores innovative approaches to preserving and presenting intangible cultural heritage (ICH) by integrating Emotional, Experiential, and Environmental (3E) dimensions with tangible cultural heritage (TCH) through immersive eXtended Reality (XR) environments. This transdisciplinary research seeks to bridge the past, present, and future by developing ontologies that formalize heritage knowledge and human narratives associated with four diverse European heritage sites: Alentejo (Portugal), Calanais (Scotland), Koli National Park (Finland), and Kavala (Greece). The project utilizes different methods, including multi-sited and sensory ethnography, to capture emotional and sensory connections between people and places. These methods are tailored to reflect the local contexts of the selected case studies, which address societal challenges such as cultural tourism, aging societies, disappearing communities, and multiculturalism. By formalizing the relationship between ICH and its tangible manifestations, INT-ACT advances new ways of engaging with cultural heritage, providing solutions for enhancing wellbeing, fostering community cohesion, and enriching visitor experiences through technology. The project's findings will inform the creation of immersive XR-based demonstrators, offering valuable insights into the preservation, accessibility, and reinterpretation of cultural heritage in a rapidly changing world[3].

[1]https://doi.org/10.54499/CEECINST/00054/2018/CP1522/CT0001, FCT: grant number: 10.54499/CEE-CINST/00054/2018/CP1522/CT0001; and CIDEHUS grant number: UIDB/00057/202

[2]https://doi.org/10.54499/CEECIND/01997/2017/CP1431/CT0001, FTC grant number CEECIND/01997/2017/CP1431/CT0001, and CIDEHUS grant number: UIDB/00057/2020.

[3]**NOTE**: In this document, AI tools such as ChatGPT were utilized solely to assist in phrasing or rephrasing the text. The primary source of the text is original, with no new information generated by AI integrated into the document. AI assistance was limited to rephrasing.

Keywords

Culture, Tangible and Intangible Heritage, eXtended Reality, Cultural Heritage Preservation, Transdisciplinary Methodology, Community Led Development.

1. Methodological approach and means towards achievement

The INT-ACT project employs a comprehensive methodological approach structured in four pillars (WPs). This structured methodology aims to integrate both tangible and intangible cultural heritage with immersive eXtended Reality (XR) environments, applied to cultural sites, with the broader goal of better addressing future challenges. The methodology applied in INT-ACT is designed with care to be generate trans-disciplinary knowledge, to integrate knowledge and techniques from various fields such as information sciences, social sciences, humanities, and technology (Birkeland et al., 2018; Järviluoma et al., 2023).

The first stream focuses on extracting more coherently the “Formalized Knowledge” (WP1). The second stream works as a follow-up from the previous one and is directed to capture “Human Narratives” (WP2). The third stream is devoted to technological advancements, the “Creation of Immersive XR Environment” (WP3). This leads to the fourth and final stream the “Case Studies for Societal Challenges” (WP4). INT-ACT seeks to address four challenges, cultural tourism, aging societies, disappearing communities, and immigration and multiculturalism, by leveraging technology (Hou et al., 2022; UNESCO, 2003). Thus, it conducts four case studies, one per societal challenge, to propose a structure for Future Societies.

Community engagement is vital throughout INT-ACT, as the project strongly depends on community involvement and planning input so as to collect vital insights about society and cultural challenges (Vahtikari et al., 2020). The mixture of digital tools and interactive spaces allows the establishment of a community that can adapt to future challenges arising from present matters (Birkeland et al., 2018). At its core, the partnership invites local communities, organizations and stakeholders, to join the project activities with particular attention to their participation in providing insights per case study, but also in dissemination. At this end it is sought to bring their ideas and feedback, while maintaining permanent benefits for the results of the project (Aula, 2023).

The methodology is visually represented in the following graphic:

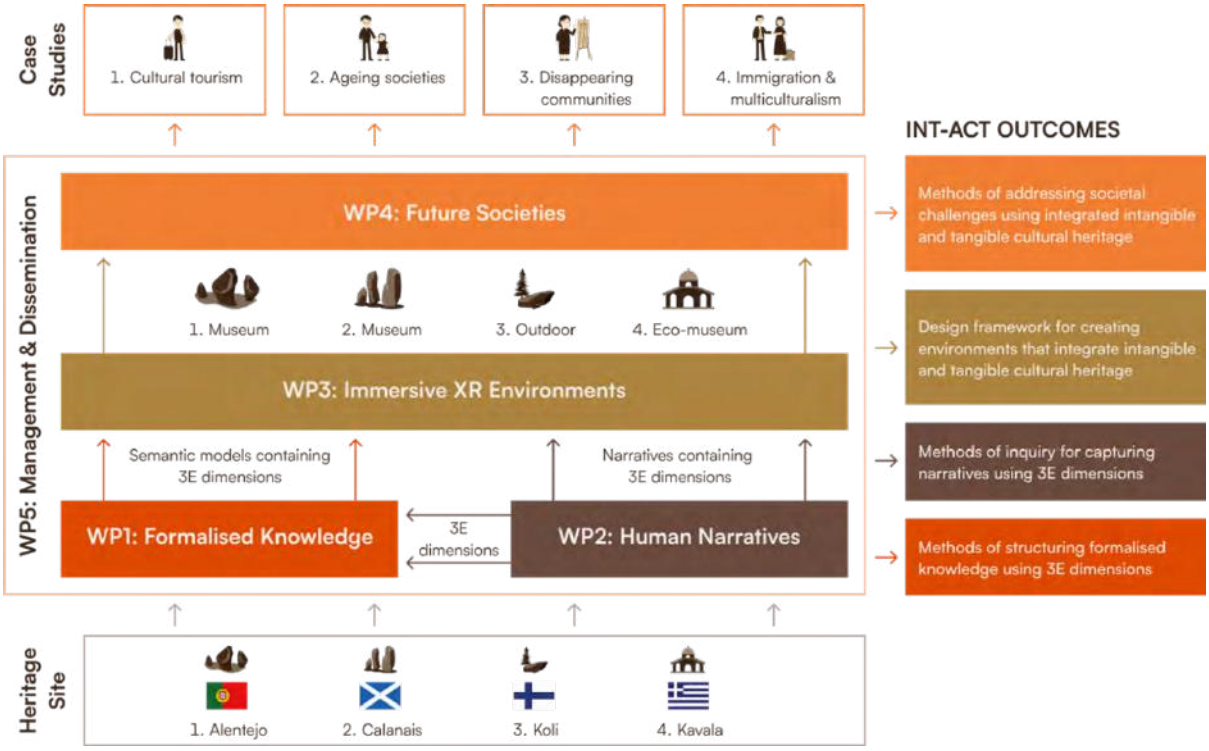


Figure 1. INT-ACT Methodological framework. Source: INT-ACT website

1.1. Formalized Knowledge

The Emotional, Experiential, and Environmental (3E) dimensions of Intangible Cultural Heritage (ICH) in association to Tangible Cultural Heritage (TCH) are met and formalized in the INT-ACT project through the application in specific pilot sites. This entails the development of semantic models (i.e. ontologies) for the specified cultural heritage sites. These ontologies –extending the International Committee for Documentation Conceptual Reference Model (CIDOC-CRM) framework, which is broadly used in cultural heritage documentation (Bruseker et al., 2017) - seek to organize and structure intangible heritage concepts. These includes human activities, emotions, and environmental connections (Lin et al., 2018). Semantic models are sought to organize the core concepts of both past and present meanings of intangible and tangible cultural heritage knowledge (Järviluoma et al., 2023).

1.2 Human Narratives

The Human Narratives stream is advancing its efforts to capture, compile, and preserve the Emotional, Experiential, and Environmental (3E) dimensions of ICH through diverse ethnographic and biosensorial methods (Hannerz, 2003; Järviluoma, 2022). These methodologies are being used to collect emotionally meaningful narratives from local communities connected to the four cultural heritage sites: Alentejo, Calanais, Koli National Park, and Kavala. The project also measures the well-being of participants and the impact of these immersive experiences, particularly in relation to broader societal challenges such as cultural tourism, aging societies, disappearing communities, and immigration and multiculturalism (Hou et al., 2022).

The knowledge formally registered in the literature about these selected sites, deriving from the first stream, will be modelled to establish links with the present-day human narratives (Feld & Basso, 1996). These will serve as a bridge between what is known and what is perceived, ensuring that the heritage knowledge can be reused in creative, informed ways to build new visitor experiences, as elaborated at the

next stage (Aula, 2023). The "Human Narratives" (WP2) uses a variety of approaches, including multi-sited ethnography, sensory ethnographic interviews, and narrative workshops, integrated into a project-specific methodology (Hannerz, 2003; Järviluoma et al., 2023). Using interviews and other multisensory techniques, establishes the established emotional bonds between people and their cultural environments (Birkeland et al., 2018). The 3E dimensions of these narratives are extracted, structured and presented using speech analysis methods so that data collected is comprehensive and captures both emotional and environmental elements (Haider et al., 2021).

1.3 Extended Realities

This stream focuses on developing immersive eXtended Reality (XR) environments that integrate the 3E dimensions of ICH with TCH sites. INT-ACT brings together culture and technology pursuing more resilient societies and to adapt with interaction techniques, narrative methods, and audiovisual media (Hou et al., 2022; Luz & Sheehan, 2020). The scope of utilising Extended Realities is to explore, to postulate and to direct the creation of immersive XR environments that contextualize and tell the 3E stories of ICH. Under this stream, four small-scale demonstrators (DM1, DM2, DM3, DM4) will be developed. These demonstrators will provide multi-sensory virtual worlds allowing visitors to travel through space and time, experiencing human narratives and formalized knowledge associated with TCH sites (Lin et al., 2018). Each demonstrator is linked to a unique heritage site, and together they address specific societal challenges.

The easy of accessibility through the use of mobile XR technology is increased as many devices are supported simultaneously (Comincioli et al., 2022). Although delivered on a unified platform, each demonstrator uses cutting-edge XR production techniques from Aalto Studios MAGICS and subcontractors, designed to provide immersive experiences that merge tangible and intangible heritage elements (Haider et al., 2021). The development process follows a Human Centred Design (HCD) approach whereby design thinking is used to make the demonstrators desirable, viable and feasible (Hou et al., 2022).

1.4 Future Societies

The final step towards building the Future Societies is to investigate how immersive XR environments, reflecting the 3E dimensions of intangible cultural heritage, can help tackle societal challenges through four case studies, one for each cultural heritage site (CS1–CS4), using a demonstrator (DM1–DM4) tied to an identified societal challenge (SC1-SC4) (Birkeland et al., 2018).

- SC1: Cultural Tourism / CS Portugal – this case study examines the practice of sustainable tourism through the first demonstrator as a means for immersive virtual access to alleviate overcrowding and environmental impact, whilst preserving cultural identity (UNESCO, 2003).
- SC2: Ageing Societies / CS2 Scotland – this case study explores, through the use of the 2nd demonstrator, the linkage between different generations and improving wellbeing by providing an opportunity for intergenerational dialogue on culture and cultural heritage (Birkeland et al., 2018).
- SC3: Disappearing Communities / CS3 – Finland – this case study, applying the third demonstrator, undertakes research actions that explores the ways in which the use of intangible heritage in an artistic context may be able to contribute to the sustainability of communities that are threatened by the quickened pace of urbanization (Pitkänen et al., 2017).
- SC4: Immigration & Multiculturalism / CS4 Greece – the last pilot, implemented in relation to the fourth demonstrator, seeks to develop a multicultural dialogue, between the population and immigrants, thus contributing to the local community (Vahtikari et al., 2020).

Local stakeholders at each site will support these studies, and outcomes will be shared via workshops and a policy brief to extend the project's impact to other heritage sites (Birkeland et al., 2018).

Figure 2. INT-ACT Study Cases. Source: Courtesy of Professor M.M., project resource.

1.5 Data Analysis and Case Study Focus

The usage of descriptive statistics, machine learning algorithms and thematic analysis in carrying out data analysis will be utilized (Haider et al., 2021; Lin et al., 2018). The Wellbeing Index responses, VAS scores and speech data will be compared pre- and post-intervention, and between the control and intervention groups, within the pilot sites. Therefore, case study-specific analyses will explore the themes of past, present, and future, memory, and perspectives related to each site:

- Cultural tourism (SC1): Potential negative impacts of cultural tourism are identified and ways for sustainability are discussed (UNESCO, 2003).
- Mental wellbeing (SC2): Improvements in mental wellbeing compared to cortisol analysis and speech data (Comincioli et al., 2022).
- Disappearing communities (SC3): The role of artists in Countering Rural Cultural Loss is identified (Pitkänen et al., 2017).
- Local-immigrant connections (SC4): S compares the degree of enhancement of linkages between local communities and immigrants (Vahtikari et al., 2020).

These four cases attempt to proceed to a further understanding of cultural heritage through sustainability, social cohesion and wellbeing. Sustainability in cultural tourism is addressed through long term preservation and the solution of adverse impacts. Mental wellbeing is explored through cortisol analysis and speech data to understand the relationship between cultural engagement and health. Artists' roles in countering rural cultural loss are examined through creative interventions in the preservation of intangible

heritage. Cultural heritage is emphasized as a process of connection and belonging, and by extension a process of social resilience that deepens those connections between local and immigrant communities. These elements are united in a forward looking, adaptable, and sustainable vision of cultural heritage (Birkeland et al., 2018).

2. Current stage of development

At this stage, the primary focus of the INT-ACT project is the development of ontologies and the conduction of narrative interviews, since the first two streams are currently undergoing.

2.1. Current State of Development in constructing Formalised Knowledge (WP1)

The work is customized around the first case study in the Alentejo region, specifically at the Cromeleque das Fontainhas site. It also involves foundational work for the second case study at Calanais, where ontology development has begun in collaboration with the Edinburgh Data Initiative (EDI) (Ashmore, 2016).

INT-ACT will employ computational ontologies to represent knowledge about the project's cultural heritage sites - creating a common understanding of concepts, relations, and categories leading to a more coherent analysis and exchange of expertise (Lin et al., 2018). While general knowledge of concepts is horizontal and the same for all sites, ontologies are tailor-made per location, thus enabling the exploration of site specificities (Bruseker et al., 2017). This tailored approach is the reason why, in some locations, there are planned workshops, while in others, 1:1 discussions with interested stakeholders are organized to define and refine the ontologies per location (Vahtikari et al., 2020).

Structured knowledge is more than just data organization tools. Ontologies form the backbone of structured knowledge within INT-ACT. They are important in formalizing the link between the tangible and the intangible aspects of cultural heritage and are important in supporting the project's key objectives (Lin et al., 2018). Adaptive to new insights and data, ontologies are dynamic models — an evolving thing. In contrast to static data models, they are better suited to the complexity inherent in cultural heritage (Hou et al., 2022).

Many phenomena connected to ICH are difficult to categorize. This complexity is addressed by the provided framework by organizing and investigating the cultural and the emotional dimensions more effectively (Birkeland et al., 2018). This is relevant to what the INT-ACT project aims to explore and present, which is the emotional, experiential and environmental dimensions of heritage (Feld & Basso, 1996).

Ontologies encourage more use of shared terms or standard mapping between unique terms, thus facilitating smoother data integration between researchers and systems (Bruseker et al., 2017). In this particular case, ontologies enable researchers to create unified frameworks that link heritage sites together as well as maintain consistency (Vahtikari et al., 2020). Sharing data is made easier and more transparent, while collaboration is encouraged, by ontologies. This is accomplished through the provision of a formalized structure that will also make research publicly available, verify results, and make them reusable in subsequent studies (Luz & Sheehan, 2020). The more we can use common language and have shared logic structures, the more precise our scientific communication is. This is essential in INT-ACT to record the dense interplay between the tangible heritage and the human narratives it is embedded in.

2.1.1 Ontology Development in INT-ACT

The ontologies developed for the INT-ACT project fulfil several critical roles. Primarily, they establish a multidisciplinary foundation, offering a shared perspective on cultural heritage data and linking the 3E dimensions to tangible heritage sites (Lin et al., 2018). These ontologies are also conformant to the CIDOC

CRM standard for cultural heritage documentation, so that they could be integrated with existing models (Bruseker et al., 2017). In practice, this involves several key steps: formally describing the heritage sites in structured terms, working with developers to ensure smooth integration into immersive XR environments, identifying and linking images or 3D model elements with the emotional and experiential dimensions of the sites, and relating specific emotions and experiences to tangible cultural features such as megaliths or stone circles (Hou et al., 2022).

2.1.2 Structure of the Ontologies

The base for the development of INT-ACT ontologies is a clear and logical framework. These are composed of classes or concepts, major elements of things like types of monuments or emotions (Lin et al., 2018). These classes are arranged hierarchically in order to create a more structure form. For each class there are defining examples (e.g. a particular stone monument). Moreover, these classes are connected via properties or relations which enables the creation of meaningful relationships between classes (e.g., the relationship between the tangible characteristics of cultural heritage sites and the emotions triggered by them (Bruseker et al., 2017; Lin et al., 2018).

2.1.3 Case Studies in Progress: Cromeleque das Fontainhas and Calanais

For the first two case studies, the ontologies focus on megalithic sites, specifically Cromeleque das Fontainhas in Alentejo and Calanais III in Scotland. These case studies are centered around the interpretation of these open-air monuments, integrated within their landscapes (Ashmore, 2016).

Cromeleque das Fontainhas

The Cromeleque das Fontainhas was identified in the 1970s by the Geological Services of Portugal and later excavated in 2005 by archaeologists Leonor Rocha and Manuel Calado. The site has a floor plan resembling that of the Vale d'El Rei, characterized by horseshoe enclosures (Birkeland et al., 2018).

The site has a "continuous" occupation or use stretching from the Early Neolithic to the Chalcolithic periods, with possible sporadic use during the Roman period. The site's chronology has been established through archaeological collections, which include prehistoric manual pottery, some of which are decorated, and lithic tools. One of the menhirs at the site is decorated with a crescent and a crosier, adding to its symbolic and artistic significance (Ashmore, 2016).

Calanais III

Work on the ontology for Calanais III, a site with iconic stone circles and associated with many myths and legends, such as men turned to stone for their misdeeds, has begun (Ashmore, 2016). Calanais is integrated into a vast and open landscape as Fontainhas is, also an outdoor monument (Hou et al., 2022).

For both Cromeleque das Fontainhas and Calanais, the ontologies capture the following 3E dimensions:

- Environment: Interaction between man-made monuments and their natural settings (Birkeland et al., 2018).
- Experience and emotions: Gasping the sense of timelessness and continuity just getting to many of these sites (Feld & Basso, 1996).

The development of XR environments is supported by the ontologies relating the emotional and environmental dimensions of the intangible site features to tangible site features, creating immersive and transformative experiences that breathe life into these heritage sites (Hou et al., 2022).

2.2. Current State of Development in collecting Human Narratives (WP2)

The current focus of Human Narratives (WP2) includes the implementation of an ethnographic study to understand the essence of intangible heritage – such as contemporary stories and experiences and how it means in these sites, and designing and organising a study to evaluate the usability and impact of the XR demonstrators developed for each case study (Hannerz, 2003; Järviluoma, 2022).

The study is designed to assess a few key aspects at each site, including the usability and user experience of the XR demonstrator, access to ICH, the impact on participants' well-being, and the ability of the demonstrator to help address the associated societal challenges (Haider et al., 2021). The study foresees a total of 300 participants and uses several different data collection and analysis methods; It is sought to evaluate the usability and user experience by open dialogue, NLP system, and System Usability Scale (SUS) questionnaire. Open dialogue and NLP are used to explore access to intangible cultural heritage and the Wellbeing Visual Analog Scale (VAS), cortisol analysis and wearable devices are used to measure the impact on wellbeing (Comincioli et al., 2022). Open dialogue and NLP are used to assess the societal challenges, with specific challenges germane to each case study site (Hou et al., 2022).

3. Technologies to be applied

For the case studies, a series of technologies have been identified throughout INT-ACT which have a significant potential:

- Mobile eXtended Reality (XR): The goal of the project is to use mobile XR technology to construct immersive environments for the purposes of cultural heritage experiences. This seeks to improve accessibility, but with less user engagement that the headset-based solutions require (Hou et al., 2022).
- Natural Language Processing (NLP): The project will be using a suite of natural language processing tools to analyze human narratives and emotional responses. The qualitative analysis and quantitative modeling of emotional states will be supported by this technology (Haider et al., 2021; Luz & Sheehan, 2020).
- Biosensorial Methods: Biosensors for capturing and assessing people's experience of cultural heritage sites in everyday situations. It includes: The stories gathered through biosensorial narrative workshops and ethnographic interviews that are emotionally powerful stories (Aula, 2023; Murray & Järviluoma, 2020).
- Semantic Models and Ontologies: The project will develop semantic models in the form of ontologies to formalize knowledge about the Emotional, Experiential and Environmental (3E) dimensions of intangible cultural heritage (Lin et al., 2018).
- Machine Learning and Speech Technology: User experience and well-being will be assessed through techniques using machine learning algorithms in the signal processing and analysis of speech data (Haider et al., 2021).
- XR Production Technologies: The project utilizes high-fidelity virtual studios and immersive sound technologies to build high-quality immersive experiences at advanced XR production facilities and infrastructure (Hou et al., 2022).

These technologies aim to develop within the project cultural interactions with the community, that will form the base for future societies. This can be achieved through the following proposed solutions:

Interactive Experiences: Immersive experiences in XR environments enable cultural heritage sites and practice exploration in virtual space. Through these platforms, users can have a multifaceted view of the heritage sites, for instance they can in fact interact with digital artifacts and even participate in a cultural event that wouldn't necessarily take place in real life. The ability of such a highly immersive experience to increase the emotional and experiential association around cultural heritage, enabling users to create a more intimate and relevant relationship with represented history and traditions (Hou et al., 2022; UNESCO, 2003).

Educational Tools: Visitors and community members experience immersive learning via XR environments, which are powerful educational tools. Gamified elements and interactive narratives tailored to specific audiences, for example with the incorporation of students or tourists, these will serve common means of stimulating and dynamic educational context about the history, importance and context of cultural heritage. Such tools can be used to achieve a deeper knowledge about cultural heritage, turning the classic education into an interactive trip (Birkeland et al., 2018; Hou et al., 2022).

Virtual Eco-Museums: The preservation and presentation of history, traditions, and contributions of several immigrant communities is possible in a virtual eco museum. This can be very useful as education and cultural exchange resources to enhance the social cohesion between local population and newcomers. By creating a dedicated space for cultural storytelling, The virtual eco-museum promotes a more inclusive society encouraging dialogue (Vahtikari et al., 2020).

3.1. Application to Study Cases

The four TCH sites selected within INT-ACT have been strategically chosen to reflect the rich cultural, linguistic, environmental, and demographic diversity of Europe. Each site in itself presents specific challenges or opportunities to probe the 3E dimensions of ICH. Given the diversity of local context, the ways to inquire will be adapted to capture and interpret the narratives of and experiences of people related to heritage sites (Hannerz, 2003; Holtorf, 2012).

All methods in INT-ACT will be adapted and tested to suit the cultural and environmental contexts of the four pilot cases, dealing with the identified societal challenges. The outcomes will feed and will be lioned with the immersive demonstrators in XR developed in WP3, informed by the ontologies developed in WP1 and the human narratives gathered in WP2. All will ensure that the T/ICH of each site is recorded and represented within their relevant societal context and challenges.

The applications for each case, with a view to cost-effectiveness and technology integration, are presented below:

The mobile eXtended Reality (XR) app could bring a virtual tour of cultural tourism to the heritage sites of Alentejo, Portugal. The app creates an opportunity for users to explore megalithic structures and local traditions without being present at the locations. Leveraging mobile XR, the app projects immersive experiences onto models of megalithic sites, accessible through personal or museum-provided devices, enhancing interactivity and accessibility (Gonçalves et al., 2022).

The youth and the older community members in Calanais, Scotland, will be brought together through transgenerational workshops based on the storytelling related to the heritage site. Speech technology assesses user experience, and NLP analyses narratives and emotional responses to enhance intergenerational ties and community wellbeing. Besides helping to preserve cultural heritage, the

initiative also helps the community in general and intergenerational bonding (Ashmore, 2016; Comincioli et al., 2022).

Community art projects engaging local artists and residents are documented through biosensorial and qualitative methods as they reflect upon the region's cultural heritage and identity. The projects will be developed in Koli, Finland to preserve community identity and increase awareness of local heritage. The community can be expressed through the artworks produced and it can be used as a testimony for the community and history and tradition of the community as well as the cultural heritage of the community (Aula, 2023; Birkeland et al., 2018).

A community storytelling initiative (with potential to grow into a virtual eco-museum), invites immigrants and locals in Kavala, Greece to share cultural narratives. These stories will then be fed into machine learning and speech technology to understand each other's stories and bring cultural groups closer together. Through those above, the outcomes will serve a space for storytelling, while at the same time fostering mutual understanding and respect amongst diverse cultural groups. The outcome is that the communities will become more resilient, inclusive and open (Vahtikari et al., 2020; UNESCO, 2003).

4. Assumptions to policymaking

The project's trans-disciplinary methods for capturing and preserving the 3E dimensions can be integrated into policy development - it creates a model for aligning diverse perspectives (Hannerz, 2003; Birkeland et al.,2018).
Policies based on evidence have a greater potential at delivering appropriate solutions to complex cultural and social matters. Moreover, the project advances original approaches in cultural heritage education, preservation, and public engagement through exploring customized XR environments. This technological framework can be adopted by policymakers and made suitable for their local context (Hou et al., 2022; UNESCO, 2003).

INT-ACT enables local communities to participate in the preservation and presentation of their cultural narratives through informing policies that allow, and support, community led initiatives and inclusive heritage management. The project's XR-based demonstrators and case studies investigate the impact of those technologies in cultural heritage management, supporting the development of evidence-based policies (Vahtikari et al., 2020).

The INT-ACT project may contribute significantly to planning and policy-making practices by leveraging a nexus between intangible cultural heritage and immersive XR environments.

- Informing Policy through ICH preservation and presentation: INT-ACT's methodology for extracting and structuring the 3E dimensions (emotional, experiential, and environmental) of ICH provides a nuanced understanding of cultural practices and narratives that can prove to be a valuable addition to policymaking – advancing cultural preservation policies and strategies that link intangible and tangible elements of heritage (Lin et al., 2018; Holtorf, 2012).
- Enhancing cultural tourism strategies: The TCH sites are brought forward in XR-based demonstrators in which visitors can interact and engage with them. This is why this methodology could also support local economies and cultural tourism in a further integration of the 3E dimensions. The insights that result can be utilized by policymakers to develop their tourism strategies by utilizing XR technologies and promoting sustainable tourism practice (Gonçalves et al., 2022).

- Addressing societal challenges with innovative solutions: INT-ACT's case studies directly respond to societal challenges by providing targeted and tailor-made insights.
- Ageing Societies: INT-ACT's work of capturing and preserving cultural narratives of older generations creates inclusive policies that are attuned to the needs and contributions of elderly populations (Ageing Societies) (Comincioli et al., 2022), helps to document and revitalize disappearing cultural practices (Disappearing Communities) (Aula, 2023), and contributes to community regeneration and social cohesion; its focus on multicultural narratives supports policies of integration and social harmony by promoting a deeper knowledge and appreciation of other cultures (Immigration and Multiculturalism) (Vahtikari et al., 2020; UNESCO, 2003).
- Transdisciplinary approaches for policy development: The INT-ACT model demonstrates how to integrate a wide range of academic perspectives and pragmatic concerns into policy making. The methods for capturing and preserving the 3E dimensions collaboratively are developed as transdisciplinary methods. Policies that can address complex social and cultural challenges are informed by broad research and are easier to like (Birkeland et al., 2018; Murray & Järviluoma, 2020).
- Technological integration in cultural policies: Advancing novel technologies in cultural heritage policies can also lead to innovative education, preservation, and cultural heritage public engagement approaches. Policymakers can adapt the technological framework developed through INT-ACT – for instance: narrative methods, testing new interaction techniques, and audio-visual media for XR environments (Hou et al., 2022; Lin et al., 2018).
- Empowering Local Communities and Stakeholders: INT-ACT's methods allow local communities to participate in the preservation and presentation of their local cultural narratives. The participatory approach enables policies that support community led initiatives and that ensure that cultural heritage management is inclusive and responsive to the needs of those it represents (Hannerz, 2003; Vahtikari et al., 2020).
- Evidence-Based Policy Recommendations: Four small scale XR based demonstrators and their associated case studies act as concrete evidence of the impact of immersive technologies on cultural heritage management. These findings are useful for policymakers to establish evidence-based policies that will stimulate the use of XR in cultural heritage sites to preserve and improve accessibility (Gonçalves et al., 2022; Hou et al., 2022).

The provision of innovative methods of ICH safeguarding and presentation will contribute to planning of policies, support sustainable cultural tourism development, solve current societal challenges with targeted solutions, foster transdisciplinary collaboration, combine advanced technologies, strengthen local communities, and deliver evidence-based policy recommendations. They will help to connect the past, present and future in order to transform society toward resolving current societal challenges (UNESCO, 2003; Birkeland et al., 2018).

5. Conclusions and Next Steps

According to a contemporary understanding of CH, a paradigm shift in the approach to CH itself is revealed, which changes it from the condition of "identity and memory repository" to a new one of "aggregator of contemporary innovative uses and services" (Elisei, P., 2020).

Heritage Site 1, Cromeleque das Fontainhas, has been characterized in 'Formalized Knowledge' (WP1) and the CIDOC CRM classes relevant to project specific needs have been identified. For instance, the type of

sites central to the project has been specialized from the original CIDOC concept of "Site" (Lin et al., 2018). This work package seeks to provide four incremental models. While this first model focuses on Environmental dimension, future models will be extended to include more heritage sites and will include Experience and Emotions dimensions.

Important progress has been made within “Human Narratives” (WP2), and the evaluation protocol has been developed and submitted to the ethics board of the University of Edinburgh. The study design protocol contains information on the design of the study, participant consent forms, information sheets for latter inclusion in the protocol and questionnaires used for the study (Murray & Järviluoma, 2020). As soon as the ethics approval is secured, this will be expanded to project partners to recruit participants and collect data. Next are finalizing storage logistics for saliva samples and wearable devices, training of research teams at all sites, and recruiting of participants at each case study site. At the end of the evaluation study, the data will be analyzed to provide insights into the usability, well-being, and more general societal impacts of the XR demonstrators (Hou et al., 2022). ‘Human Narratives’ (WP2) continues to fulfil part of INT-ACT’s mission to deliver rich visitor experience and to face societal issues through preservation and presentation of intangible cultural heritage by following these steps.

INT-ACT will be the first project to use immersive XR environments to preserve, present and interpret intangible cultural heritage pertaining to cultural heritage sites across Europe. Four demonstrators along with case studies each will address INT-ACT societal challenges of tourism, active aging, vital rural communities and multicultural integration (Birkeland et al., 2018). By leveraging state of the art mobile XR and a human centered design approach, INT-ACT makes the experience accessible and multi-sensory, and so connects people of different generations, cultures and geographies (Hou et al., 2022; UNESCO, 2003). Finally, the project integrates innovative tools and participative processes to create a robust framework for cultural heritage community engagement, while also improving resilience and sustainable practices (Vahtikari et al., 2020; Gonçalves et al., 2022). Through its case studies, the project forwards significant societal challenges (cultural tourism, aging societies, disappearing communities, immigration and multiculturalism). By leveraging XR technologies, INT-ACT provides solutions that increase well-being, raise community cohesion and augment visitor experiences.

Acknowledgements:
INT-ACT receives funding from the European Union's Horizon Europe 2023 research and innovation program under agreement #101132719. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or REA. Neither the European Union nor the granting authority can be held responsible for them.

This work is supported by MAGICS, the Finnish national infrastructure for human in the digital world.

UK participants in Horizon Europe Project INT-ACT are supported by UKRI grant number 10102226.

This work is supported by the Portuguese Foundation for Science and Technology (FCT)

6. References

Ashmore, PJ (2016) *Calanais Survey and Excavation, 1979-88*. History Environment Scotland.

Aula, I (2023) Urban nature and digital media technologies entangled. Sensobiographies of young people in Turku, Finland. In: Järviluoma, H, & Murray, L (Eds.) *Sensory Transformations: Environments, Technologies, Sensobiographies.* Routledge.

Birkeland, I, Burton, R, Parra, C & Siivonen, K (Eds.). (2018). *Cultural Sustainability and the Nature-Culture Interface: Livelihoods, Policies, and Methodologies*. Routledge. https://doi.org/10.4324/9781315625294

Comincioli, E., Hakoköngäs, E., and Masoodian, M. (2022*) Identifying and Addressing Implicit Ageism in the Co-design of Services for Ageing People.* International Journal of Environmental Research and Public Health, 19(13), 7667. https://doi.org/10.3390/ijerph19137667

Elisei, P., Draghia, M., Dane, G., and Onesciuc, N. (2020). *Crowd Flow Analysis for Measuring the Impact of Urban Transformation Actions in City's Heritage Areas*. In Schrenk, M., Popovich, V. V., Zeile, P., Elisei, P., Beyer, C., Ryser, J., Reicher, C., and Çelik, C. (eds.), *REAL CORP 2020 Proceedings/Tagungsband*, 15–18 September 2020. Vienna: CORP – Competence Center of Urban and Regional Planning, pp. 1065. ISBN: 978-3-9504173-8-8 (CD), 978-3-9504173-9-5 (print).

Feld, S & Basso, KH (1996). *Senses of place*. SAR Press.

Gonçalves AR, Dorsch LLP, Figueiredo M. (2022) *Digital Tourism: An Alternative View on Cultural Intangible Heritage and Sustainability in Tavira*, Portugal. Sustainability, 14(5), 2912. https://doi.org/10.3390/su14052912

Grammarly. (2025). *Grammarly writing assistant*. https://www.grammarly.com

Haider, F, Pollak, S, Albert, P, & Luz, S. (2021). *Emotion Recognition in Low-Resource Settings: An Evaluation of Automatic Feature Selection Methods*. Computer Speech and Language, 65, 101119. https://doi.org/10.1016/j.csl.2020.101119

Hannerz, U (2003) *Being there… and there… and there! Reflections on multi-sited ethnography.* Ethnography 4 (2), 201–216. https://doi.org/10.1177/14661381030042003

Holtorf, C (2012). *The Heritage of Heritage,* Heritage Studies, 5(2), 153–166. https://doi.org/10.1179/hso.2012.5.2.153

Hou, Y; Kenderdine, S; Picca, D; Egloff, M & Adamou, A (2022). *Digitizing Intangible Cultural Heritage Embodied: State of the Art.* In Proceedings of the 2022 ACM Symposium on Applied Perception (pp. 10–21). https://doi.org/10.1145/3494837

Järviluoma, H & Murray, L (Eds.). (2023). *Sensory Transformations: Environments, Technologies, Sensobiographies.* Routledge.

Järviluoma, H (2022). *Sensobiographic walking and ethnographic approach of the Finnish school of soundscape studies.* In G. Stahl & M. Percival (Eds.), *The Bloomsbury handbook of popular music, space, and place* (pp. 83–97). Bloomsbury.

Luz, S & Sheehan, S (2020). *Methods and visualization tools for the analysis of medical, political, and scientific concepts in Genealogies of Knowledge*. Palgrave Communications, 6(1), 42. https://doi.org/10.1057/s41599-020-0423-6

Lin, R., Amith, M. T., Liang, C., Duan, R., Chen, Y., & Tao, C. (2018). *Visualized Emotion Ontology: A model for representing visual cues of emotions.* BMC medical informatics and decision making, 18 (1), 101-113. https://doi.org/10.1186/s12911-018-0634-6

Murray, L & Järviluoma, H (2020). *Walking as transgenerational methodology*. Qualitative Research, 20(2), 229–238. https://doi.org/10.1177/1468794119830533

OpenAI. (2025). ChatGPT (January 21 version) [Large language model]. https://chat.openai.com/

Pitkänen, K, Sireni, M, Rannikko, P, Tuulentie, S & Hiltunen, MJ (2017). *Temporary mobilities regenerating rural places*. The Journal of Rural and Community Development, 12(2/3), 93-113.

Thesaurus.com. (2025). *Thesaurus powered by Dictionary.com*. https://www.thesaurus.com

UNESCO (2003). *Convention for the Safeguarding of the Intangible Cultural Heritage*. Article 2.1. Retrieved from: https://ich.unesco.org/doc/src/15164-EN.pdf

Vahtikari, T, Kivilaakso, A & Latvala-Harvilahti, P (2020). *Heritage and Participation: A Critical Heritage Studies' Perspective.* In: Enabling Heritage Involvement: Participatory Models for Cultural Heritage (pp. 10-15).

Research Paper

Preservation of intangible heritage and empowering non-native ethnic communities in Indian context

Purbita SAMANTA, Indian Institute of Technology Kharagpur, India
Subrata CHATTOPADHYAY, Indian Institute of Technology Kharagpur, India
Archiman BISWAS, Indian Institute of Technology Kharagpur, India

1. Abstract

Urban memories, as collective intangible heritage, are crucial to the cultural fabric and identity of urban spaces. It encapsulates the narratives, traditions, and experiences of city inhabitants. In the Indian context, there is a significant gap in preserving these memories, especially for non-native ethnic communities, such as Kolkata's Chinese community. This study addresses this gap by examining how urban memories within this community capture cultural contributions, adaptation, and integration spanning generations. Considering the case study of the Chinese community in Kolkata, India, the study investigates the urban memories of the community members that combine social integration, culinary contributions, and cultural resiliency. By collecting viewpoints from a range of age groups, the study shows how urban memories differ. The results indicate that younger generations emphasize hybrid identities and modern expressions, while older generations recall migration and settlement difficulties. Findings highlight the role of urban memories in promoting social inclusion and mutual respect, as well as empowering marginalized communities. Key strategies for preservation include digital archiving and community storytelling initiatives like oral history programs and cultural festivals, which honour and maintain the community's heritage. By supporting these efforts, cities can become more welcoming places that value the accomplishments of ethnic groups which are not native to the area.

Keywords

Cultural resilience, Chinatown, Chinese community, Ethnocultural communities, Cultural heritage

2. Introduction

The term "cultural heritage" (CH) refers to artifacts, relics, architectural creations, landscapes, and national treasures that are connected to a country's past and cultural development (Thuc *et al.*, 2024). It represents a continuity of traditions and practices transmitted over generations, embodying the core of a society's collective memory (Banda *et al.*, 2024). It describes the items and concepts that members of a community or group have inherited from previous generations, are preserved in the present, and will be utilized by generations to come. Cultural heritage includes tangible forms, intangible forms, and natural heritage (Banda *et al.*, 2024). Historical sites, monuments, structures, artifacts, and other comparable items that are kept for preservation in the future are all regarded as belonging to the tangible cultural heritage (TCH). Intangible cultural heritage (ICH) is another type of CH. In addition to related tools, objects, artifacts, and cultural locations, ICH includes practices, representations, expressions, knowledge, and skills that communities, groups, and sometimes individuals recognize as being crucial to their cultural heritage (Qiu, 2023). This aspect includes traditions or living expressions that are transmitted from ancestors to

descendants, and includes oral traditions, performing arts, social practices, rituals, festive events, and knowledge related to nature and the universe, as well as the skills required for traditional crafts (Xiao *et al.*, 2023). ICH, as delineated by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) in the Convention for the Safeguarding of the Intangible Cultural Heritage, pertains to 'the practices, representations, expressions, knowledge, skills – along with the instruments, objects, artefacts, and cultural spaces linked to them – that communities, groups, and, in certain instances, individuals acknowledge as integral to their cultural heritage' (Xiao *et al.*, 2023; Zhao *et al.*, 2023). ICH is intricately embedded in the customs of communities. It serves as an essential link to the historical narrative and identity of a people, functioning as a nation's symbolic representation and brand (Zhao *et al.*, 2024). In heritage sites, ICH enhances social cohesiveness and promotes a sense of identity and belonging among locals while also enriching place identification and the travel experience for tourists (Qiu, 2023). It serves as both a reflection of historical traditions and a vital foundation for development and innovation (Arcos-Pumarola, Paquin and Sitges, 2023). For non-native ethnic populations, intangible cultural heritage (ICH) aids in the preservation of their distinct identities. It signifies not only cultural divergence but also a means of safeguarding their history within a predominantly dominant society.

The non-native ethnic communities face the dual challenge of integrating themselves into mainstream society while protecting the cultural practices that define their heritage (Samanta and Chattopadhyay, 2024). ICH provides these communities with a sense of continuity and belonging and reinforces ties to their ancestral roots despite geographic displacement. The performing arts, religious ceremonies, traditional festivals, storytelling, and culinary arts are all essential ways for passing down cultural values to future generations. These activities create unity within the group and establish a feeling of common identity. Protecting the intangible cultural resources is crucial as they make their way through the urban landscape. This is mostly because their social standards have been impacted by modernization and globalization. These communities face assimilation pressures, acculturative stress, social marginalization, or cultural dilution. Therefore, resilience towards these is required. The ability of these communities to maintain and modify their cultural practices while interacting with the larger socioeconomic and political structures of the host society is referred to here as cultural resilience. ICH is not simply a collection of historical traditions; it is a dynamic resource that enables communities to affirm their identity, maintain intergenerational connections, and develop solidarity in urban environments that frequently threaten their uniqueness.

In this regard, this paper seeks to address the following research questions:

1. How do urban memories differ between older and younger generations in non-native ethnic communities?
2. What are the key factors that influences the preservation of intangible cultural heritage among different age groups?
3. How have cultural practices evolved over time across generations?

This study is an attempt to ensure that the intangible cultural heritage of non-native ethnic communities not only survives but thrives in the rapidly changing urban context. Therefore, this study considers the case study of the Chinese community in Kolkata, India to provide insights into how cultural practices are preserved, changed, or even lost. This paper further emphasizes on the intergenerational dynamics within this non-native ethnic community. This research makes it possible to investigate how these communities' changing cultural memories influence their wider assimilation into urban settings while preserving their unique cultural identities. This paper also aims to identify effective strategies for empowering the Chinese community. The understanding of the factors that affect their cultural preservation will help the urban planners and policymakers to empower these communities through cultural resilience.

3. Literature review

3.1. Role of urban memories as an efficient agent to preserve intangible heritage

Urban memories play a vital role in the preservation of intangible heritage, and act as a dynamic and adaptive force that links the past to the present. They serve as a repository of cultural knowledge, practices, and values. They are cherised by people through collective and personal experiences within a city. Intangible heritages are kept alive through the everyday lives and memories of a community. In this context, urban memories act as the bridge that preserves and transmits this heritage across generations (Lak and Hakimian, 2019).

Urban environments are constantly changing. They are evolving due to changing landscapes, infrastructure, and demographics. People and the community still hold onto memories of cultural practices despite changes. These recollections are frequently connected to particular places, social gathering spots, or regular occasions that act as benchmarks for cultural celebrations and opportunities (Gurler and Ozer, 2013). People prefer to revisit these place as they occupy a strong place in their memories. Urban memories can sustain the continuity of intangible heritage by making sure that practices like festivals, rituals, or social gatherings, are remembered and passed on. These recollections ensure that traditions continue to be meaningful and relevant even when the physical surroundings change. The adaptability of urban memories is a crucial feature. This adaptability enables the preservation of intangible heritage while being sensitive to the demands and conditions of modern life. The memory is a vital resource to maintain attachments to remembered environments that people can no longer access (Huss, 2024).

According to earlier research, urban memories give people a feeling of belongingness, identity and attachment (Lak and Hakimian, 2019). These urban memories stimulate the brain. They are a powerful tool for transferring intangible cultural heritage from one generation to the next. The younger generation learn from the older generation. The customs and cultures are paased down. These are not wriiten scriptures, but experiences that are carried forward. Younger generations rely heavily on older generations to preserve their memories of cultural customs, rituals, and practices. Even in urban environments where modern influences might predominate, the memories aid younger community members in connecting with their cultural heritage. Through oral traditions, storytelling, and participation in communal activities, urban memories ensure that intangible heritage is not lost, but rather adapted and retained across time. Urban memories also promote a deep sense of identity and belonging within communities (Bachleitner, 2022). Research shows that reconnecting with one's roots and heritage often happens through the act of remembering and participating in cultural traditions. Collective memory is essential to the formation of a national identity over time, even if (and maybe precisely because) it deviates from historical fact (Bachleitner, 2022). This shared memory strengthens the community's cultural resilience and ability to maintain its distinct identity in the face of a larger sociocultural context. People feel connected to their cultural past through these memories, which motivates them to keep traditions alive and pass them on. For minority or non-native ethnic communities who are facing challenges like assimilation or cultural dilution, this resilience is vital in safeguarding their intangible heritage (Huss, 2024). Why is it vital to safeguard the intangible cultural heritage of these communities? Interstingly, this resilience is not just preservation, but also about ownership. The sense of ownership will organically help in keeping these ICH alive. In this situation, the participatory approach guarantees researchers that community-based intangible heritage preservation is not solely reliant on external organizations or official documentation. It is based on the actual experiences and actions of the people who make up the community.

3.2. Intangible Cultural heritage (ICH) of Chinatown in Kolkata, India

India is a South Asian nation recognised for its cultural pluralism. Various non-indigenous ethnic groups, including the Chinese, Tibetan, Nepali, and Afghan communities, have settled over the ages. Among the various ethnocultural communities, the Chinese community has managed to maintain their identity owing to their unique tangible and intangible practicres. Their presence is felt uniquely among the natives. The Chinatowns in Kolkata are the home to India's only and largest Chinese living community. However, rapid urbanization, socioeconomic change, and cultural homogenization pose a serious threat to their intangible heritage. The preservation of ICH is not only a cultural necessity but also a means to empower these communities to ensure that their cultural identities are not marginalized.

Food is considered Intangible Cultural Heritage (ICH), which refers to a non-material legacy that is embodied and ritualized in everyday cooking It is a way to express culture that goes beyond the tangible qualities of food to include the cultural symbolic aspects of stories, customs, embodied knowledge, and memories that link the past and present (Lee, 2023). Food memories are important, as the Chinese community influences the distinctive Indo-Chinese cuisine, which amalgamates traditional Chinese culinary methods with indigenous Indian ingredients. Hakka noodles, chilli chicken, and momo have become emblematic of Chinatown. They draw culinary enthusiasts from the city and its surroundings. These culinary customs include not only providing for basic needs but also preserving cultural identity through the use of group meals and cooking.

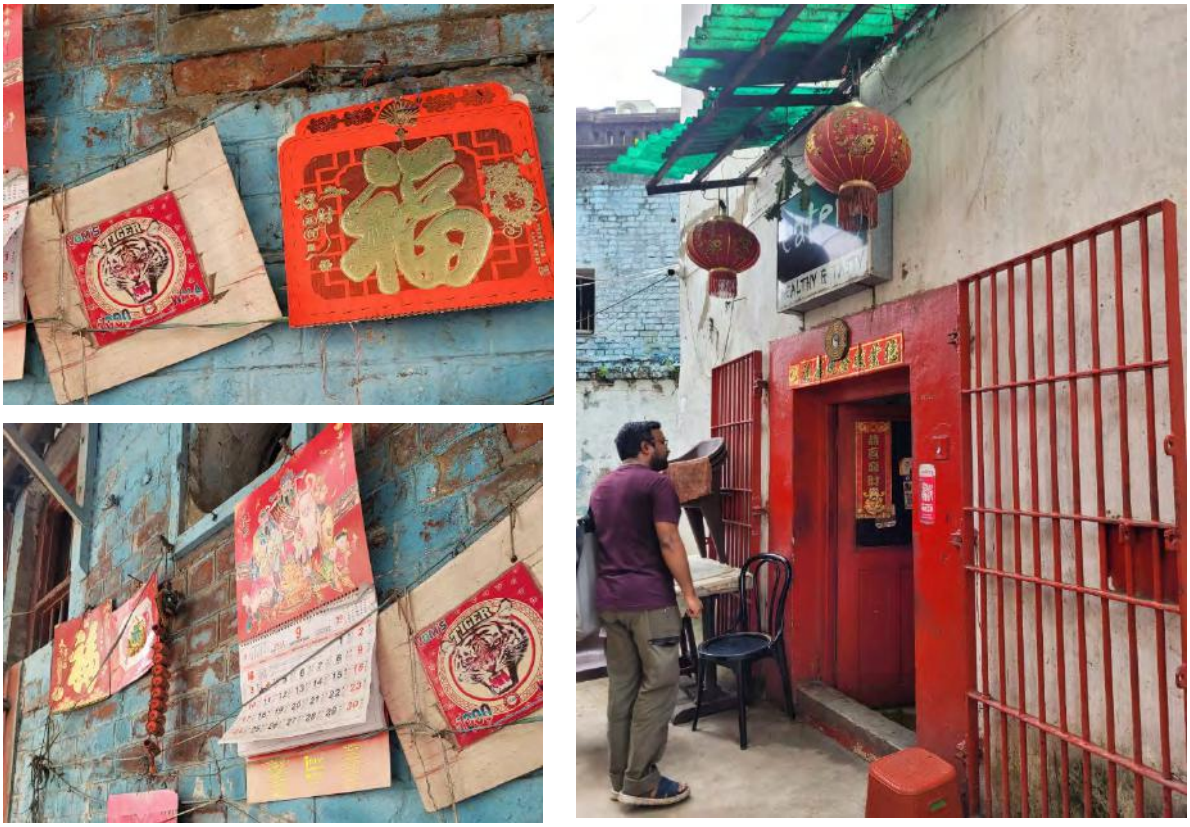
Figuur 1: Indo-Chinese food. Source: Authors

The cultural festivals are another significant ICH that ensures the preservation of traditional memories. They exemplify immaterial cultural heritage, as they are experiential goods that dissipate upon production. These festivals reflect the artistic innovations of the community members while also drawing upon historical, and cultural contexts, regarded as accumulated cultural capital (Del Barrio, Devesa and Herrero, 2012). The celebration of festivals is another vital aspect of intangible heritage in Chinatown. The Chinese celebrate their New Year on the streets of the city. Festivals such as Chinese New Year (Spring Festival), the Lantern Festival, Mid-Autumn Festival (Moon Festival), and the Hungry Ghost Festival unite the community in lively celebrations characterised by rituals, performances, and familial gatherings. People from different other communities come to witness the celebration. During these celebrations, traditional customs such as lantern lighting, dragon dances, and ancestral food offerings strengthen cultural connections and build a sense of continuity with history. The Chinese members dress themselves uniquely to represent their own traditions.

Figuur 2: Chinese New Year celebration. Source: Authors

Additionally, the practice of Chinese calligraphy, papercutting, and the creation of lanterns serve as artistic expressions that keep alive centuries-old traditions. The calligraphies and papercuttings reflect the traditional chinese art forms. They include the chinese letters and fonts. They are distinct in the unique combination of red and black colour. These art forms are not only important cultural practices but also symbols of identity and creativity. They enrich the cultural fabric of Kolkata's Chinatown and ensure the continuity of Chinese intangible heritage in the city. However, the decline of skills, alterations in the

craftsmanship environment, and the ineffectiveness and challenges in advancing traditional pedagogical approaches significantly hinder the transmission and evolution of papercutting art (Silva *et al.*, 2019).



Figuur 3: Chinese lanterns, papercuttings and calligraphies used in everyday lives. Source: Authors

4. Methodology

This study employs a comprehensive methodology to examine the role of intangible cultural heritage in sustaining urban memories within Kolkata's Chinatown. Data is collected from the third and fourth generation community members. The study seeks to identify intergenerational differences in cultural memory and attachment by using carefully selected indicators and gathering data from both older and younger generations. The research uses pairwise t-test to empirically investigate the determinants that affects the cultural resilience and the preservation of intangible heritage over generations within an urban diaspora group.

1.1. Study area

The research examines the Chinatown regions of Kolkata, India, namely the neighbourhoods of Tiretta Bazaar and Tangra. These areas have historically been inhabited by Chinese immigrant communities. These regions are recognised for their abundant cultural history, traditional Chinese architecture, temples, and markets. The presence of TCH makes them appropriate sites for the exploration of intangible cultural heritage (ICH) in an urban context. The Chinese community in Kolkata has a historical presence since the 18th century, and its members persist in upholding cultural traditions and social events that strengthen their ethnic identity within the broader Indian socio-cultural context. Kolkata's Chinatown serves as an exemplary instance for examining the continuity and transformation of cultural legacy through generations.

1.2. Selection of indicators

The ICH indicators are selected for their significance to the cultural identity and memory of the Chinese community in Kolkata. Each indicator represents a significant cultural element that plays a role in shaping individual and collective memories. Ten indicators are selected, each addressing different aspects of cultural heritage, with corresponding descriptions:

Tabel 1: Selected indicators of Intangible Cultural Heritage

Code	Intangible Cultural Heritage	Description
ICH1	Cultural Festivities	The traditional Chinese festivals celebrated in Kolkata (e.g., Chinese New Year, Moon Festival) contribute significantly to my memories of the city
ICH2	Religious and Spiritual Spaces	The presence of Chinese temples and shrines in Kolkata holds a special place in shaping my connection to the city
ICH3	Social Gatherings and Community Events	Participating in Chinese community events in Kolkata strengthens my emotional ties and memories of the urban environment
ICH4	Culinary Heritage	Experiencing authentic Chinese food in my home enhances my sense of belonging and connection to my community
ICH5	Language and Communication	Hearing Chinese dialects spoken within the community in Kolkata plays a vital role in maintaining my urban memories
ICH6	Intercultural Exchange	My interactions with other ethnic communities in Kolkata influence the way I remember and perceive the city's social fabric
ICH7	Traditional Chinese Arts and Crafts	The preservation of Chinese art forms (e.g., calligraphy, martial arts) in Kolkata is important for my memories of the city
ICH8	Family Heritage and Ancestral Stories	The stories passed down through my family about our life in Kolkata are central to my sense of connection with the city
ICH9	Neighbourhood Familiarity	Walking through Chinese neighbourhoods in Kolkata evokes strong emotional memories tied to my experiences in the city
ICH10	Sense of Safety and Security	Feeling safe and secure within the Chinese community spaces in Kolkata enhances my positive memories of the urban environment

1.3. Data collection

A structured survey questionnaire based on the ten indicators of intangible cultural heritage was used to gather data. Questions on a 5-point Likert scale, with answers ranging from "strongly disagree" to "strongly agree," were used to evaluate each indicator. The purpose of the survey was to find out how participants felt each indicator influenced their recollections and sense of belonging to Kolkata.

The survey was conducted with two age groups:

i. Older Generation: Ages 46 and above

ii. Younger Generation: Ages 15 to 45

Sampling was necessary for analysing the data using pairwise t-test, with responses gathered by household surveys utilising a pre-designed questionnaire based on the 10 selected intangible cultural heritage indicators (Refer Tabel 1). Utilising Slovin's formula (Dey and Mandal, 2024), the sample size was calculated for the Chinese community, which have lesser than 1500 population in the city (Biswas, 2019). Taking an average household size of 4.1 for India (Ministry of Statistics and Program Implementation, 2021), the approximate number of Chinese households in Kolkata is 365. We are considering a confidence level of 95% and a margin of error of 5%. The margin of error will be represented in the formula as 5/100, or 0.05. The equation is as follows:

$$n = \frac{N}{(1 + Ne^2)}$$

Where,

n = Number of samples, N = Total population and e = margin of error.

The calculation of sample size resulted in estimated sample of 191. A total of 195 participants completed the survey, that provided insights into how urban memories and intangible cultural heritage are perceived and maintained across generations within Kolkata's Chinatown. The sample includes individuals are born and raised in Kolkata's Chinese community and represents a cross-sectional view of age-based perceptions.

1.4. Sample profile

The sample comprised 195 individuals, with about equal representation from both older and younger generations. Basic demographic information, covering age, gender, education, and duration of residence in Kolkata's Chinatown, was gathered to contextualise the investigation. The participants are inhabitants of Chinatown, which ensured that their replies accurately represented genuine experiences and recollections pertaining to the community's intangible cultural heritage..

1.5. Data analysis

A t-test was performed for each of the ten indicators to assess intergenerational differences in views of intangible cultural heritage. The t-test is suitable for comparing the means of two independent groups in order to determine whether there is a statistically significant difference between the older and younger generations' perceptions of the significance of specific intangible heritage items. If the resulting t-value was lower than the critical t-value, it indicated that the perceptions on ICH among the different generations are not statistically different. The goal of the analysis is to identify any generational differences or similarities in urban memories related to religious sites, cultural celebrations, language use, culinary heritage, and other markers. This will provide light on the tenacity of cultural heritage within the Chinese community in Kolkata by enabling insights into how these aspects are valued across generations.

5. Results and discussion

The paired t-test is a statistical technique utilised to compare the means of two groups or conditions. The analysis of survey and observation data, conducted using the paired t-test, explains the distinct impacts of intergenerational experiences on urban memories. Random sampling methods are employed to get a substantial sample size of 195 people, that is in consistent with the assumptions of the paired t-test.

Tabel 2: Results of t-test

		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
ICH1	Equal variances assumed	-17.523	198	.000	-2.07770	.11857
	Equal variances not assumed	-17.446	189.236	.000	-2.07770	.11909
ICH2	Equal variances assumed	-25.534	198	.000	-2.47705	.09701
	Equal variances not assumed	-26.459	182.060	.000	-2.47705	.09362
ICH3	Equal variances assumed	3.750	198	.000	.52496	.14000
	Equal variances not assumed	3.664	165.663	.000	.52496	.14328
ICH4	Equal variances assumed	-9.288	198	.000	-1.12721	.12136
	Equal variances not assumed	-9.285	192.697	.000	-1.12721	.12140
ICH5	Equal variances assumed	-42.851	198	.000	-2.98671	.06970
	Equal variances not assumed	-42.829	192.569	.000	-2.98671	.06974
ICH6	Equal variances assumed	10.139	198	.000	1.40217	.13829
	Equal variances not assumed	9.923	167.889	.000	1.40217	.14131
ICH7	Equal variances assumed	-29.277	198	.000	-2.58253	.08821
	Equal variances not assumed	-28.764	173.396	.000	-2.58253	.08978
ICH8	Equal variances assumed	-14.652	198	.000	-1.40378	.09581
	Equal variances not assumed	-14.111	144.199	.000	-1.40378	.09948
ICH9	Equal variances assumed	-41.203	198	.000	-2.93035	.07112
	Equal variances not assumed	-41.198	192.890	.000	-2.93035	.07113
ICH10	Equal variances assumed	-5.402	198	.000	-.51087	.09458
	Equal variances not assumed	-5.208	145.963	.000	-.51087	.09809

The findings show that people aged 46 and up have better emotional ties to the city's intangible cultural heritage. This is especially true when it comes to cultural events, religious sites, language, and knowing the area well. Conversely, the younger generation (15–45 years old) relies more on social gatherings and cross-cultural interactions to recall their urban experiences. The older group (46 years and up) and the younger group (15–45 years) both play important parts in protecting the Intangible Cultural Heritage (ICH) of the Chinese community in Kolkata.

Older Group (46 and Above):

- Cultural Festivities and Religious Spaces: Traditional Chinese festivals, temples, and shrines are maintained in large part by the elder generation. They actively participate in these practices and passes down rituals and traditions to the younger generation to preserve the spiritual and cultural essence of the community.

- Culinary Heritage: The older generation often supports real Chinese food by keeping family-owned restaurants open or teaching traditional recipes. This helps to keep the food practices alive.
- Language and Communication: The older generation ensures the preservation of linguistic heritage by frequently using and teaching Chinese dialect. This is a critical component of cultural identity.
- Traditional Arts and Crafts: Chinese arts like calligraphy and martial arts are still practiced and taught by many elderly people. This ensures that the knowledge of these traditional art forms is passed to the next generation.
- Family Heritage and Ancestral Stories: The older generation shares stories about their ancestors to keep the cultural memories alive. They share stories about their previous generation's history of migration and how their family tradition has been kept alive.

Younger Group (15-45):

- Social Gatherings and Community Events: The younger generation actively participates in community events and gatherings. Their engagement often attracts wider audiences that keeps the community's traditions alive in a more contemporary format.
- Intercultural Exchange: This group encourages people of different ethnicities to get to know each other and mix beliefs and cultural practices to fit the diverse city environment. Their willingness to talk to people from other cultures helps people understand each other and work together, and it also makes cultural history easier for more people to access.
- Technological Preservation: Young people often use digital tools and social media to share, promote, and record their heritage, such as cultural events, culinary adventures, and artistic acts. This digitization helps keep traditional practices alive in a way that future generations can understand.

In summary, while the older group focuses on maintaining the core traditions, language, and rituals that directly link the community to its heritage, the younger group leverages modern tools, social events, and intercultural exchanges to adapt and spread awareness of these traditions, to ensure their survival in a changing urban environment. Together, both groups contribute significantly to the ongoing preservation and evolution of the community's Intangible Cultural Heritage in Kolkata. The preservation efforts of Intangible Cultural Heritage (ICH) by both the older and younger age groups play a pivotal role in shaping and sustaining urban memories within Kolkata's Chinese community. For the older generation, participating in cultural festivities, maintaining religious spaces, and preserving language and traditional arts anchors their memories deeply within the city's landscape. These efforts provide a tangible link to their heritage and reinforce a strong emotional connection to their surroundings, embedding their sense of identity and belonging within Kolkata's cultural fabric. They keep adding personal and group histories to the city's memory through activities like culinary heritage and family stories. These give the city additional levels of significance that relate to both the past and the present. For the younger generation, engaging in social gatherings, promoting intercultural exchange, and using digital platforms to document and share heritage not only connects them to their roots but also allows them to create new, adaptive urban memories. Their efforts to integrate ICH within modern and multicultural contexts bring traditional practices into the everyday lives of both community members and the broader public, enriching the city's collective memory. Together, these intergenerational preservation activities transform urban spaces into

lived memory sites where cultural continuity, adaptation, and shared experiences reinforce Kolkata's identity as a home for diverse heritage.

6. Conclusion

In conclusion, the preservation of Intangible Cultural Heritage (ICH) by Kolkata's Chinese community highlights that cultural practices play a significant role in shaping and sustaining urban memories across generations. The older generations keep their basic traditions alive through languages, festivals, stories passed down through families, and food practices. Conversely, the younger generation uses digital platforms to make heritage accessible to a wider audience. They adapt and revitalizes their traditions in modern settings, and attempts to engage in intercultural exchanges. Together, these initiatives support the community's feeling of continuity, identity, and belonging in Kolkata's multicultural setting. ICH preservation strengthens the city's identity as a patchwork of memories, histories, and shared cultural experiences by incorporating customs into the urban landscape and interacting with locals and the general public. Future programs that emphasizes on digital documentation, intergenerational knowledge transfer, and culturally designated areas will further ensure that the Chinese community's heritage remains a vibrant, living part of Kolkata's urban environment.

Future efforts to preserve Kolkata's Chinese community's Intangible Cultural Heritage (ICH) might concentrate on developing organized intergenerational programs in which elders guide younger members and guarantee the smooth transfer of traditional knowledge, including language, culinary arts, and festival customs. The conservation architects can take initiatives for digital archiving efforts to include and share customs, celebrations, and ancestors' stories on online forums would make the legacy more accessible for current and future generations as well as people all over the world. Lastly, working with city officials to make cultural areas in the city would allow cultural events, art shows, and interactions between people of different cultures to continue.

7. Acknowledgements

This work is supported by the Indian Institute of Technology Kharagpur and Prime Minister's Research Fellowship, Government of India.

8. References

Arcos-Pumarola, J., Paquin, A. G. and Sitges, M. H. (2023) 'The use of intangible heritage and creative industries as a tourism asset in the UNESCO creative cities network', *Heliyon*, 9(1). doi: 10.1016/j.heliyon.2023.e13106.

Bachleitner, K. (2022) *Collective memory and the social creation of identities: Linking the past with the present and future*. 1st edn, *Progress in Brain Research*. 1st edn. Elsevier B.V. doi: 10.1016/bs.pbr.2022.07.002.

Banda, O. L. L. *et al.* (2024) 'Preserving Cultural Heritage: A Community-Centric Approach to Safeguarding the Khulubvi Traditional Temple Malawi', *Heliyon*, 10(18), p. e37610. doi: 10.1016/j.heliyon.2024.e37610.

Del Barrio, M. J., Devesa, M. and Herrero, L. C. (2012) 'Evaluating intangible cultural heritage: The case of cultural festivals', *City, Culture and Society*, 3(4), pp. 235–244. doi: 10.1016/j.ccs.2012.09.002.

Biswas, D. (2019) 'Identity development, acculturation among Bowbazar Chinese community', *Asian Ethnicity*, 20(2), pp. 250–261. doi: 10.1080/14631369.2018.1527213.

Dey, P. and Mandal, K. (2024) 'Socio-economic vulnerability assessment of culturally unique ethnic communities using RIDIT scoring: a case of Rann of Kutch, India', *GeoJournal*, 89(5). doi: 10.1007/s10708-024-11233-0.

Gurler, E. E. and Ozer, B. (2013) 'The Effects of Public Memorials on Social Memory and Urban Identity', *Procedia*

- *Social and Behavioral Sciences*, 82, pp. 858–863. doi: 10.1016/j.sbspro.2013.06.361.

Huss, M. (2024) 'Walking tours as transcultural memory activism: Referencing memories of trauma and migration to redefine urban belonging', *Memory Studies*, pp. 1–19. doi: 10.1177/17506980241247271.

Lak, A. and Hakimian, P. (2019) 'Collective memory and urban regeneration in urban spaces: Reproducing memories in Baharestan Square, city of Tehran, Iran', *City, Culture and Society*, 18(June), p. 100290. doi: 10.1016/j.ccs.2019.100290.

Lee, K. S. (2023) 'Cooking up food memories: A taste of intangible cultural heritage', *Journal of Hospitality and Tourism Management*, 54(December 2022), pp. 1–9. doi: 10.1016/j.jhtm.2022.11.005.

Ministry of Statistics and Program Implementation (2021) *Estimated number of households, average household size and sex ratio (no. of female per 1000 male)*, *Government of India*. Available at: https://www.mospi.gov.in/estimated-number-households-average-household-size-and-sex-ratio-no-female-1000-male-2 (Accessed: 18 September 2024).

Qiu, Q. (2023) 'Identifying the role of intangible cultural heritage in distinguishing cities: A social media study of heritage, place, and sense in Guangzhou, China', *Journal of Destination Marketing and Management*, 27(December 2022), p. 100764. doi: 10.1016/j.jdmm.2023.100764.

Samanta, P. and Chattopadhyay, S. (2024) 'Exploring the perception of ethnic migrants in Kolkata, India: A comparative study using sentiment analysis', *Journal of Urban Affairs*, 00(00), pp. 1–20. doi: 10.1080/07352166.2024.2345649.

Silva, G. *et al.* (2019) 'The Impact of Traditional Chinese Paper-Cutting in Digital Protection for Intangible Cultural Heritage under Virtual Reality Technology', *Sustainable Materials and Technologies*, p. e00132. doi: 10.1016/j.heliyon.2024.e38073.

Thuc, L. D. *et al.* (2024) 'Prioritizing barriers to the conservation of cultural heritage buildings in adaptation to urbanization and climate change', *Journal of Cleaner Production*, 473(August), p. 143529. doi: 10.1016/j.jclepro.2024.143529.

Xiao, J. *et al.* (2023) 'Using choice experiments to assess tourist values for intangible cultural heritage – the case of Changdao fishermen's work song in China', *Journal of Cultural Heritage*, 60, pp. 50–62. doi: 10.1016/j.culher.2023.01.008.

Zhao, X. *et al.* (2023) 'A study on tourists' tendency towards intangible cultural heritage as an attraction (case study: Isfahan, Iran)', *City, Culture and Society*, 3(December 2022), pp. 50–62. doi: 10.1016/j.heliyon.2023.e13106.

Zhao, X. *et al.* (2024) 'Sustainable tourism development for traditional Chinese drama's intangible cultural heritage', *Heliyon*, 10(3), p. e25483. doi: 10.1016/j.heliyon.2024.e25483.

Research Paper

Planning of a Community- based festival to empower local communities and their cultural identity

A study of the Behdieñkhlam Festival in Jowai Meghalaya, India

Haziel. M. BUAM, Indian Institute of Technology Kharagpur, India
Shreyas. P. BHARULE, Indian Institute of Technology Kharagpur, India

Abstract

Communities often identify themselves with the place they come from and more importantly the traditions and culture that they pass down through generations. The Behdieñkhlam Festival is one such festival that has been meticulously preserved by the community of the Jaintia Tribe in Northeast India over many years which has become an integral part of their cultural identity. This festival is celebrated in Jowai, in the Jaintia Hills of Meghalaya, India. The traditional governance, planning, and celebratory aspects of the festival which is spearheaded by the community showcase the unity and cohesiveness of the tribe. This four-day long festival revolves around the community and it is fundamentally related to the agricultural cycle of the tribe. The community celebrates and prays together for a rich harvest for that year. The paper attempts to deepen the understanding of this intangible heritage of the community through the analysis of an observational survey of the festival and interviews conducted with the local community representatives and authorities of the town. This festival has garnered increasing attention of various tourists, which has led to the collaboration of the community with other stakeholders like the State Tourism Department of Meghalaya to further improve infrastructure, promote the festival, increasing the awareness of the community to preserve and reinforce the significance of this intangible tradition. Additionally, this festival also serves as a platform for various villages and localities in and around the town to address social, economic and environmental issues, educating the community and also the tourists. Hence, the study of how tourism is being accommodated into the planning and management process of this festival is crucial for this research. Consequently, this paper examines the festival from the lenses of governance, planning and tourism all of which are deeply rooted in the community and its cultural identity.

Keywords

Behdieñkhlam Festival, Northeast India, community, governance, tourism, planning

1. Introduction

Festivals are a way of promoting the rich culture and maintaining the welfare of the community (Jepson and Alan, 2016). It provides a platform for the communities to showcase their intricate governance and management system that has been imbibed in the lives of the community thereby inspiring other

communities to learn and appreciate what is being offered to them. Indigenous community festivals that have been celebrated for a long time and that are thriving on primary sources of income like agriculture are celebrated for the reason of prospering the community or for gratitude for the resources they have, other than direct revenue generation. Nevertheless, economic prosperity or social prosperity can be observed as benefits of such festivals (Mair and Duffy, 2015; Son, Huang and Padovan, 2021).

Behdieñkhlam Festival is one such festival that is being celebrated in the town of Jowai, which is the headquarters of the Jaintia Hills of Meghalaya in Northeast India. This festival is celebrated annually by the Jaintia community who are known to be the indigenous tribe of the Jaintia Hills of Meghalaya. Meghalaya is one of the states in India that has the highest tribal population (Govt. of India, 2011). The local governance system of the Behdieñkhlam Festival shows how the tribal community of Jowai participates in planning and management of the same to make the festival into a thriving space for various people to participate and also observe. This leads to the next aspect of the paper which looks into the booming tourist activity of the place due to the festival throughout the past years and it is also being promoted as a festival by the Tourism Industry.

Hence, this paper tries to understand:

Aim: "How the community benefits from the festival and consequently how its cultural identity is being preserved and shared with people coming from outside the town?"

a) Comprehending the governance framework and the stakeholders involved in planning and managing the festival.
b) Assessing the planning and management tasks taken up by the community.
c) Understanding the way tourism is being incorporated into the festival.

2. Literature Review

The definition for the word "community" has evolved throughout the years (Bradshaw, 2008). Primarily a "community" is usually defined based on their geographic location however, the fact that they share common interests, traditions and heritage amongst each other is also very important (Webster, 1828). Therefore, a community-based festival is an event which revolves around the notion of community and when it is conducted it gives the community a certain characteristic or definition through which the community identifies with (Mair and Duffy, 2015). The planning of such a community-based festival by the local government should be cognizant of the way the community carry out their long-lived traditions (Wood, 2009). These festivals can also be important for community-based tourism because they can involve the local community for a holistic cultural, economic, environmental, political and social development" (Adi *et al.*, 2017).

In the northeast region of India, most of the communities are in the upper rung of the "Ladder of Citizen Participation" as the resources and lands in the community are managed by the clan or community members at the local level thereby, encouraging community-based development and tourism in the region (Arnstein, 1969). A governing body like the local government or an organisation that is involved as a stakeholder in any community-based tourism event or activity has been recognised to possess the following characteristics in order for it to be successful: "a motivator, a facilitator and a dynamist" (Adi *et al.*, 2017). Governance at local levels as explored in (Widjanarko *et al.*, 2020) observed that the role of various stakeholders is important as it reduces the chances of conflict between them, and provides them an opportunity to see benefits economically. Secondly, these festivals also facilitate social benefits like

"social justice" evoking a spirit of inclusivity and equal access as they are simultaneously celebrating their culture and identity through the festivals (Mair and Duffy, 2015).

Festivals or events have the power to change the "landscape" of the area. Though temporary, the changes or planning done to the surroundings to cater to the needs and rituals of the community can navigate the crowd to the right spaces for optimum usage of the services provided (Brown *et al.*, 2015). The conscious provision of such spaces strengthens the community in such a way that their practices are taken into consideration, where each and every one is encouraged to participate in the activities instead of just being cognisant of the characteristic of the community or their wants (Mair and Duffy, 2015).

3. Methodology

3.1 Site Context

Jowai a town located in the Jaintia Hills (West Jaintia Hills District) of Meghalaya has a municipality population of 28,430 people (Directorate of Census Operations, 2014) and is home to predominantly the Jaintia Tribe (see Figure 1) who speak "Pnar" language mostly (Administration and West Jaintia Hills District, Developed, 2025).

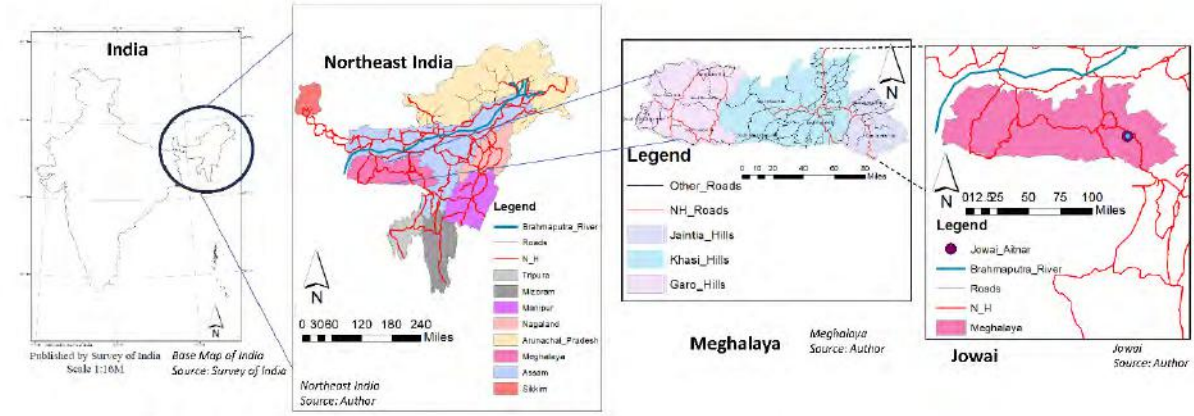


Figure 1. Location of Jowai. Source: Survey of India Online Portal, and Author

The Behdieñkhlam Festival, an important festival for the tribe, is celebrated after the sowing period of the lunar year. The festival is believed to have been celebrated for time immemorial however there were years where the festival was cancelled temporarily due to various problems (Public, 2020). The word Behdieñkhlam meant "To drive away the plague" in the past, however now, the festival is celebrated to "To drive away evils that plague the human society, bring peace and prosperity and foster fraternity" (Lamar, 2015).

The main festival is celebrated for four days and the rituals of the festival involve the community and the representatives at household levels, town level and neighbourhood levels (Lamar, 2015) (Times, 2021). Indigenous Community-Based Festivals like Behdieñkhlam Festival can be promoted as a form of Community-Based Tourism in Northeast India as it can aid in increasing the tourist footfall here.

3.2 Research Design and Data collection

The paper follows an explorative and descriptive form of research. Pictures and maps have been used in this study to convey the various aspects. An observational survey and interviews (in Khasi language and translated to English) were conducted with one of the main members of the cultural and religious organisation called the Sein Raij Niamtra Jowai ("religious and cultural organisation of the Jaintia community in Jowai") and Sein Raij Niamtra Shillong ("religious and cultural organisation of the Jaintia community in Shillong") where the members were asked about the festival, the governance structure that the planning and management of the festival and finally how tourism plays a role in the lives of the community due to this festival.

4. Results and Discussion

4.1 Governance

The Sein Raij of the Jaintia (a Socio-cultural and religious organisation) aims to preserve and revive the traditions of the indigenous religion, called Niamtre (Times, 2021). For the Behdieñkhlam Festival, the Sein Raij, takes the initiative to plan and manage the festival. There are different organisations (Sein Raij) for different clusters of villages (Raij) across Meghalaya and the members are elected from different clans and appointed by the community. The Sein Raij consists of the following members: Religious Head (U Doloi) who takes up religious and administrative responsibilities, the Priest (U Langdoh), the Priestess (Ka Langdoh), Assistant (Pator), Town Crier (Sangot) and other Assistant Priests (Wasan/ other members). The Sein Raij Jowai has fourteen members and they perform mostly religious responsibilities. An Executive Committee is formed every year where a President and Secretary are elected every year from the community. The members of this Committee look into the finance and the decoration responsibilities of the festival (information from the interviews conducted).

4.2 Community Decisions

The Religious Head (U Doloi) has the responsibility to choose the date of the festival every year. Various other decisions like these are made in the Sein Raij Jowai and these decisions are disseminated to the community by announcing them at the Religious Council (Dorbar Niam) which is attended by the community. It has also been understood from the interviews conducted that since the festival has been celebrated for many years now, the community are aware of their roles and responsibilities which displays a sense of community trust within the community.

"Happens every year so the Sein Raij takes initiative to let the community know about the various aspects of the festival. The programs are circulated in the community after the decisions are made".

Sein Raij Jowai Representative (Translated from Khasi to English)

It is interesting to note that the Sein Raij from other village clusters or regions are also informed of the decisions made by the Sein Raij Jowai and they are informed through the Religious Council (Dorbar Niam), thereby displaying solidarity amongst the Jaintia Community in Jowai and also those who have settled outside Jowai.

4.3 Planning and Tourism: Linkages and Roles

The Behdieñkhlam Festival is an indigenous community festival which involves the active participation of various stakeholders. Therefore, this section will discuss the roles played by various stakeholders, some

who have been participating for a long time and some who joined recently as the festival has started gaining popularity in various fields like tourism and cultural studies.

4.3.1 Community

The Jaintia community of the area has the most important role to play in the commencement and celebration of this festival. Starting from preparing the area for the festival, people from each locality in Jowai (like the females of the community) are involved in the cleaning drive every year before and after the festival (Lamar, 2015). They also participate by performing various rituals throughout the festival and finally on the last day most of them are involved in making the celebration grand by coming to the celebration in their traditional dresses.

"The women participate by adorning …traditional attires, cooking for the people and being spectators to the festival."

Sein Raij Jowai Representative (Translated from Khasi to English)

From the point of view of providing services to the community and tourists women play an important role in opening shops and eateries during the festival (see Figure 2) which leads to economic and social benefits (Son, Huang and Padovan, 2021) and also providing their homes for tourists and researchers during the course of the festival though this is currently done informally. The males also play an important and active role in the festival, as the head of homes (when performing rituals at household level), head of the clan, head of the locality (when performing rituals at neighbourhood level), religious duties (for example felling sacred tree trunks and transporting them to their designated places before and during the festival and many more) (see Figure 2) and constructing and carrying the structures called "Rot" to the sacred ground ("Madan Aitnar") before and during the festival (see Figure 2).

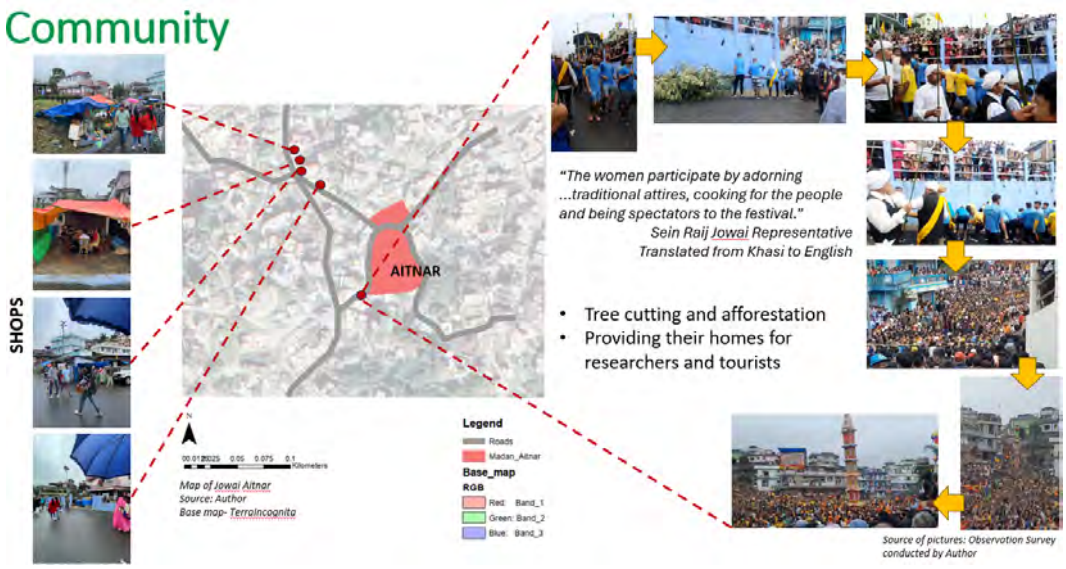


Figure 2.Community Roles. Source: Author

4.3.2 Sein Raij and Government

Through the Sein Raij (a Socio-cultural and religious organisation) the community also collaborates with the government on various levels. The planning and management of human and vehicle traffic around the premises of the Madan Aitnar (the sacred ground where the festival is celebrated) was achieved meticulously in collaboration with the Police Department (see Figure 3). The entry to the main town centre of Jowai happened through the "Iaw Musiang" where information desks were placed, and these desks were placed by the State Tourism Department and the Sein Raij (see Figure – the Designated Parking 1). The areas around the Madan Aitnar (the sacred ground where the festival is celebrated) were made walkable as much as possible. This was achieved by providing "Car Pass" to few people, mostly the locals who reside around the ground. Additionally, most vehicles were not allowed beyond a certain point and different spaces for parking were identified and provided by the community. These spaces were strategically identified so that people could easily park their cars and walk to the ground using these roads, which would take them around 9-15 minutes to reach (Loomkrywiang Road, Dulong Iongpiah Road and Road to Khimusniang) (see Figure 3).

Different roads that lead to the Madan Aitnar (the sacred ground where the festival is celebrated) also were designated as different zones for various activities and better circulation of people and the structures. The road from "Loomkyrwiang" to the ground (road in the Northwest) was predominantly used by spectators and community to enter into the ground (see Figure 3 – the road denoted by red). The road from Dulong-Iongpiah (in the Northeast) was assigned chiefly for the carrying of the structures. People started the procession of the structures from the Sein Raij office located in Iongpiah all the way to this sacred ground through the road from Dulong-Iongpiah (see Figure 3 – the road denoted by yellow). The road leading out from the sacred ground to Khimusniang (in the Southwest) was reserved as an exit for the crowd and locals who wanted to leave (see Figure 3 – the road denoted by pink). Though these three roads were specifically earmarked for the crowd, other roads within the vicinity of the sacred ground could also be used for circulation. This depicts the conscious planning of the Sein Raij for the community.

In addition to the information desks the State Tourism Department also acted as the facilitators by aiding the community to improve the facilities in the Madan Aitnar (the sacred ground where the festival is celebrated) through the central scheme called PRASHAD Scheme ("Pilgrimage Rejuvenation and Spiritual Augmentation Drive") by the Ministry of Tourism, India with the aim of preserving the religious and cultural activities of the community (India, 2021). The capacity of the gallery within the premises was increased to 400 people throughout the years with other facilities being added to it. The construction of the Facilitation Centre, for tourists was finished by the Department recently in 2023, and handed over to the community just before the 2024 festival in July. However, the facilitation centre could not be used much because there were still some works that had to be finished. The Sein Raij Jowai has now taken the responsibility for the maintenance of the Facilitation Centre.

"…The facilitation centre has a kitchen, toilets (male-urinal and female toilets- 2 in number) and hall..."

Sein Raij Jowai Representative (Translated from Khasi to English)

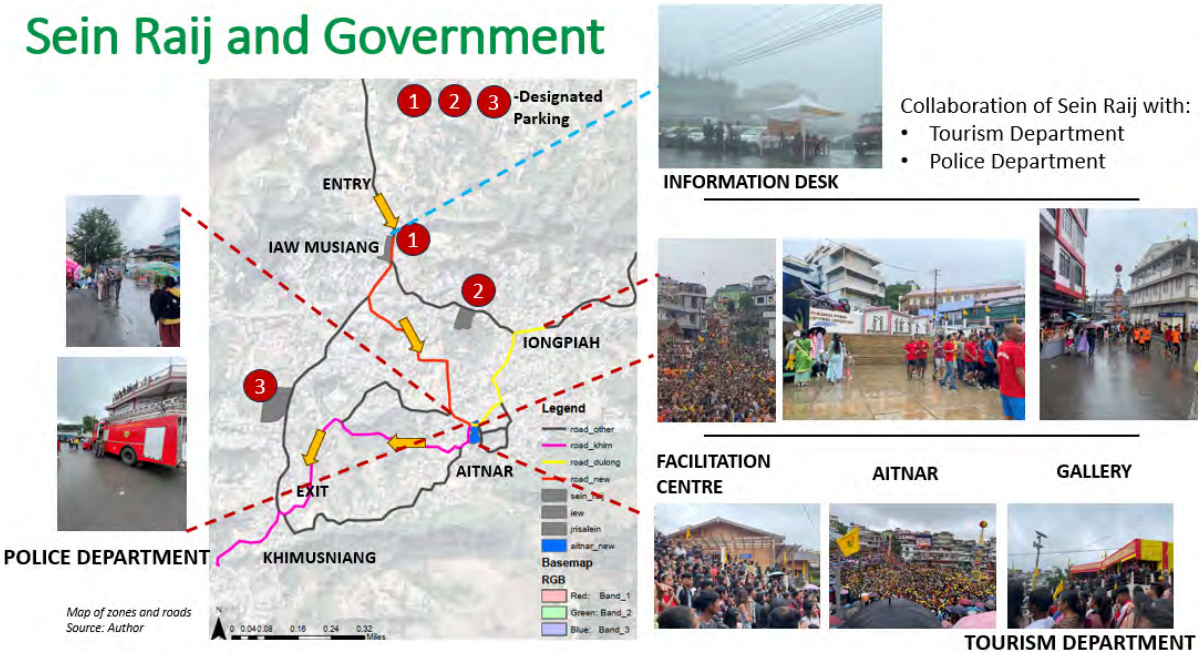


Figure 3. Sein Raij and Government roles and linkages. Source: Author

4.3.3 Other Stakeholders

The festival also included other stakeholders like the Seng Khasi (a Socio-cultural and religious organisation of the Khasi Tribe) and the Sein Raij Shillong (a Socio-cultural and religious organisation of the Jaintia community in Shillong) who joined the festival in solidarity by bringing their structures respectively to be showcased in the festival (see Figure 4). The members of The Sein Raij Shillong (a Socio-cultural and religious organisation of the Jaintia community in Shillong) highlighted that though they migrated to Shillong the capital city of Meghalaya for better opportunities, they come back to Jowai during the festival as they also have a role to play at various levels, in the rituals that are performed in Jowai.

"Most of the rites and rituals connected with Niam Behdieñkhlam of Raid Jowai are performed in Jowai itself…. Sein Raij Niamtre Shillong performed a ritual known as Ngooh Blai Choh Thyndai in each and every household of the Niamtre believers. Also, Chad Dong is organized for three days."

Interview with Sein Raij Shillong Representative

Additionally, other stakeholders like the Jaintia Hills Autonomous District Council (JHADC) Government of Meghalaya, the Department of Arts and Culture Government of Meghalaya and others help the community by providing funds for the festival. This further iterates on the community being adaptable as times change as they collaborate with other stakeholders.

Figure 4. Structures called "Rot" brought by the Sein Raij Shillong and Seng Khasi to the festival. Source: Author

5. Conclusion

The study tried to explore how the Behdieñkhlam Festival integrates the features of governance, planning and tourism into it.

5.1 Governance-Planning

Governance and planning in the festivals pivots the focus to the way the festival is being planned by the various stakeholders every year. This leads to the exploration of the various resources like the "space/place" that has been designated for various activities. For example, the "Madan Ainar" being a sacred place of worship and celebration of the main festival was renovated to accommodate more people. Spaces outside the Sein Raij Office were chosen for placing all the structures where the procession would start. For the ease of the community and tourists, parking areas, shopping areas and separate entry and exit points for the crowd and vehicles were planned. Promotion of the festival was also done across Meghalaya by setting up banners in cities.

Additionally, "people/stakeholders" like the community members, Sein Raij Jowai, the government and organisations from other places joined together in solidarity to make this celebration a success depicting a sense of belonging in the community. The Police Department deployed their personnels for the reason of safeguarding and providing security for the community and the tourists. Their service also extended towards the management of the crowd around the vicinity of the ground. Throughout the years the addition of other stakeholders and their acceptance of the community to take help shows that they are open to welcoming people from outside the community. Therefore, we see that the community of Jowai are well adept at providing the resources (Son, Huang and Padovan, 2021) required for the festival and are also adaptable to accommodate new people into their ecosystem.

5.2 Planning-Tourism

From the survey and interviews conducted it was observed that stakeholders like the State Government saw the potential of promoting this festival through tourism (Meghalaya, 2025) (Meghalaya, 2024). While the discussion of the community providing the resources, has been discussed in the previous section, the exploration of the provision of infrastructures to support the tourism industry that has just started of late, is also important.

The initiative of the community to be willing to collaborate with the State Tourism Department through the Sein Raij Jowai to add facilities and improve the existing infrastructure shows that tourism is an industry that can thrive here in the coming future. In addition to the renovation of the facilities on the ground and addition of new facilities, local cuisine was also sold by the locals in the festival thereby catering to the community and the tourists. The information desk at the entrance of the town made access to information very easy. Across the neighbourhoods surrounding the sacred ground various sites of architectural, heritage and cultural importance were sighted, which serves as sites of great curiosity for the tourists.

5.3 Governance-Tourism

As tourism here is still at its nascent stage, the interplay of governance and tourism leads us to explore the tourism policies that could further be added in the future. Considering the festival is purely community-based it is imperative to state that the tourism policies should benefit the community and should align with their interests as much as it benefits the tourists. The facilitation centre which was built by the Government using the PRASHAD Scheme through the Central Financial Assistance (CFA) and has now been handed over to the community for maintenance. This depicts a model where the community is given the opportunity to maintain their assets by giving them the initial impetus from other sources, thereby empowering the community.

Currently, though collaborations are seen with potential stakeholders, it was observed from the interviews that celebrating the festival is still considered to be the first priority by the community and providing the tourism services is considered an outcome of the festival which shows the pride of the community towards celebrating their culture. However, the community has started showing willingness to cater to tourists and researchers as they see that the representatives are encouraging the same by collaborating with the Tourism Department.

"Everyone is involved in the festival…Therefore, people are not free to take care of tourists personally. However, tourists from other states like Maharashtra etc. do stay in the houses of the locals during the festivals".

Sein Raij Jowai Representative (Translated from Khasi to English)

5.4 Governance-Planning-Tourism

Finally, the interplay of the three domains- governance-planning-tourism leads to a development for the community that is holistic in nature. The study delves into the three objectives and explores how the main aim of the paper is being fulfilled: "How the **community benefits** from the festival and consequently how its **cultural identity is being preserved** and **shared with people** coming from outside the town?":

5.4.1 Community Benefits

The festival is primarily a community festival because it brings the community together even if they are displaced to various places (Public, 2024). This is observed from the interview conducted with the representatives from the Sein Raij Jowai and Sein Raij Shillong.

"Behdieñkhlam …brings people together with full participation. The Deiñkhlam (Giant tree trunk) of each locality brought from forest with difficult terrain on a rainy day is a testimony to the participation of the community."

Interview with Sein Raij Shillong Representative

The festival also gives the opportunity to the community to address various social and environmental issues as also observed in (Brown *et al.*, 2015). For instance, though this festival involves the cutting of the sacred tree trunk for the festival, the community plants more trees thereby leading to an afforestation drive by the community. In addition to that the art of making the structures called "Rot" is still being encouraged within and outside the community, where showcasing of creativity and art meets the willingness to address current issues of the world.

"They cut sometimes from sacred forests or private forests if they do not find the right tree. This festival is purely related to nature because it is done after sowing because before people used to be agriculturalists. They pray to mother nature. Now since many people do not go to the forests anymore, this festival allows the people to get close to nature. They even plant trees where they cut the tree as a village."

Sein Raij Jowai Representative (Translated from Khasi to English)

In addition to this as tourists and researchers visit the festival, they are also encouraged to visit other tourist destinations across the Jaintia Hills which improves the tourism industry (Brown *et al.*, 2015).

5.4.2 Cultural identity is being preserved

Throughout the festival the community celebrates all its traditions throughout the four days and this has garnered attention of the government, tourists and researchers as the festival is now being promoted at various platforms. This is the reason that schemes like PRASHAD scheme are being implemented for this festival thereby improving the chances of employment for the community and evoking a sense of pride in the community to continue these traditions in the coming years.

"Sein Raij Shillong endeavours to preserve the art of making tradition 'Rot'.

Interview with Sein Raij Shillong Representative

In addition to this the community members invite friends from outside Jowai and they work as guides which allows the community to share their knowledge and encourages them to preserve their cultural identity.

5.4.3 Shared with people

Researchers, tourists and people from other parts of Meghalaya also come to Jowai during the festival. The locals are now accommodating domestic and international tourists and researchers in their homes for a span of days to months.

The community is also observing the potential they have to accommodate tourism and endeavour to increase the services and facilities required for tourism through the present funding and assistance they get from various sources like central schemes. This shows that there is a sense of awareness within the community to expand their reach through tourism.

"Since we are using the scheme for the facilitation centre… we will have to build facilities for the tourism industry here. Later, the facilitation centre could have other floors to cater to more tourists."

Sein Raij Jowai Representative (Translated from Khasi to English)

Figure 5. Conceptual framework. Source: Author

The Behdieñkhlam Festival is an event that embodies the true essence of how governance, planning and tourism interact with each other to preserve the cultural identity of a tribal community and how this same festival is being shared with people outside the community. The celebration of this event, with new stakeholders joining in solidarity year after year is an exemplary showcase of the efficiency of the community governance, evoking a sense of identity through conscious planning, economic benefits through tourism and environmental awareness and practices through the rituals performed.

This study has its own limitations because it could not cover the whole community, as this study is purely explorative and descriptive in nature. Further, future studies can involve community perspective on the governance, planning and the tourism, exploring the potential collaboration with stakeholders like the Tourism Department, assessing the waste management practices as tourist footfall increases and proposing a potential community-centred tourism circuit that covers other forms of destination within the Jaintia Hills.

6. References

Adi, I.N.R., Utama, M.S., Budhi, M.K.S. and Purbadharmaja, I.B.P. (2017) 'The Role of Government in Community Based Tourism and Sustainable Tourism Development at Penglipuran Traditional Village - Bali', *IOSR Journal of Humanities and Social Science*, 22(06), pp. 15–20. Available at: https://doi.org/10.9790/0837-2206131520.

Administration, D. and West Jaintia Hills District, Developed, G. of M. (Last Updated 2025) *West Jaintia Hills Disrict*, *Government of Meghalaya*. Available at: https://westjaintiahills.gov.in/history/ (Accessed: 10 March 2025).

Arnstein, S.R. (1969) 'A Ladder Of Citizen Participation', *Journal of the American Planning Association*, 35(4), pp. 216–224. Available at: https://doi.org/10.1080/01944366908977225.

Bradshaw, T.K. (2008) 'The Post-Place Community: Contributions to the Debate about the Definition of Community', *Community Development*, 39(1), pp. 5–16. Available at:

https://doi.org/10.1080/15575330809489738.

Brown, G., Lee, I.S., King, K. and Shipway, R. (2015) 'Eventscapes and the creation of event legacies', *Annals of Leisure Research*, 18(4), pp. 510–527. Available at: https://doi.org/10.1080/11745398.2015.1068187.

Directorate of Census Operations, M. (2014) *Census of India 2011 Meghalaya District census handbook Jaintia Hills Village and Town Directory*. New Delhi.

Govt. of India (2011) *STs Statistical Profile at a Glance*. Available at: https://tribal.gov.in/downloads/Statistics/STsStatisticalProfileAtaGlance_09072024.pdf.

India, M. of T.G. of (2021) *Guidelines Pilgrimage Rejuvenation And Spiritual Augmentation Drive*. Available at: https://tourism.gov.in/sites/default/files/2023-08/PRASHAD 15th FC Scheme Guidelines.pdf.

Jepson, A. and Alan, C. (2016) *Managing and Developing Communities, Festivals and Events*. 1st edn. UK: Palgrave Macmillan. Available at: https://link.springer.com/book/10.1057/9781137508553.

Lamar, D. (2015) *An insight into Behdieñkhlam Festival*. Edited by E.M.H. Passah. Shillong: Eddie Murphy H. Passah, East Panorama Offset, Keating Road, Shillong.

Mair, J. and Duffy, M. (2015) 'Community events and social justice in urban growth areas', *Journal of Policy Research in Tourism, Leisure and Events*, 7(3), pp. 282–298. Available at: https://doi.org/10.1080/19407963.2014.997438.

Meghalaya, G. of (Last Updated 2025) *Behdienkhlam Festival*. Available at: https://meghalaya.gov.in/behdienkhlam (Accessed: 10 March 2025).

Meghalaya, G. of I. (Last Updated 2024) *Experiences-Behdienkhlam Festival.*, *Meghalaya Tourism*. Available at: https://www.meghalayatourism.in/experiences-4/behdienkhlam-festival-2/ (Accessed: 10 July 2024).

Public (2020) *The Rainbow of Behdieñkhlam*, *The Shillong Times*. Shillong. Available at: https://theshillongtimes.com/2020/07/06/the-rainbow-of-behdienkhlam/ (Accessed: 10 July 2024).

Public (2024) *Significance of Ka Behdieñkhlam*, *The Shillong Times*. Shillong. Available at: https://theshillongtimes.com/2024/07/01/significance-of-ka-behdienkhlam/ (Accessed: 10 July 2024).

Son, I.S., Huang, S. (Sam) and Padovan, D. (2021) 'Realising the goals of event leveraging: The tourism and hospitality SME perspective', *Journal of Hospitality and Tourism Management*, 49(July), pp. 253–259. Available at: https://doi.org/10.1016/j.jhtm.2021.09.018.

Times, T.S. (2021) *Touching base with their roots*, *The Shillong Times*. Shillong. Available at: https://theshillongtimes.com/2021/07/04/touching-base-with-their-roots/ (Accessed: 10 July 2024).

Webster, M. (1828) *community*. Available at: https://www.merriam-webster.com/dictionary/community (Accessed: 4 July 2024).

Widjanarko, H., Utomo, H., Wibawa, T., Suratna, S. and Wahyurini, E. (2020) 'Community-Based Tourism Village Governance: a Case Study.', in *Environmental Science, Sociology, Business*, pp. 104–111.

Wood, E.H. (2009) 'An impact evaluation framework: Local government community festivals', *Event Management*, 12(3–4), pp. 171–185. Available at: https://doi.org/10.3727/152599509789659768.

Research Paper

Exploring Urban Resilience and Dichotomy of Transformation Projects in İstanbul:

A Comparative Study of Gasworks Museum and Galataport İstanbul

Deniz CAN, Middle East Technical University, Türkiye

Abstract

Urban transformation in İstanbul reflects a complex interplay between preserving cultural heritage, promoting inclusive development, and accommodating economic narrative of land rent sharing amidst rapid urbanization pressures. In recent years urban transformation projects in İstanbul increased in number with the aim of achieving a more resilient city, to combat the crises today's cities face. The rationale for the urban transformation projects varies from climate and disaster risks to regeneration of inert or unused areas. While increasing number of transformation projects present distinct approaches, they give rise to controversies on the social, economic trade-offs. This research focuses on two pivotal industrial area transformation projects: the Gasworks Museum (Müze Gazhane) and Galataport İstanbul, each representing distinct transformation models and operating paradigms in urban regeneration. These projects illustrate contrasting approaches to balancing historical preservation with modern development needs; thereby influencing urban resilience across economic, social and ecological dimensions at different levels. While the Gasworks Museum (Müze Gazhane) project exemplifies a preservation-oriented mode, rooted in adaptive reuse of industrial heritage to promote cultural continuity and community identity, Galataport İstanbul as a large-scale cruise-port transformation project epitomizes a commercial-driven approach underpinned by neoliberal policies. This study contributes to the understanding of the underlying dynamics driving transformation processes and their impacts on urban resilience, illustrated through two distinct transformation projects in İstanbul.

Keywords

Urban Resilience, Urban Transformation Projects, Industrial Heritage Preservation, Economic and Social Trade-offs, İstanbul.

1. Introduction

İstanbul, as a city under immense urbanization pressure, is experiencing a rise in urban transformation projects aimed at making it more resilient. These projects often balance the preservation of cultural heritage, inclusive development, and economic growth. However, they also reveal tensions, particularly between social, ecological, and economic trade-offs. This study investigates two such transformation projects: the Gasworks Museum and Galataport, which highlight contrasting models of development.

The Gasworks Museum exemplifies a preservation-oriented model that enhances social and ecological resilience by fostering community engagement and adaptive reuse of historical sites. It promotes cultural

continuity, social cohesion, and the development of local creative industries (Özgüner, 2021). The transformation of Gasworks Museum is paved with the activities of the civil society organization called Gazhane Environmental Volunteers. By repurposing the historic gasworks complex into a museum and cultural hub, the project not only preserves tangible and intangible urban memories but also fosters local economic activities through cultural and creative industries taking its power from the local. This model enhances social cohesion by engaging local communities in the regeneration process, thereby bolstering community resilience for its surrounding area (Leblebici, 2023). Galataport represents a commercial-driven model focused on economic revitalization through luxury tourism and mixed-use development (Çobanyımaz, 2018). It prioritizes economic growth but compromises social inclusivity and raises environmental concerns, limiting its broader resilience impact. While the project focuses on economic revitalization and job creation, debates are emerging over the impact on local businesses, displacement risks and environmental sustainability (Boz, 2018; Bilal, 2019). Galataport project's focus on luxury tourism and high-end commercial spaces and subsequent transformation of the urban fabric and socio-economic dynamics of the area, poses challenges to social inclusivity and community resilience. The transformation of the port into a large-scale infrastructure development also raised debates of preservation of coastline along with the discussions on how a newly built building complex would be incorporated to a historic urban fabric. Analyzing these projects through urban resilience framework reveals their broader implications on Istanbul's socio-economic landscape. The Gasworks Museum model demonstrates how adaptive reuse of industrial sites can foster economic diversity, preserve cultural heritage, and empower local communities, thereby enhance overall urban resilience. Conversely, Galataport model reflects the trade-offs between economic growth and social inclusiveness, underlining the need for a balanced development strategy that would mitigate negative socio-economic impacts and reduce environmental degradation.

By examining these two transformation processes in İstanbul through the framework of urban resilience this study aims to deepen our understanding of the underlying dynamics in urban transformation processes and their significant impacts on urban resilience. By examining the unique cases of Galataport and the Gasworks Museum, it sheds light on how distinct transformation and operational models influence urban resilience across economic, social, and ecological dimensions in complex, evolving urban contexts like Istanbul. This research emphasizes how adaptive reuse, commercialization, and controlled access strategies affect not only the physical landscape but also the social fabric, economic stability, and ecological sustainability of urban areas. Furthermore, it explores how resilience is created and affected by inclusivity, public accessibility, and the trade-offs between preserving heritage and fostering economic growth. The multidimensional nature of resilience within these projects offers a comprehensive approach to the study and offers insights to create resilient urban spaces that can adapt to socio-economic pressures and environmental uncertainties while maintaining the cultural and historical identity of the city.

2. Theoretical Framework: Urban Resilience and Transformation Projects

2.1. Conceptualizing Urban Resilience

Urban resilience has emerged as a vital concept in urban planning, focusing on cities' ability to withstand, adapt to, and recover from various shocks and stresses, including environmental, social, and economic disruptions (Meerow et al., 2016; Adger, 2000). Rooted in both ecology and social sciences, resilience is often framed as a multifaceted capacity that allows urban systems to maintain function despite changing conditions, thereby ensuring long-term sustainability and adaptability (Ahern, 2011). This approach has gained traction as cities face increasing pressures from climate change, rapid urbanization, and socio-economic inequalities, underscoring the need for adaptive strategies that span diverse dimensions of

resilience. Pickett et al. defines resilience as "the ability of a system to adjust in the face of changing conditions, while Godschalk (2003) explains the concept of resilience as a sustainable network which consist of physical systems and human communities. In the literature mainly resilience is defined through systems or a city's own capacity to withstand any disturbances of stresses and usually hazards. Focusing on the essential functions in a city such as housing, commerce, industry governance and social interaction, Hamilton (2009) asserts a resilient city has the capacity to bounce back and maintain its essential functions despite facing. In several cases resilience to one particular hazard or a disturbance is addressed such as climate-resilience, disaster resilience, earthquake resilience etc. (Datola, 2003; Saez Ujaque, 2021; Freitag et al., 2014; Cutter et al., 2008). Meerow et al. (2015) combines all these with as systematic approach an proposes the following explanation: "Urban resilience refers to the ability of an urban system-and all its constituent socio-ecological and socio-technical networks across temporal and spatial scales-to maintain or rapidly return to desired functions in the face of a disturbance, to adapt to change, and to quickly transform systems that limit current or future adaptive capacity."

2.2. Dimensions of Urban Resilience

Urban resilience is the capacity of cities and urban systems to absorb shocks, stresses or crises; quickly bouncing back and maintain its essential functions, well-being and quality of life. It is about a city's ability not only to recover from disruptions but also to adapt to changing conditions in order to sustain stability and continuity. Various studies highlight a broad spectrum of resilience dimensions, with scholars emphasizing socio-economic, infrastructural, institutional, and governance-related factors as essential components of resilient urban systems (Meerow et al., 2016; Ahern, 2011; Chelleri, 2012). For instance, socio-economic resilience focuses on the community's adaptability and economic robustness, while infrastructural resilience emphasizes the durability and flexibility of physical systems and networks. Institutional resilience looks at how policies and structures provide support to adaptation, while governance resilience underlines the role of effective, inclusive decision-making.

This study bases its analysis of urban resilience among four key dimensions: social, economic, ecological, and governance, which will be very important in understanding the resilience within Istanbul's dynamic urban landscape. These four dimensions of resilience both independently and collectively impact a city's ability to respond to contingencies, shocks, stresses or other crises.

Social Resilience: Social resilience inclues key dimensions such as inclusivity, culture, community building and a high sense of community identity. A socially resilient community can absorb, adapt, and thrive in response to disruptions due to supportive social networks and equal access to resources. While promoting equity and inclusivity, social resilience ensures all groups, especially vulnerable population, to have the oppotunity to participate in urban life and access essential urban services. Another factor that fosters social resilience is cultural and historial continuity of communities in the face of a crisis or change. Stong bonds in a community reflects its ability to mitigate, withstand and adapt to the risks. The displacement risk and loss of the urban identity and concequently loss of social resilience is closely linked with and should be considered in rapid urban transformation projects. (Kwok et al., 2018; Renchler, 2010).

Economic Resilience: Economies that promote a diversified economy that can withstand external shocks and sustain development (and economic growth), promote innovation and collaboration and are community driven, encourage local businesses are resilient economies. Resilient urban economies provide diverse employment opportunities and support small and medium-sized enterprises (SMEs), which increase adaptability and distribute economic benefits more broadly. An economically resilient city is less dependent on a single industry or market and instead fosters sustainable economic activities that can

respond to both global economic shifts and localized disruptions. In the case of a economic shock or a crisis, diversity of economic activities play an important role to provide stability by enabling cities to recover faster.

Ecological Resilience: Ecological resilience emphasizes sustainable resource management, green infrastructure, nature-based solutions, and the protection of natural ecosystems that reduce environmental risks and maintain biodiversity. Ecological resilience enables cities to maintain ecosystem services that support urban life while also reducing vulnerability to climate change impacts (Tong, 2021). Ecologically sustainable and resilient cities support a livable environment not only for the present but also for future generations by utilizing and creating the necessary increntives for sustainable solutions such as energy efficiency, reusable energy, waste reduction, circular economy, prioritizing green infrastructure and nature based solutions.

Governance (Institutional) Resilience: Urban resilience requires effective governance through inclusive, transparent, and adaptive decision-making processes that allow the involvement of a wide range of stakeholders. Governance resilience sustains the need for participatory structures encouraging collaboration between government agencies, private sector actors, and community organizations to enable quicker responses to crises, equitable allocation of resources, and adaptable plans toward long-term urban needs (Kwok et al., 2018). It means that resilient governance systems will allow cities to implement adaptive strategies, make resources available more equitably, and respond inclusively to the needs of communities while reinforcing all dimensions of resilience (Pickett et al., 2013).

2.2. Urban Transformation Projects and Their Role in Urban Resilience

The rapid population growth and fast urbanization increases the pressure in urban systems leading to problems of climate change, ecological crises, the unequal distribution of resources and socio-economic disparities. While urban transformation projects carry the potential to foster urban resilience by creating just and inclusive spaces, they can also create new vulnerabilities that deepen the existing problems. These projects often involve reimagining and transforming urban areas, such as neglected waterfronts, industrial zones, and historical sites, into adaptive and multi-functional areas that are able to respond to current needs while still preserving cultural heritage.

Transformation projects can contribute to urban resilience by fostering economic diversity, enhancing public spaces, and promoting ecological sustainability, while also considering the needs of the existing community and responding to these need. Mixed-use developments, for example, provide adaptable spaces that support both economic activity and social interaction, creating vibrant, multi-functional neighborhoods that can create an boost for the local economy. Projects that incorporate nature-based solutions, green infrastructure and energy-efficient design choices support ecological resilience by mitigating environmental impacts.

The success of an urban transformation project depends on its demeanor, objectives and the tools it uses. It is also shaped by what the project prioritizes and what are the trade-offs for this prioritization. For a resilient urban area, the transformation that follows inclusive planning and governance framework, which engages communities and addresses their needs could be much more successful on the long run. When managed inclusively, transformation projects can increase social cohesion, strengthen local identity and provide resources equally for resilient urban environments while responding effectively to future uncertainties.

3. Methodology

3.1. Analytical Framework of the Study

This study provides a critical comparative analysis of two distinct urban transformation project examples in İstanbul, Müze Gazhane (Gasworks Museum) and Galataport İstanbul projects, with their contributions to the framework of urban resilience. Investigating social, economic, ecological, and governance dimensions, it explains how each approach contributes or contests the urban resilience framework. A comparative study approach is employed to reveal how differing transformation models impact these four key dimensions, providing insight into the broader implications of each project.

To investigate these dynamics, the following research questions have been formulated to guide the study, enabling a systematic exploration of the ways these transformation models interact with urban resilience:

a.) How do the Gasworks Museum and Galataport projects impact urban resilience across social, economic, ecological, and governance dimensions? This question investigates to what extent each of these initiatives integrates social inclusivity, economic viability, conservation of the environment, and effective governance. It inquiries the impact of these factors in terms of the ability of the projects to respond and mitigate urban challenges such as displacement, economic inequality, and environmental degradation.

b.) How do differing approaches to community involvement in the Gasworks Museum and Galataport projects influence their overall contribution to urban resilience? This question examines the role of community engagement in the planning and implementation of each project. By analyzing the presence or absence of local participation, this question aims to unravel the outcomes in terms of social cohesion, local identity, and the projects' alignment with the needs of local residents.

4. Gasworks Museum: Revitalizing Heritage for Resilient Communities

Located in İstanbul's Kadıköy district, The Gasworks Museum is an adaptive reuse project that transforms a historic industrial complex into a vibrant cultural and creative community hub. The facility was originally constructed as a gasworks facility in the late 19th century and became the main source of gas energy for the city (Bilal, 2019; Özgüner, 2021; Kıraç, 2023). In 1993 the gasworks facilities operation ceased and the facility was left to be abandoned. After decades of abandonment, the complex was in danger of deterioration, but efforts were mobilized to preserve its architectural and historical integrity, thanks to a coalition of local civil society advocates known as Gazhane Environmental Volunteers. These efforts resulted in a transformation project that emphasizes cultural preservation, community engagement, and reuse to ensure the continuity of heritage sites and strengthen local identity.

While blending heritage with modern functionality, the preservation-focused transformation of Gasworks Museum not only revitalizes the site but also reintroduces the site as a public cultural asset. Presently, the museum holds a variety of spaces for exhibitions, workshops, performances, and educational programs, inviting a diversity of visitors to discover Istanbul's industrial heritage (Figure 1). Gasworks Museum is an exemplary project that shows how heritage sites can be throughtfully adapted to meet contemporary urban needs while preserving their historical significance (Leblebici, 2023). In this project the preservation was possible through adaptive resused of cities and preserving the original architecturall elements.

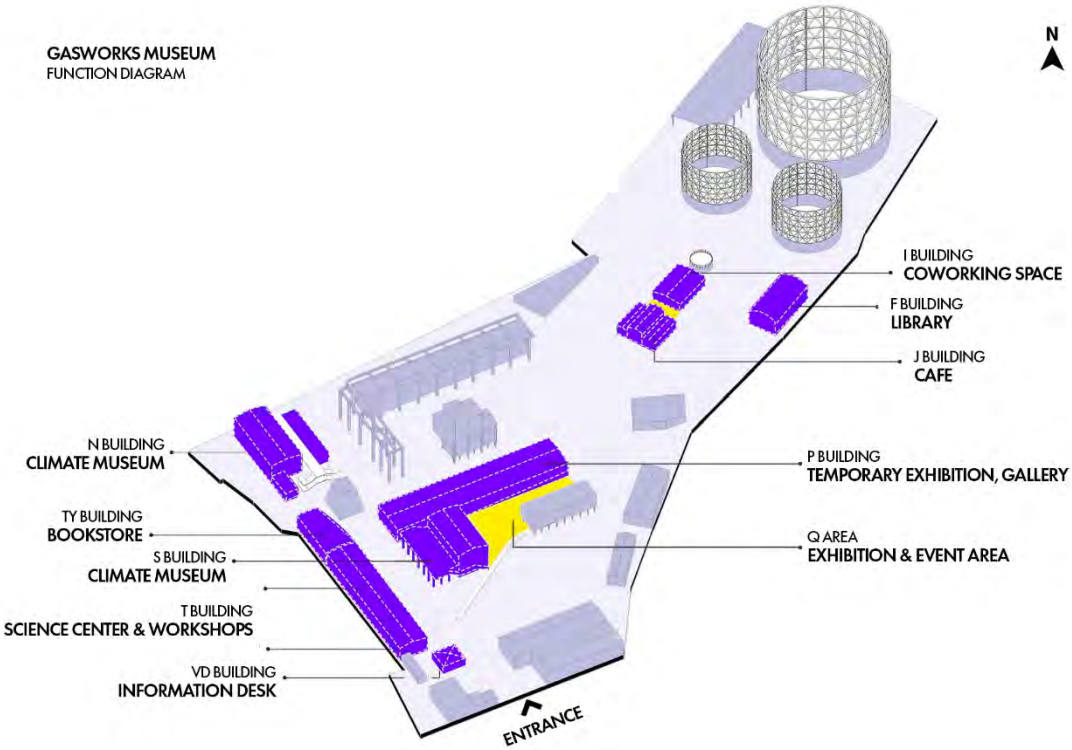


Figure 1. Plan Layout of Gasworks Museum showing museum and exhibition areas, collective working areas, galleries and recreational open areas. Source: https://www.arkitera.com/proje/muze-gazhane-muze-ve-kutuphane-binalari-yeniden-islevlendirme-ve-ic-mekan-tasarimlari/.

Figure 2. The J Building, the café and the shared recreational open area, Gasworks Museum. Source: Authors Archive.

Figure 3. Stages and Library, Gasworks Museum. Source: Authors Archive.

4.1. Impacts on Urban Resilience

Social Resilience: The Gasworks Museum enhances social resilience by creating inclusive spaces for public gatherings, cultural events and educational activities. This focus on community, fosters a strong sense of place and belonging, promoting social cohesion and inclusivity while celebrating Istanbul's industrial heritage. Through active community engagement and the development of a variety of social programs, the museum strengthens social ties and promotes local identity, creating a strong foundation for community building.

- **Economic Resilience**: The transformation of the Gasworks into a cultural hub has generated opportunities in the creative and cultural industries. Thus it reinforces the opportunities to attract tourists, foster local job creation, and support small businesses. By strengthening the cultural economy of the region, the museum promotes diversity and stability in terms of economy, and strengthens the region's resilience to economic and financial crises and shocks.
- **Ecological Resilience**: The project enhances ecological resilience by repurposing a former industrial site, minimizing the environmental impact of new building, and integrating sustainable practices such as green landscaping and energy-efficient technology. These attributes foster an environmentally sustainable urban environment that enhances biodiversity, alleviates urban heat, and offers green public spaces, benefiting both humanity and the ecosystem.
- **Governance Resilience**: Through a collaborative approach involving civil socity, local governments and private stakeholders, the Gasworks Museum is a striking example of governance resilience. The active involvement of the Gazhane Environmental Volunteers and other community organizations secure local interests and enhances the public embrace of the cultural site. The participatory governance model ensures transparency, adaptability, and accountability, and in doing so, strengthens the sustainability of the museum and provides a model for future heritage ventures to replicate.

By working together with local government, commercial stakeholders, and civil society, the Gasworks Museum is a remarkable example of governance resilience. The project represents local interests and enhances public ownership of the cultural site thanks to the proactive involvement of the Gazhane Environmental Volunteers and other community organizations. The museum's sustainability is enhanced by this participatory governance model, which also offers a repeatable governance framework for upcoming heritage initiatives by encouraging accountability, flexibility, and transparency.

5. Galataport İstanbul: Navigating Neoliberalism in Urban Renewal

Galataport İstanbul, situated on the Bosporus waterfront, represents a landmark urban renewal project launched in 2013 and finished in 2023 in the historic Salı Pazarı area, Karaköy near İstanbul Bosphorus. Designed to revitalize a previously underutilized industrial waterfront, Galataport spans over 1.2 kilometers and incorporates mixed-use spaces, including a cruise port, retail, dining, cultural centers, offices, and residential units (Figure 4) (Bilal, 2019; Boz, 2018; Çobanyılmaz, 2018). During this transformation, the Karaköy Passenger Hall, an architectural competition project from the 1930s designed by Rebii Gorbon in the modernist style, was demolished, sacrificing a historical piece of Istanbul's modern architectural heritage. This large-scale project, orchestrated mainly by private investment, embodies a neoliberal approach to urban renewal, emphasizing privatized, consumer-driven spaces.

A defining feature of the project is its controlled access, particularly prioritizing the needs of high-income consumers and international cruise ship tourists (Erbil, 2024). The design ensures regulated entry to key areas, maximizing economic gains from transient high-income groups while limiting easy public access. Although the project provides renewed public spaces, these are largely structured to promote consumption, prioritizing retail and leisure activities over community needs. The fencing around Galataport also spatially segregates it from the adjacent historic fabric, creating a perceptible divide that disrupts continuity with surrounding neighborhoods and further reinforces economic exclusivity. Consequently, while the project brings economic vitality, it raises concerns regarding social inclusivity and the displacement of local, lower-income populations, reflecting the broader tensions in Istanbul's neoliberal urban strategies (Kara, 2022).

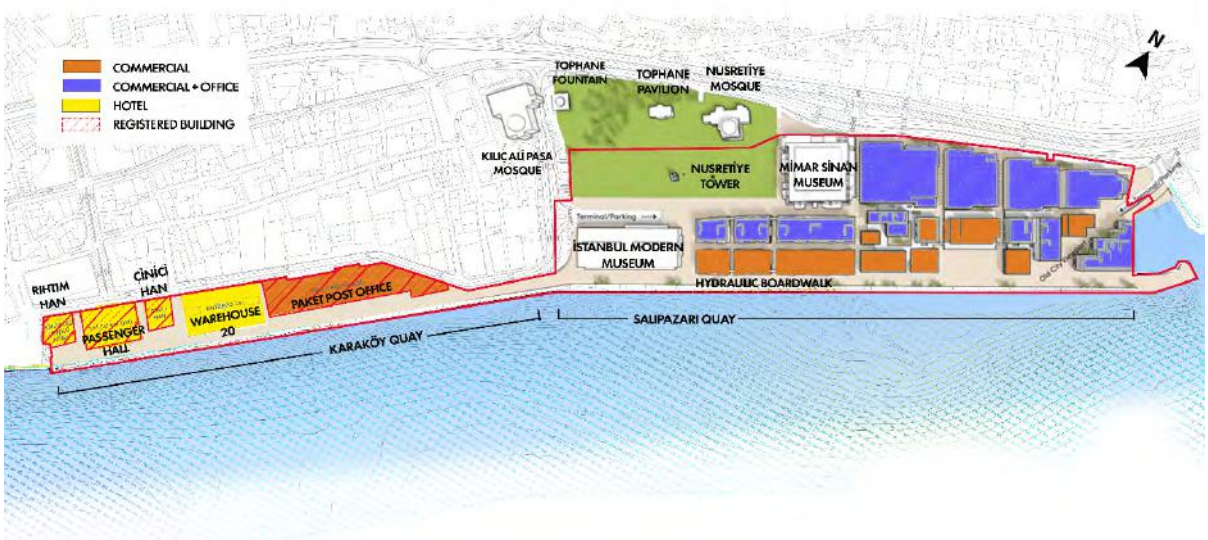


Figure 4. Galataport İstanbul Transformation Plan (Site Plan shows the locations and functions of the structures planned within the scope of the project in the Environmental Impact Assessment Report) Source: http://arkita.com/haber/galataportun-master-planini-dror-ve-gensler-tasarliyor/

Figure 5. Galataport İstanbul, coast view when a cruise ship docked. Source: Authors Archive.

Figure 6. Aerial View of Galataport İstanbul. Source: https://www.instagram.com/galataportistanbul/

5.1. Impacts on Urban Resilience

Social Resilience: Galataport development, with its high-end tourism and high-class commercial spaces, has produced an environment that appeals predominantly to high-spending visitors and tourists, possibly at the expense of local populations' interests. The restricted access and high-end orientation of the development have restricted accessible and affordable public spaces, raising concerns regarding social inclusivity and community resilience. The exclusion of lower-income residents from this redeveloped waterfront reduces opportunities for social interaction and weakens the sense of community that supports social resilience. Furthermore, insufficiency of affordable cultural and recreational amenities may weaken the cultural ties between the local comminities and the urban space.

Economic Resilience: The Galataport İstanbul transformation project aims to enhance Istanbul's economy by attracting international tourists and creating employment opportunities in hospitality, retail, and associated sectors. This surge in economic activity bolsters local enterprises serving affluent tourists, although the advantages may be inequitably allocated, resulting in a disparity between beneficiaries of the luxury-driven economy and those marginalized by it. Existing social and economic gaps in the region can become amplified through such a high-end economy model, constraining overall economic resilience in the community at a larger level.

Ecological Resilience: Galaport being one od the large-scale infrastructure development along İstanbul's historic waterfront raises concerns about ecological sustainability and potential threats for the preservation of natural coastal ecosystem. While the project claims to integrate sustainable solutions and practices, the long term impact of a large scale coastal project and cruise traffic in the coastal areas raises questions on preservation of biodiversity, water quality, mucilage and other disturbances to the ecology. Overall ecological resilience entails a balanced urban development with a minimum impact over environment degradation and a maximization of renewable use of resources with adequate regulations.

Governance Resilience: In Galataport, the top-down model, which prioritizes private investment and large commercial interests, has generated little public consultation, which may make it less attuned to local needs and less sustainable in the long term with community support. Governance resilience values participatory, inclusive decision-making processes that adapt to emerging challenges. Galataport has also been embroiled in many controversies with civil society organizations and professional chambers (Çobanyılmaz, 2018). In order to foster governance and institutional resilience the future adjustments in Galataport project should include a highly collaborative governance model that creates the opportunity for citizen involvement and consider community needs and expectations.

6. Comparative Discussion of Findings

Gasworks Museum prioritizes heritage preservation, community engagement, and sustainability, offering a model of transformation that supports social cohesion and ecological balance. Galataport, on the other hand, emphasizes economic growth through luxury tourism and commercial development, yet it brings challenges related to social inclusivity and environmental impact. This comparison highlights the contrasting approaches and their broader implications for urban resilience in İstanbul.

6.1. Diverging Approaches to Urban Resilience

The Gasworks Museum exemplifies a preservation-oriented model that enhances social and ecological resilience by fostering community engagement and adaptive reuse of historical sites. It promotes cultural continuity, social cohesion, and the development of local creative industries.

In contrast, Galataport represents a commercial-driven model focused on economic revitalization through luxury tourism and mixed-use development. This approach prioritizes economic growth but compromises social inclusivity and raises environmental concerns, limiting its broader resilience impact.

6.2. Community Involvement versus Market-Driven Development

The Gasworks Museum's transformation was rooted in civil society involvement, particularly through local groups like the Gazhane Environmental Volunteers. The participatory process rooted in Gasworks Museum strengthens community belonging and acceptance of the project. This is apparent in the locals using this space frequently marking the museum complex area as a meeting and socializing point.

On contrary Galataport transformation comes from a top-down development in which neoliberal policies and market forces play pivotal roles. This led to social displacement and reduced public access to coastal areas, weakening the social resilience of local communities.

6.3. Trade-offs in Economic and Ecological Resilience

Galataport has generated economic growth and provided employment through the establishment of luxury commercial spaces and tourism; nevertheless, it has also prompted concerns regarding the long-term sustainability of this model due to its effects on the local economy and ecology.

The Gasworks Museum fosters local economic initiatives via cultural programs and the creative economy, while enhancing ecological resilience by converting an industrial site into a sustainable cultural center (cultural hub).

These findings emphasize the necessity of integrating social, economic, and ecological factors in urban transformation initiatives to bolster urban resilience across several dimensions.

7. Conclusion

The Gasworks Museum and Galataport projects represent the complex urban landscape of İstanbul, where swift developmental demands contrast with the imperative to save cultural heritage and promote social inclusion. Although both projects are crucial in influencing İstanbul's spatial and socio-economic environments, they exemplify two divergent agendas and trade-offs in urban development initiatives. This study enhances the discourse on urban resilience by highlighting the integral understanding of social, economic, and ecological objectives, as well as community engagement in the planning process. It underscores the need of acknowledging the risks linked to prioritizing economic growth over diversity and sustainability. These insights provide essential direction for urban designers, policymakers, and communities aiming for resilient cities.

For future studies, key opportunities can be sought after to enhance resilience in large scale transformation projects like Galataport İstanbul. Addressing social inequalities, instead of prioritizing commercializing the area in the sake of economic profit would offer a one step forward for social resilience. This would be further enforced if more community involvement in planning enables future projects to reflect more accurately the needs and values of the community. The balance between long-term economic growth and sustainability involves reducing environmental harm and enhancing ecological health. This study underlines that urban resilience is multidimensional, with social, economic, and ecological priorities to be carefully balanced. The comparative analysis of Gasworks Musem and Glataport reveal important insights about urban transformation trade-offs, suggesting that transformation projects must prioritize inclusivity, cultural preservation and environmental sustainability ro truly foster resilience.

8. References

Adger, W.N. (2000) Social and ecological resilience: are they related? *Progress in Human Geography*, 24(3), p347-364.

Ahern, J. (2011) From fail-safe to safe-to-fail: Sustainability and resilience in the new urban world. *Landscape and Urban Planning*, 100(4), p341-343.

Bilal, E. (2019) *Galataport yenilenme sürecinde Cumhuriyet dönemi kültür mirası üzerine bir değerlendirme: Galata-Karaköy yolcu salonu.* Master's thesis, Maltepe University, Turkey.

Boz, M. (2018) Kentlerdeki Değişimlerin Kentsel Bellek ve Kullanıcı Algısına Etkileri: Galataport Projesi Örneği. *Türkiye Kentsel Morfoloji Ağı*, p1055-1073.

Cafer, A., Green, J., & Goreham, G. (2022) A community resilience framework for community development practitioners building equity and adaptive capacity. In *Community development for times of crisis* (p56-74). Routledge.

Chelleri, L. (2012) From the Resilient City to Urban Resilience. A review essay on understanding and integrating the resilience perspective for urban systems. *Documents d'anàlisi geogràfica*, *58*(2), p287-306.

Cutter, S. L., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., and Webb, J. (2008) A place-based model for understanding community resilience to natural disasters. *Global environmental change*, *18*(4), p598-606.

Çobanyılmaz, P. (2018) Urban movements related to (re) production of urban space: debates on selected projects in İstanbul, Doctoral dissertation, Middle East Technical University, Turkey.

Datola, G. (2023) Implementing urban resilience in urban planning: A comprehensive framework for urban resilience evaluation. *Sustainable Cities and Society*, 98, p104821.

Erbil, A. Ö., and Erbil, T. (2024) Unveiling the role of the state in Istanbul's urban transformation: Insights from Galataport redevelopment. *Journal of Infrastructure, Policy and Development*, *8*(11), p7631.

Freitag, R. C., Abramson, D. B., Chalana, M., and Dixon, M. (2014) Whole community resilience: An asset-based approach to enhancing adaptive capacity before a disruption. *Journal of the American Planning Association*, *80*(4), p324-335.Godschalk, D. R. (2003) Urban hazard mitigation: Creating resilient cities. *Natural hazards review*, *4*(3), p136-143.

Hamilton, W. A. H. (2009) Resilience and the city: the water sector. *Proceedings of the Institution of Civil Engineers-Urban Design and Planning*, *162*(3), p109-121.

Kara, F.E. (2022) *Karaköy ve Salıpazarı Limanı'nın tüketim odaklı mekansal dönüşümü: Galataport İstanbul.* Master's thesis, Bursa Uludağ University, Turkey.

Kıraç, A.B. (2023) Hasanpaşa'da Öncü Koruma Mücadelesi: Müze Gazhane. *Mimarlık*, 430, p56-64.

Kim, B., Lee, G. S., Kim, M., Lee, W. S., and Choi, H. S. (2023) Developing and Applying an Urban Resilience Index for the Evaluation of Declining Areas: A Case Study of South Korea's Urban Regeneration Sites. *International Journal of Environmental Research and Public Health*, *20*(4), p3653.

Kwok, A. H., Paton, D., Becker, J., Hudson-Doyle, E. E., & Johnston, D. (2018) A bottom-up approach to developing a neighbourhood-based resilience measurement framework. *Disaster Prevention and Management: An International Journal*, *27*(2), p255-270.

Larimian, T., Sadeghi, A., Palaiologou, G., & Schmidt III, R. (2020) Neighbourhood social resilience (NSR): Definition, conceptualisation, and measurement scale development. *Sustainability*, *12*(16), p6363.

Leblebici, E. (2023) *Impact of intermediate and informal adaptations on the reuse of post-industrial sites: from Hasanpaşa Gasworks to Müze Gazhane*, Doctoral dissertation, Bilkent University, Türkiye.

LopezDeAsiain, M., and Díaz-García, V. (2020) The importance of the participatory dimension in urban resilience improvement processes. *Sustainability*, *12*(18), p7305.

Meerow, S. and Newell, J.P. (2019) Urban resilience for whom, what, when, where, and why? *Urban Geography*, 40(3), p309-329.

Meerow, S., Newell, J.P. and Stults, M. (2016) Defining urban resilience: A review. *Landscape and Urban Planning*, 147, p38-49.

Murray, K. and Zautra, A. (2011) Community resilience: Fostering recovery, sustainability, and growth. In *The social ecology of resilience: A handbook of theory and practice* (p337-345). New York, NY: Springer New York.

*Özgüner, B. A. (2021). Bir Uzun Koruma Mücadelesi: Tarihî Hasanpaşa Gazhanesi'nden Müze Gazhane'ye. *Mimarlık*, (421), p10-15.

Pickett, S.T.A., et al. (2004) Resilient cities: meaning, models, and metaphor for integrating the ecological, socio-economic, and planning realms. *Landscape and Urban Planning*, 69(4), p369-384.

Renschler, C. S., Frazier, A. E., Arendt, L. A., Cimellaro, G. P., Reinhorn, A. M., & Bruneau, M. (2010) Developing the 'PEOPLES' resilience framework for defining and measuring disaster resilience at the community scale. In *Proceedings of the 9th US national and 10th Canadian conference on earthquake engineering* (p25-29). Canada Toronto.

Saez Ujaque, D., Roca, E., de Balanzó Joue, R., Fuertes, P., and Garcia-Almirall, P. (2021) Resilience and urban regeneration policies. Lessons from community-led initiatives. the case study of canfugarolas in Mataro (Barcelona). *Sustainability*, *13*(22), p12855.

Sennett, R. (2018) *Building and Dwelling: Ethics for the City.* Farrar, Straus and Giroux.

Tong, P. (2021) Characteristics, dimensions and methods of current assessment for urban resilience to climate-related disasters: A systematic review of the literature. *International Journal of Disaster Risk Reduction*, 60, p.102276.

Wang, Z., Fu, H. and Zhou, L. (2023) Multiple urban resilience evaluation of resource-based cities' sustainable transformation effect. *Resources, Conservation and Recycling*, 191, p.106912.

Research Paper

Spatial Justice in Heritage Communities

Resident Perceptions of Recreational Spaces in Suzhou's Classical Garden Areas

Siyuan HAO, School of Architecture, Southeast University, China

Xiliu HE, School of Architecture, Southeast University, China

Abstract

This study examines spatial justice in heritage communities surrounding Suzhou's eight UNESCO World Heritage Classical Gardens. While these gardens have transformed from private estates to public spaces, their development patterns have led to varying impacts on surrounding communities. Through analysis of land use patterns, facility distribution, and 39 in-depth interviews with residents, this research investigates how different development patterns influence spatial justice and residents' daily experiences. The study reveals that spatial differentiation manifests beyond physical accessibility, encompassing temporal, social, and perceptual dimensions. Findings indicate that similar heritage types under different development patterns create distinct community experiences, with social class significantly influencing space utilization patterns. The research contributes to understanding how micro-scale social space differences affect spatial perception and choices in heritage communities, extending beyond traditional macro-scale facility distribution analysis. The study concludes with recommendations for differentiated development strategies that promote spatial justice while respecting community characteristics.

Keywords

Spatial Justice; Heritage Tourism; Community Development; Social Space; Classical Gardens Of Suzhou

1. Introduction

Heritage tourism development has brought unprecedented transformation pressures to communities surrounding World Heritage sites. The Classical Gardens of Suzhou, among China's most significant UNESCO World Heritage sites, exemplify the evolution from private gardens to public spaces. This transformation not only manifests in physical accessibility but profoundly impacts community social structures and residents' daily lives. Under the dual pressures of heritage preservation and tourism development, these garden communities exhibit significant spatial differentiation, raising fundamental questions about spatial justice.

The Classical Gardens of Suzhou, inscribed on UNESCO's World Heritage List between 1997 and 2000, represent the pinnacle of Chinese garden art. These gardens, originally constructed between the 11th-19th centuries, demonstrate the sophisticated integration of art, nature, and ideas in garden design. The gardens selected for this study represent different historical periods and social contexts, from the imperial-

scale Humble Administrator's Garden to the more intimate Scholar's gardens like the Master of the Nets Garden.

Dating back to the 6th century BCE, Suzhou's Classical Gardens have evolved from elite private estates to contemporary public cultural spaces. Through this transformation, surrounding communities have undergone significant changes. While some gardens' tourism development has led to community gentrification and population turnover, others have integrated deeply with community life, becoming vital spaces for residents' daily recreation. These divergent development patterns provide unique insights into spatial justice issues in heritage communities. Figure 1 demonstrates the significant disparity in tourist attention among these gardens. The Humble Administrator's Garden receives over 12,000 reviews, while less prominent gardens like the Garden of Cultivation attract fewer than 1,000 reviews. This disparity in tourism intensity directly influences community development patterns and residents' daily experiences.

Figure 1. Number of reviews of eight Suzhou gardens on travel websites.

Source: Data collected from Ctrip, September 2024

This study examines communities surrounding eight UNESCO World Heritage gardens in Suzhou, investigating how residents of different social classes perceive and use recreational spaces under various development patterns. The research addresses three key questions:

(1) How do residents across social classes perceive and use recreational spaces in heritage communities amid social-spatial differentiation?

(2) How do different development patterns of similar heritage sites influence residents' daily experiences and spatial justice?

Through field surveys and in-depth interviews, this research analyzes spatial usage patterns and cultural identity variations across different residential types. Findings reveal that social-spatial differentiation influences not only living conditions but also profoundly shapes residents' spatial perception and usage intentions. Based on these findings, the study proposes recommendations for promoting spatial justice in heritage communities, offering new perspectives on balancing heritage preservation with community development.

2. Literature Review

Research on heritage tourism's community impacts has evolved significantly. Heritage tourism research initially focused on European contexts, with Van der Borg et al. (1996) revealing differentiated tourism

impacts on historic districts through systematic studies of European heritage cities. This framework inspired exploration of Asian contexts, where Su and Teo (2009) analyzed social space restructuring in Chinese heritage tourism through Lijiang case studies. Wang and Bramwell (2012) examined tensions between heritage preservation and tourism development in Hangzhou, while Su and Wall (2014) identified systematic barriers to community participation at the Great Wall.

The perspective on urban renewal and spatial differentiation has shifted from physical to social space. He and Wu (2009) connected spatial differentiation in Chinese urban renewal to neoliberalization processes, while Wu (2016) highlighted state dominance in urban redevelopment. This institutional characteristic significantly influences heritage community development trajectories.

Public space usage patterns reveal social disparities. Peters et al. (2010) demonstrated how social cohesion effects in urban parks vary by user group, while Byrne and Wolch (2009) explained these differences' sociocultural roots. Graham (2002) further emphasized heritage's dual role as knowledge and cultural capital, influencing value distribution in urban societies.

Methodological developments offer new approaches to understanding community spatial perception. Winchester and Rofe (2016) highlighted qualitative research's value in revealing spatial cognition differences, while Bandarin and Van Oers (2012) proposed the historic urban landscape management approach for balancing preservation with development.

Current research gaps include limited systematic comparison of multiple heritage sites within one city and insufficient understanding of how different development patterns affect spatial perception and community experiences. This study addresses these gaps through comparative analysis of Suzhou's eight World Heritage gardens, examining how similar heritage types under different development patterns influence community spatial justice.

3. Research Design and Methods

3.1. Study Area

This research examines eight UNESCO World Heritage classical gardens in Suzhou: the Humble Administrator's Garden, Lion Grove Garden, Lingering Garden, Master of the Nets Garden, Canglang Pavilion, Ou Yuan, Garden of Cultivation, and Huanxiu Mountain Villa. Following Bandarin and Van Oers' (2012) historical urban landscape approach, we defined a 500-meter radius (10-minute walking circle) from each garden's main entrance as the primary study area. This boundary aligns with both residents' daily activity patterns and the spatial characteristics of Suzhou's historic district. Due to geographic proximity, some adjacent gardens were combined into unified study areas (Figure 2).

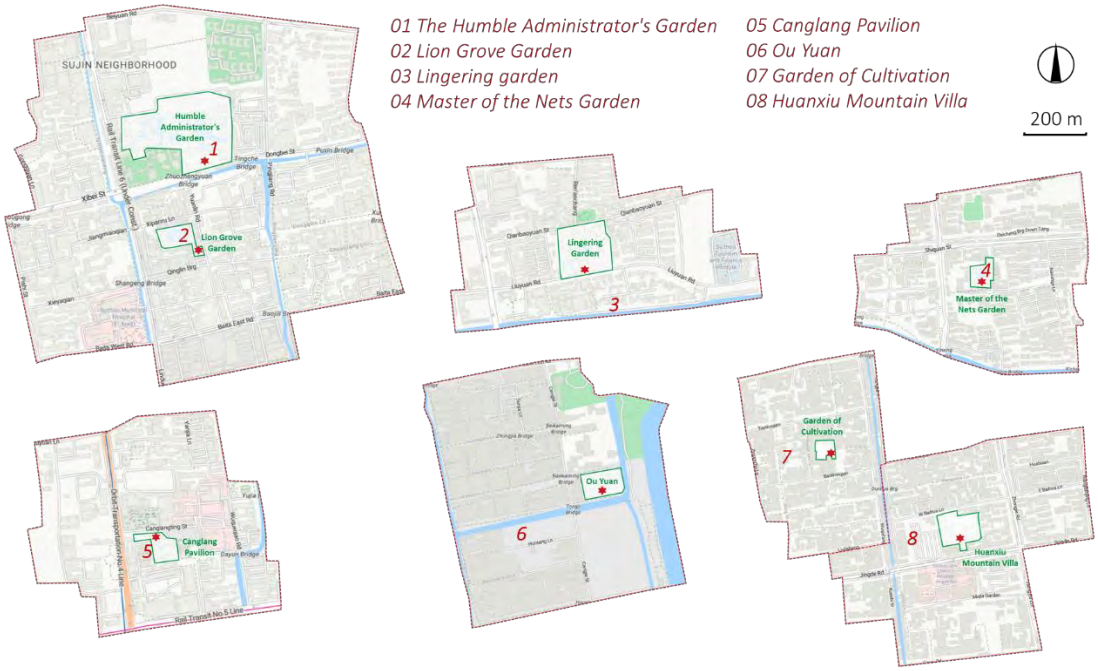


Figure 2. Study Population and Scope of Heritage Communities

The research examines two spatial scales:(1) Community scale: 500-meter radius for analyzing immediate neighborhood dynamics. (2) Extended neighborhood scale: 2-3 km² area (15-minute living circle) for assessing broader public facility distribution

3.2. Methodology

The study employs a mixed-methods approach combining field surveys, interviews, and supporting data analysis. Field investigation includes mapping of land use patterns and public facility distribution within defined study areas. Semi-structured interviews (n=39) were conducted with residents (n=26), garden and community managers (n=9), and local business owners (n=6). The resident interviews were stratified by housing type to ensure representation across different social groups. Besides, the interviews followed a carefully designed protocol addressing three key aspects: daily recreational patterns, cultural recognition, and spatial accessibility perception. The interviews adopted a focused format, with each conversation lasting approximately 10-20 minutes to accommodate residents' daily routines while capturing key information about their spatial experiences. The interview questions were carefully designed and refined through pilot studies to ensure efficient data collection focusing on three key aspects: daily recreational patterns, cultural recognition, and spatial accessibility perception. The resident interviews were stratified by housing type to ensure representation across different social groups.

Supporting data includes analysis of online platforms (Ctrip, Anjuke, Dianping) for tourism, housing, and consumption patterns, alongside government planning documents and historical records. This multi-source approach enables triangulation of findings and comprehensive understanding of community dynamics.

The analysis framework examines both physical and social space characteristics. Physical space analysis focuses on residential land proportion, facility accessibility, and spatial configuration. Social space analysis considers community demographics, activity patterns, and social interactions. This integrated approach allows for systematic examination of how different development patterns in heritage communities influence residents' daily experiences and spatial justice issues.

4. Research Findings

4.1 Spatial Differentiation in Heritage Communities

The systematic investigation of eight classical gardens and their surrounding communities reveals distinct patterns of spatial differentiation. Through analysis of residential land proportion and public facility distribution four development patterns emerge in these heritage communities (Table 1).

Table 1. Assessment of residential area proportion and surrounding facilities of heritage community.

		Proportion of residential area	Tourism service	Hospital	School	Cultural venue	Exercise area	Pattern
1	The Humble Administrator's Garden	49.98%	●	●	●	●	/	Tourism
2	Lion Grove Garden							
3	Lingering garden	45.91%	○	/	/	○	○	Synthesis
4	Master of the Nets Garden	40.26%	○	/	●	/	/	Synthesis
5	Canglang Pavilion	15.98% (min)	○	●	●	●	○	Facility
6	Ou Yuan	56.64%	●	/	/	●	●	Tourism
7	Garden of Cultivation	67.67% (max)	/	/	/	/	○	Marginali-zation
8	Huanxiu Mountain Villa	45.34%	/	●	○	○	/	Facility

● Adequate ○ Medium in quantity or quality / Hardly any

The distribution of public facilities shows complex patterns beyond simple quantity measures. Tourism service facilities in the Humble Administrator's Garden area, for example, demonstrate a hierarchical structure, ranging from high-end hotels to local guesthouses, creating a complete tourism service chain. This contrasts with areas like the Garden of Cultivation, where tourism facilities are not only limited but also lack systematic organization.

Medical and educational facilities show distinct spatial logics. The concentration of high-quality medical resources near Canglang Pavilion reflects historical institutional land use patterns, as this area traditionally hosted important public facilities. Educational resources demonstrate a more dispersed pattern, though quality disparities exist. The presence of key schools has become a significant factor influencing residential choices, particularly among middle-class families, further reinforcing social-spatial differentiation.

Cultural venues and exercise areas exhibit different accessibility patterns across development types. In tourism-oriented areas, cultural facilities primarily serve visitors, with operating hours and programming that may limit local access. Exercise areas in these zones often take the form of formal parks with regulated access, while traditional neighborhoods rely more on informal spaces like street corners and small squares for community activities.

At the community level (500m radius from garden entrances), residential land use proportions vary significantly. The Humble Administrator's Garden area maintains 49.98% residential land within its immediate surroundings, while the Garden of Cultivation area shows the highest residential density at 67.67%. The Canglang Pavilion area exhibits the lowest residential proportion at 15.98%, reflecting its public service orientation.

Analysis of the extended neighborhood scale (15-minute walking circle, approximately 2-3 km²) reveals differentiated patterns of public facility distribution. Cultural facilities, including museums, libraries and exhibition halls, are predominantly concentrated in tourism-oriented areas, particularly around the Humble Administrator's Garden and Lion Grove Garden. Medical resources show the highest concentration near Canglang Pavilion, with varied levels of accessibility across different communities. Educational facilities demonstrate relatively balanced distribution in synthesis development areas, though quality

resources tend to cluster in certain districts. Exercise and leisure spaces are better provided in tourism-oriented zones, while traditional neighborhoods rely more on informal public spaces.

Based on these spatial characteristics, four distinct development patterns emerge. Tourism-driven areas, exemplified by the Humble Administrator's Garden, demonstrate intensive tourism development while maintaining substantial residential functions. Mixed development areas like the Lingering Garden achieve a relative equilibrium between tourism services and residential needs. The Canglang Pavilion area represents a public service-oriented pattern, with concentrated educational and healthcare facilities. In contrast, the Garden of Cultivation area shows characteristics of marginalization with limited facility development despite its high residential density.

4.2 Residential Typology and Social Space

Field research and in-depth interviews reveal that social class significantly influences residents' recreational space choices and usage patterns. The research identifies three distinct community types, each exhibiting unique spatial-social characteristics. (Table 2).

Table 2. Characteristics of Different Residential Types in Heritage Communities

Type	Built Environment	Social and Usage Features	Resident Voice
Villa Areas	• Low plot ratio (0.35-1.30) • High green coverage (40-60%) • Gated layout • Private facilities	• Wealthy residents • Private activities • Self-sufficient spaces	"The community has excellent facilities, we prefer exercising here." (Retired resident, Lion Grove area)
Multi-storey Residential	• Medium plot ratio (1.0-1.5) • Medium green coverage (30%) • Semi-open layout • Mixed facilities	• Mixed income groups • Active community life • Regular public space use	"We often visit Guangji Park, it's conveniently close." (Residents, Lingering Garden area)
Traditional Residence	• Low plot ratio (<1.0) • Low green coverage (10%) • Open streets • Limited facilities	• Elderly and migrants • Time constraints • Public space dependent	"No leisure places nearby, too busy working to have free time." (Resident, Master of Nets area)

The residential composition analysis (Figure 3) reveals patterns of socio-spatial stratification in the heritage communities. The figure shows the distribution pattern of the three residential types - villa areas, multi-storey residential buildings and traditional houses - across the eight garden communities in different color scales. The types of residential spaces and their proportions greatly influence the social structure and interaction patterns of the communities.

In areas such as the Humble Administrator's Garden (Community 1), the social spatial differentiation is most pronounced, with upscale villas adjoining traditional homes, creating distinct physical and social boundaries. This juxtaposition of contrasting housing types creates what Graham (2002) calls “micro-scale social enclaves” within heritage communities. Spatial proximity paradoxically widens social distance, as evidenced by the limited interaction between these neighboring but socially distinct groups.

In contrast, Neighborhood 3 and Neighborhood 4 demonstrate a more mixed housing pattern, with multi-story buildings serving as transition zones between different housing types. This gradual transition of housing types seems to favor a more balanced pattern of social interaction. Neighborhood 7 Garden of Cultivation area), however, shows a more homogenous pattern with a predominance of traditional housing. The population in this area is aging, with younger local residents moving out and being replaced by vulnerable groups.

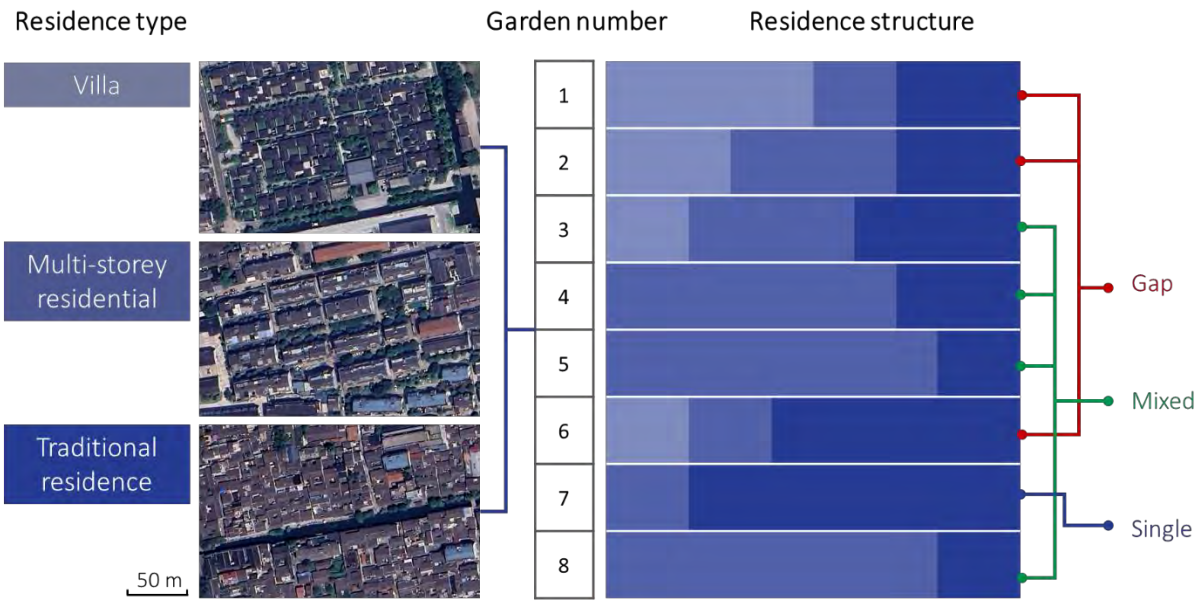


Figure 3. Residential typology analysis

The spatial and social characteristics revealed in this typological analysis demonstrate significant variations in how different resident groups interact with heritage spaces. As Su and Wall (2014) observe in their research on heritage tourism impacts, residential patterns often reflect complex relationships between spatial configuration and social practices.

4.3 Spatial Usage and Cultural Recognition

The analysis of interview data reveals significant variations in spatial usage and cultural recognition across different community types (Table 3).

Table 3. Analysis of residents' interviews and garden usage patterns

Garden number	1	2	3	4	5	6	7	8
Development Pattern	Tourism	Tourism	synthesis	synthesis	facility	Tourism	marginalization	facility
Urban leisure space compensation	○	○	●	○	○	●	/	/
Use of Gardens and surrounding spaces	○	/	/	○	●	/	●	/
Garden culture recognition	60% of the surveyed residents agreed Vulnerable groups: 47% other groups: 88%							

● Many Medium ○ Medium / Hardly any

The research finds that spatial usage patterns are closely related to community development modes. In synthesis development areas, residents show more active engagement with both garden spaces and surrounding public areas. However, in tourism-intensive areas, despite better facility conditions, residents demonstrate lower usage rates of heritage spaces, supporting Su and Wall's (2014) findings about the impact of tourism intensity on local community participation.

Cultural recognition presents a notable disparity between different social groups, with an overall recognition rate of 60%. The significant gap between vulnerable groups (47%) and other groups (88%) in cultural recognition suggests that heritage cultural capital is not equally accessible to all community members, confirming Graham's (2002) theory about the uneven distribution of heritage values in urban societies. This disparity manifests in multiple ways: through participation in cultural activities, understanding of garden history and design principles, and sense of connection to heritage spaces.

Interview data reveals that cultural recognition is closely tied to residents' daily experiences and economic conditions. Vulnerable group members often express appreciation for the gardens' aesthetic value but feel disconnected from their cultural significance. As one resident from a traditional neighborhood noted, "The gardens are beautiful, but they feel like they belong to others." This sentiment reflects broader issues of cultural capital distribution and access to heritage interpretation resources.

The relationship between development patterns and cultural recognition is particularly noteworthy. Areas with synthesis development patterns tend to show more balanced cultural recognition rates across social groups, suggesting that moderate tourism development might actually facilitate cultural transmission within communities. This finding challenges simplistic assumptions about tourism's impact on local cultural identity.

5. Discussion

5.1 Multi-dimensional Spatial Differentiation

Physical proximity to heritage sites does not guarantee equitable access to recreational spaces. Our research reveals that social space differences significantly influence spatial perception and usage patterns. For instance, a community library adjacent to both villa areas and traditional residences shows contrasting utilization patterns - wealthy residents have alternative resources and show little interest, while residents from traditional neighborhoods, despite geographic proximity, face invisible barriers to access.

The temporal dimension emerges as a critical factor in spatial justice. Heritage communities demonstrate adaptive usage patterns across different development modes. In tourism-intensive areas, residents utilize cultural plazas for evening activities after tourist hours, while in residential areas, elderly residents engage in morning exercises in garden spaces. This temporal adaptation reflects both constraints and opportunities in heritage space utilization.

5.2 Heritage Integration Challenges

The integration of heritage spaces into community life varies significantly across development patterns. Tourism-driven areas face tensions between preservation, commercial development, and community needs. Our findings support Graham's (2002) argument about heritage's dual role as cultural capital, revealing how social class shapes cultural recognition and space utilization.

Different development patterns require distinct approaches to community space provision. The research demonstrates that successful heritage integration depends not only on physical accessibility but also on addressing social barriers and temporal constraints. This finding extends Wu's (2016) observations about state-led urban development by highlighting the importance of community-specific solutions.

5.3 Planning Implications

Research findings suggest three key planning considerations:

First, inclusive design strategies must address both physical and social accessibility. This includes creating flexible spaces that accommodate different user groups and considering temporal use patterns in facility planning.

Second, community participation mechanisms need strengthening, particularly for vulnerable groups. The significant disparity in cultural recognition rates between social classes (47% vs. 88%) indicates the need for more inclusive heritage interpretation and community engagement approaches.

Third, development strategies should be differentiated based on community characteristics while maintaining spatial justice principles. This might involve time-sharing arrangements in tourist-heavy areas or integrated community facilities in residential zones.

6. Conclusion

This research advances our understanding of spatial justice in heritage communities through systematic comparison of Suzhou's eight World Heritage gardens. Three key findings emerge from the study:

First, spatial justice in heritage communities extends beyond physical accessibility. The research reveals how social space differences significantly influence residents' perception and usage of recreational spaces, challenging traditional approaches that focus primarily on facility distribution.

Second, similar heritage types under different development patterns create distinct community experiences. The study identifies four development patterns - tourism-driven, synthesis, facility-oriented, and marginalized - each generating unique challenges and opportunities for community space utilization.

Third, temporal dynamics play a crucial role in spatial justice. Communities demonstrate adaptive usage patterns, suggesting the need for flexible and time-sensitive approaches to heritage space management.

These findings have important implications for heritage community planning. While the study focuses on Suzhou's Classical Gardens, the analytical framework and findings contribute to broader discussions of spatial justice in heritage contexts. Future research could explore long-term changes in community adaptation patterns and examine the effectiveness of different policy interventions in promoting spatial justice.

The research has certain limitations, particularly in capturing the full complexity of residents' subjective experiences. Additionally, the study's focus on current conditions could be complemented by longitudinal research examining how community spaces evolve over time.

7. References

Bandarin, F. and Van Oers, R. (2012) The Historic Urban Landscape: Managing Heritage in an Urban Century. Chichester: Wiley Blackwell.

Byrne, J. and Wolch, J. (2009) 'Nature, race, and parks: past research and future directions for geographic research', Progress in Human Geography, 33(6), pp. 743-765.

Graham, B. (2002) 'Heritage as knowledge: capital or culture?', Urban Studies, 39(5-6), pp. 1003-1017.

Gu, H. and Ryan, C. (2008) 'Place attachment, identity and community impacts of tourism—the case of a Beijing hutong', Tourism Management, 29(4), pp. 637-647.

Harvey, D. (2010) Social Justice and the City. Revised Edition. Athens: University of Georgia Press.

He, S. and Wu, F. (2009) 'China's emerging neoliberal urbanism: Perspectives from urban redevelopment', Antipode, 41(2), pp. 282-304.

Lefebvre, H. (1991) The Production of Space. Oxford: Blackwell.

Liu, Y. and Wu, F. (2006) 'Urban poverty neighbourhoods: Typology and spatial concentration under China's market transition, a case study of Nanjing', Geoforum, 37(4), pp.610-626.

Low, S. (2011) 'Spatializing culture: embodied space in the city', in Bridge, G. and Watson, S. (eds.) The New Blackwell Companion to the City. Oxford: Wiley-Blackwell, pp. 463-475.

Pendlebury, J. (2009) Conservation in the Age of Consensus. London: Routledge.

Peters, K., Elands, B. and Buijs, A. (2010) 'Social interactions in urban parks: Stimulating social cohesion?', Urban Forestry & Urban Greening, 9(2), pp. 93-100.

Silverman, D. (2013) Doing Qualitative Research: A Practical Handbook. 4th edn. London: SAGE.

Smith, L. (2006) Uses of Heritage. London: Routledge.

Soja, E.W. (2009) 'The city and spatial justice', Justice Spatiale/Spatial Justice, 1(1), pp. 1-5.

Su, M.M. and Wall, G. (2014) 'Community participation in tourism at a world heritage site: Mutianyu Great Wall, Beijing', International Journal of Tourism Research, 16(2), pp. 146-156.

Su, X. and Teo, P. (2009) The Politics of Heritage Tourism in China: A View from Lijiang. London: Routledge.

Van der Borg, J., Costa, P. and Gotti, G. (1996) 'Tourism in European heritage cities', Annals of Tourism Research, 23(2), pp. 306-321.

Wang, Y. and Bramwell, B. (2012) 'Heritage protection and tourism development priorities in Hangzhou, China: A political economy and governance perspective', Tourism Management, 33(4), pp. 988-998.

Winchester, H.P. and Rofe, M.W. (2016) 'Qualitative research and its place in human geography', in Hay, I. (ed.) Qualitative Research Methods in Human Geography. 4th edn. Oxford: Oxford University Press, pp. 1-28.

Wu, F. (2016) 'State dominance in urban redevelopment: Beyond gentrification in urban China', Urban Affairs Review, 52(5), pp. 631-658.

Wu, Q., Cheng, J., Chen, G., Hammel, D.J. and Wu, X. (2014) 'Socio-spatial differentiation and residential segregation in the Chinese city based on the 2000 community-level census data: A case study of the inner city of Nanjing', Cities, 39, pp.109-119.

Wu, Q., Zhang, X. and Waley, P. (2016) 'Jiaoyufication: When gentrification goes to school in the Chinese inner city', Urban Studies, 53(16), pp.3510-3526.

Zhu, H., Qian, J. and Gao, Y. (2011) 'Globalization and the production of city image in Guangzhou's metro station advertisements', Cities, 28(3), pp.221-229.

Zukin, S. (2012) 'The social production of urban cultural heritage: Identity and ecosystem on an Amsterdam shopping street', City, Culture and Society, 3(4), pp. 281-291.

Case Study Report

The Problem of Cultural Heritage: What Is Heritage Value for Residents?

Polina IVANOVA, BTU Cottbus – Senftenberg, Germany

Abstract

Heritage plays an important role in the collecting, preservation, and development of the memory of our past. Representatives of different levels participate in this process - official institutions, the expert community, and users, including the local community. This article is devoted to studying the value of heritage for residents. The study of this issue took place through the search for narratives about the heritage of residents of the village of Solovetsky. The main research method is qualitative methods, in-depth interviews. As an example, a place with a high concentration of cultural heritage sites was chosen - the village of Solovetsky, Russia. The article aims to expand the understanding of the role of residents in the process of creating and preserving heritage. As a result of the study, it was concluded that heritage values tend more toward the recent past and are associated with rituals common to a social group. The results confirm the need to consider the experience and opinions of the local community when working with heritage. To preserve the collective memory and identity of the community, it is necessary to use the heritage in the present and create a space for dialogue between the past and the present.

Keywords

Cultural heritage, Value, Community, Heritage protection

1. Introduction

«The city is the collective memory of peoples. Just as memory is tied to facts and places, the city is a locus of collective memory. This connection between the locus and the citizens forms the dominant image, architecture, and landscape; and just as facts enter memory, new facts are built into the city. In this quite positive sense, great ideas fill and shape the history of the city», wrote Aldo Rossi [2015:184]. Continuing his thought, let's say that memory plays a significant role in the process of forming the space of the city. We preserve the evidence of the past and create new monuments so that the memory takes on a material embodiment. But the preservation process is not absolute, it is like a sieve separating what will be forgotten from what will be preserved as a legacy. With the emergence of institutions and organizations dealing with heritage issues, the process of preserving the past becomes associated with legal procedures, and the determination of historical value becomes the task of the expert community. In our opinion, the process of formation and determination of historical value takes place not only at the expert, highly professional level, but also at the everyday level - residents endow objects with their meanings. This process is especially noticeable during the demolition of objects that were important for residents not only from a functional point of view but also as part of their identity, their collective memory.

The purpose of this work is to study the narration of the inhabitants of the village of Solovetsky to identify the characteristics that form the value of objects in collective memory. Answers to these questions will expand the understanding of the role of residents in the process of creating and preserving heritage.

1.1. Case study

As a case, a space with a high concentration of heritage sites, the village of Solovetsky, was chosen. The Solovetsky archipelago located in the White Sea at the entrance to Onega Bay. The village of the rural type Solovetsky located on the western coast of the Big Solovetsky Island, one of the six large Solovetsky Islands. The Solovetsky Islands are an interconnected complex of architectural, archaeological, natural, spiritual heritage, and natural and cultural landscape context [Kuleshova 2016: 9]. During its existence, the village of Solovetsky has gone through various stages of historical development. A conditional division can be made as follows: the first traces of a person, monastic existence, the period of functioning of the Solovetsky Special Camp, the time of the management of the Navy, and modernity. Each of the periods remained imprinted in architecture and monuments.

The value and uniqueness of the Solovetsky archipelago is also emphasized by UNESCO. The International Council for the Protection of Monuments and Sites included the archipelago under IV criterion. On the Solovetsky Archipelago, 189 historical and cultural monuments are included in the Unified State Register of Cultural Heritage Objects, 75 of which are in the village of Solovetsky.

The heritage of the Solovetsky Archipelago plays an important role in Russian and international conservation discourse. The territory of Solovki is also associated with the discourse on the topic of camp heritage, as a space of memory about the Gulag period and those who suffered during political repressions. Thus, a field of meanings is created around the heritage of the Solovetsky Archipelago with the participation of many external agents. At the same time, the opinion of residents is often outside the discourse.

Research Methods

Qualitative methods, namely in-depth interviews, were chosen as the main research method. The choice of this method is a common tactic in the study of narration and heritage. In addition, language itself is an example of a supra-individual phenomenon [Olik 2012: 31].

Residents of the village of Solovetsky were selected as respondents. The Solovetsky community lives in the settlement of Solovetsky and consists of a single community, numbering from 700 to 1300 people [Plyusnin 2021]. As part of the study, interviews were taken with employees of the naval base and descendants of military personnel; workers of the agar plant and their descendants; museum workers and "urban intelligentsia" [Plyusnin 2021].

The main stage of the study took place during two field trips. During the first trip, an initial study of the Solovetsky community was carried out. It was concluded that for this community the thesis of A. Appadurai is relevant that the local is not so much belonging to a place, but rather a connection with space [Appadurai 1996].

Most of the in-depth interviews were conducted during the second field study, which took place in early March and lasted a week. The search for respondents was carried out using the snowball method, based on those residents who were recommended by the first respondent. Additionally, paper announcements were posted on the information board in the central part of the village, and the news was published in communities dedicated to the village of Solovetsky on social networks, but no response was received.

As part of this study, 11 in-depth interviews were conducted, lasting from 40 to 120 minutes. The interview results were processed according to the thematic blocks of interest to us.

A typical respondent can be described as a Solovetsky resident aged 45-60 who came to the island at an early age with his family. The work is connected either with the activities of the museum or with employment in the tourism sector during the period from May to October.

Figure 1: Solovetsky settlement (2022)

2. Resident's criteria for the value of the heritage

One of the defining characteristics of heritage is its value. Value is what is attributed to an object, place or practice by certain people at certain times for certain reasons. [Harrison 2009:26].

The first parameter that forms the value is the glorification and mythologization of the past. In Solovki, this is manifested in the narratives about the heritage of the monastic period. There is not just building a relationship with the ancestors: «Everything must be preserved, everything that was created by us, what was before us», but also admiration for the activities of the monks in the past – «Such boulders, screed. Everything was provided. You can say it's genius». The image of the monk is heroized – «People before us did it, as they could do everything. I am ready to kneel before them. What they did, they did for ages». Their work is perceived as heroic: «Who will build such a road now? Such boulders had to be raised to build the Kremlin. There was no such technology». In contrast to the present, this myth is reinforced. It seems that nothing like this can be created. As D. Lowenthal wrote: "We admire the relics of the past, but we are no longer inspired by our actions and works" [2004: 26]. Admiration for the heritage of the monastic period allows the formation of a positive self-identification and collective identity.

The second parameter of the value of heritage is the ritualization of the past. This is the process of creating a certain ritual, in its simplified understanding, as general behavioural practices [Chernykh 2012:25]. An additional criterion for creating a ritual is its connection with the unique functional purpose of the object. As an example, can be Beletskaya banya, a boulder masonry structure built at the end of the 18th century. Until the mid-1990s, the bath was used for its functional purpose. Bath in Slavic culture is of great importance, both functional and symbolic [Chernykh 2012: 25]. In the village of Solovetsky, this is intensified because hot water was not available in all houses for a long time. The situation has changed only in recent years. Since the mid-1990s, the Beletskaya bath has ceased to be used for its functional purpose. Instead, a new bathhouse was built not far from it. It did not last long and was closed due to economic inexpediency. During its existence, the ritual did not take shape and its value is not manifested in the collective memory. The value of the Beletskaya bath increased in contrast to the old and the new. «The bath that was restored, did not give what it was before. Lost unity. In this bath, which was now working, for about half a year, people came only to wash themselves. And in the former [Beletskaya] they came to wash and talk, discuss, invite a friend to visit, agree on fishing, invite them to tea. In general, it was different». This example confirms the importance of preserving the heritage. Attempts to recreate the same functions, but in a different building, do not make up for what was lost – «The bathhouse was simply turned into a washing room. And not in a place where they communicate»

The third parameter of the value of heritage objects is historical value. In Alois Riegl's classification of values, the historical value «consists in the fact that it presents us with a completely definite, so to speak, individual stage in the development of any area of human creativity" » [2018]. In the narratives of the inhabitants of the village, the historical value manifests itself as a reflection of the events of the past in the object. Heritage objects store evidence of the events that took place on this territory. «It's part of history, part of us. Because we are not just cut out of cardboard there. We are assembled from something, nourished by something. Our ancestors tried».

Historical value also includes evidence of tragic events. Monuments of the camp period are valuable because they serve as a reminder of what should not be repeated. «Of course, this is our memory. To not repeat. We must remember not only the good. This is our whole history, like our life - there is good and bad. We must remember. This is experience, these are mistakes, this is the possibility of not repeating». Memory must be preserved and passed on so that it is not forgotten.

Additionally, the residents' narratives about the importance and necessity of preserving the heritage were explored. At the stage of direct actions for conservation, institutions become the main actor. If we take the example of the Beletskaya Banya, then from the point of view of residents and existing practice, the strategy for preserving the building as a museum. This means the impossibility of carrying out the ritual - going to the bathhouse. The disappearance of the ritual will lead to the loss of some of the values. The loss of the values of the heritage, in turn, will lead to the gradual forgetting of narratives in the collective memory and the possible disappearance of the heritage. «Preservation is not an action or an epilogue, it is only a prologue» [Lowenthal 2989:153]. The study suggests that the use of heritage in the present and its participation in the daily life of the inhabitants multiplies values. D. Lowenthal points to three options for preserving the material heritage the preservation of fragments; preservation of the process of manufacturing materials and building objects for the possibility of reproduction; representation of images of the past through painting, paper, non- verbalized memories [1989:145].

Figure 2: Beletskaya Banya (2022)

3. Conclusion

As a result of the study, what parameters influence the value of heritage, and how the process of preserving heritage is interpreted in the narratives of residents. In conclusion, we would like to repeat the main conclusions, as well as give a few theses about the reasons for the need to study the values of the heritage for residents.

Residents of the village of Solovetsky attribute to the heritage elements of the natural component and historical monuments located in the village and on the archipelago. They see heritage, to a greater extent than the experts, as turned to the recent past and is associated with events, habitual rituals that were common to the social group. When analysing the values of the heritage for residents, three parameters were identified - glorification and mythologization of the past: historical value and ritualization of the past.

Understanding what values are laid down by a social group is necessary for expert work with a territory. When revitalizing heritage sites, the use of residents' narratives allows us to understand and preserve the meanings and values that are created by the social group. This allows not only to form a connection between the past and the present, but also to preserve the heritage as a process of creating values.

Speaking about the strategies for preserving the heritage, it seems important to consider the experience and opinion of the local community. Using heritage to create a platform for uniting a social group will allow creating a space for dialogue between the present and the past. Saving the past can be a way of teaching future generations [Lynch 1972:43] but can also be a way of maintaining a collective identity in the present. Residents should not be isolated from the process of heritage conservation. Not only their opinion about how the object will look like and what its functional purpose will be, but also what meanings and values are contained in the collective memory of residents should be considered.

4. References

Appadurai A. (1996). Modernity at Large, Minneapolis and New York: University of Minneapolis Press.

Chernykh A. I. (2012). Rituals in a mediatized society. M.: Ed. home of the Higher School of Economics.

Harrison R. (2009). Understanding politics of heritage. Manchester: Manchester University Press in association with the Open University.

Kolesnik A., Rusanov A. (2020). Heritage-As-Process and Its Agency: Perspectives Of (Critical) Heritage Studies // *Working Papers of Humanities.* WP. M., Publishing house NRU HSE.

Kuleshova M. E. (2016). The concept of a cultural landscape for the purposes of heritage protection and evaluation of management decisions. Solovetsky Archipelago// Polar Readings on the Krasin icebreaker, 3.

Lowenthal, D.T. (1989). Material Preservation and Its Alternatives. *Perspecta, 25*, 66.

Lowenthal, D.T. (2014). Past is a foreign country.

Lynch K. (1972). What time is this place. The MIT Press.

Olik J.K. (2012). Memory Figuration: A Process- Relational Methodology Illustrated in Germany. *Sociological Review,* 11(1), pp. 40-74.

Olik J.K. (2018). Memory is not a thing or an object. Memory is a continuous process." Interview with J.K. Olik. *Historical expertise.* 4(17).

Plyusnin Y. (2021). Materials of the seminar “Sociology of isolated societies. An example of Solovki in the dynamics of its local political history, 1990-2020 ”. Plusnin Y. M.

Riegl A. (2018). Modern cult of monuments: its essence and origin. Moscow: V - A - C press.

Rossi A. (2015). City architecture. Moscow: Strelka Press.

Research Paper

A Study on the Evaluation and Creation of Community Cultural Spaces from the Perspective of Scene Theory

A Case Study of Tianjin Community

Qiu, Zhiyong. School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China.

Zhang, Xinjian. School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China.

Yin, Conghui. School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China.

Yang, Ling. Architecture Design and Research Institute of HIT, China.

Abstract

Cultural locality and diversity have become the driving forces of community development. In the existing studies, scene theory has guided the transformation of general public space into cultural production space, which not only pays attention to the creation of a material environment but also pays more attention to the characteristics of cultural behaviors of the people, and has far-reaching significance in expanding the way of 'materializing culture' and promoting the renewal of urban community space. However, its inner mechanism and practical influencing factors need to be further studied. In this paper, we deconstruct the space under the framework of the scene, translate the elements of the scene in the community context, construct an evaluation system, take the community cultural space as the object of evaluation, and empirically select 28 sample communities in six types of districts in Tianjin, and summarise the problems of insufficient and poor quality of community hardware resources, the tendency of the cultural scene to be conservative and lack of characteristics, and the limited development of the residents' participation paths and self-organization, and so on. Combining the matching, guiding, and endogenous dynamics of scenario theory, the study proposes guidelines for community cultural development in terms of optimizing spatial quality, reshaping symbolic value, and coordinating people's activities.

Keywords

elements of scenario theory, community cultural space, cultural scenario creation, optimising the creation of guidelines

1. 1. Introduction

1.1. Research Background

Currently, China's community construction has entered a stage of high-quality development, with the constitution cultural consumption gradually becoming a new driving force for urban development, and community cultural development becoming an important component of urban cultural construction. The

lack of cultural facilities at the community level and the decline of cultural spirit at the community core have led to the loss of a sense of belonging in public space, which brings about a lack of original community dynamics. Therefore, it is necessary to link community governance, community identity, and cultural practice to promote the development of community culture; to combine public space, living facilities, and cultural practice to facilitate the formation of community internal vitality; and to combine spatial design, crowd guidance, and cultural practice to enhance the ability of community development action and change.

As a new perspective for urban research, scenario theory focuses on the support of culture for urban development and constitutes the function and significance of cultural values for urban development, which is more suitable for starting from the community dimension and avoids too macroscopic and abstract expressions of culture. Through research on the organization of micro-space, the perception of people, and the adaptation of cultural activities, it is found that scene theory is conducive to shaping the values and lifestyles of community members and enhancing their sense of belonging and responsibility. Through the interaction of environmental, behavioral, and population elements in a specific community scene, a differentiated and targeted specific scene is created, which promotes cultural development as an endogenous driving force of the community.

1.2. Content and Significance of the Study

Terry N Clark and his research team introduced the concept of Scenes into urban research as a new perspective on urban form, focusing on the interactions between the physical environment, socio-cultural and human behaviors, and through the study of specific scenarios, understanding the evolution of urban form trends and highlighting cultural values. Unlike traditional research on public cultural service systems, scenario theory emphasizes the interaction between space and cultural practices and explores the expression and influence of cultural patterns in scenarios. Scenario creation is a holistic approach to creating spaces with a sense of design and attraction through the inclusion of facilities and activities, and the combination of cultural comforts that match the needs of different groups of people.

Scene theory emphasizes the five elements of the neighborhood, physical structures, individual persons, activities, and value, where the value element is more serves as a basis for the neighborhood scope, and the ingredients of space, people, and activities work together to form a good scene effect.

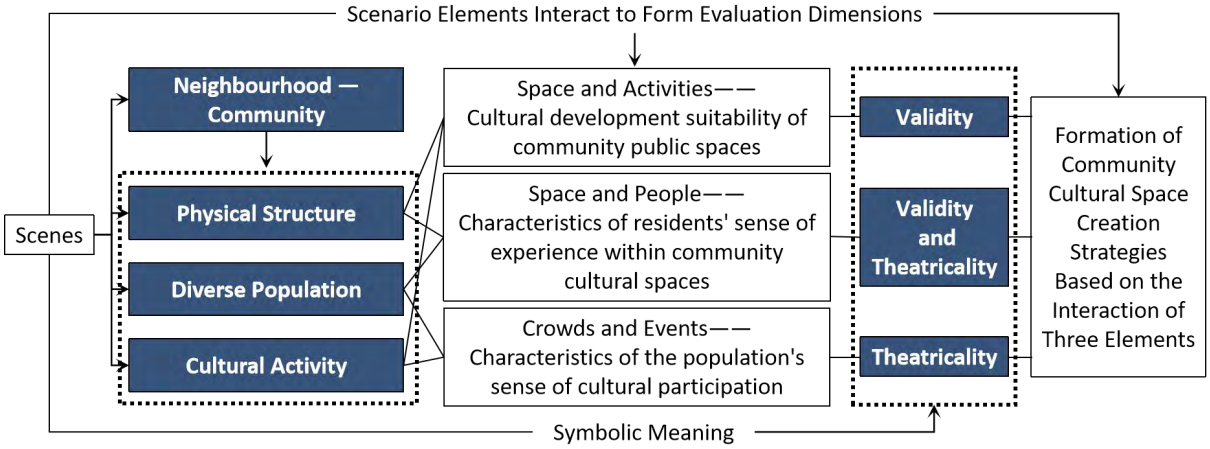


Figure 1. Definition of Elements in Scene Theory. Source: Author's self drawn.

This paper analyses the adaptive mechanism of scene theory and community cultural development through the characteristics and value of cognitive scene theory, defines the interpretation of scene elements in the context of community cultural space, and takes ‘determining the evaluation model, applying empirical analysis and proposing optimization guidelines’ as the main line of research. Through

the empirical study of 28 sample communities of 6 categories in Tianjin, the study explores the construction of community cultural space and facilitation of the overall development of community culture through the creation of cultural scenes at the micro level.

1.3. The Applicability of Scene Theory to Community Culture

(1) Endow the community with diverse material structural elements

Scene theory focuses on the construction and communication of the texture characteristics and cultural values in the cultural space of multi-form communities. Research data on various cultural facilities in cities shows that comfortable objects in scenes can reflect distinct local cultural characteristics, and the characteristics of multiple types of material spaces can also make people perceive different cultural values. Some studies apply the scene concept to the updated design of material structures, such as transforming community landscapes through cultural and artistic techniques and reshaping community cultural facilities with local cultural resources. Scene theory enables the study of material structures in a "unitized" manner, facilitating the collection and design positioning of research data, and enabling more precise and detailed adjustment of space to meet different needs.

(2) Extended scenario multi-level cultural practice activities

Scenarios can guide diverse populations to form interactive relationships, explicitly or implicitly shaping individuals' perceptions of community culture and establishing emotional connections within the community. Improving the quality of the scene and promoting nonessential activities such as walking, stopping, chatting, and socializing can stimulate the cultural vitality of the community. For specific group behaviors, such as planning age-appropriate cultural activities, focusing on the history of the community and the Indigenous ecology of the older can evoke cultural resonance within the scene. There is no fixed way to create a scene, and attention needs to be paid to the true characteristics of the community. Through multi-level practical activities, the preservation and management of local culture can be achieved.

(3) Satisfy the cultural and spiritual pursuits of diverse populations

Scene theory focuses on the "human scale" and "human needs", paying attention to residents' participation and expression of opinions. By stimulating participants' senses and emotions, the scene can generate a pleasant and immersive buzz, further enhancing the audience's attention to cultural values. Research has found that by using collective emotions as a bond and collaborating with residents, experts, businesses, and governments to jointly build communities, residents can gain a strong sense of participation and enhance their sense of ownership in the community-building process.

2. Evaluation of Community Cultural Space Based on Scene Theory

2.1. Approach to evaluation system under scenario framework

The community cultural space discussed in this article is the physical field on which residents' cultural life relies, and it is also a holistic concept that covers cultural practice activities, cultural operation mechanisms, and community cultural resources. Research from the perspective of scene theory, this study translates the content of scene theory from the aspects of theoretical logic, basic connotation, and constituent elements, and investigates the "element mechanism" relationship between scene theory and the community cultural field, as a support for evaluating and optimizing community cultural space. And form a research dimension that combines space, crowds, and activities in pairs.

(1) Space and Activities - Cultural Development Adaptability of Community Public Spaces

In the interaction between material structure and cultural activity elements, space is the carrier of activity, and activity is the foundation of production space. Residents' needs for cultural products are mainly based on the experience of cultural symbols in the space, thus creating an intangible driving force for cultural production itself. This endogenous force comes from the service level of cultural facilities in the community space, the cultural activity practice environment, and the cultural scene composed of residents' cultural experiences. In the scene, it is necessary to continuously optimize the material structure, and reserve design flexibility and adaptability, to achieve a good match between spatial cultural production and cultural practice.

(2) Space and Crowd - Characteristics of Residents' Experience in Community Cultural Space

Different scenarios are combinations of comfortable facilities and activities, which contain functions and convey cultural values and lifestyles. The characteristic attributes of the scene attract different groups of people and the cultural values, lifestyle, and quality of life it contains play an important role. The crowd constantly adjusts, transforms, and adapts to the material space as time and space change, and these spaces with their characteristics and functions reflect people's value tendencies and actual needs. The cultural features of space also influence social thought, and people's behavior and interaction are constantly changing in the evolution of space. The relationship between people and space is interdependent, and evaluating community cultural spaces requires attention to residents' experience of using the space, as well as the emotional benefits gained by residents after the space influences changes in their behavior patterns.

(3) Crowds and Activities - Characteristics of Residents' Cultural Participation

In the interaction between diverse groups of people and cultural activity elements, people's choices and participation in activities are a manifestation of free will, and activities can also affect the thoughts and behaviors of the participating groups. People's reactions and evaluations of activities can directly or indirectly affect their popularity and operational development. Activities can also help people understand themselves, promote communication, and even change their values and ways of thinking. There is a complex dialectical relationship between people and activities. When evaluating the relationship between activities and people, it is necessary to evaluate the attractiveness of the activities themselves and the social impact they bring.

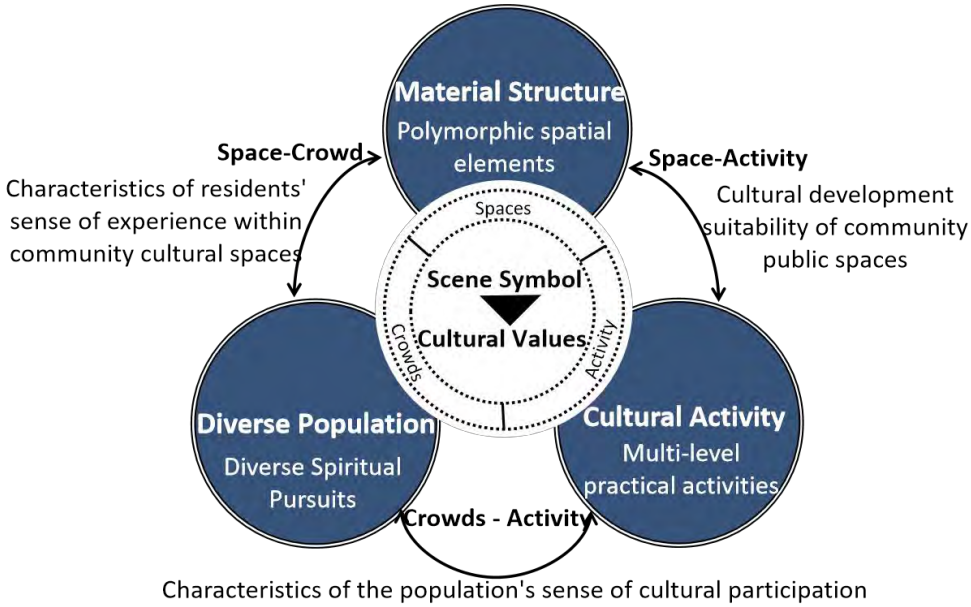


Figure 2. The process of forming an evaluation framework for scene elements. Source: Author's self drawn.

2.2. Exploration of evaluation indicators under scene elements

Communicating in a scene is a channel for obtaining resident information and providing real-time and accurate information dissemination and services to the population. In the scenario theory system, scenario measurement can quantitatively analyze and evaluate the impact and service effectiveness of specific scenarios. Referring to the classification of the New Chicago School, scenario analysis sets the subjective value system into three main dimensions: authenticity, theatricality, and legitimacy, 15 dimensions are divided under these three levels. By establishing a framework of primary and secondary dimensions and performing multidimensional assignment calculations, the value orientation of the scene can be determined. This article adopts the method of on-site visits to understand the subjective needs of residents, observes and studies the objective structure on-site, and combines the research results of relevant literature to screen and refine 6 categories and 16 measurement indicators based on actual usage effects.

The analysis method constructs a structural model consisting of a target layer (A), a criterion layer (B), a factor layer (C), and an indicator layer (D). The indicators are classified into levels according to the factor layers of the three dimensions, and the evaluation system is finally obtained.

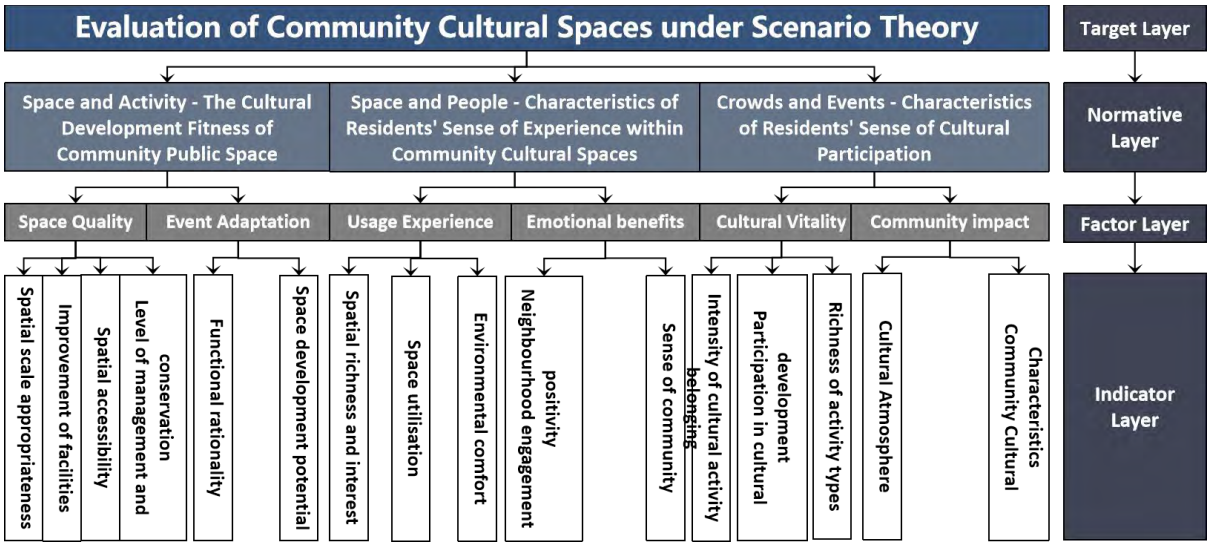


Figure 3. Construction of evaluation index system. Source: Author's self drawn.

2.3. Application of Tianjin Typical Community Evaluation System

As the birthplace of the old city area, the six districts within Tianjin city are rich in historical heritage and cultural resources. In 2021, the Tianjin Planning and Natural Resources Bureau released the "Guidelines for Urban Design of New Residential Communities in Tianjin" (hereinafter referred to as the "Guidelines"). Within the block units, specific types of neighborhood committees with different characteristics have been classified based on factors such as location conditions, built environment, transportation conditions, and historical protection. This study selected 6 typical areas within 6 districts of Tianjin city, including 28 sample communities. The occupancy rate of the sample community is relatively high, and the age limit for community construction is over 3 years. The total number of households in the community exceeds 500. The selection of research subjects comprehensively considers factors such as the distribution of different locations in the community area, local economic conditions, and community types, covering all molds of neighborhood committees within the built-up area of the city as specified in the Guidelines, to ensure the typicality and representativeness of the research sample communities.

Community type	Select communities	Location Resources	Community characteristics	Resident characteristics
Surrounding communities of the park	4	City Park	Multi story buildings are the main focus, with a good ecological environment and complete living facilities	All age group population
Old community	5	Cultural and educational facilities	Built for a long time, with low building quality, insufficient open space, and aging infrastructure	Mainly middle-aged and elderly people
Multi layer TOD community	4	Subway stations, large commercial districts	The public transportation system is complete, the living facilities are abundant, and the block scale is pleasant	All age group population
Medium to high intensity community	4	City squares, large commercial districts	High level of openness, highly mixed functions, and sufficient public space	All age group population
Historical Community	9	Historical scenic spots, urban squares	It has a historical background and was built for a long time. Rich cultural and tourism resources	Mainly elderly and tenants
High-intensity community	2	Street living facilities, community cultural facilities	Significant agglomeration effect, multiple functions meet the demand for cultural facilities	More middle-aged and young people

Figure 4. Analysis of the current situation of the research community. Source: Author's self drawn.

This study developed an expert questionnaire for evaluating the importance of evaluation indicators for cultural spaces in typical communities in Tianjin and obtained a judgment matrix. Interviews were conducted with staff members from 28 sample communities to compare and score the importance of indicators, and 128 valid data were collected. Calculate the average score of each evaluation indicator, adjust according to the degree of dispersion, construct a judgment matrix based on this, conduct consistency testing, and calculate the weight values.

Target layer	Criteria layer	Absolute weight	Factor layer	Comprehensive weight	Indicator layer	Comprehensive weight	Sort
Community Cultural Evaluation under Scene Theory—A	Space - Activities	0.5813	Space quality—C1	0.4359	Suitability of spatial scale—D1	0.0531	6
					Facility completeness—D2	0.2432	1
					Spatial accessibility—D3	0.0248	10
					Management and maintenance level—D4	0.1148	3
			Activity adaptation—C2	0.1453	Functional rationality—D5	0.1211	2
					Potential for spatial development—D6	0.0242	11
	Space - Crowd	0.3092	User's experience—C3	0.2473	Space utilization rate—D7	0.1124	4
					Space richness and fun—D8	0.0225	12
					Environmental comfort level—D9	0.1124	5
			Emotional benefits—C4	0.0618	Positive neighborly interaction—D10	0.0464	8
					Sense of community belonging—D11	0.0155	13
	Crowd - Activity	0.1096	Cultural vitality—C5	0.0913	Cultural activity intensity—D12	0.0531	7
					Participation in cultural construction—D13	0.0282	9
					Rich variety of activity types—D14	0.0100	15
			Community impact—C6	0.0183	Creating a cultural atmosphere—D15	0.0137	14
					Community cultural characteristics—D16	0.0046	16

Figure 5. Summary Table of Indicator Weight Values. Source: Author's self drawn.

Research in the light of constructing a fuzzy comprehensive evaluation model for the evaluation index system and its associated weight reconstruction. Firstly, each factor in the evaluation factor set (U) is quantitatively scored according to 5 rating levels to determine the evaluation factor set (V). Then, the questionnaire survey data will be classified and counted according to the percentage system for the

number of respondents on different comment sets, and finally used as the membership matrix (R) of the indicator on the corresponding comment set. Based on the previous expert scoring data, the weight values of the indicators are calculated, and the weight set (ω) of the factors is determined. The fuzzy comprehensive evaluation vector (B) is obtained through matrix operation. Finally, the actual scores of each indicator layer are calculated by multiplying B by V.

3. Empirical Analysis of Community Cultural Space Evaluation Results

This study adopted three approaches for data collection. The first method is field research, which collects data through real-life photography. The second method adopts the in-depth interview method in "qualitative research", selecting 28 community members for semi-structured interviews. The interviewees include community workers, cultural activity organizers, and ordinary residents, collecting their willingness to use community cultural spaces and construction management information, and obtaining 28 valid interview samples. The third method is a questionnaire survey, which distributes questionnaires to 28 sample communities in 6 districts to obtain the basic information of the surveyed population and their feedback on the indicators. Each district distributed 100 questionnaires, totaling 600, and received 583 valid questionnaires, with an effective rate of 97.17%. The target layer (A) score of 128 sample communities is 2.93 (<3), with a rating close but not reaching a good level. The score of factor level indicators shows that the community has obvious shortcomings in creating characteristic cultural scenes, mobilizing residents' spontaneity and organization, and promoting joint participation in the cultural construction.

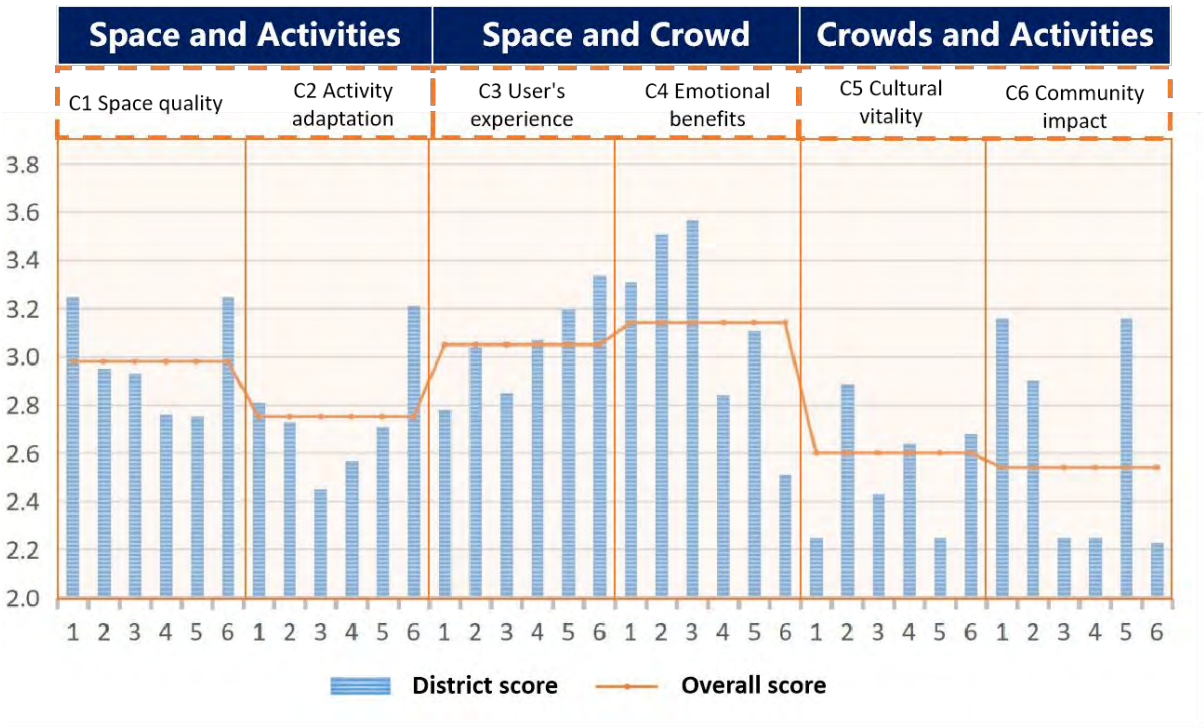


Figure 6. Comprehensive comparison of factor layer scores in different regions. Source: Author's self drawn.

3.1. Space and Activities - Adaptability between Space and Cultural Development

The spatial activity criterion layer (B1) includes two-factor layer indicators, spatial quality (C1) and activity adaptation (C2), as well as six fourth-level indicators. The relationship between spatial and cultural development adaptation is analyzed based on the scores.

(1) Shortage of material space resources and poor quality of facilities

There are few public spaces available for activities in old communities, and the quantity and quality of hardware facilities need to be improved. The scoring results show that the investment in public cultural resources is insufficient and uneven, and there is a significant gap in environmental facilities among different types of communities. The problem of missing public facilities is particularly prominent in most early-built communities, where residents who stay for rest usually bring their seats, resulting in a low score for facility completeness (D2). The public spaces in most communities are monotonous and lack spatial hierarchy and design sense, and few device designs stimulate residents' interest in participation. Some communities have limited space and small public spaces, lacking the possibility of long-term sustainable development. The poor level of spatial development potential (D6) in historical communities is because the area is located in the historic district of Wudao, and public space resources are limited by historical development factors and geographical environment, making it difficult to obtain sufficient spatial support for the development of community culture.

(2) Imbalance in material structure supply and low functional rationality

The development effectiveness of community cultural space is not yet prominent, and the rationality of activity functions is poor. Field research has found that the cultural service space in the community has homogeneous and single functions, and residents have limited access to it. As most cultural activity stations in the community are located in the same building as the office of the community neighborhood committee, the cultural space is encroached upon and the area is insufficient to meet the needs of diverse cultural activities. Compared to outdoor activity plazas and fitness equipment with higher usage rates, indoor cultural venues, and facilities are less visited by people. Most of the interviewed residents expressed uncertainty about whether their community has indoor cultural activity venues and facilities, while a well-equipped community cultural service center in the area has been closed and unused for more than a year. Due to the lack of effective operational management and long-term maintenance, the low utilization efficiency of community cultural spaces leads to resource waste and the inability to meet the site conditions required for cultural activities, making it difficult to implement community cultural development plans.

Figure 7.Space quality and activity adaptation. Source: Author's self drawn.

3.2. Space and Crowd - Characteristics of Residents' Experience in Space

The spatial crowd criterion layer (B2) includes two-factor layer indicators, user experience (C3) and emotional benefits (C4), as well as five fourth-level indicators. The characteristics of residents' experience perception in the space are discovered from the scores (Figure 6).

(1) The characteristics of the development scenario need to be organically combined with the surrounding resources

The sharing and location of resources around the community are important factors that affect the creation of cultural scenes. Through the high-scoring features in the sample community, it was found that there are open and shared commercial activity spaces adjacent to cultural resources such as historical districts and urban parks, or around the community, which can expand new cultural activity scenes. In

sample areas 1 and 5, residents around the park and in historical communities share high-quality cultural resources with tourists nearby. The Five Avenues Historical District has high-quality cultural scenic spots, and the urban park contains diverse cultural spaces such as cultural and sports plazas and themed exhibition halls. Community residents near these resources score significantly higher in the emotional benefit (C4) evaluation of neighborhood interaction enthusiasm (D10) and sense of belonging (D11). The cultural spaces used by community residents in Zone 4 mainly come from the sharing of resources in commercial areas, such as the construction of shared sports fields in commercial districts, the opening of commercial activity spaces to residents, and the support of commercial plazas for residents to gather. Analysis shows that optimizing the comfort supply system can help community residents obtain high-level cultural scenes in street spaces and even in their daily lives.

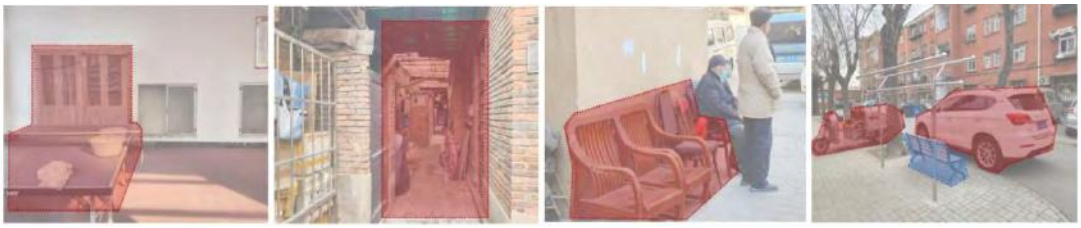


Figure 8.User experience and emotional expression. Source: Author's self drawn.

(2) Creating a Neighborhood Interaction Scene with Diversified Living Facilities

Filling and improving community life circles with diversified infrastructure can help create a scene of neighborhood interaction. In areas with high emotional benefit (C4) scores, the 5-minute living circle of the community often includes relatively complete living infrastructure. Area 3 is mainly a multi-story TOD community type, with community medical service centers, district-level key middle schools, and primary schools, kindergartens, and other facilities built within the four enclosed neighborhoods. Within the 10-minute living circle of the community, there are supermarkets and street squares, which enhance the quality of life for residents, strengthen their sense of belonging to the community, and create many scenes of neighborhood interaction. This increases opportunities for social interaction between residents, naturally narrowing the interaction distance between neighbors and building a relatively strong social network. Infrastructure is the material foundation of community cultural space and also the "generator" of individual public activities, connecting people with different symbolic features and activity intentions to participate in the scene space.

3.3. Crowds and Activities - Characteristics of Residents' Cultural Participation

Under the criteria layer of population activity (B3), there are two-factor layer indicators of cultural vitality (C5) and community influence (C6), as well as five-level four indicators. The cultural participation characteristics of residents are analyzed through scores (Figure 7).

Figure 9.Performance of spatial activities. Source: Author's self drawn.

(1) The technical aspect of organizational training is not strong, and there is a lack of participation from resident organizations

Lack of multi-stakeholder participation makes it difficult to implement event planning. Residents generally have a low evaluation of the cultural construction initiated by the community, and their involvement in cultural construction is relatively low. In interviews, residents mentioned phenomena such as cultural space being occupied and misappropriated, unreasonable opening hours, and lack of cultural connotation and educational experience in activities, which have already influenced their enthusiasm for participation. Poor implementation of event planning also leads to rare participation of residents. Research has found that many cultural event planners lack resident participation and support from surrounding businesses, resulting in community activities being promoted but not carried out.

Lack of professional guidance and weak impact of residents' self-organized activities. Neighborhood committees and other organizations lack professional technical capabilities, making it difficult to organize and build high-quality community cultural spaces as an assisting force. The problem of organizational capacity is a major factor restricting the development of community self-organization, and the low awareness and support of residents towards it also becomes a limiting factor. Many people in the interview were unclear about what cultural organizations exist in the community, and even if they have the willingness to develop their strengths and interests, they are not clear about the channels through which they can join the corresponding resident cultural groups.

(2) Poor dramatic scenes in community culture and insufficient creation of cultural characteristics

The community cultural space exhibits low neighborly scene characteristics, resulting in poor cohesion and atmosphere creation of the community. Through the survey results, it was found that there are relatively few traditional festival activities in the community, and most residents believe that the importance of traditional cultural festivals in their community is low, and there are fewer events held; The intensity of daily cultural activities in the community is generally moderate, with standardized forms of activities and a lack of attractive cultural characteristics that are close to residents' lives. In recent years, the diversification of residential structures has made it increasingly difficult for people within communities to reach consensus and connect, while the diversification of lifestyles has made people's social circles more dispersed, making it difficult to form an emotional community within the community, and the connections within the community have become increasingly difficult to maintain. The dramatic display of urban personality and community characteristics is gradually decreasing, and cultural scenes are becoming more conservative and singular.

4. Guidelines for Optimizing Community Cultural Space under the Influence of Scenarios

According to empirical evaluation analysis, the scene creation of community cultural space mainly consists of three parts: optimizing spatial quality, reshaping symbolic value, and coordinating crowd activities. Scene "regards space as a cultural value mixture that gathers elements, symbols, and interactions. Through the matching effect of scene creation, it combines existing resources with application needs, and transforms material structures to promote the daily use of scenes; By guiding and combining the subjective needs of the crowd with objective local factors, we aim to enhance the perception of the crowd and promote the dissemination of the scene; By coordinating scene elements to stimulate endogenous motivation within the community and improving operational mechanisms to promote the implementation of scenes. The community cultural scene formed from this can shape unique spatial symbolic connotations, spread cultural values through practical activities, guide public behavior and lifestyles, construct a two-way feedback mechanism between space and people, and cultivate collective cultural spirit.

4.1. Optimize material structure and expand cultural activity scenes

The role of scene matching contributes to the significance of the quality of community cultural space. The fixed user group in the community enables the social interaction role of the scene to be more fully utilized. While optimizing the material structure of the community through the hierarchical layout of public spaces, improvement of community living facilities, design of all-age sports spaces, and addition of interactive technology devices, the local cultural scene of the community is preserved to achieve cultural production in the space. Scene creation, as the main means of optimizing community public cultural spaces, is demand-oriented, enhancing the physical environment while forming community-specific cultural values to expand community activity scenes.

4.2. Reshaping spatial symbols and enhancing cultural perception among the masses

The guiding role of the scene helps to reshape the symbolic value. Starting from the positive construction approach and taking the local culture of the community as the starting point, combined with location conditions and resources, specific imagery and symbolic expression of the space are constructed. From the perspective of reverse construction, the cultural characteristics of the community are reprocessed from the aspects of theme grasp and form extraction, combined with the dynamic growth of social needs, and cultural innovation is used to infer the reshaping and development of spatial scenes. From the perspective of theme construction, targeting the new youth-oriented community, modern media technology and operational models are utilized to creatively interact and showcase specific spatial plots or cultural themes, rendering symbolic imagery through multi-sensory experiences. The above three approaches, activate the driving force of community culture from the production of spatial symbols and the perception of population values.

4.3. Improve the operating mechanism and create a good cultural atmosphere

The intrinsic motivation of the scene helps to maximize the effectiveness of community cultural services. In scene creation, attention should be paid to residents' participation and long-term investment in operation, actively expanding the service population for all age groups. Firstly, enhance residents' awareness of co-construction and promote self-organizing development. The government empowers community cultural development, professionals empower community volunteers, and media platforms empower community image promotion. Secondly, encourage residents to engage in self-organized development, discuss needs and resources together, and attract effective participation from diverse populations. Thirdly, we advocate for government guidance to obtain financial support, establish a community cultural development fund, ensure stable construction investment, and guarantee sustainable operation and maintenance.

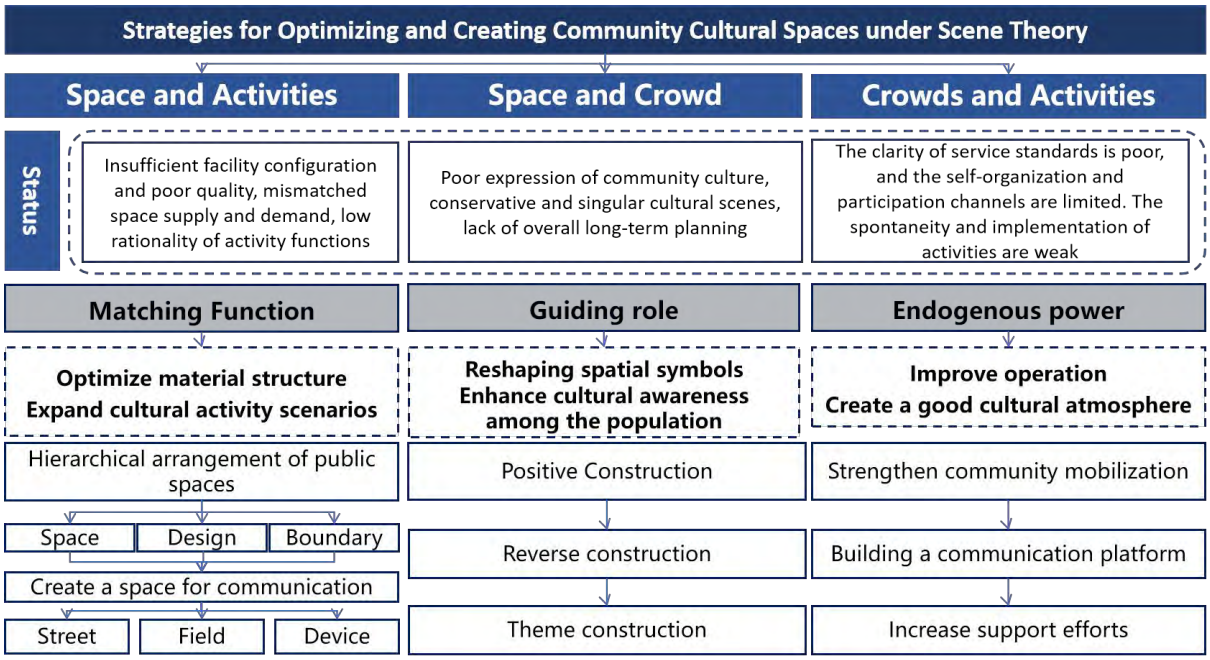


Figure 10.Ideas for Creating Community Cultural Space under Scene Theory. Source: Author's self drawn.

4.4. summary

The locality and complexity of culture are strong demands of community members for scene creation and comfortable object setting. This article is based on the structure of an evaluation system for community cultural space from the perspective of scene theory. Through empirical research, the scene indicators are quantified, providing a data foundation and example materials for related research. In the evaluation results, the differential characteristics of the area were extracted and summarized, and the common current problems and influencing factors were summarized, making the conclusions of this study have few universal values and providing data basis and example materials for establishing community cultural scenes.

5. References

Chai Yanwei, Zhang Xue, Sun Daosheng.'Research on Urban Life Circle Planning Based on Spatiotemporal Behavior: A Case Study of Beijing', Journal of Urban Planning, 2015 (03), p61-69.

Zhao Wanmin, Wu Siyu, Yang Guang.'Exploration of Scene based Renovation Strategies for Public Spaces in Old Residential Areas in Chongqing',Planner, 2021(17), p38-44.

Wu Jun. 'Cultural Dynamics: A New Thinking for Explaining Urban Development and Transformation', Journal of Beijing Institute of Administration, 2015 (04), p10-17.

Li Heping, Jin Hong, Terry N. Clark, Jiang Wen. 'Scene Theory and Its Application in the Protection and Renewal of Historical Towns in China', Urban Planning Forum , 2022(03), p102-110.

Chen Bo, Lin Xinyu. 'Analysis of patterns and characteristics of cultural scenes in Chinese cities: an empirical study based on 31 cultural comfort objects in cities', Chinese Soft Science, 2020 (11), p71-86.

Zhou Yiying, Gao Mengwei. 'The Construction of Cultural Scenes in Chengdu Park City under the Theory of Cultural Scenes', Resources and Human Settlements, 2021 (12), p22-29.

Liu Kejin. 'Types and creation paths of cultural scenes in foreign cities', China Cultural Industry Review, 2019, 27 (01),p324-338.

Meng Dancheng, Xu Leiqing. 'Creating Healthy Communities Based on Scene Theory', Southern Architecture, 2021 (03), p36-44.

Tan Chenwen, Kong Weijie, Wang Lin. 'Application and Prospect of Scene Theory in Urban and Rural Planning in China: A Bibliometric Analysis Based on CiteSpace ', Urban Architecture, 2022, 19 (19), p67-71.

Wang Chengxu. 'Spatial Interpretation of Urban Culture', Planner, 2006, (4), p69-72.

Fan Wei. 'Research on the Construction Mechanism of Urban Cultural Scenes: A Case Study of Toronto, Canada', Administrative Management Reform, 2020 (05), p83-91.

Huang Ling, Wang Ting. 'Quality Improvement Plan for Mountain City Trail in Yuzhong District, Chongqing: A Study on Street and Lane Renewal in Mountain Cities Based on Scene Theory', Beijing Planning and Construction, 2021 (01), p36-41.

Yang Lihua, Wang Yun. 'Evaluation of Outdoor Space Renovation in Old Communities Based on Scene Theory: Taking the Construction of "Beautiful Home" in Minhang District, Shanghai as an Example', Architecture and Culture, 2022 (08), p165-168.

Xu Suning, Zhao Zhiqing, Li Hanzhe. 'Urban Design and Designing Cities', Urban planning 2005, (07), p75-78.

Qi Ji, Qi Ran. 'Urban cultural innovation from the perspective of buzzing theory', Theoretical Monthly, 2020 (10), p89-98.

Cao Zhikui, Chen Xueying, Wu Qianbo, Wu Konglu. 'Research on Future Rural Construction Elements and Scene Types under the Framework of Scene Theory: A Case Study of Dalu Village, Tonglu County, Hangzhou City', Planner, 2022, 38 (12), p125-130.

Huang Ling, Zhou Meng. 'Research on Urban Community Renewal Strategies under the Background of Cultural Renaissance', Western Journal of Human Settlements and Environment, 2018, 33 (04), p1-7.

Liu Daiyun, Qiu Zhiyong, Dong Yu. 'Exploration of the Evolution and Laws of Urban Design under the Background of Economic Transition', Planner, 2008, No. 151 (07), p91-95.

Wei Wei, Liu Chang, Zhang Shuaiquan, Wang Bing. 'International experience and inspiration in shaping urban cultural spaces: taking London, New York, Paris, and Tokyo as examples', International Urban Planning, 2020, 35 (03), p77-86+118.

Research Paper

Reprogramming Urban Communities

Enhancing Children's Well-being through a Value-Based Programming Approach in Inclusive Planning and Design

Shitao JIN, Department of Architecture, Tongji University, China
Yuan DENG, Department of Architecture, Tongji University, China
Huijun TU, Department of Architecture, Tongji University, China

Abstract

With the acceleration of urbanization, children's well-being in urban communities has become a growing concern. By conducting a semantic analysis of community street view data and administering surveys with multiple stakeholders, this study analyzes the key factors influencing children's well-being and constructs a value-based programming framework centered on cultural identity, safety, inclusivity, and multi-stakeholder collaboration. The findings indicate that environmental quality, interactivity, cultural identity, and social interaction have a direct impact on children's psychological health, sense of belonging, and feelings of safety. Additionally, multi-stakeholder collaboration plays a critical role in the sustainable improvement of children's well-being. The study concludes that through the integration of diverse values and the optimization of collaborative mechanisms, children's well-being in communities can be systematically enhanced. This study provides a new theoretical framework and practical approach for future urban community planning, with significant potential for broader application.

Keywords

Children's well-being, Architectural programming, Street View images, Semantic segmentation, Questionnaires, Linear regression

1. Background

Urbanization has led to higher building density in cities (Song and Zhu, 2011). This has reduced the size of community public spaces, which no longer support safe and independent activities for children (Bochaver et al., 2016). Areas once reserved for public use are now taken over by motor vehicles, commercial facilities, and other functions. This change has greatly limited the space available for children's activities in urban areas (Guo et al., 2023; De Visscher and Bouverne-de Bie, 2008).

In 2018, the United Nations urged communities to improve children's well-being in its report Shaping Urbanization for Children: A Handbook on Child-Responsive Urban Planning (UNICEF, 2018). This report emphasizes that communities are central to children's daily lives. The planning and design of public spaces in these communities are key to their healthy development. In China, urban planning often prioritizes functionality—such as transportation and commercial development—while neglecting spaces for children's activities (Wang et al., 2023). This can harm their quality of life and developmental potential (Shen et al., 2022).

A value-based architectural programming approach can help reprogram urban communities to better support children's well-being (Pyburn, 2017; Kalayci and Ozdemir, 2021). This approach uses sound, fair conflict-resolution strategies to ensure that the planning and design process considers the needs of all stakeholders (Jin et al., 2024; Xiang et al., 2021). By addressing gaps in urban research, this approach focuses on understanding and meeting children's needs, promoting more inclusive urban spaces. The study investigates the following questions:

1. How do different groups perceive children's well-being in urban public spaces?

2. What are the key factors in urban communities that influence children's growth and quality of life?

3. How can a value-based programming approach improve children's well-being in urban communities?

2. Literature review

2.1. Children's well-being in urban communities

In modern urban areas, children's well-being has become a key concern in urban planning (Collins et al., 2024). Research mainly focuses on three areas: green environments, urban infrastructure, and community services.

First, a well-maintained green environment offers children spaces for play and outdoor activities. These areas support cognitive development and emotional regulation (Bikomeye et al., 2021). Lyons et al. (2024) found that urban green spaces provide a peaceful retreat for young people. These spaces also strengthen family bonds and improve community cohesion.

Second, urban infrastructure, especially transportation, affects children's safety and quality of life (Fenton, 2012). De Macédo et al. (2022) showed that children's ability to move freely, without adult supervision, enhances their well-being. Access to open spaces like streets and parks supports this independent mobility.

Finally, community services such as education, healthcare, and recreation are essential for children's holistic development. These services help safeguard their mental health and socio-emotional growth (Poon et al., 2022). Sullu (2024) argued that urban planning should consider the needs of all community members, especially children, who have the right to participate in these decisions.

In conclusion, the quality of urban environments—including green spaces, infrastructure, and community services—plays a crucial role in supporting children's well-being.

2.2. Value-based architectural programming

As cities focus more on livability and quality of life, value-based architectural programming has gained attention (Jin, 2024). This approach not only addresses building design but also considers how social, cultural, and environmental values can improve urban communities and residents' well-being (Tu and Jin, 2024).

Recent studies on urban programming emphasize improving community environments by integrating different values, especially those that impact residents' well-being. Milovanovic et al. (2023) discussed how the EU's "Housing-Centered" framework can help redevelop large housing neighborhoods. This approach uses design guidelines to evaluate community programming. Other studies, like that of Kalayci and Ozdemir (2021), focus on creating inclusive, sustainable urban spaces by integrating historical, social, and cultural values. They presented a three-step model for urban programming, focusing on historical research, site analysis, and strategic planning.

In summary, value-based architectural programming is a key tool for improving urban livability. Whether through preserving historical elements or incorporating stakeholder input, this approach helps meet the complex needs of modern urban environments.

3. Methodology

3.1. Case study

This study uses the Weifang New Village Subdistrict in Pudong New District, Shanghai, as a case study. The area covers 3.89 square kilometers and has a population of 122,000 people across 29 communities (Figure 1).

Figure 1. Location of the case study area. Source: Authors' own work.

The reasons for choosing this case are:

1. The site includes a mix of old urban areas and modern communities, representing different stages of urban development in Shanghai.

2. The area has a high population density, with people from diverse backgrounds in terms of age, income, and occupation.

3. The communities vary greatly in terms of green space and environmental quality.

3.2. Data collection

This study uses a mixed-methods approach, combining both quantitative and qualitative data to gain a comprehensive understanding of children's well-being in the community (Figure 2).

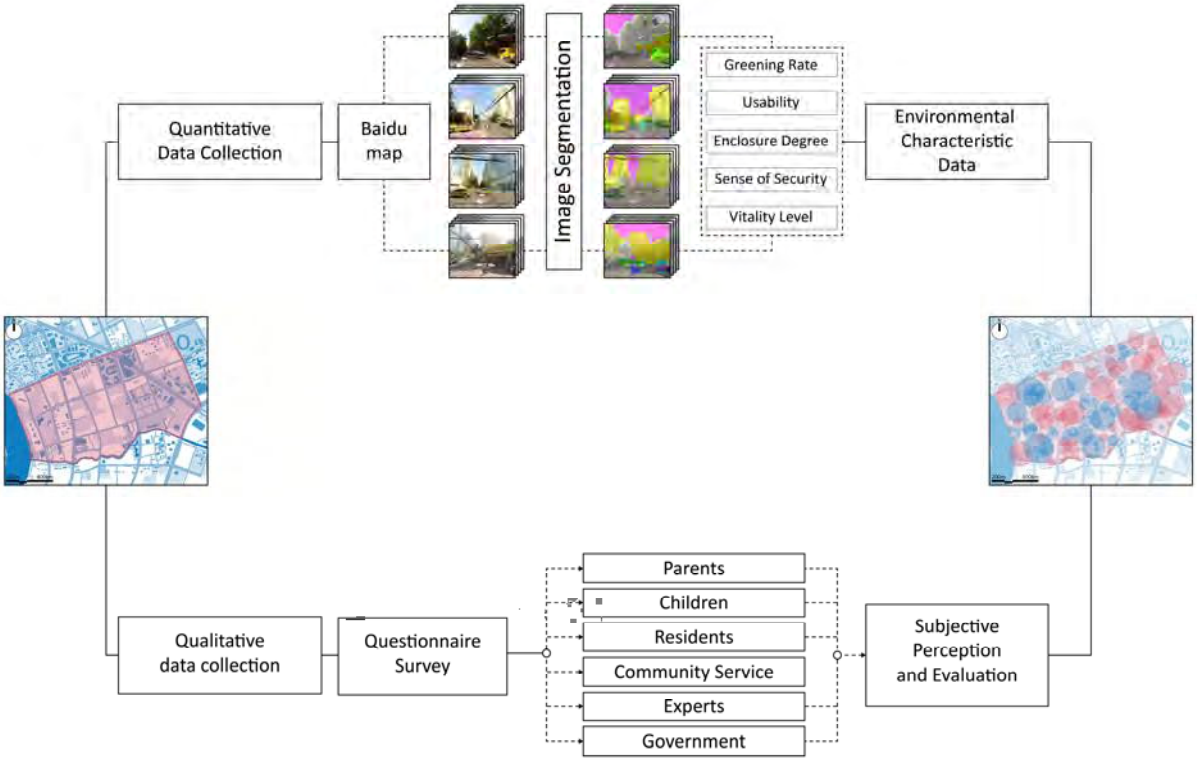


Figure 2. Data collection process of this study. Source: Authors' own work.

(1) Community environment data

The study collected community environment data using semantic segmentation techniques on street view images. Road network data was obtained from OpenStreetMap, and images were captured every 50 meters along roads using the Baidu Maps API. A sample point was set at each 50-meter interval, and street view images were taken in four directions (0°, 90°, 180°, 270°). The Segformer-B4 scene parsing and segmentation database was used to train a Fully Convolutional Network (FCN-8s) model, which performed semantic segmentation on the images.

The study calculated the proportion of pixels occupied by different objects in each image. The mean pixel ratio of each object was calculated across all four directions at each sample point (Wang et al., 2020). The study selected five indicators—greening rate, usability, enclosure, sense of security, and vitality—to examine how these factors relate to children's well-being (Table 1).

Table 1. Definitions and calculation methods of community public space indicators. Source: Authors' Own Work.

Indicator	Definition	Formula	Explanation
Greening rate	This factor reflects the distribution of natural elements and the ecological quality of the community environment.	$G_i = \frac{1}{n}\sum_{k=1}^{n}\frac{1}{m}\sum_{j=1}^{m} g_{jk} \times 100\%$	G_i represents the greenery coverage of community i, g_{jk} is the proportion of green vegetation pixels in the jth street view image at the kth sample point in community i, n is the number of sample

			points, and m is the number of images at each sample point.
Usability	This factor reflects the accessibility and potential usability of community spaces for residents, especially children.	$U_i = \frac{1}{n}\sum_{k=1}^{n}\frac{1}{m}\sum_{j=1}^{m}\frac{p_{jk}}{t_{jk}+r_{jk}} \times 100\%$	U_i represents the usability of community i, p_{jk} is the proportion of pixels for non-motorized lanes and sidewalks, t_{jk} is the proportion of pixels for motorized lanes, and r_{jk} is the proportion of pixels for other transportation facilities.
Enclosure degree	This factor reflects the sense of enclosure and visual privacy in the community, which directly impacts perceptions of safety and privacy.	$E_i = \frac{1}{n}\sum_{k=1}^{n}\frac{1}{m}\sum_{j=1}^{m}\frac{b_{jk}+t_{jk}}{r_{jk}+p_{jk}}$	E_i represents the enclosure of community i, b_{jk} is the proportion of pixels for buildings, t_{jk} is the proportion of pixels for trees, while r_{jk} and p_{jk} are the proportions of pixels for motorized lanes and sidewalks, respectively.
Sense of security	This factor reflects the perceived safety of the space, particularly for children.	$S_i = \frac{1}{n}\sum_{k=1}^{n}\frac{1}{m}\sum_{j=1}^{m}(f_{jk}+sl_{jk}+tl_{jk}+c_{jk}+w_{jk}) \times 100\%$	S_i represents the sense of security in community i, f_{jk} represents the proportion of pixels for fences, sl_{jk} for streetlights, tl_{jk} for traffic signals, c_{jk} for cameras, and w_{jk} for street-facing windows, reflecting the impact of these facilities on safety.
Vitality level	This factor reflects the level of activity in the community and the degree of engagement and social interaction opportunities for residents, especially children.	$V_i = \frac{1}{n}\sum_{k=1}^{n}\frac{1}{m}\sum_{j=1}^{m}(pd_{jk}+bc_{jk}) \times 100\%$	V_i represents the vitality of community i, pd_{jk} represents the proportion of pixels for pedestrians, and bc_{jk} represents the proportion of pixels for bicycles, indicating the vibrancy and social interaction potential of community public spaces. Higher values suggest a more vibrant and socially interactive community.

(2) Questionnaire survey data

To collect qualitative data, the study used a multi-perspective questionnaire survey. This survey aimed to understand the needs and opinions of various stakeholders, including parents, children, residents, community service personnel, experts, and government officials.

The survey consisted of three sections:

The first section gathered basic information about the respondent, such as community, child's age, gender, and education level.

The second section assessed the perceived well-being of children in the community. Respondents rated their satisfaction with the state of children's well-being in eight areas: environment, humanity, society, systems, temporary needs, economy, aesthetics, and safety.

The third section asked for overall satisfaction with the community's ability to meet children's well-being needs.

A total of 800 questionnaires were distributed, with 691 valid responses after excluding incomplete ones.

3.3. Data analysis

This study uses a multi-level data analysis approach to analyze both quantitative and qualitative data. The goal is to develop a value-oriented programming framework to improve children's well-being in urban communities (Figure 3).

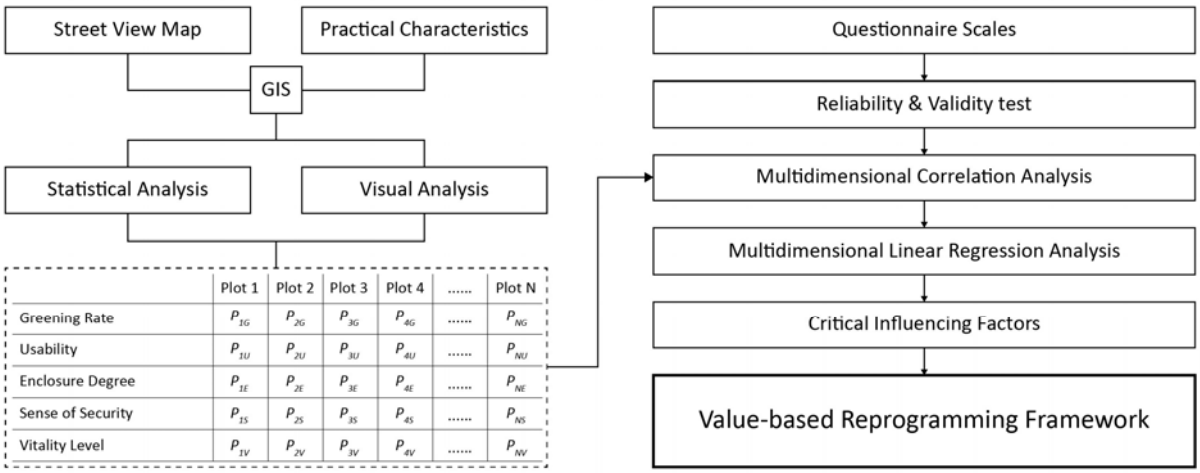


Figure 3. Data analysis process of this study. Source: Authors' own work.

First, ArcGIS software was used for spatial visualization analysis of the community environment data. This showed how different elements are distributed across the community. To ensure the reliability of the qualitative data, we tested the questionnaire data for reliability and validity using SPSS 26.0 software. This step helped confirm the accuracy of the analysis results.

Second, we performed descriptive statistical analysis on the community data and survey responses. This provided an overview of community environment features and residents' perceptions. We also used Pearson correlation analysis to explore relationships between the characteristics of community public spaces and factors influencing children's well-being. This analysis identified key areas for improvement in urban community programming.

Finally, to understand the relationship between community programming factors and children's well-being, we built a linear regression model. This model helped identify the most effective programming factors for improving children's well-being. The results led to the creation of a value-oriented programming framework through comparative analysis among different stakeholders.

4. Findings

4.1. Current status of the public spaces and perception in urban communities

The respondents in this study represented a wide range of ages and family backgrounds. Their demographic characteristics are shown in Table 2.

Table 2. Demographic characteristics of participants in the questionnaire. Source: Authors' own work.

Basic information		Quantity	Proportion
Age	8 to 14 years old	154	22.3%
	15 to 35 years old	229	33.2%
	36 to 45 years old	212	30.7%
	Over 46 years old	95	13.8%
Sex	Male	332	48%
	Female	359	52%
Educational background	Primary school and below	254	36.8%
	Middle school and high school	65	9.44%
	Bachelor degree or above	372	53.8%
Annual household income	Less than 100,000 yuan	123	17.8%
	100,000 to 200,000 yuan	390	56.5%
	More than 200,000 yuan	178	25.7%
Groups	Children	154	22.3%
	Parents	198	28.6%
	Residents	127	18.4%
	Community service	122	17.6%
	Experts	81	11.7%
	Government	10	1.4%

Next, we used semantic recognition technology based on street view maps to analyze the public spaces in the study area (Figure 4). The data revealed that residential areas had the highest greenery coverage, averaging 45.5%. In terms of usability, parks had good walkability, with well-covered pedestrian paths and bicycle lanes, meeting the activity needs of children and parents. Regarding enclosure, residential areas had higher enclosure, with more vertical space occupied by buildings and vegetation than parks or streets. This provided children with a more enclosed and safer environment for activities. The security analysis showed that residential areas scored highest in safety, followed by streets, while parks had a moderate score.

Figure 4. Spatial characteristics of community public space indicators. Source: Authors' own work.

Lastly, the survey assessed respondents' satisfaction with children's well-being in the community, focusing on eight aspects: environment, humanity, society, systems, temporary needs, economy, aesthetics, and safety. Descriptive statistical analysis results are shown in Table 3.

Table 3. Survey results on the current status of satisfaction perception of children's well-being in the community. Source: Authors' own work.

Dimension	Min	Max	Mean	SD	Variance
Environment	1	5	4.1481	0.77763	0.605
Human	1	5	3.1622	0.76984	0.593
Society	1.25	5	3.6272	0.78237	0.612
System	1.06	5	3.8481	0.72872	0.531
Temporary	1.33	5	3.5426	0.72944	0.532
Economy	1	5	3.0813	0.78604	0.618
Aesthetics	1	5	3.9813	0.90534	0.823
Safety	1	5	4.2292	0.80393	0.646

4.2. Children's well-being in the community from a multi-stakeholder perspective

Respondents were grouped into six categories: parents, children, other residents, community service personnel, experts, and government officials. This allowed us to compare satisfaction levels regarding children's well-being in the community (Figure 5).

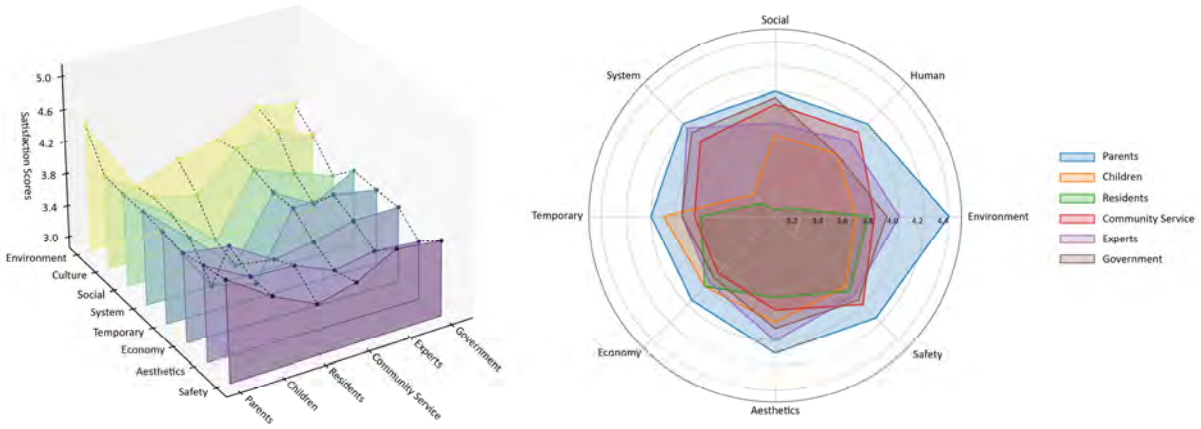


Figure 5. Satisfaction perception results of community public space indicators from a Multi-Stakeholder Perspective. Source: Authors' own work.

In the environmental dimension, parents and experts gave the highest satisfaction scores, 4.4 and 4.0, respectively. They particularly appreciated the community's greenery and air quality. In the human dimension, parents and community service personnel gave higher satisfaction scores of 4.05 and 3.95. They praised the community's support for children's social and cultural activities. In the social dimension, parents and community service personnel also gave high scores of 4.0 and 3.9. They valued the community's platforms for social interaction and its support for family structures. In the systems dimension, parents and experts gave the highest scores of 4.05 and 4.0, believing that the community's education and healthcare systems meet children's needs. In the temporal dimension, both parents and children gave relatively high scores, 4.0 and 3.9, showing appreciation for the scheduling of community activities. In the economic dimension, parents and other residents gave relatively high scores of 3.95 and 3.8, indicating satisfaction with the affordability of children's activities and services in the community. In the aesthetics dimension, satisfaction levels were similar across all groups. Parents, experts, and children gave scores of 4.1, 4.0, and 3.85, respectively. They particularly appreciated the community's architectural and landscape design. In the safety dimension, satisfaction scores were generally high across all groups. Parents gave the highest score of 4.15, emphasizing community security and safety facilities.

4.3. Correlation analysis between community environment and children's well-being

We used Pearson correlation analysis to explore how community environmental characteristics relate to children's well-being perceptions.

First, we calculated a composite score for five environmental characteristics: greening rate, usability, enclosure, sense of safety, and vibrancy. These scores were averaged and weighted to derive an overall environmental score for each area (ranging from 1 to 5). The survey data was then checked for reliability and validity using SPSS (Table 4).

Table 4. Cronbach's alpha, KMO, and Bartlett's test. Source: Authors' own work.

Cronbach's alpha		0.941
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.715
Bartlett's Test of Sphericity	Chi-Square	161.362
	Degrees of freedom	78
	p-value	0.000

The analysis results, shown in Figure 6, reveal a significant positive correlation between the greening rate and the environmental dimension of children's well-being ($r = 0.77$, $p < 0.01$). This suggests that greening in the community plays a crucial role in improving perceptions of children's well-being. Usability showed a significant positive correlation with the social ($r = 0.59$, $p < 0.05$) and systems ($r = 0.69$, $p < 0.05$) dimensions, highlighting the importance of accessible community facilities for improving children's well-being. Enclosure also showed a strong correlation with the safety dimension ($r = 0.73$, $p < 0.01$), indicating that spatial layout affects residents' sense of security.

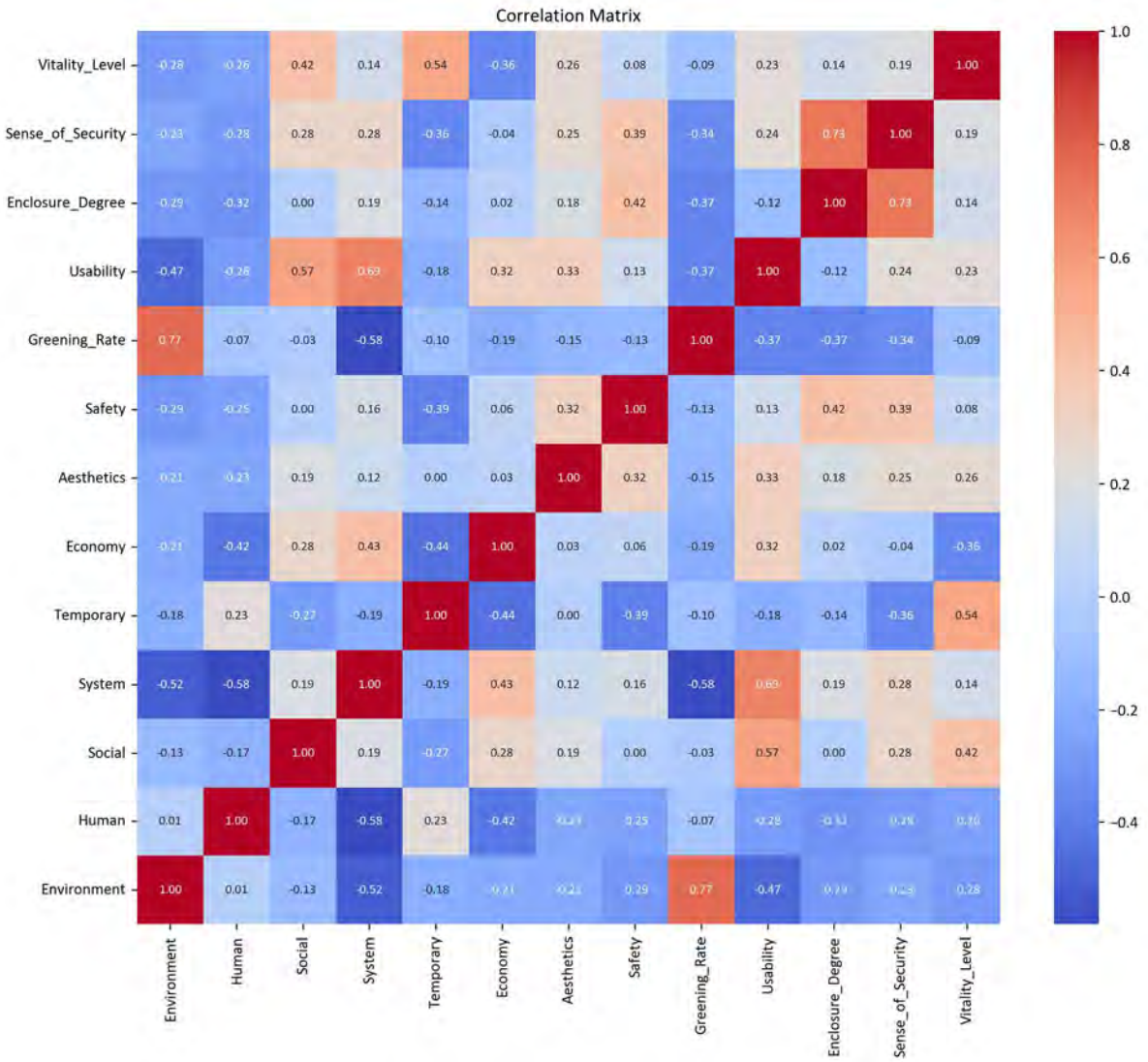


Figure 6. Correlation matrix between community environment and programming perception factors. Source: Authors' own work.

4.4. Key environmental factors affecting children's well-being in the community

This study uses a multiple linear regression model to identify key programming factors that influence children's well-being in urban communities. The model evaluates eight programming factors based on their effect on overall children's well-being. To account for demographic influences, we tested variables like gender, community, household income, and education level. These tests showed no significant effects from these demographic factors.

As shown in Table 5, the environment ($\beta = 0.42$, $p < 0.01$), social ($\beta = 0.38$, $p < 0.05$), safety ($\beta = 0.35$, $p < 0.05$), and aesthetics ($\beta = 0.31$, $p < 0.05$) all have a significant positive impact on overall satisfaction with children's well-being. The environmental factor, in particular, showed the highest regression coefficient, highlighting its strong role in improving children's well-being. The model also had a good fit, with an R^2 value of 0.605, meaning these factors explain 60.5% of the variation in children's well-being needs.

Table 5. Linear regression results between community programming factors and children's well-being requirements. Source: Authors' own work.

Variable	B	Standard error	Beta	T-value	Significance
（constants）	1.635	0.779		1.987	0.081
Environment	0.419	0.151	0.420	4.505	0.004***
Social	0.380	0.177	0.378	4.620	0.006***
Safety	0.348	0.125	0.316	1.907	0.058**
Aesthetics	0.312	0.187	0.272	0.851	0.071**
R=0.690	R^2=0.679	Adjusted R^2=0.605			
Dependent variable：Overall children's well-being requirements					

5. Discussion

Based on the findings, we propose a value-based programming framework to improve children's well-being in urban communities.

5.1. Enhancing environmental quality and interactive experiences

Improving environmental quality and interactive experiences is essential for promoting children's well-being. Community spaces should be multifunctional and adaptable to meet the needs of children at different stages of development.

The design should include natural elements like plants, water features, and varied terrain to create a lively ecological environment. These elements offer sensory stimulation and help children feel more engaged and connected to their environment. Communities should also have multifunctional spaces, such as flexible activity areas and exploratory playgrounds. These spaces should encourage children to explore independently and interact with others. They should be adaptable to different seasons and activities to keep children interested over time.

5.2. Integration of cultural and social values

Cultural identity and social interaction are vital for children's mental health. Community programming should integrate cultural and social values through design and activities that strengthen children's cultural identity and social connections.

This can be done by creating cultural education spaces and hosting community events. The design should include culturally significant places, such as museums or craft workshops. These places provide valuable learning opportunities for children and act as hubs for social interaction. Organizing festivals, cultural exhibitions, and cross-cultural exchanges will further support children's cultural identity and increase their sense of belonging in the community.

5.3. Optimization of safety and inclusive design

Safety and inclusivity are key considerations in community design, especially in diverse urban environments. It is essential that all children can safely and equally participate in community activities.

To improve safety, community designs should incorporate smart technologies like surveillance systems and real-time alert features. These measures will make children's activity areas safer. The design should also include accessibility features to ensure that children with different abilities can easily use public spaces. Additionally, inclusive design should account for different cultural backgrounds and family structures. Multifunctional spaces and flexible designs will create a more diverse and inclusive environment.

5.4. Sustainable implementation through multi-stakeholder collaboration

Sustainable implementation of the programming framework requires collaboration among multiple stakeholders. Successful community planning depends not only on advanced design but also on active involvement from government bodies, experts, community service personnel, and residents.

Government agencies should lead by providing policy support and allocating resources. They should promote child-friendly policies and encourage new or renovated projects to follow the programming framework's principles. Experts and community service personnel should provide technical support and ensure that planning is both scientific and practical. They should also train residents and help them understand new planning concepts. Finally, the involvement of parents, children, and other residents is crucial for making the framework effective.

6. Conclusion

This study explores the current state and key factors affecting children's well-being in urban communities through semantic analysis of community street view data and multi-stakeholder surveys. Based on these insights, a value-based programming framework was constructed, offering a new perspective and practical approach to enhancing children's well-being in urban communities.

Specifically, the study concludes the following: (1) The quality of the environment and its interactivity are core factors influencing children's well-being, with elements such as greening rates, space usability, and enclosure directly linked to children's physical and mental health and sense of security. (2) Cultural identity and social interaction are crucial for children's mental health, and community design must actively incorporate local cultural elements and social activities to strengthen children's sense of belonging. (3) Safety and inclusivity are foundational to ensuring children's well-being; community planning should employ smart technologies and accessible design to create public spaces that are both safe and inclusive. (4) Multi-stakeholder collaboration is proven to be a key pathway for the sustainable implementation of children's well-being, with the active involvement of governments, experts, community service personnel, and residents effectively integrating diverse needs and resources to ensure comprehensive and flexible community planning.

7. References

Bikomeye, J. C., Balza, J. and Beyer, K. M. (2021), 'The Impact of Schoolyard Greening on Children's Physical Activity and Socioemotional Health: A Systematic Review of Experimental Studies', International Journal of Environmental Research and Public Health, 18(2), p535.

Bochaver, A., Korzun, A. and Polivanova, K. (2016), 'Kids, Streets, and Activities', Higher School of Economics Research Paper No. WP BRP, 71.

Collins, P. Y., Sinha, M., Concepcion, T., Patton, G., Way, T., McCay, L., Mensa-Kwao, A., Herrman, H., de Leeuw, E., Anand, N. and Atwoli, L. (2024), 'Making cities mental health friendly for adolescents and young adults', NATURE, 627(8002), p137-148.

de Macédo, C., Gil, M. and Strelhow, M. (2022), 'Urban Mobility and Subjective Well-Being among Brazilian Children', Child Indicators Research, 15(2), p467-485.

De Visscher, S. and Bouverne-de Bie, M. (2008), 'Recognizing urban public space as a co-educator: Children's socialization in Ghent', International Journal of Urban and Regional Research, 32(3), p604-616.

Fenton, M. (2012), 'Community Design and Policies for Free-Range Children: Creating Environments That Support Routine Physical Activity', Childhood Obesity, 8(1), p44-51.

Guo, D., Shi, Y. and Chen, R. (2023), 'Environmental affordances and children's needs: Insights from child-friendly community streets in China', Frontiers of Architectural Research, 12(3), p411-422.

Jin, S. T., Tu, H. J., Li, J. F., Fang, Y. W., Qu, Z., Xu, F., Liu, K. and Lin, Y. Q. (2024), 'Enhancing Architectural Education through Artificial Intelligence: A Case Study of an AI-Assisted Architectural Programming and Design Course', Buildings, 14(6), p1613.

Jin, S. (2024), 'Interdisciplinary perspective on architectural programming: current status and future directions', Engineering, Construction and Architectural Management, ahead-of-print(ahead-of-print) [online]. Available at: https://doi.org/10.1108/ECAM-04-2024-0408 (Accessed: 15 November 2024)

Kalayci, P. D. and Ozdemir, D. A. (2021), 'Transmitting Values from Past to Future: A Strategic Program Inquiry for Ankara Victory Square (Zafer Meydani)', Megaron, 16(1), p27-38.

Lyons, R., Colbert, A., Browning, M. and Jakub, K. (2024), 'The relationship between urban greenspace perception and use within the adolescent population: A focused ethnography', Journal of Advanced Nursing, 80(7), p2869-2879.

Milovanovic, A., Nikezic, A. and Ristic Trajkovic, J. (2023), 'Introducing Matrix for the Reprogramming of Mass Housing Neighbourhoods (MHN) Based on EU Design Taxonomy: The Observatory Case of Serbia', Buildings, 13(7233), p723.

Poon, B. T., Atchison, C. and Kwan, A. (2022), 'Understanding the Influence of Community-Level Determinants on Children's Social and Emotional Well-Being: A Systems Science and Participatory Approach', International Journal of Environmental Research and Public Health, 19(10), p5972.

Pyburn, J. (2017), 'Architectural programming and the adaptation of historic modern era buildings for new uses', Journal of Architectural Conservation, 23(1-2), p12-26.

Shen, Y., Zhang, X. & Liu, S. (2022), 'Translation and application of international "child-friendly community" assessment tool: taking the investigation of the status quo of children's rights in Changsha as an example', City Planning Review, 46(12), p45-56.

Song, T. Q. and Zhu, X. G. (2011), 'The forgotten urban street space', Modern Urban Research, 26(2), p86-91.

Spencer, C. and Woolley, H. (2000), 'Children and the city: a summary of recent environmental psychology research', Child Care Health and Development, 26(3), p181-197.

Sullu, B. (2024), 'Children's access to play during the COVID-19 pandemic in the urban context in Turkey', Childrens Geographies, 22(1), p182-187.

Tu, H. and Jin, S. (2024), 'A group decision-making model for architectural programming in megaprojects', Engineering, Construction and Architectural Management, 31(13), p342-368.

UNICEF (2018) Shaping Urbanization for Children: A handbook on child-responsive urban planning. United Nations.

Wang, R. Y., Yang, B. Y., Yao, Y., Bloom, M. S., Feng, Z. Q., Yuan, Y., Zhang, J. B., Liu, P. H., Wu, W. J., Lu, Y., Baranyi, G., Wu, R., Liu, Y. and Dong, G. H. (2020), 'Residential greenness, air pollution and psychological well-being among urban residents in Guangzhou, China', Science of The Total Environment, 711, p134843.

Wang, X., Huang, D., Liu, Y., Yao, Y. & Xiang, L. (2023), 'Impact of human-scale street space quality on walking to school by school-age children: a case study of Beijing', City Planning Review, p1-12.

Xiang, L., Tan, Y., Jin, X. and Shen, G. (2021), 'Understanding stakeholders' concerns of age-friendly communities at the briefing stage: a preliminary study in urban China', Engineering Construction and Architectural Management, 28(1), p31-54.

Yao, Y., Liang, Z. T., Yuan, Z. H., Liu, P. H., Bie, Y. P., Zhang, J. B., Wang, R. Y., Wang, J. L. and Guan, Q. F. (2019), 'A human-machine adversarial scoring framework for urban perception assessment using street-view images', International Journal of Geographical Information Science, 33(12), p2363-2384.

Research Paper

Evolving Socio-Spatial Dynamics in Traditional Chinese Village Dwellings

A typological analysis of Xiwu Village

Jingwei JU, School of Architecture, Tsinghua University, China

Chengyan XIA, Stuart Weitzman School of Design, University of Pennsylvania, USA

Abstract

Traditional Chinese villages embody rich built heritage and social memory but face crises of spatial degradation and memory loss due to rapid urbanization. Dwelling, as the main element of traditional villages, reflect social structure most directly. This study uses Xiwu Village for case study to trace the evolution of dwelling layout patterns from the mid-17th to mid-20th century and investigate their correlation with changes of social structure. Employing typological and statistical analysis to floor plans of 40 traditional dwellings, along with genealogies, archives, historical satellite images, in-depth interviews and other materials, the study identifies a simplified trend of layout patterns, which reflects a shift in social structure from big lineage-based to small family-centered. The study proposes planning suggestions for heritage preservation in Xiwu based on socio-spatial analysis, highlighting the importance of integrated preservation of tangible built heritage and intangible social memory in traditional villages.

Keywords

Dwelling, Socio-spatial dynamic, Typology, Social memory, Layout pattern, Integrated preservation

1. Introduction

Traditional Chinese villages encompass rich built heritage and social memory, holding significant historical, cultural, and social value. However, with the rapid development of urbanization, both tangible and intangible cultural heritage of traditional villages face the risk of extinction. For tangible cultural heritage, top-down government-led renewal and bottom-up resident-initiated renewal have led to the demolition of a large number of built heritage. For intangible cultural heritage, population loss and aging have led to the demise of social memory. Therefore, it is urgent to understand the value of built heritage and social memory in traditional villages and to implement strategic preservation and utilization.

The preservation of traditional villages should focus not only on distinct public buildings like ancestral halls and temples but also on the traditional dwellings that form the backbone of villages and shape their overall character. As Rapoport stated in *House Form and Culture*, dwellings most clearly illustrate the connection between spatial form and life pattern (Rapoport, 1969). He emphasized that dwellings were not just physical structures but institutional formations organized by socio-cultural factors. Among the various elements of dwellings, he focused on the layout, orientation, and decoration of dwellings, which align with the spatial forms of everyday lives. For traditional Chinese villages, dwellings are a major component of the built heritage, closely related to various daily activities (Knapp, 1989). There are ceremonial ancestor

worship spaces and functional living spaces in these dwellings, which constitute the dwelling layout pattern and reflect the social structure at the time of construction by showing homeowners' intention in the designs. Therefore, preserving traditional dwellings can help preserve the built heritage and social memories of traditional villages at the same time.

Current research mainly explores the relationship between settlement space and social structure on two scales: settlement and architecture. Settlement scale focuses on the socio-spatial connections within a single settlement (Shen, 1992; Chen et al., 1999; He and Sun, 2017; Dai, 2020), interpreting its cultural connotations (Lin, 2022; Yang and Zhang, 2020), analyzing its historical evolution(Pan et al., 2015), or conducting comparative studies of different settlements (Pan and Shi, 2014; Wang, 2009). Architecture scale traces the cultural origins of architectural forms (Zhang, 2020), focusing on their cultural connotations (Cai, 2020), socio-spatial connections reflected in dwelling layout patterns (Bustard, 1999), and their spatiotemporal evolutionary characteristics (Ruggiero et al., 2019; Zanfi et al., 2020; Yin and Liu, 2023; Li et al., 2023). It is necessary to integrate these two scales to preserve settlement and architecture. However, current research either focuses on one aspect or discusses the two separately due to limited materials (Gu and Huang, 2017; Yang et al., 2021). Most studies rely on floor plans and photos, and a few utilizing historical documents such as genealogies. Little research uses archives or in-depth oral histories.

This study quantitatively analyzes the floor plans of 40 dwellings from various periods and forms within the same settlement, integrating genealogies, archives, and oral histories. By integrating the settlement scale and architecture scale, it explores the evolution of dwelling layout patterns in traditional villages and how this evolution aligns with the changes in social structure.

2. Study area and method

2.1. Case study area

Xiwu Village, located in Ningbo City in eastern China, has three key features (Figure 1). First, it has a long history and a large lineage organization. Lineage organization refers to a large group residing within the same area based on patrilineal kinship. For example, the Wu lineage, settled in Xiwu since the mid-14th century, has grown into a large village of 6,000 people. Second, Xiwu is located on a plain at the foot of the mountains and was historically a key port for land and water transportation. It links important regional nodes like Ninghai, Taizhou, Fenghua, and Ningbo. Consequently, it enjoyed prosperous trade and had a marketplace since the mid-18th century. Third, Xiwu is located in the Yangtze River Delta, a wealthy region in late imperial China and open to international trade since the 1840s. Many new foreign cultural norms spreaded to this area and significantly impacted its rural areas.

Due to these factors, villagers in Xiwu accumulated rich capitals to construct high-quality dwellings, many of which have been well-preserved. Additionally, influenced by the ports, dwelling designs had transitioned from traditional to modern styles. Therefore, Xiwu offers a valuable case for studying the evolution of socio-spatial dynamics of cultural heritage and guiding integrated preservation efforts (Figure 2).

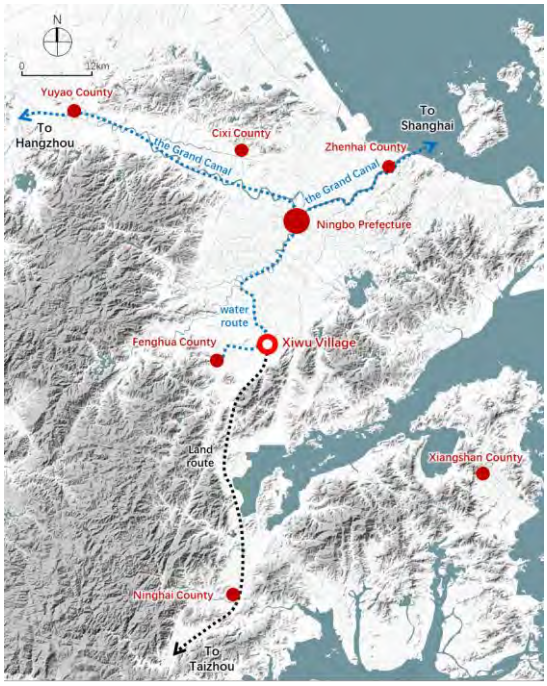


Figure 1. (left) Xiwu Village was an important port for water and land transportation. Source: Authors.

Figure 2. (right) Xiwu Village has preserved a large number of traditional dwellings. Source: USGS/Google Earth.

2.2. Study method

This study conducted several field surveys from 2019 to 2022. Research materials include in-depth interviews, historical documents, drone photography, detailed floor plans of 40 traditional dwellings from local museums, historical satellite images, and other materials such as village protection plan issued by government. We then utilized ArcGIS and AutoCAD to digitalize the dwelling layout patterns in Xiwu Village, which serves as our fundamental database for typological analysis. The study uses the first-floor plans of 40 dwellings in Xiwu as as key materials, which are constructed from the mid-17th century to the mid-20th century.

Layout pattern reflects the relationship between the spatial configurations and how the owners use them. The typical dwelling layout pattern in the Eastern Zhejiang region, where Xiwu is located, follows an H-shape pattern (Cai and Dai, 2009; He and Sun, 2017) (L2). Based on this, an incremental pattern (L1) is formed by expanding horizontally or vertically, while a reduced pattern (L3) is formed by decreasing elements or changing the orientation (Figure 3). The dwelling layout is used for both lineage ritual and everyday lives. A dwelling typically contains one to two centralized lineage ritual spaces and a number of residential units. Different functions impose different requirements on space. For lineage rituals, ritual spaces should face south, with the residential units symmetrically arranged around them. For everyday lives, the size of the dwelling should align with the number of residents (Zhou, 2020). These factors shape the choice of dwelling layout.

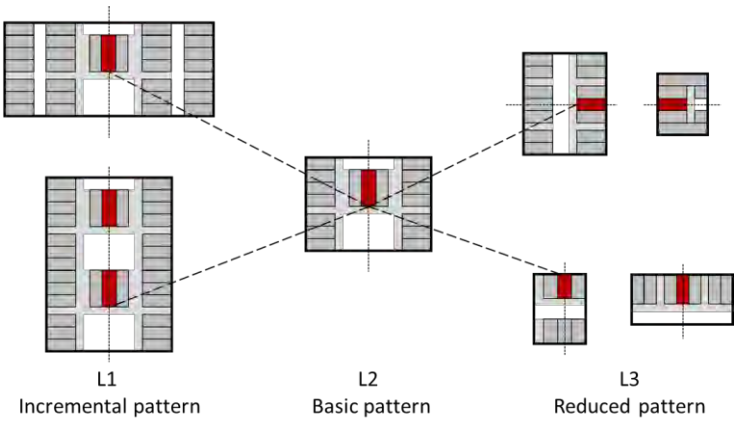


Figure 3. Three typical dwelling layout patterns in Xiwu Village. Sourse: Authors.

Therefore, the analysis of the dwelling layout pattern refers to several important indicators (Figure 4), including overall metrics such as historical period and layout pattern, as well as specific metrics based on dwelling layout like floor area, orientation, number of residential units, and number of stairs per household. Some of these indicators reflect underlying social structure through spatial forms. According to in-depth interviews with local villagers, lineage organization required that dwellings should strictly face south in ancient times. However, this requirement had become more flexible over time. Thus, changes in orientation can reflect the varying constraints of lineage organization on dwelling design. Additionally, the number of residential units reflects whether a dwelling is designed for extended families or individual households, showcasing changes in lifestyle. Moreover, the number of stairs per household partially reflects the comfort level of living in a dwelling. More stairs imply more shared facilities, leading to greater comfort for each family. All these indicators can reflect the rise and fall of the lineage organization in history.

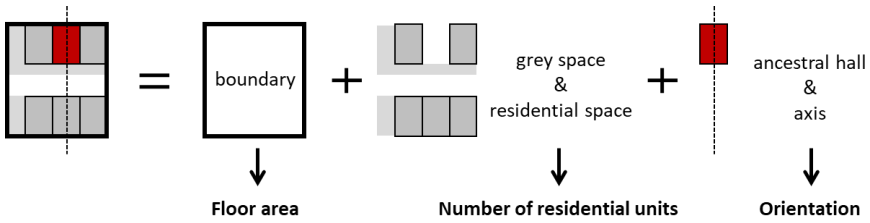


Figure 4. Decomposition of the basic elements of dwelling layout pattern and their spatial significance. Source: Authors.

Social structure refers to the composition of social members in a region who possess certain resources and opportunities, as well as the patterns of their relationships. In the southeastern region of the late imperial China, lineage organization is considered the most prominent form of social organization(Freedman, 1960). Lineage organization refers to a social group formed by families connected through patrilineal kinship, governed by patriarchal norms. It represents not only a biological relationship but also conscious organizational activities. As an organization based on patriarchal principles, lineage organization often pursues spatial order in settlements and architecture; the larger the lineage organization, the greater its influence on the spatial configuration of the settlement, which can lead to layouts that align more closely with ritual norms. Conversely, when the power of lineage organization is weaker, the authority over dwelling layout patterns shifts more to the homeowners.

This research analyzes the relationship between layout pattern and social structure. For layout pattern, it quantitatively analyzes the key indicators mentioned above to study the evolution of layout patterns across three periods. For social structure, it combines macro trends with micro evidence to analyze the rise and

fall of lineage organization. Based on this, the study explores the relationship and mechanisms, as well as practical strategies for value excavation and integrated preservation.

3. Result

3.1. Transformation of layout pattern

Based on significant historical events, the history of the 40 dwellings is divided into three periods (Figure 5): 1650s to 1850s (H1), 1850s to 1900s (H2), and 1900s to 1950s (H3). Dwellings are scattered throughout Xiwu. Those from the same period do not show clear clustering, indicating that the dwelling construction is a long, dynamic self-organizing process. The layout pattern mainly reflects the intentions of the owner.

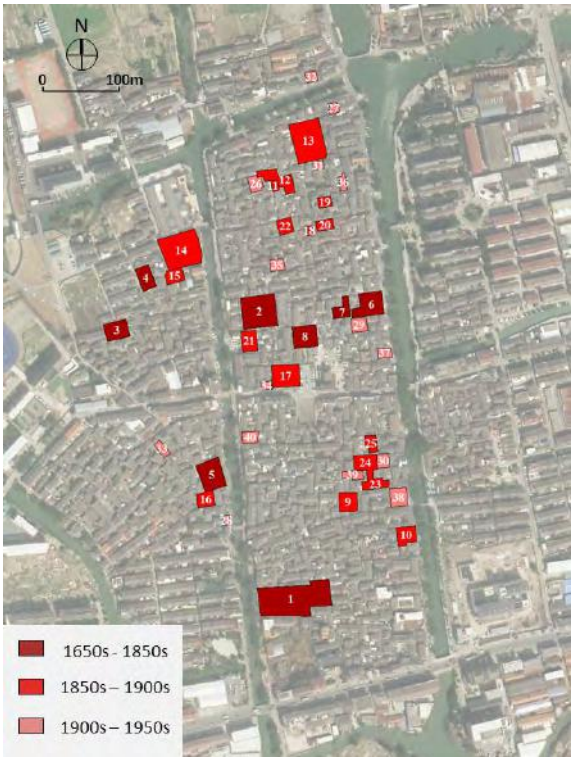


Figure 5. The temporal and spatial distribution of the 40 dwellings in Xiwu Village. Source: Authors.

Based on the three types of layout patterns and the three historical periods, the dwellings are classified (Figure 6). The study shows that incremental pattern mainly appeared in the early period, while the reduced pattern was more prevalent in the later period. In the early period, orientation of dwellings was predominantly north-south, whereas in the later period, orientation was more varied.

The evolution of dwelling layout patterns shows trends of miniaturization, simplification and a decrease in the number of residents. Overall, the dwelling layout patterns show a trend toward miniaturization and simplification. In terms of specific indicators, the decrease in floor area and number of units indicates a decrease in the number of nuclear families in each dwelling, reflecting the transition from large family to small one. At the same time, the gradual increase in the number of staircases per household reflects the improved life quality (Figure 7). These trend reflect several structural changes in society: first, the reduction of lineage restrictions on dwelling reflects the weakening of lineage power; second, the shift to smaller family units marks the transition from communal to individual living and people's pursuit of a higher quality of life.

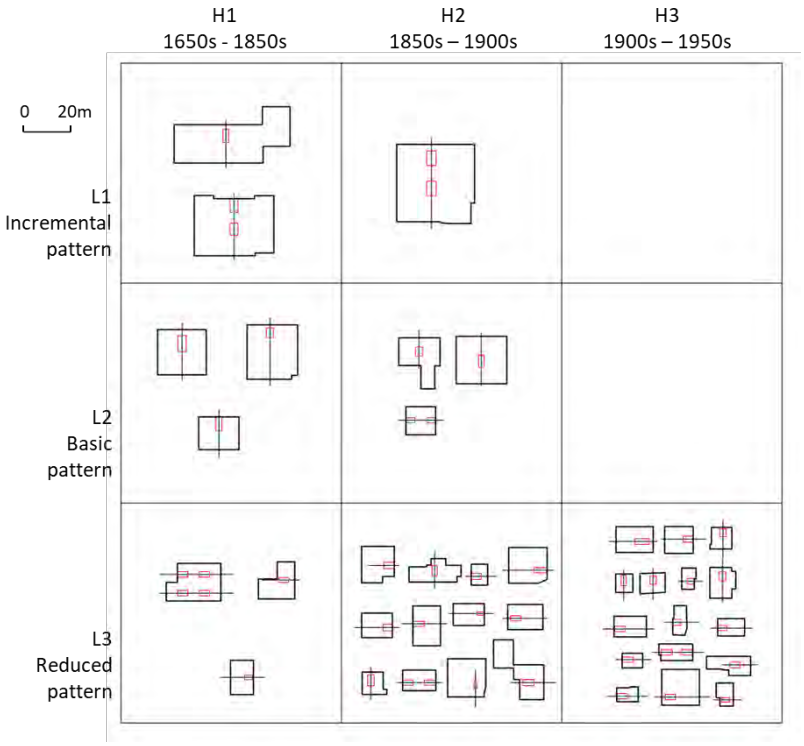


Figure 6. Classification of dwelling floor plans by construction year and layout pattern at the same scale. Source: Authors.

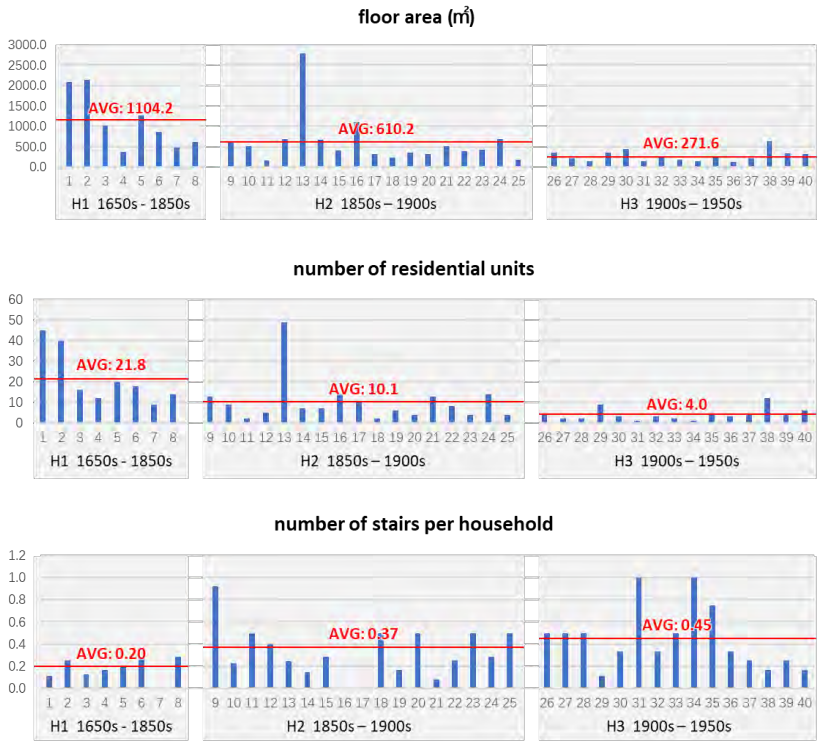


Figure 7. Trends of the average values of the three indicators over three history periods. Source: Authors.

3.2. Transformation of social structure

3.2.1. Decline of lineage organization

Since the Treaty of Nanking in 1842, Shanghai and Ningbo successively opened treaty ports and were the first five cities in China to engage in modern international trade. Consequently, international economic and cultural influence starts to manifest on China, slowly changing the socio-economic structure in the Qing dynasty. Although the major industry in regions around these trading ports was small-scale agriculture, an increasing number of people began to engage in commercial trade and physical labor at the ports. This led to a continuous flow of capitals and new perspectives and concepts back into rural areas, gradually shifting local social structure.

By the end of the 19th century, many villagers in Xiwu had already conducted business at the ports and were influenced by external thoughts. According to oral history, Wu Caiqin was baptized in 1868 at a church in Ningbo, which led to him being expelled from the lineage organization. His son, Wu Tingsheng, president of the Ningbo Shanghai Township Association, built the Zhenshen Tang (Jesus Church) in the center of Xiwu in 1923, which still stands today. Over more than fifty years, Xiwu shifted from rejecting to coexisting with Catholicism, reflecting a profound change in traditional lineage concepts, as evidenced by changes in dwelling layout patterns.

3.2.2. The change of occupation of dwelling owners in different periods

Representative dwellings with rich materials in three periods are selected to reveal the connection between changes in social structure and dwelling layout, focusing on homeowners.

In period 1 (1650s-1850s), the cases of Jiudai Changmen (1-H1-L1), Chengsan Changmen (6-H1-L3), and Houfan Changmen (13-H2-L1) are chosen. They have large and orderly layouts, which are representative of this period (Figure 8). According to genealogies and interviews, their owners were officials of the Qing Dynasty through the imperial examination system. Lineage played an important role in this process as these owners are usually supported by the lineage organization and expected to help the lineage organization when they succeeded. Therefore, lineage influences dwelling design, typically resulting in a similar layout: large, south-facing, and regular in form, accommodating extended families.

In period 2 (1850s-1900s), the cases of Tang Fang (14-H2-L3), Yu Fang (9-H2-L3), Shang Fang (23-H2-L3), and Zhou Fang (24-H2-L2) are selected. Compared to the previous period, they transitioned from orderly to more free layouts (Figures 9). According to genealogies, owners of these buildings were the sons of the same family (Figures 10). However, their dwellings exhibit entirely different forms, and there is a notable trend of donating to secure official positions. Donating to secure official positions refers to a practice where individuals could donate money or goods to the state to obtain noble titles or official positions. This trend reveals that the development of this lineage relied more on economic means rather than imperial examination. Consequently, the role of the lineage organization in supporting the examination diminished, which allows the four brothers to build their houses flexibly without being restricted by lineage rules.

In period 3 (1900s-1950s), the cases of Hongkuan Fang (12-H2-L3), Meichuan Fang (26-H3-L3), Wu Zhihai's Former Residence (33-H3-L3), and Chengbai Fang (36-H3-L3) are selected. They are characterized by smaller and more flexible layouts (Figure 11). According to in-depth interviews and history documents, the owners of these dwellings engaged in business or managed commercial activities in port cities like Ningbo and Shanghai, primarily residing there and occasionally returning home. Thus, the relationship between homeowners and the lineage organization weakened during this time, which further liberated dwelling layout.

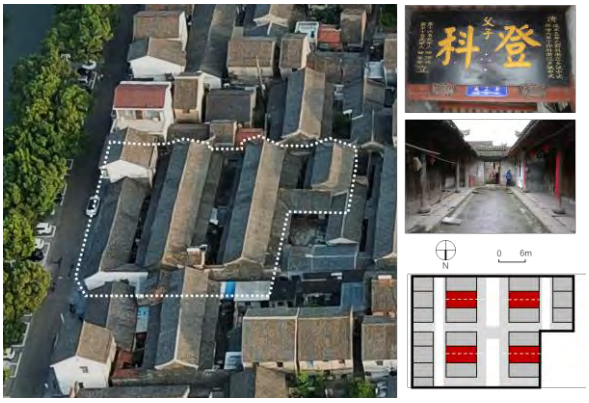
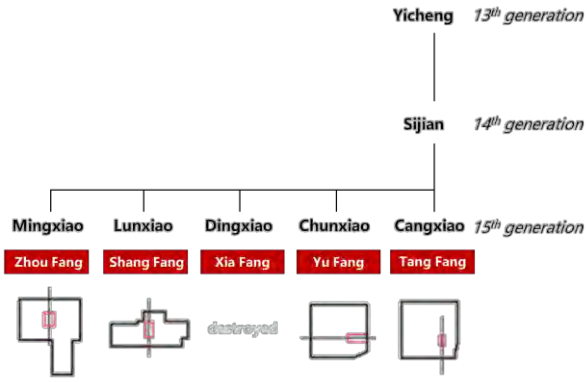


Figure 8. (left) In period 1, a typical case is Chengsan Changmen, where the homeowner succeeded in the imperial examination system. This is evidenced by the plaque in the upper right corner, which records that a father and son achieved the rank of Juren in 1855 and 1867, respectively. This reflects the imperial examination as the mainstream developmental path for individuals within the lineage organization at that time. Source: Authors.

Figure 9. (right) In period 2, a typical case is Zhou Fang, where the homeowner engageed in local business activities. Source: Authors.



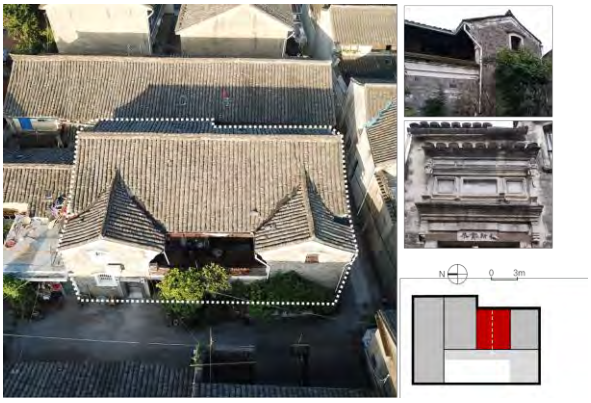


Figure 10. (left) Four typical cases from period 2, each displaying distinct forms. Source: Repainted from historical documents.

Figure 11. (right) In period 3, a typical case is Chengbai Fang, the homeowner conducted business in Shanghai. Source: Authors.

The comparation of representative dwellings from the three periods reveals a simplification of layout patterns over time. The identities of homeowners shifted from officials to local merchants and then to merchants in port cities. Homeowners increasingly embraced external cultural influences, prioritizing individual comfort over collective living. Their choices reflect broader social structural changes: with regional economic development and international cultural impacts, the traditional lineage society gradually transformed into a more atomized modern society. Correspondingly, dwelling layouts shifted from orderly to flexible, and from ritual constraints to comfort.

3.3. Interaction mechanism

The mechanism of social structure and dwelling layout pattern is summarized in Figure 12. In the case of Xiwu, the lineage organization is the original social structure, and lineage rituals impose strict regulations on building orientation and layout for homeowners. However, since the mid-19th century, many villagers engaged in business outside the village, weakening the relationship between the lineage and the villagers. This migration brought capitals and new cultural concepts from port cities, enabling villagers to break free

from lineage constraints and pursue individual comfort in housing design. This mechanism applies not only to Xiwu but also offers insights for the transformation of other traditional Chinese villages. Within this mechanism, social structure influences homeowners through economic and cultural factors, and the homeowners' values are reflected in the design of their dwelling layout. The former constitutes an important part of social memory, while the latter represents built heritage. Dwellings embody both invisible social memory and visible built heritage, making them crucial for the integrated preservation of intangible and tangible heritage in traditional village.

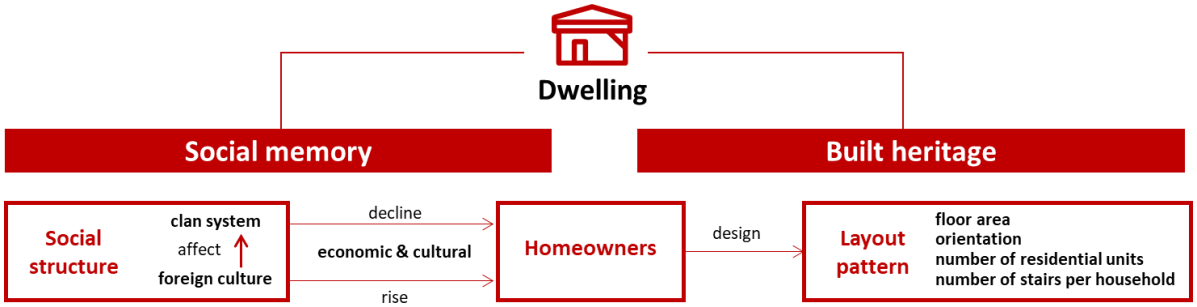


Figure 12. The socio-spatial mechanism in the modern transformation of traditional Chinese villages

3.4. Planning suggestions

In 2019, the "Protection Plan for the Historical and Cultural Village of Xiwu in Fenghua District, Ningbo City" was issued. This plan delineates zones for preservation, construction control, and environmental coordination based on village layout, cultural heritage sites, historical buildings, and environmental factors. It emphasizes the preservation of festive customs, traditional crafts, and historical narratives to address both tangible and intangible cultural heritage (Figure 13, left). However, the plan still has several shortcomings. For tangible heritages, only one historic bridge is designated as a cultural heritage site, while the majority of historical buildings, primarily traditional dwellings, lack targeted preservation methods, which leads to a loss of focus in preservation efforts. For intangible heritages, the approaches are shallow and cannot fully reveal the social structure dynamics that's worth preserving.

Findings of this paper provides insights into planning recommendations. The 40 historical buildings can be classified into three types. For each type, those with high-value should be prioritized for preservation, while others will undergo general preservation methods (Figure 13, right). This approach makes preservation practices more actionable by combining preservation priorities with diversity concerns. Furthermore, one representative dwelling from each type should be chosen for exhibitions, providing a spatial medium for the display of social memory and its transmission.

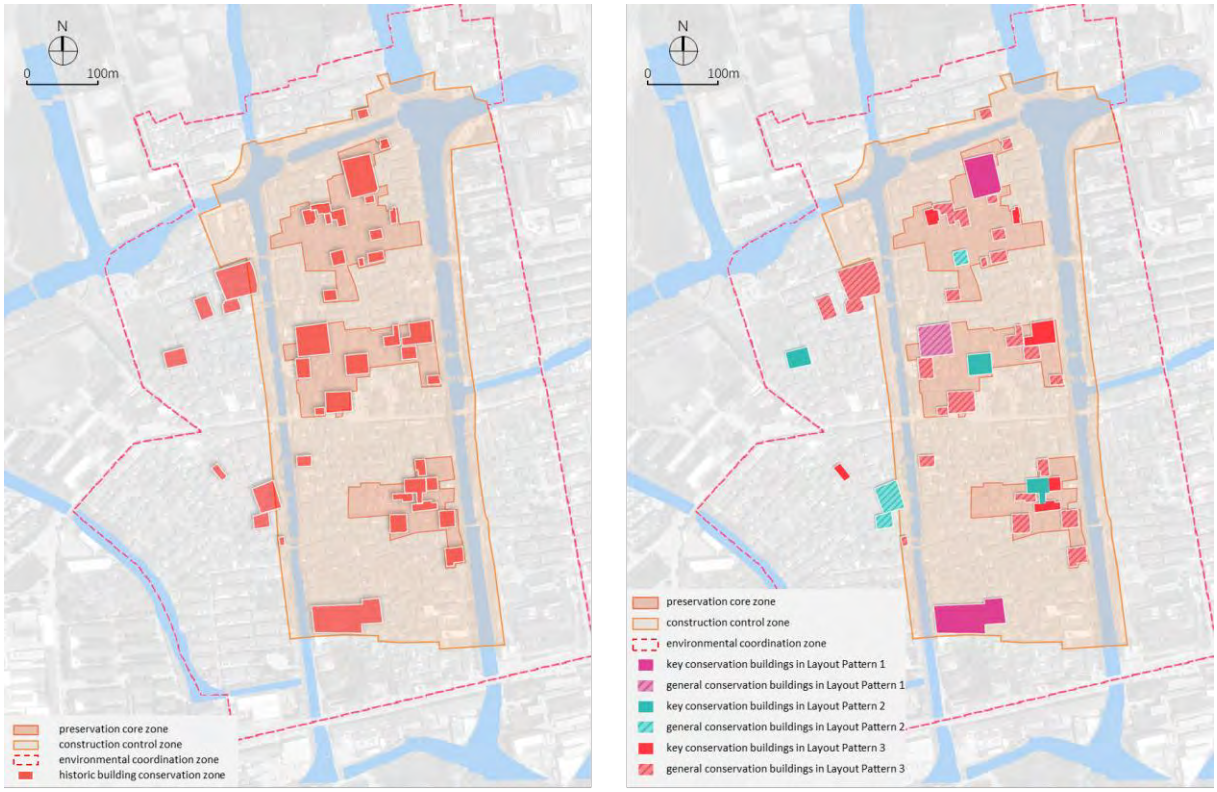


Figure 13. Adjusting the existing preservation strategies based on socio-spatial analysis by classifying historic buildings into different levels of preservation. Source: The left map is repainted from the perservation planning provided by the local government, the right map is redrawn by the authors on the basis of the left map.

4. Conclusion and discussion

This study focuses on the evolution of dwelling layout patterns in traditional Chinese villages and how it reflect changes in broader social structure. It selects 40 dwelling layouts from Xiwu Village as research subjects, and employs typological analysis and statistical methods to explore socio-spatial evolution.

This research identifies three distinct periods in the evolution of dwelling layout patterns: 1650s to 1850s, 1850s to 1900s, and 1900s to 1950s. A trend toward simplification is evident, characterized by decrease in floor area and residential units, increase in the average number of staircases per household, and shifts in architectural orientation. Regarding homeowners identities, there was a transition from officials to merchants, and from local towns to port cities. Overall, these changes reflect a weakening of constraints imposed by lineage organization and the rise of individual consciousness during the modernization process. Regional economic development and the influence of external culture were driving factors in this proces.

Since the mid-19th century, external cultural influences penetrating deeper inland through port cities, which influenced social structure across various regions and were manifested in settlement spaces. In southeastern China, exemplified by Xiwu, the power of lineage organization gradually diminished under the influence of external culture, leading to a shift from a big lineage-based social structure to small family-centered social structure. Dwelling layout patterns therefore evolved from large and formal to small and flexible. These phenomena and their underlying socio-spatial mechanisms have broad applicability in southeastern China and beyond.

In order to preserve and revitalize traditional villages, it is crucial to consider the relationship between dwelling layout patterns and social structure, and establish a socio-spatial framework to reveal the spatial carriers of social memory. For Xiwu, the broader social context, shifts in homeowner identities, and changes in lineage concepts represent valuable social memories, with dwelling layout patterns serving as spatial carriers. A more inclusive perspective should be adopted to revitalize traditional villages and excavate social memories, focusing not only on heritage classification but also on preserving dwellings from different periods and of different layout patterns. By doing so, we can ensure an integrated preservation of both tangible and intangible heritage.

There are a few limitations in the study. First, the relatively small sample size of early dwellings may affect the measurement of certain indicators. Future research should go beyond individual villages to include more case studies to further validate the generalizability of the findings. Second, in-depth interviews with case studies could also be conducted to analyze the specific mechanisms of socio-spatial interactions.

Acknowledgments

We would like to thank to Ningbo Fenghua District Museum for providing the dwelling plans, and thank to the villagers of Xiwu for providing historical documents and receiving interviews.

Funding

This work was supported by “National Social Science Foundation of China”(NO. 23&ZD256).

Declaration of AI-assisted technologies in the writing process

During the writing process of this paper, the authors used AI-assisted technology (ChatGPT) to improve language because the mother language of the authors is not English. After using it, the authors reviewed and edited the paper carefully and take full responsibility for the content of the publication.

5. References

Bustard, W. (1999). Space, Evolution, and Function in the Houses of Chaco Canyon. *Environment and Planning B: Planning and Design,* 26(2)**,** 219-240.

Cai, H. (2020). Henglou Hall: Ritual Space Expansion in the Evolution of Dacuo in Eastern Fujian. *Architectural Journal,* (06)**,** 22-27.

Cai, L. & Dai, L. (2009). Analysis of Characteristics of Traditional Dwellings in Ningbo Plain Area: Case Study of Ancient Village of Zoumatang. *Journal of Ningbo University (Science and Technology),* 22(03)**,** 430-434.

Chen, Z., Lou, Q. & Li, Q. (1999). *Zhuge Village : Chinese Vernacular Architecture,* Chongqing: Chongqing Press.

Dai, F. (2020). Morphological Study of Vernacular Settlements Based on Lineage Social Structure: Beilei Chen Settlement in Yiwu, Zhejiang Province. *Heritage Architecture,* (01)**,** 35-43.

Freedman, M. (1960). *Lineage Organization in Southeastern China,* London: The Athlone Press.

Gu, Y. & Huang, X. (2017). Spatial Representation of Rural Clan-Organized Society Structure: the Case of Chaoshan Culture Area. *Urban Planning Forum,* (03)**,** 103-109.

He, Y. & Sun, L. (2017). A Study on the Courtyard Unit of Traditional Settlements Based on Clan Structure as Exemplified in Zoumatang Village, Ningbo. *Architectural Journal,* (02)**,** 90-95.

Knapp, R. G. (1989). *China's Vernacular Architecture: House Form and Culture,* Honolulu: University of Hawaii Press.

Li, X., Chen, D., Xu, W., Chen, H., Li, J. & Mo, F. (2023). Explainable dimensionality reduction (XDR) to unbox AI 'black box' models: A study of AI perspectives on the ethnic styles of village dwellings. *Humanities and Social Sciences Communications,* 10(1)**,** 1-13.

Lin, X. (2022). The "Ideal Pattern" of Vernacular Settlements along the Yellow River: An Anthropological Investigation of the Haijia Village. *Architectural Journal,* (11)**,** 96-103.

OpenAI. (2024). *ChatGPT*[Large language model]. Available at: https://chat.openai.com.

Pan, Y. & Shi, Y. (2014). Comparative Study on Traditional Settlement Patterns of Hunan-jiangxi Clan and Guang-fu Clan. *South Architecture,* (03)**,** 79-85.

Pan, Y., Zhou, X. & Shi, Y. (2015). 100 Years of Two Villages: Study of Modernization of Rural Settlements in Chaoshan Area. *South Architecture,* (03)**,** 71-78.

Rapoport, A. (1969). *House Form and Culture,* London: Englewood Cliffs, N.J.

Ruggiero, G., Parlavecchia, M. & Dal Sasso, P. (2019). Typological characterisation and territorial distribution of traditional rural buildings in the Apulian territory (Italy). *Journal of Cultural Heritage,* 39**,** 278-287.

Shen, K. (1992). Settlement Structure and Social Organization in Longmen Village, Fuyang County. *Architectural Journal,* (02)**,** 53-58.

Wang, Y. (2009). *Space Concept in Traditional Settlement Structure,* Beijing: China Architecture & Building Press.

Yang, X., Ma, H., Zhang, L. & Song, K. (2021). Inheritance, fusion, and variation during migration: An analysis of spatio-temporal morphological development of traditional Guangdong Hakka architecture and settlements. *Geographical Research,* 40(04)**,** 958-976.

Yang, X. & Zhang, L. (2020). The Form and Structure of Hakka Rowhouse Villages in Shenzhen: a Case Study of the Old Guihu Pond Village. *Architectural Journal,* (09)**,** 111-115.

Yin, L. & Liu, P. (2023). Type expression and spatial differentiation of planar archetype genes of traditional dwellings of the Xiangjiang River Basin. *Geographical Research,* 42(08)**,** 2191-2210.

Zanfi, F., Merlini, C., Giavarini, V. & Manfredini, F. (2020). A portrait of Italian 'Family houses': diversified heritage in a redefined territorial and demographic context. *City, Territory and Architecture,* 7(1)**,** 1-16.

Zhang, L. (2020). Three Prototypes of Southern Han Chinese Houses and Related Anthropological Meanings. *Architectural Journal,* (07)**,** 20-25.

Zhou, Y. (2020). Pedigree and Spatial Analysis of Zhe-style Vernacular Architecture. *Heritage Architecture,* (01)**,** 2-17.

Research Paper

Planning A "Cultural Center" for Athabasca Oil Sand Mining Region in Canada:

Establishing A Cultural Ground for Techniques of Reclamation in Fort Mckay First Nation

Yiqun WANG*, University of Innsbruck, Austria & Harvard Graduate School of Design, United States

*Corresponding author: Yiqun Wang, yiqunwang24@gmail.com

Abstract

In order to address the environmental and cultural issues brought on by heavy resource extraction, this article examines the planning of a "Cultural Center" for the Athabasca Oil Sand Mining Region (AOSMR) within Fort McKay First Nation (FMFN). The project, which draws inspiration from Baku's urban planning paradigm, aims to achieve regional harmony by integrating both industrial and natural landscapes in a balanced development approach. There are three primary centers identified: Fort McKay, Fort McMurray, and Fort Chipewyan. Fort McKay is positioned as the cultural center to meet the social and cultural needs of the indigenous community. At the heart of this idea is the construction of a "non-stop tailings pond," which combines cultural practices and reclamation to create a dual-use landscape that promotes indigenous customs and ecological restoration. The idea of the "Toxic Sublime," which turns contaminated industrial areas into places of cultural significance, further strengthens this strategy. The design promotes sustainable practices, indigenous land use, and "community capitalism" that honors both regional customs and the demands of the global market. The strategy's ultimate goal is to combine reclamation and cultural reoccupation to build a resilient and culturally thriving future for Fort McKay.

Keywords

Athabasca oil sands, Fort McKay First Nation, reclamation, cultural hub, regional planning, toxic sublime

1. Regional Scope and Planning Models: From Baku to Athabasca

1.1. The Regional Complex: Integrating Urban and Natural Landscapes

In *the Oil City of Socialist Man*, Eve Blau introduced a model for viewing Baku through a regional lens. During the city planning of 1969–1973, Baku was conceptualized as an urban region comprising an integrated system of production and reproduction. The plan aimed to balance the distribution of people, services, and goods through new towns, satellite cities, and existing urban hubs, with municipal and industrial centers interconnected by small clusters of nearby neighborhoods. An essential component of this vision was the establishment of "vacation zones" with holiday homes, tourist sites, sanatoria, and health facilities, which were seen as integral parts of the metropolitan area (Blau, 2018).

The case of Baku suggests several regional planning principles that resonate in resource extraction contexts, like the Athabasca Oil Sand Mining Region (AOSMR) and its Fort McKay First Nation (FMFN). In the article *The Regional Framework of Civilization*, Lewis Mumford's framework offers insights on the concept of "regional planning," precisely in contrast with "metropolitan planning" (Mumford, 1995). Applied to the realities of AOSMR and FMFN, this framework supports exploring the potential for regional planning to create distinct identities within the region.

Regional planning is characterized by its "constitution." It alludes to integrating permanent rural areas, cities, and villages into the regional complex. Unlike metropolitan planning, which views the surrounding open country as eventually being eaten by human expansion, regional planning seeks to maintain a balance between the urban setting and the surrounding agricultural and natural environment. Regional planners recognize the value of easy access to the city for people living in rural areas and reasonable access to the countryside for the culture and education of city dwellers. Based on this idea, regional planning starts with a regional assessment. Instead of concentrating on the city as a whole, it seeks to maximize the utilization of all of its resources. This approach doesn't always require decentralization or homogeneous urban sprawl across the region. A portion of the population may be relocated from crowded metropolitan areas to more beneficial locations, nevertheless (Mumford, 1995).

This definition makes the Athabasca Oil Sand area, which includes the city of Fort McMurray, the community of Fort Mckay, and the surrounding forest land rich in oil sands, a region in the northeastern part of the Canadian province of Alberta (Figure 1). In the late 1950s, the area was a wilderness outpost with only a few hundred people living there, mostly working as fur trappers and salt miners. However, the population of the Fort McMurray boomtown and the surrounding area, known as the Regional Municipality of Wood Buffalo, increased significantly to 37,222 by 1996. A 30,504-person "shadow population" who resided in work camps constructed by Oil Sand Companies was among the 106,059 residents as of 2021. The village made a great effort to house and serve the migrant workers, many of whom came from Eastern Canada, particularly Newfoundland. Fort McMurray became an urban service area of Wood Buffalo after losing its municipal status in 1995 (Regional Municipality of Wood Buffalo, 2021).

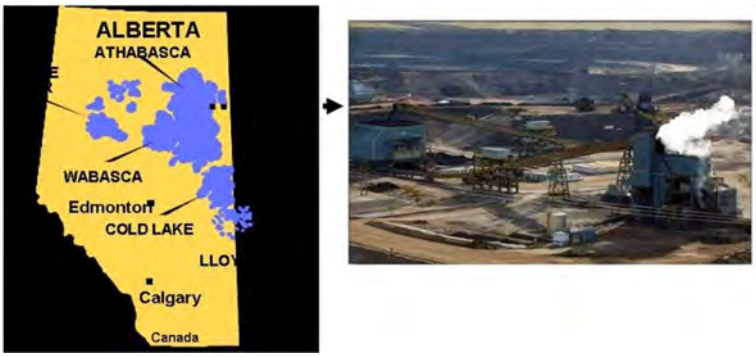


Figure 1. Athabasca Oil Sand area. Source: "Athabasca Oil Sands: Environmental and Societal Impacts," Eugene Dembicki, Canadian Heavy Oil Association, 2007.

1.2. Balanced Environment and Stable Life

The commitment of regional planning to preserving a stable way of life and a healthy environment is another essential component. Over the course of the last century's land development and urbanization, the ideas of stability and balance were overlooked. A strong focus on extracting coal and iron from the earth while optimizing returns for investors led to the development of coal agglomerations and financial metropolises. Unfortunately, keeping pure, picturesque landscapes was sacrificed in order to achieve these goals. These settlements produced unprecedented amounts of coal, textiles, pig iron, chemicals, and

money, but they also produced a startling quantity of filth, depravity, and human suffering, in contrast to claims of progress and enlightenment (Mumford, 1995). These disparities and adverse impacts are also present in the Athabasca Oil Sand Mining Region. For the First American villages of Athabasca, the oil sands industry is a major source of income. The movement of materials between Canada and the states across the world is increasing (Nikiforuk, 2010). Large tailings ponds are used to recycle tailings slurry at mining operations. The four strata of the slurry are topped and bottomed by sand and water (Figure 2) (Oil Sands Magazine, 2021). Super hazardous tailings will be banned for 150 years in the meantime. However, the Fort McKay First Nation region, which is encircled by mining operations, is the site of major disputes. In addition to causing an increase in pollution and health problems, the growth of tailings ponds between 1975 and 2020 also resulted in the destruction of lands and their traditional uses, including hunting, trapping, gathering, and studying (Figure 3). These activities were the foundations of Fort Mackay First Americans' culture and subsistence methods.

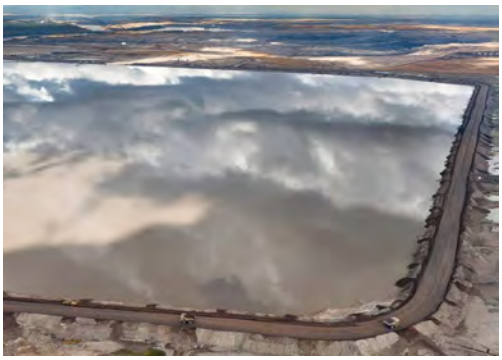


Figure 2. Tailings Ponds in Alberta, Canada. Source: National Geographic Photo of the Day, 2024.

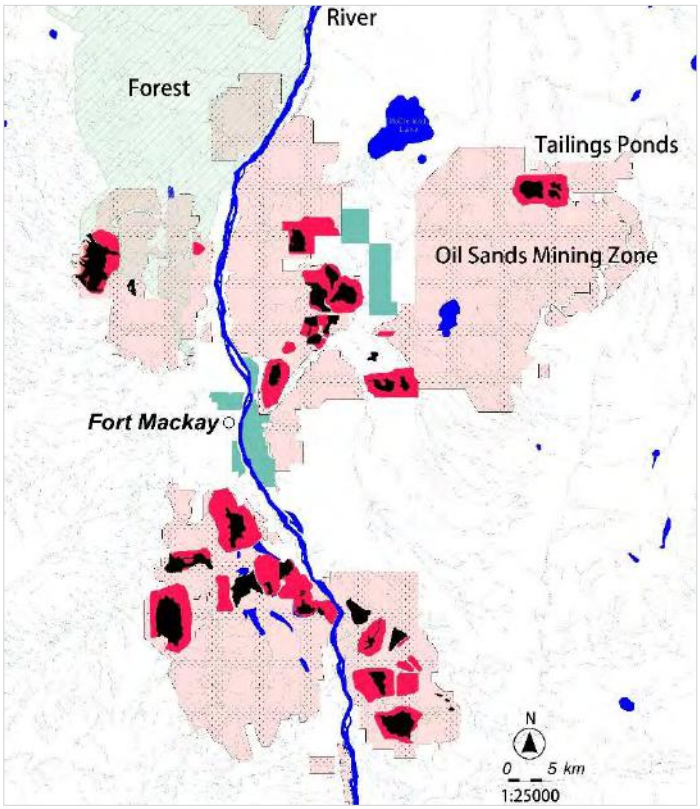


Figure 3. Map of Oil Sands Operations Indicating Surface Mines and Tailings Ponds Locations. Source: Author.

1.3. The Regional City: New Norms for Sustainable Development

The solution to the question, "What is the proper size of the city?" is the final point of regional planning. Lewis Mumford argues that the size of a city is tied to the institutions and services to be serviced rather than being clearly defined by its current or potential boundary lines or by a superficial area to be filled. The farms, marketplaces, and industries that support the city's existence, as well as the institutions that support the cultural and educational lives of its residents, define it. Civic institutions and population are closely related; more institutions are needed to meet the needs of increasing populations. Thanks to improvements in communication and transportation, cities may now concentrate on certain activities instead of trying to satisfy every possible requirement. There is no compelling reason for any city to attempt to meet every human need given the state of communication and transportation today. This suggests that the new regional model will be made up of interlinked municipalities that are united by a regional governing body to form joint ventures and are divided by permanent farmlands and green areas. Every city would have all the necessary local facilities to sustain its operational existence, including clubs, churches, theaters, auditoriums, schools, and local marketplaces. Additionally, each center would focus on a particular cultural or social institution, such a university in one, a radio broadcasting station in another, or a museum of natural history in a third. This new kind of city model is made possible by the simultaneous elimination of the necessity for ongoing urban sprawl. No city would strive to be the regional hub for everything, but each city might be able to act as a regional hub for at least one function (Mumford, 1995).

Three distinct centers—Fort McKay, Fort McMurray, and Fort Chipewyan—do not exhibit this model for the Athabasca Oil Sand Mining Region (Figure 4). There is an urgent need for a center that focuses on the social and cultural life of First Americans. More significantly, regional planners can assist in making this a reality. Lewis Mumford stated that the regional planner's goal is to "create a new pattern of regional and civic activities and to establish new norms of city growth." One of the main responsibilities of the regional planner is to identify these different norms, connect them to civic duties, and implement them in communities (Mumford, 1995). Thus, the following hypothesis is developed in order to improve this region's prospects through regional planning: Fort Mckay First Nation is located in the middle of the region, encircled by many tailings ponds. There is a chance to empower the First American people and create a cultural center in the Athabasca Oil Sand Mining Region by reclaiming these tailings ponds and giving the land back to the community.

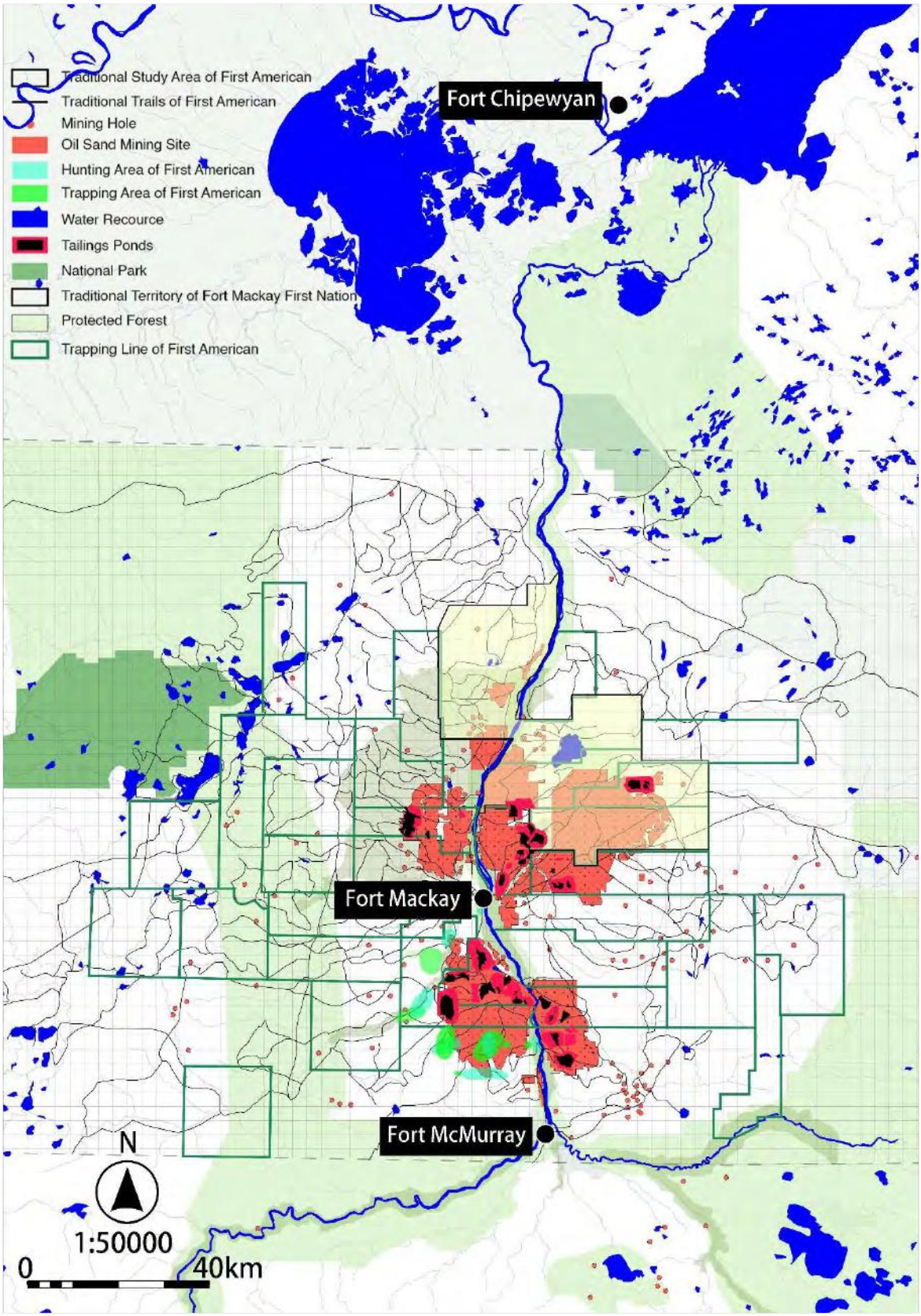


Figure 4. Community of Fort McKay, Fort McMurray, and Fort Chipewyan in Athabasca Oil Sand Mining Region. Source: Author.

1.4. Respect for New and Emergent Elements in Our Civilization

Regional planning sets itself apart from metropolitan planning by acknowledging new and emerging societal elements. The advent of modern utilities such as the radio, moving pictures, airplanes, telephones, electric power, and automobiles have increased the potential benefits of the region as a whole compared to the congested metropolis. These instruments have removed the unique advantage of densely populated areas, and their benefits are now distributed equally. This reason supports the regional planner's interest in small-scale communities, as they offer greater flexibility, ease of adaptation to new situations, and faster utilization of the latest technological advancements. However, this is only feasible if there is intelligent leadership in place to take command (Mumford, 1968).

Back to the Athabasca Oil Sand Mining Region, the cold weather, vast forests, and mobile populations make it easy for new technologies to be used in regional planning. Besides cars, airplanes are the most used transportation in this area. Different oil sand companies often have small airfields within their fields to make commuting easier for employees within the region. At the same time, First Americans could take these planes to remote forests, like Moose Lake and Buffalo Lake， for hunting, fishing, and other cultural practices. Thus, "fly in, fly out" becomes a promising transportation mode for short journeys within the region. Imagine a future where Fort McKay's oil sands are recycled, but each small airport is retained as transportation infrastructure for this cultural center —— First Americans from across the region can easily reach and practice their culture here (Dorow and Jean, 2022).

2. Indigenous Culture and Environmental Sustainability

2.1. Forest-Based Culture and Traditional Land Use

Understanding the forest-based traditions that form the Fort McKay First Nation's cultural foundation is essential to building a cultural center in AOSMR. The urban, political, and ecological consequences that are concurrently produced at other scales by the same processes—all of which are closely related to human agency—are invariably overlooked by Lewis Mumford's argument, even if it has solidified a specific vision of the urban outside around the scale of "region." Another question that must be addressed in order to create a culture center in the Athabasca Oil Sand Mining Region is: What is the culture of Fort McKay? To respond to this topic, one must comprehend the First American's natural home, the forest, from which they have historically farmed their means of subsistence as well as shaped a modern political ecology practice.

Figure 5. Fort McKay Cultural Model. Source: The Human Environment Group in Canada, 2009.

The idea of "Cultural Keystone Species" (CKS) sheds light on Fort McKay First Nation's forest-based culture (Garibaldi, 2009). Certain plants and animals at Fort McKay are essential for sustenance and cultural identity, influencing storytelling, spiritual rituals, and social norms, much like salmon is for the Northwest Coast peoples and bison is for the Plains tribes (Figure 5) (Human Environment Group, 2009). By integrating themselves into everyday life and cultural narratives, these animals have an impact on environmental philosophy and resource management. Moose, caribou, beaver, and birch can be found in the coniferous and deciduous forests and muskegs of Fort McKay's boreal forest. These grounds are essential to Fort McKay's history because they provide food, medicine, supplies, and water. However, these landscapes are undergoing substantial change due to the industrial push for oil sands extraction, which has an impact on both Indigenous land use patterns established since the growth of the fur trade in the 17th century and ecological integrity (Garibaldi, 2009).

An excellent resource for Fort McKay is Jose R. Oliver's *The Archaeology of Forest Foraging and Agricultural Production in Amazonia*, which provides an illustration of how to comprehend the agricultural habitat and associated cosmology in the prehistoric Amazon Forest. The article defines a "agricultural plot" as a micro-habitat that has been systematically altered and tended by humans. The "natural habitat" is nevertheless greatly impacted by non-human elements such soil chemistry, creatures, microorganisms, and climate. Depending on the area and time, the extent of human-induced disruption can vary widely, from biotic circumstances that may be hard to notice by Western standards to nearly undetectable changes. To comprehend the development of Indigenous agricultural knowledge and farming technology, it is essential to compare the natural habitat with the manipulated and modified agricultural ecosystem (Oliver, 2008).

As the author pointed out, "'agricultural potential' is not something inherent in nature when we consider human agency." The word "culture" is part of the notion. According to Oliver (2008), "the tropical forest is not a homogeneous entity but rather a complex ecological mosaic offering significantly different potential for its inhabitants." It alludes to the fact that different agroeconomic systems based on indigenous peoples of the Amazonian rainforest have evolved in distinct macro-habitats. All upland rainforest communities have a mutually beneficial connection with plants, animals, and resources that follow sustainable ecological principles, despite variations in their dietary tactics. They see themselves as an integral part of the ecosystem rather than as being above the natural order. The forest-based cultural heritage of Fort McKay, which is firmly anchored in the rootedness, rhythm of nature, and reverence of the forest land, is equally subject to such reasoning and ideals. Therefore, it is possible to view the Fort McKay First American

community's traditional land usage and various harvesting practices as a depiction of their traditional culture.

2.2. Community Capitalism: Economic Models Rooted in Indigenous Practices

Bottom-up Community Capitalism is another aspect of Amazon that can be used as a guide for Fort Mckay. Indigenous communities' economies range from micro and community levels to the oil extraction sites in Amazonia. In communes like Añangu, which have effectively established their environmental tourism and related land management, labor organization, and infrastructure building without sacrificing their cultural and ecological legacy, local and worldwide market circuits are integrated. A comparatively optimal stage of community capitalism is the trans-scalar economic ecosystem created in the agglomeration process of Amazonia villages, which links the regional and the global (Durán Calisto, 2018).

Community capitalism has become a tactic in Fort McKay to deal with the significant cultural and environmental effects of the oil sands sector (Flanagan, 2018). The approach taken by Fort McKay has focused on developing business relationships with oil corporations, in contrast to Añangu's ecotourism model in Amazonia, which balances economic activity with ecological preservation. Through the Fort McKay Group of Companies, which supports oil sands operations logistically and operationally, the community has established an economic base since 1986. In addition to creating jobs locally and abroad and bringing in a sizable amount of tax money for the Canadian government, these endeavors strengthen the local economy. Due to the presence of 13 major operations within a 50-kilometer radius, oil sands mining, which started in the Fort McKay area in 1964 with Suncor Energy's development, has brought about considerable landscape changes, economic gains, and cultural issues. Areas used for hunting, fishing, and collecting have changed, affecting traditional customs and raising health issues. Because of the environmental damage and industrial operations occurring on or close to holy and historically significant locations, the community has greater incidence of respiratory problems, stress, and a sense of cultural alienation from their land. Residents of Fort McKay face a difficult balancing act as a result of this type of community capitalism, as many struggle to maintain their traditional way of life while also finding full-time work (Westman et al., 2019). The issue highlights the necessity for reclamation initiatives to preserve culturally significant species and respect Indigenous ties to the land, as it represents a complex trade-off between economic survival and the preservation of Fort McKay's cultural heritage (Garibaldi, 2009).

3. Transforming Toxic Landscapes: Toward a Cultural Ground for Reclamation

3.1. The Aesthetic of Toxic Sublime and Ethical Dilemmas

The "Toxic Sublime" concept, which depicts industrial landscapes that are both aesthetically stunning and fundamentally damaging (Figure 6), captures the complex moral and aesthetic dilemmas raised by the environmental impact of the oil sands industry near Fort McKay (Peeples, 2011). As per this hypothesis, even if these landscapes endure a lot of pain, their bare, almost majestic aspect is revealed from overhead views that emphasize their grandeur and intricate features. These powerful images, however, often hide the continuous destruction inflicted on neighboring towns. According to Indigenous Climate Action (2024), these distant, dehumanizing images do not adequately depict the severe health, environmental, and cultural impacts that the toxicity directly affects vulnerable groups, especially Indigenous communities.

Figure 6. Tailings Pond #2, Wesselton Diamond Mine, Kimberley, Northern Cape, South Africa. Source: Edward Burtynsky, 2018.

While recognizing the environmental implications of these landscapes, the initiative suggests that such "toxic" sites might be converted into places of cultural significance, reestablishing Fort McKay First Nation's connection to its history and the environment. Seeing these places' beauty and peril via the "Toxic Sublime" lens encourages a new approach to regional planning that transforms contaminated landscapes into cultural spaces that respect Indigenous heritage. Here, industrial trash is not only hidden but also incorporated into landscapes that hold cultural significance, making a strong statement about adaptability and resilience (Garibaldi, 2009).

The ethical dilemma of striking a balance between acknowledging the harm done and respecting cultural values arises when a cultural center is built among these altered environments (Roncken, 2018). While businesses may take pride in the aesthetic impact of their industrial sites as representations of their manufacturing prowess, an assessment of these sites' aesthetic value must also take into account the suffering that the impacted populace face. A dedication to maintaining Indigenous ties to the land in the face of continuous industrial impacts is strengthened by converting these polluted sites into places that honor cultural history and serve as a reminder of environmental sacrifices.

This situation also relates to Lewis Mumford's assertion that regional planning is an issue in the Regional Framework of Civilization. The environment was neither lively, instructive, or recreational. He said, "We created an environment that in part—its inefficiencies were so great that one must stress this phrase—in part was good for machines and money-making: but it was not good for men." He continued after the lumber cutter had decimated the Appalachian forests, the pioneer had stripped the soil, and the miner had exhausted his mine. Mumford (1995) asserted that "all these social types left rack and ruin behind them." The regional planner should be aware that a society cannot endure as an unstable and itinerant one. An established way of life focused on the constant resupply and care of the environment is necessary for a sustainable lifestyle. Regional planning, which involves a balanced social life and resource usage, facilitates the settlement of an area. It is impossible to achieve such equilibrium in an unbalanced environment.

3.2. The Toxic as Habitat: Creating a Non-Stop Tailings Pond

Thus, from a regional planning scope, the project, viewing "toxic as cure," seeks to use the environmental impacts of the oil sands industry as a foundation for ecological and cultural restoration. The severe ecological damage caused by oil sand extraction has enriched global markets but devastated local ecosystems and Indigenous ways of life. Reclaiming these sites as cultural grounds, the proposal aims to reconnect Fort McKay First Nation with its heritage and ecology, bridging industrial recovery and Indigenous cultural values.

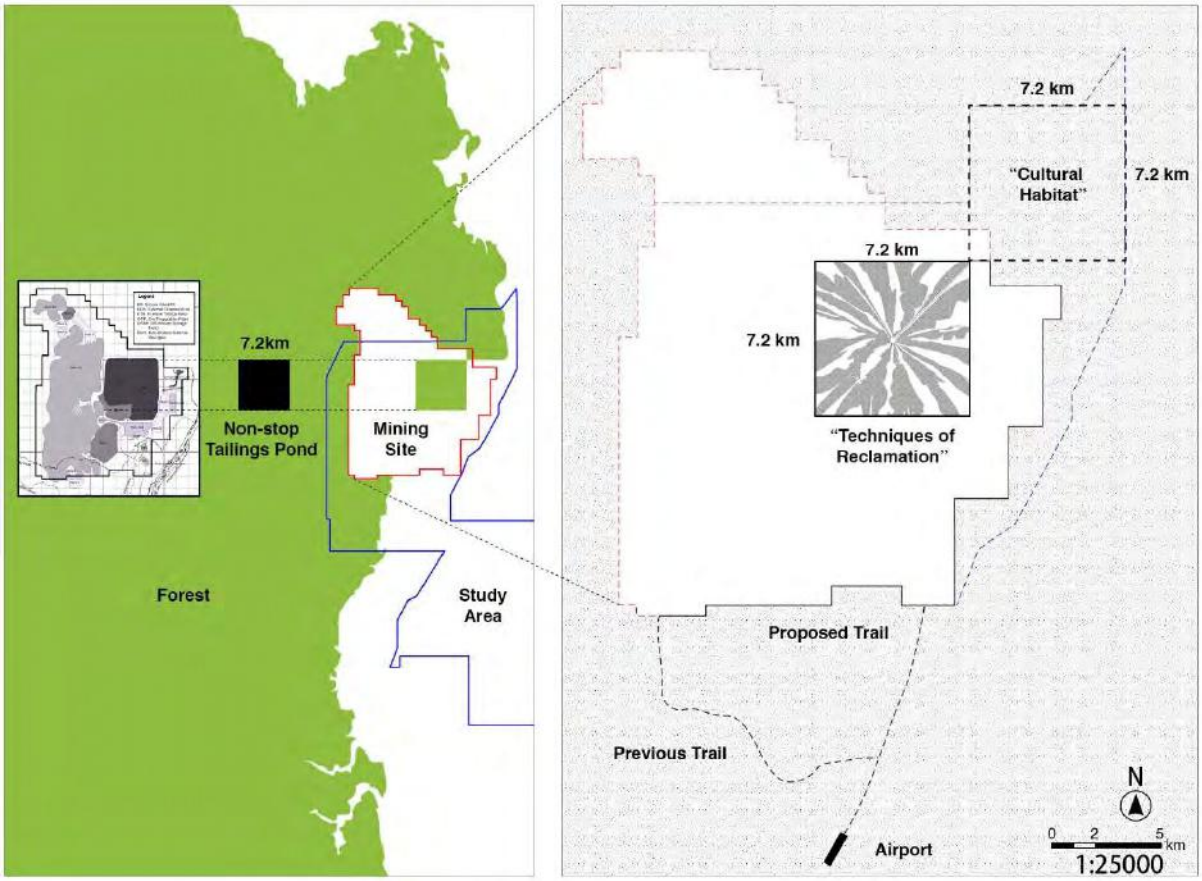


Figure 7. Area plan. Source: Author.

The main tactic is around a "non-stop tailings pond," which is a continuous reclamation method that combines ecological restoration, cultural reoccupation, and mining operations. This idea aims to create a dual-use landscape that supports ecological recovery and functions as a cultural place by transforming a 7.2-square-kilometer tailings pond in the northern forest close to Fort McKay (Government of Alberta, 2018). To reclaim the tailings pond area, vegetation would be transplanted from a "twin landscape" in the forest, resulting in a coordinated, ongoing restoration process (Figure 7).

In order to create a cultural center that balances Indigenous and industrial temporal cycles, the proposal makes use of the common idea of circular time. Reclamation for the oil sands sector occurs 50 years after closure, but traditional cultural processes for First Nations are guided by seasonal cycles (Figure 8). These rhythms are combined in the "non-stop tailings pond," which permits mining, reclamation, and cultural pursuits to coexist inside a common "time circle" (Sobkowicz, 2013).

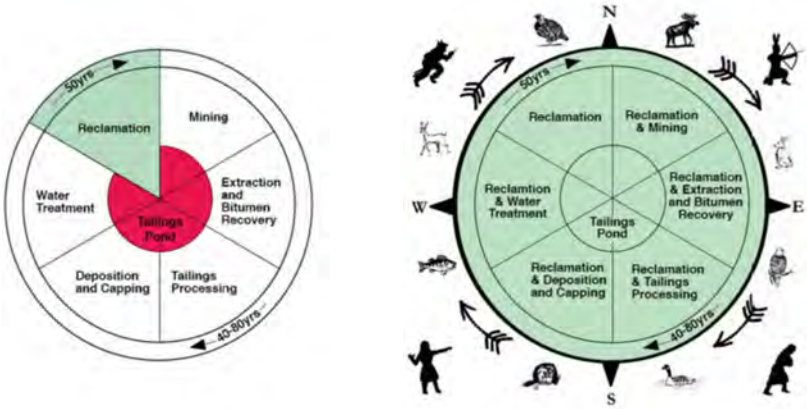


Figure 8. Time circle of the "Non-stop tailings pond". Source: Author.

3.3. Twin Landscapes: Reclaiming and Revitalizing Cultural and Ecological Spaces

A twin landscape will be developed in neighboring forests to aid reclamation. It has the ultimate goal of becoming a cultural center for Fort McKay First Nation. Only the community will have access to these areas, which will be reachable by planes that oil corporations offer. Locals would follow paths, spending time on customary activities like hunting and trapping before heading back home. This strategy offers a place for Fort McKay to resume customary practices in a restored ecosystem while honoring ecological and cultural elements.

Reclamation is a technical undertaking that combines ecological and cultural elements. The plan is to use reclamation methods that cover the contaminated areas as much as possible. In order to create an ecotone grid that adjusts to the territories of different species, trees will be moved from the twin forest to the tailings pond. The tailings ponds can be reclaimed in a circular fashion thanks to this synchronous process, and branching logging pathways produce different biological zones and a diverse cultural environment (Figure 9) (Sobkowicz et al., 2013).

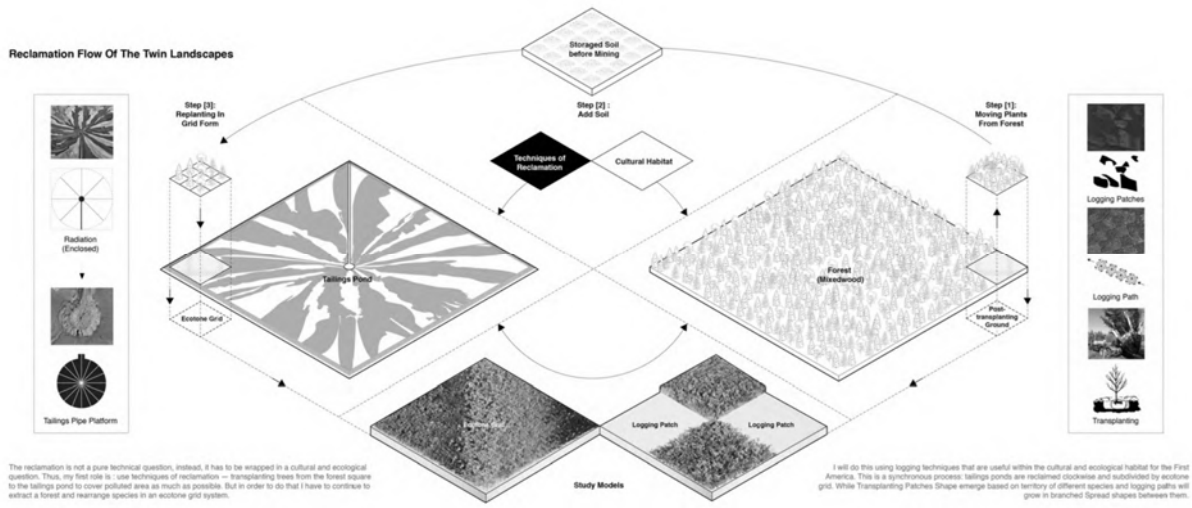


Figure 9. Reclamation techniques. Source: Author.

According to the "Strategic Plan of Twin Landscapes," the forest and tailings pond will change dynamically over a 45-year period. These two landscapes would be established by initial reclamation and cultural reconstruction, and the ecological and cultural loop would be gradually altered by the return of animals. With a center circle platform that transforms from an industrial slurry pipe to a meeting place for Fort

McKay inhabitants, the Ecotone Grid offers a habitat for the tailings pond that is home to a variety of species and hues. Grid boundaries are blurred in the restoration phase, signifying the gradual reclaiming of nature while maintaining historical memories of previous pollution (Figure 10).

The project establishes cultural ecosystems in the forest that give priority to Indigenous people and wildlife while restricting access for outsiders. Using carefully thought-out logging methods, the habitat will be developed to facilitate moose and bison hunting and trapping based on community input. Three primary elements are involved in this process: first, traditional logging patterns must be followed to allow light to reach the forest floor; second, crops and bushes must be planted along the margins to draw animals; and third, routes must be blocked with vegetation to prevent non-residents from accessing the area. By doing these actions, Fort McKay's cultural heritage is preserved through a sustainable cycle of extraction, replanting, and track maintenance (Oil Sands Monitoring Program, 2019).

The idea of "tree islands," which are tiny, 10- to 100-meter-wide clumps of trees left in the middle of each forest area, is crucial to this process. In addition to providing people of Fort McKay with a way to track the decline of biodiversity, these modular "islands" draw wildlife and improve the habitat for animals like bison and moose.

The Fort McKay First Nation can modify this strategic plan in accordance with their extensive knowledge of the forest and customs, as it is a flexible framework rather than a strict master plan. By giving the community the ability to actively manage and shape the landscape, it promotes a cooperative reclamation strategy that honors Indigenous agency, cultural history, and ecological resilience.

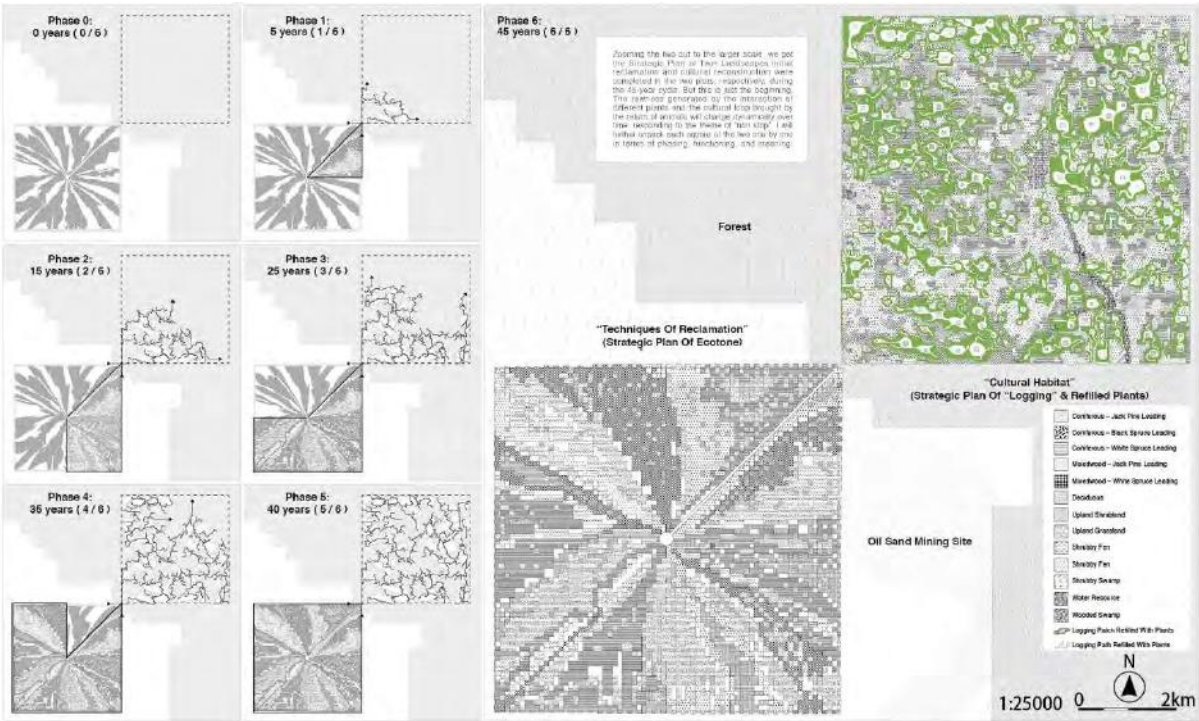


Figure 10. Strategic Plan of Twin Landscapes. Source: Author.

Acknowledgments

The author wishes to acknowledge the use of artificial intelligence (AI) applications, including Grammarly and ChatGPT, during the writing process of this paper. Grammarly was employed for stylistic and

grammatical corrections, ensuring clarity and accuracy, while ChatGPT provided iterative suggestions that enhanced the coherence and structural framework of the content.

The author would also like to express gratitude to Professor Sergio Lopez-Pineiro, (Former) Lecturer of Landscape Architecture at Harvard University Graduate School of Design (GSD), for providing invaluable guidance on this project through the Option Studio "The Immeasurable Enclosure," Fall 2022.

4. References

Blau, E. (2018) *Baku: Oil and Urbanism*. Zürich: Park Books.

CPAWS Northern Alberta and Environmental Defence Canada (2022) *50 Years of Sprawling Tailings: Mapping Decades of Destruction by Oil Sands Tailings* [online]. Available at: https://environmentaldefence.ca/wpcontent/uploads/2022/05/TailingsPondsReport_edcv2_web.pdf (Accessed: 27 October 2024).

Dorow, S. and Jean, S. (2022) 'Managing liminal time in the fly-in fly-out work camp', *Human Relations*, 75(4), pp. 681–704 [online]. Available at: https://doi.org/10.1177/0018726721989792 (Accessed: 27 October 2024).

Durán Calisto, A.M. (2018) 'For the Persistence of the Indigenous Commune in Amazonia', *e-flux Architecture* [online]. Available at: https://www.e-flux.com/architecture/overgrowth/221618/for-the-persistence-of-the-indigenous-commune-in-amazonia/ (Accessed: 27 October 2024).

Flanagan, T. (2018) *The Community Capitalism of the Fort McKay First Nation: A Case Study* [e-book]. Available at: https://www.fraserinstitute.org/sites/default/files/community-capitalism-of-the-fort-mckay-first-nation.pdf (Accessed: 27 October 2024).

Garibaldi, A. (2009) 'Moving from Model to Application: Cultural Keystone Species and Reclamation in Fort McKay, Alberta', *Journal of Ethnobiology*, 29(2), pp. 323–338 [online]. Available at: https://doi.org/10.2993/0278-0771-29.2.323 (Accessed: 27 October 2024).

Government of Alberta (2018) *Environmental Impact Assessment: Teck Resources Limited Frontier Oil Sands Mine* [online]. Available at: https://open.alberta.ca/publications/eia-teck-resources-limited-frontier-oil-sands-mine (Accessed: 27 October 2024).

Grammarly (2025) *Grammarly* [AI software]. Available at: https://www.grammarly.com (Accessed: 18 January 2025).

Human Environment Group (2009) *Indicators of Cultural Change (1960 to 2009): A Framework for Selecting Indicators Based on Cultural Values in Fort McKay* [online]. Available at: https://landuse.alberta.ca/Forms%20and%20Applications/FMFN%20-%20Application%20App%2014%20O%201%20Appendix%20B%20CHA%20Baseline_2014-03-05_PUBLIC.pdf (Accessed: 27 October 2024).

Indigenous Climate Action (2024) 'Imperial Oil Toxic Leak: Historic & Ongoing Harm' [online]. Available at: https://www.indigenousclimateaction.com/entries/imperial-oil-toxic-leak-historic-ongoing-harm (Accessed: 27 October 2024).

Mumford, L. (1968) 'Preface: The Fourth Migration' in *The Urban Prospect*. New York: Harcourt, Brace & World, Inc., pp. ix-xx.Nikiforuk, A. (2010) *Tar sands: dirty oil and the future of a continent*.

Mumford, L. (1995) 'The Regional Framework of Civilization' in Miller, D.L. (ed.) *The Lewis Mumford Reader*. Athens: University of Georgia Press, pp. 207–216.

Nikiforuk, A. (2010) *Tar Sands: Dirty Oil and the Future of a Continent*. Vancouver: Greystone Books [e-book]. Available at: https://archive.org/details/tarsandsdirtyoil0000niki_m9u3/page/186/mode/2up (Accessed: 27 October 2024).

Oil Sands Magazine (2021) *Tailings Ponds 101* [online]. Available at: https://www.oilsandsmagazine.com/technical/mining/tailings-ponds (Accessed: 27 October 2024).

Oil Sands Monitoring Program (2019) *Oil Sands Monitoring Annual Report 2018–2019* [online]. Available at: https://open.alberta.ca/dataset/dbe8811a-962e-4ce1-b2c2-ff40b8daad7a/resource/4e2dff3e-4ad3-44c2-a3f0-b1e61c18b72e/download/aep-2018-19-oil-sands-monitoring-annual-report-2019-09.pdf (Accessed: 27 October 2024).

Oliver, J. (2008) 'The Archaeology of Agriculture in Ancient Amazonia' in Silverman, H. (ed.) *Handbook of South American Archaeology*. New York: Springer, pp. 185–216 [e-book]. Available at: https://doi.org/10.1007/978-0-387-74907-5_12 (Accessed: 27 October 2024).

OpenAI (2025) *ChatGPT (Jan 2025 version)* [AI software]. Available at: https://www.openai.com (Accessed: 18 January 2025).

Peeples, J.A. (2011) 'Toxic Sublime: Imaging Contaminated Landscapes', *Environmental Communication*, 5(4), pp. 373–392 [online]. Available at: https://doi.org/10.1080/17524032.2011.616516 (Accessed: 27 October 2024).

Regional Municipality of Wood Buffalo (2021) *Census Report 2021* [online]. Available at: https://www.rmwb.ca/en/permits-and-development/resources/Documents/Census/Census-Report-2021.pdf (Accessed: 27 October 2024).

Roncken, P.A. (2018) *Shades of Sublime: A Design for Landscape Experiences as an Instrument in the Making of Meaning*. PhD thesis. Wageningen University [online]. Available at: https://doi.org/10.18174/427612 (Accessed: 27 October 2024).

Sobkowicz, J.C. et al. (2013) 'The Alberta Oil Sands Tailings Roadmap Project' in Jewell, R. et al. (eds.) *Paste 2013: Proceedings of the 16th International Seminar on Paste and Thickened Tailings*. Perth: Australian Centre for Geomechanics, pp. 313–325 [online]. Available at: https://doi.org/10.36487/ACG_rep/1363_24_Sobkowicz (Accessed: 27 October 2024).

Westman, C., Joly, T. and Gross, L. (eds.) (2019) *Extracting Home in the Oil Sands: Settler Colonialism and Environmental Change in Subarctic Canada*. 1st edn. London: Routledge [e-book]. Available at: https://doi.org/10.4324/9781351127462 (Accessed: 27 October 2024).

Research Paper

Analysis of the influencing factors of urban street space on the health of people of all ages

Based on partial least squares structural equation model

Kai ZHANG, School of Architecture and Design, Harbin Institute of Technology, Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Yushuang TANG, School of Architecture and Design, Harbin Institute of Technology, China

Xinrou HUANG, School of Architecture and Design, Harbin Institute of Technology, China

Lingran TAO, School of Architecture and Design, Harbin Institute of Technology, China

Yibo LIU, School of Architecture and Design, Harbin Institute of Technology, Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Abstract

The positive impact of urban spatial environment on residents' health has increasingly become an important topic in the field of urban planning and design. Although existing research has extensively explored how urban spatial environments can meet the needs of residents of different age groups, a more in-depth analysis of the relationship between urban spatial environmental elements and the health of residents of different age groups is still lacking. This paper aims to fill this research gap by using the partial least squares structural equation model (PLS-SEM) to establish an evaluation system for creating health-friendly spaces for children, youth, and the elderly from the perspective of urban spatial environmental elements. The research results indicate that for children, creating a health-friendly urban street space should focus on landscape environment, site environment, transportation and nature, facilities and crowds. For the youth population, the design of health-friendly spaces should emphasize public facilities, landscape facilities, sports facilities, recreational facilities, transportation and cultural facilities. And for the elderly population, focusing on outdoor environments and infrastructure is crucial for creating a suitable urban spatial environment for their living and activities. These findings provide scientific basis and practical guidance on how to promote health-friendly spatial environments for residents of different age groups, especially in urban planning and design, and are of great significance for improving the overall well-being and quality of life of urban residents.

Keywords

Urban governance, Resident survey, Personal demand, Quantitative analysis

1. Introduction

The health level of urban residents is receiving increasing attention, with numerous countries and organizations successively implementing relevant policies(World Health Organization, 1986; Ministry of health, 2000; Healthy China Action Promotion Committee, 2019). Research has shown that the urban environment significantly affects residents' health, encompassing both physical(Cao, Handy and Mokhtarian, 2006; Boone-Heinonen *et al.*, 2010) and mental aspects(van den Berg et al., 2016; Rojas-Rueda et al., 2019; Birch, Rishbeth and Payne, 2020) . Although many scholars have conducted research on this issue from multiple perspectives, there are still shortcomings in the existing results. From a spatial perspective, most studies have focused on cities or residential areas as units of analysis regarding the impact of the environment on residents' health(Wang *et al.*, 2016; Gruebner *et al.*, 2017), lacking specific investigation into urban streets. Urban streets play a crucial role in facilitating various activities for residents, such as social interactions and exercise, and are one of the essential types of public space within cities(Tang and Long, 2019).

In terms of targeted groups, existing studies often focus on specific vulnerable populations, such as children or the elderly(Fitrinitia, 2019; Hsu and Bai, 2021), addressing only a subset of residents' health needs concerning the urban environment. However, health needs related to the urban environment can differ across age groups, and urban development should not solely prioritize the health needs of one particular group but should consider the health requirements of residents across multiple age brackets.

Surveys, as a method for gathering subjective feelings and opinions from respondents, are frequently employed in the fields of medicine and health(Duracinsky et al., 2007; Mikhail et al., 2020. This paper uses questionnaires to obtain feedback on health needs related to the urban environment from residents of different age groups—namely children, youth, and the elderly. Employing the PLS-SEM method, we construct separate evaluation frameworks for health-friendly urban street spaces tailored to each age group. This study aims to provide insights into residents' true health needs concerning urban street spaces, thereby assisting urban managers in improving the health levels of street environments.

2. Data and methods

2.1.Selection of evaluation indicators

This study is based on the population classification standards from the United Nations Population Division's World Population Report and combines general patterns of physical development and psychological characteristics. It defines childhood as the stage for individuals under 14 years old, youth as those aged 15 to 40 years, and old age as individuals over 60 years old(United Nations, 2024). The research focuses on the impact of material elements of urban street space on residents' health, thus selecting material factors related to residents' health as evaluation indicators. The selection of indicators adheres to the principles of scientific rigor, representativeness, and operability, with specific evaluation indicators chosen for children, youth, and elderly residents. This study conducts a preliminary screening of the material elements of urban street space from five main aspects: basic facilities, ecological environment, public space, traffic environment, and cultural environment. However, due to the differences in physical development and psychological characteristics among children, youth, and the elderly, the evaluation indicators after preliminary screening vary accordingly.

Child health-friendly street space refers to street environments that are considerate of children and attentive to their health. After expert preliminary screening, this study has identified a total of 21 indicators (Table 1).

Table 1 Pre-screening evaluation indicators of street space in children's health-friendly cities. Source:Author. Year:2024.

First Level Indicator	*Secondary Indicator*	*Symbol*
Basic Facilities	Seats	BF1
	Rails	BF2
	Electronic Screens	BF3
	Sunshade Tents	BF4
	Public Interactive Devices	BF5
	Bookcases	BF6
Ecological Environment	Green land	EE1
	Water Areas	EE2
	Animals	EE3
	Mountains	EE4
	Flowers and Vegetation	EE5
Public Space	Running tracks	PS1
	Event Venues	PS3
	Sports Facilities	PS2
	Swimming Pools	PS5
	Bike Lanes	PS4
Traffic Environment	Roads	TE1
	Traffic Lights	TE2
	Buses	TE3
Cultural Environment	Decorative Landscapes	CE2
	Crowds	CE1

Youth health-friendly street space focus on meeting the needs of young people. After expert preliminary screening, this study has identified a total of 27 indicators (Table 2).

Table 2 Pre-screening evaluation indicators of street space in youth health-friendly cities. Source:Author. Year:2024.

First Level Indicator	*Secondary Indicator*	*Symbol*
Basic Facilities	Seats	BF1
	Public Conveniences	BF7

	Electronic Screens	BF3
	Sunshade Tents	BF4
	Trash Cans	BF8
	Monitoring	BF9
	Kiosks	BF10
Ecological Environment	Green Land	EE1
	Sky	EE6
	Water Areas	EE2
	Mountains	EE4
	Green Plants	EE7
	Flower Beds	EE8
	Fountains	EE9
Public Space	Running tracks	PS1
	Bike Lanes	PS4
	Event Venues	PS3
	Sports Facilities	PS2
Traffic Environment	Roads	TE1
	Traffic Lights	TE2
	Buses	TE3
	Cars	TE4
Cultural Environment	Plaques and Flags	CE6
	Sculptures	CE3
	Street Graffiti	CE4
	Tall Buildings	CE5
	Crowds	CE1

Elderly health-friendly street space refers to an environment that caters to the needs of the elderly. After expert preliminary screening, this study has identified a total of 20 indicators (Table 3).

Table 3 Pre-screening evaluation indicators of street space in health-friendly cities for the elderly. Source:Author. Year:2024.

First Level Indicator	*Secondary Indicator*	*Symbol*
Basic Facilities	Seats	BF1

	Rails	BF2
	Public Conveniences	BF7
	Sunshade Tents	BF4
	Trash Cans	BF8
	Escalators	BF11
Ecological Environment	Green Land	EE1
	Sky	EE6
	Flower Beds	EE8
	Tree Shade	EE10
Public Space	Event Venues	PS3
	Sports Facilities	PS2
	Animals	PS6
Traffic Environment	Roads	TE1
	Traffic Lights	TE2
	Buses	TE3
	Bicycles	TE5
Cultural Environment	Plaques and Flags	CE6
	Sculptures	CE3
	Crowds	CE1

2.2.Data Sources and Data Processing Principles

This study collected data through the distribution of questionnaires, creating three distinct sets of surveys tailored for children, youth, and elderly residents. Each set of questionnaires consists of two main parts: the first part gathers background information about the respondents, measured using categorical scales. The second part investigates the respondents' health needs regarding the pre-screened material elements of urban space, measured using a five-point Likert scale. And the article only uses AI tools for language translation work(OpenAI, 2023).

2.3.Research Methods

(1) Questionnaire Survey Method

The questionnaire survey method enables the rapid acquisition of firsthand information from respondents at a relatively low cost in terms of time, money, and human resources(Lu J.Y., Xu J.H. and Sun X., 2024). This study aims to gather the direct preferences of children, youth, and elderly residents regarding the factors influencing health-friendly urban street spaces. Therefore, separate evaluation questionnaires for health-friendly urban street spaces were developed for children, youth, and elderly individuals.

(2) Exploratory Factor Analysis

Exploratory factor analysis is used to study the internal structure of items within a scale and can group highly correlated items(Zhang C, Xu Y and Chen P, 2007). Since the evaluation indicators selected in this study are derived from existing research and may not fully represent the true preferences of residents, exploratory factor analysis was employed to analyze the questionnaires. This method helps identify the indicators that reflect residents' preferences and groups them accordingly.

(3) Partial Least Squares Structural Equation Modeling (PLS-SEM)

Partial Least Squares Structural Equation Modeling (PLS-SEM) can measure the structure, correlation, and weight of indicators, and can also reflect the strength of the influence of factors on the research object, it has advantages in handling small sample sizes and non-normally distributed data, making it suitable for causal research questions(Wold and Herman, 1982; Chin and Wynne W, 1998; Wang Y.X., 2019.Given the relatively small data size obtained through the questionnaires in this study, and the goal of quantifying the impact intensity of material elements of urban spatial environments on residents' health, the use of PLS-SEM is appropriate for constructing an evaluation indicator system for health-friendly urban street spaces for children, youth, and the elderly.

3. Constructing an Evaluation System for Age-Friendly Health in Urban Street Spaces

3.1.Statistical Analysis of Questionnaire Results

A total of 150 questionnaires were distributed and 150 valid responses were collected, with 50 responses each from children, youth, and elderly individuals. The background distribution of the respondents was found to be reasonable and meets the requirements for data analysis.

(1) Reliability Test of Data

A Cronbach's Alpha value greater than 0.70 indicates high reliability, making the data suitable for subsequent research(Li Q., 2023). The Cronbach's Alpha values for the children, youth, and elderly questionnaires were 0.927, 0.940, and 0.747, respectively, all exceeding 0.7, indicating that the questionnaires can be used for further research.

(2) Validity Test of Data

A KMO value closer to 0 indicates lower validity, while a value closer to 1 indicates higher validity(Wu Q.X. *et al.*, 2023). As shown in Table 4, the KMO values for the children, youth, and elderly questionnaires are all greater than 0.6, and Bartlett's test is less than 0.05, indicating that each questionnaire has high validity and is suitable for constructing a structural equation model.

Table 4 Questionnaire KMO and Bartlett's test. Source:Author. Year:2024.

Questionnaire type		*KMO and Bartlett's test*	*KMO value*	*Bartlett sphericity test*	*Degrees of Freedom (df)*	*Significant value (P-value)*
Child Friendly	Health	Value	0.714	741.361	210	0.000
Youth Friendly	Health	Value	0.762	1172.047	351	0.000
Elderly Friendly	Health	Value	0.610	353.457	190	0.000

3.2.PLS-SEM Model Construction

The results of the exploratory factor analysis indicate that the health-friendly evaluation indicators for children should be divided into 4 categories, while those for youth can be categorized into 5 categories, and the indicators for the elderly can be divided into 4 categories.

This study uses the findings from the exploratory factor analysis as a reference and makes minor adjustments to the classification results based on existing literature. Consequently, separate models are established for the evaluation systems of health-friendly urban street spaces for children, youth, and the elderly (as illustrated in Figures 1, 2, and 3).

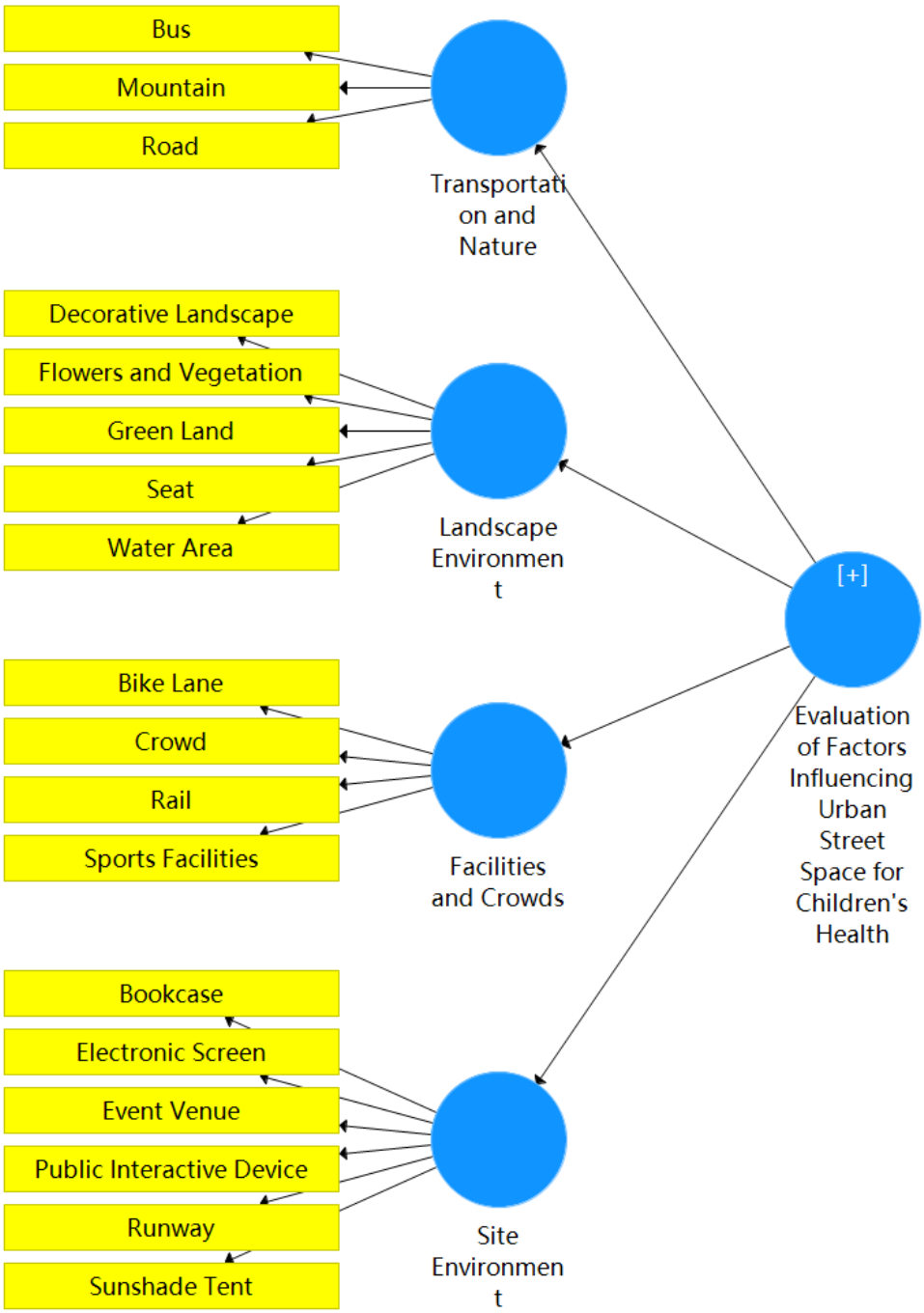


Figure 1. Evaluation System Model for Street Space in Children's Health Friendly Cities

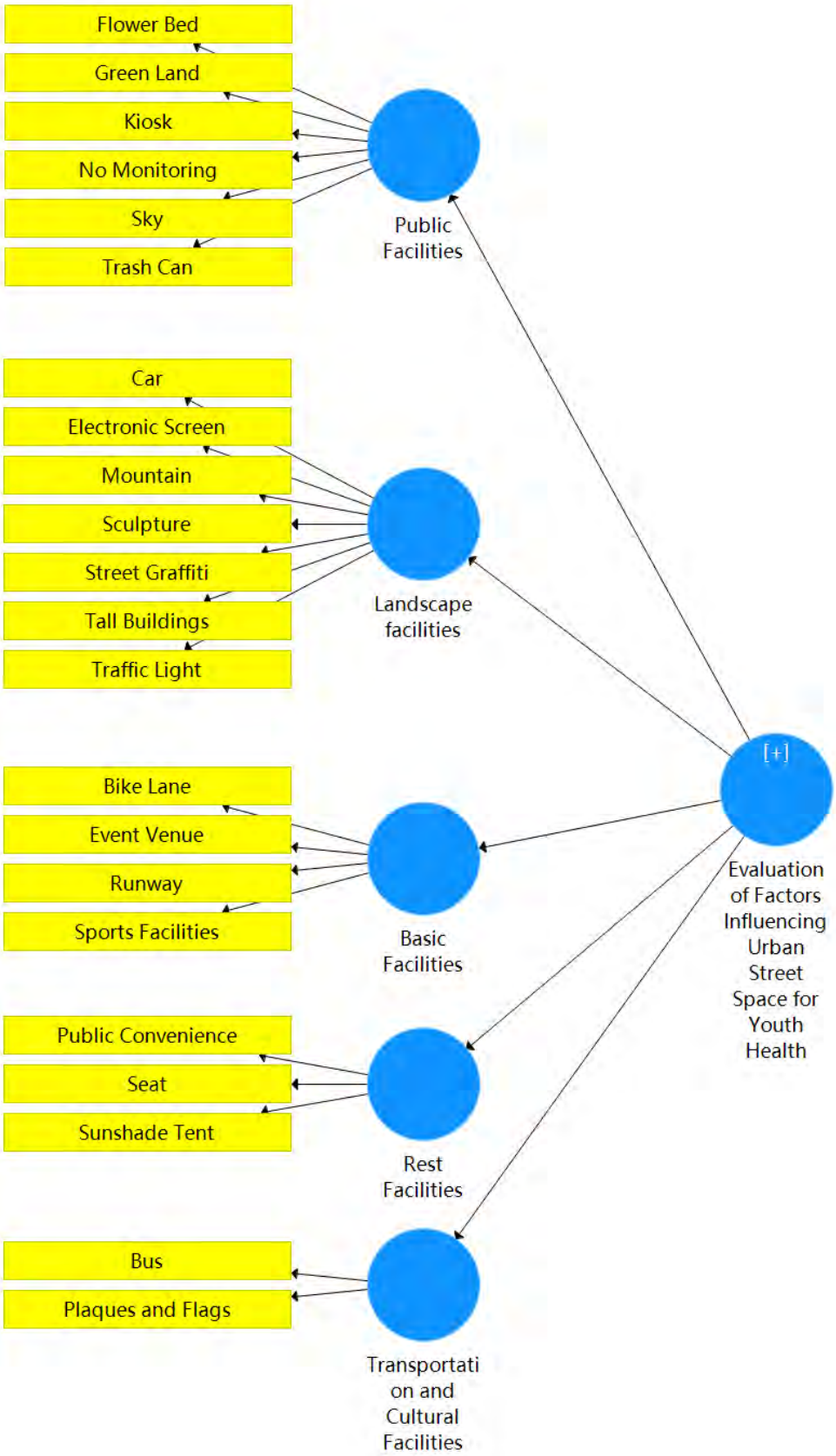


Figure 2. Evaluation System Model for Street Space in Youth Health Friendly Cities

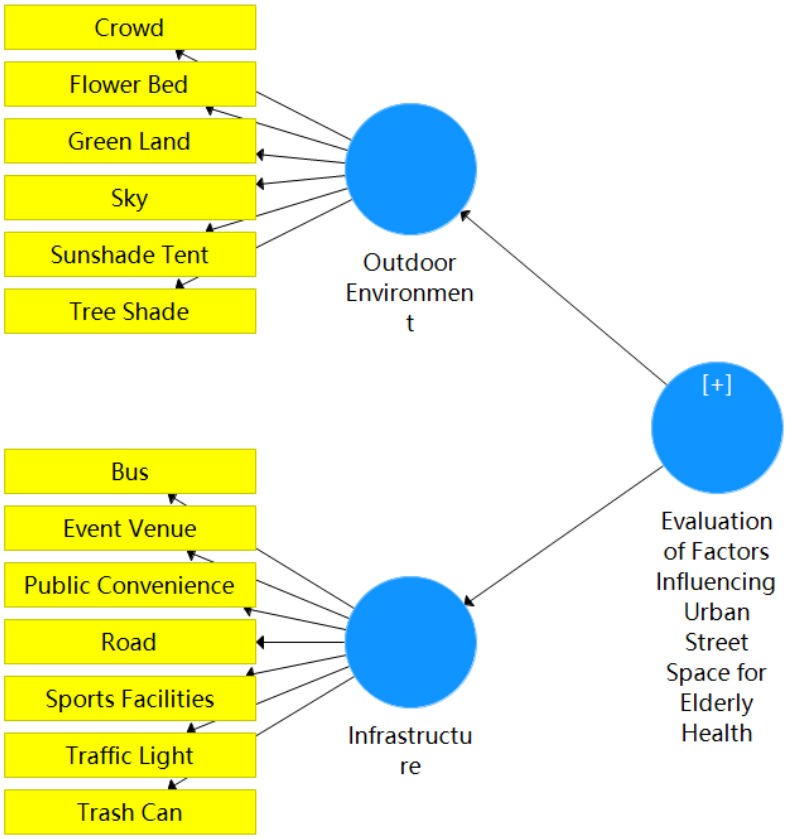


Figure 3. Evaluation System Model for Street Space in Elderly Health Friendly Cities

First, this study primarily evaluates the reliability of the scales using internal consistency testing. Internal consistency is assessed through Composite Reliability (CR) values, where a CR value greater than 0.7 is considered indicative of internal consistency, thus making the data suitable for further research(Holmbeck and Devine, 2009). Additionally, an Outer Loading value greater than 0.5 is also considered a supportive criterion for reliability testing(Hulland, 1999). Secondly, this study employs multicollinearity statistics (Variance Inflation Factor, VIF) as a measure to evaluate the collinearity among variables in order to eliminate the impact of linear relationships between the evaluation indicators on the model's interpretability. VIF is a positive indicator, where larger values indicate higher levels of collinearity. Generally, a VIF value less than 5 can pass the multicollinarity test (Hair *et al.*, 2016).Finally, this study uses R^2 to assess the goodness of fit of the explanatory variables to the outcome variables, indicating how well the observed variables explain the latent variables. An R^2 value greater than 0.26 is considered indicative of a model with strong explanatory power(Cohen, 2013).

Table 5 displays the Composite Reliability (CR), Average Variance Extracted (AVE), Outer Loading, and R^2 values for the theoretical models of health-friendly urban street space evaluation systems for children, youth, and the elderly. The results show that the VIF values for the health-friendly urban street space evaluation models for children, youth, and the elderly are all 1. Furthermore, it can be observed that the CR, AVE, Outer Loading, and R^2 values for all three theoretical models meet the required criteria, indicating that all three evaluation system theoretical models are reliable.

Table 5. Theoretical Model of Street Space Evaluation System for Children, Youth, and Elderly Health Friendly Cities: CR, Loading, R^2 . Source:Author. Year:2024.

Model type	*Construct*	*Loading*	*Item*	*Composite reliability（CR）*	*Loading*	*R^2*
Children Health Friendly Type	Facilities and Crowds	0.904	Bike Lanes	0.829	0.722	0.584
			Crowds		0.791	
			Rails		0.61	
			Sports Facilities		0.828	
	Site Environment	0.887	Bookcases	0.862	0.876	0.817
			Electronic Screens		0.726	
			Event Venues		0.725	
			Public Interactive Devices		0.83	
			Running Tracks		0.849	
			Sunshade Tents		0.84	
	Transportation and Nature	0.764	Buses	0.929	0.848	0.517
			Mountains		0.829	
			Roads		0.789	
	Landscape Environment	0.719	Decorative Landscapes	0.929	0.89	0.786
			Flowers and Vegetation		0.86	
			Green Land		0.89	
			Seats		0.80	
			Water Areas		0.81	
Youth Health Friendly Type	Public Facilities	0.769	Green Land	0.924	0.880	0.591
			No Monitoring		0.794	
			Sky		0.773	
			Flower Beds		0.836	
			Trash Cans		0.786	
			Kiosks		0.834	
	Landscape Facilities	0.876	Tall Buildings	0.926	0.855	0.768
			Electronic Screens		0.849	
			Traffic Lights		0.791	
			Cars		0.768	

			Sculptures		0.81	
			Street Graffiti		0.75	
			Mountains		0.783	
	Basic Facilities	0.85	Bike Lanes	0.897	0.808	0.722
			Sports Facilities		0.894	
			Running Tracks		0.833	
			Event Venues		0.774	
	Rest Facilities	0.561	Sunshade Tents	0.874	0.889	0.315
			Public Conveniences		0.84	
			Seats		0.774	
	Transportation and Cultural Facilities	0.705	Buses	0.922	0.906	0.496
			Plagues and Flags		0.943	
Elderly Health Friendly Type	Outdoor Environment	0.903	Sky	0.808	0.618	0.815
			Tree Shade		0.739	
			Green Land		0.809	
			Flower Beds		0.828	
			Sunshade Tents		0.551	
			Crowds		0.222	
	Infrastructure	0.888	Public Conveniences	0.785	0.732	0.789
			Trash Cans		0.502	
			Event Venues		0.507	
			Traffic Lights		0.779	
			Roads		0.543	
			Sports Facilities		0.503	
			Buses		0.503	

3.3.Evaluation System Construction

The Loading values derived from PLS-SEM represent the impact relationships among variables. In this study, these values were normalized to obtain the weights of the secondary evaluation indicators (as shown in Formula 1).

$$w_i = \frac{LD_i}{\sum_{n=1} LD_n} \quad (1)$$

In this context, w_i is the weight of the second level (first level) evaluation indicator i, LD_i represents the loading value of i, and LD_n is the sum of the loading values of all evaluation indicators in the upper level classification of i.

(1) Health-Friendly for Children

According to the results of the health-friendly urban street space evaluation system for children (Table 6), the secondary indicators related to children's health identified by children and their guardians include seats, water areas, green land, among others, totaling 18 items. Conversely, the three secondary indicators anticipated by the researchers—animals(EE3), swimming pools(PS5), and traffic lights(TE2)—do not align with the preferences of children and their guardians, resulting in an accuracy rate of approximately 85.7%.

Furthermore, the construction of health-friendly urban street spaces for children can be categorized into four aspects: landscape environment, site environment, transportation and nature, and facilities and crowds. Among these, the site environment and facilities and crowds aspects have the most significant impact on spatial development.

Table 6. Evaluation System for Street Space in Children's Health Friendly Cities. Source:Author. Year:2024.

First Level Indicator	*Weight*	*Secondary Indicator*	*Symbol*	*Weight*
Landscape Environment	0.22	Seats	BF1	0.19
		Green Land	EE1	0.21
		Water Areas	EE2	0.19
		Flowers and Vegetation	EE5	0.20
		Decorative Landscapes	CE2	0.21
Site Environment	0.28	Electronic Screens	BF3	0.15
		Sunshade Tents	BF4	0.17
		Public Interactive Devices	BF5	0.17
		Bookcases	BF6	0.18
		Running Tracks	PS1	0.18
		Event Venues	PS3	0.15
Transportation and Nature	0.23	Mountains	EE4	0.34
		Roads	TE1	0.32
		Buses	TE3	0.34
Facilities and Crowds	0.27	Rails	BF2	0.21
		Sports Facilities	PS2	0.28
		Bike Lanes	PS4	0.24

	Crowds	CE1	0.27

(2) Health-Friendly for Youth

According to the results of the health-friendly urban street space evaluation system for youth (Table 7), the secondary indicators identified by the youth group as related to their own health include seats, event venues, buses, among others, totaling 22 items. In contrast, the five secondary indicators anticipated by the researchers—water areas(EE2), fountains(EE9), green plants (EE7), roads(TE1), and crowds(CE1)—do not align with the preferences of the youth group, resulting in an accuracy rate of approximately 81.5%.

Moreover, the construction of health-friendly urban street spaces for youth can be categorized into five aspects: public facilities, landscape facilities, basic facilities, rest facilities, transportation and cultural facilities. Among these, basic facilities and transportation and cultural facilities have the most significant impact on spatial development, followed by recreational facilities.

Table 7. Evaluation System for Street Space of Youth Health Friendly Cities. Source:Author. Year:2024.

First Level Indicator	*Weight*	*Secondary Indicator*	*Symbol*	*Weight*
Public Facilities	0.20	Green Land	EE1	0.18
		No Monitoring	BF9	0.16
		Sky	EE6	0.16
		Flower Beds	EE8	0.17
		Trash Cans	BF8	0.16
		Kiosks	BF10	0.17
Landscape Facilities	0.23	Tall Buildings	CE5	0.15
		Electronic Screens	BF3	0.15
		Traffic Lights	TE2	0.14
		Cars	TE4	0.14
		Sculptures	CE3	0.14
		Street Graffiti	CE4	0.13
		Mountains	EE4	0.15
Basic Facilities	0.85	Bike Lanes	PS4	0.24
		Sports Facilities	PS2	0.28
		Running Tracks	PS1	0.25
		Event Venues	PS3	0.23
Rest Facilities	0.561	Sunshade Tents	BF4	0.36
		Public Conveniences	BF7	0.34
		Seats	BF1	0.30

Transportation and Cultural Facilities	0.705	Buses	TE3	0.49
		Plaques and Flags	CE6	0.51

(3) Health-Friendly for the Elderly

According to the results of the health-friendly urban street space evaluation system for the elderly (Table 8), the secondary indicators identified by the elderly population as relevant to their health include flower beds, green land, public conveniences, among others, totaling 13 items. However, the researchers expected that a total of 7 secondary indicators, including animals(EE3), rails(BF2), seats(BF1), escalators(BF11), bicycles(TE5), Plaque and flags(CE6), and sculptures(CE3), did not meet the wishes of the elderly population, resulting in an accuracy rate of 65%.

The PLS-SEM model, based on survey questionnaire results, regrouped the secondary indicators according to their internal logic. The construction of health-friendly urban street spaces for the elderly can be broadly categorized into two aspects: outdoor environment and infrastructure, both of which have a significant and comparable impact.

Table 8. Evaluation System for Street Space in Elderly Health Friendly Cities. Source:Author. Year:2024.

First level indicator	*Weight*	*Secondary Indicator*	*Symbol*	*Weight*
Outdoor Environment	0.50	Sky	EE6	0.16
		Tree Shade	EE10	0.20
		Green Land	EE1	0.21
		Flower Beds	EE8	0.22
		Sunshade Tents	BF4	0.15
		Crowds	CE1	0.06
Infrastructure	0.50	Public Conveniences	BF7	0.18
		Trash Cans	BF8	0.12
		Event Venues	PS3	0.13
		Traffic Lights	TE2	0.19
		Roads	TE1	0.14
		Sports Facilities	PS2	0.12
		Buses	TE3	0.12

Comparing the three evaluation systems, it can be observed that the health-friendly urban street space evaluation system for youth has the highest number of indicators, totaling 22, while the evaluation system for the elderly has the fewest indicators, with only 13. Additionally, all three evaluation systems include some common evaluation indicators, specifically green land(EE1), sunshade tents(BF4), buses(TE3), event venues(PS3), and sports facilities(PS2), while each evaluation system also has its own unique indicators.

4. Conclusion

This study proposes a method based on PLS-SEM to quantify the relationships between the material elements of urban street spaces and the health impacts on children, youth, and elderly residents from the residents' perspective, addressing the personalized needs of these demographic groups. Health-friendly urban street space evaluation systems for children, youth, and the elderly have been constructed. The results provide a bridge for interdisciplinary research in urban planning, urban design, and public health, offering urban managers insights into enhancing the health needs of children, youth, and the elderly.

The study concludes the following: (1) The health-friendly urban street space evaluation system for children encompasses four aspects: landscape and environment, site environment, transportation and nature, and facilities and crowds, all of which have significant positive impacts, swith the site environment having the greatest effect. (2) The health-friendly urban street space evaluation system for youth includes five aspects: public facilities, landscape facilities, basic facilities, rest facilities, transportation and cultural facilities, all of which exert significant positive impacts, with landscape facilities and sports facilities having the most substantial influence. (3) The health-friendly urban street space evaluation system for the elderly consists of two aspects: outdoor environment and infrastructure, both of which have significant positive influences, and their impacts are comparable. (4) There is a gap between the health-related factors pre-screened by experts and those recognized by residents. (5) Among the three evaluation systems, the youth health-friendly urban street space evaluation system involves the most types of material spatial elements, while the system for the elderly involves the fewest. (6) All three evaluation systems include some common material spatial elements, specifically green land(EE1), sunshade tents(BF4), buses(TE3), event venues(PS3), and sports facilities(PS2). However, each evaluation system also contains personalized material spatial elements unique to its demographic focus.

5. References

van den Berg, M. *et al.* (2016) 'Visiting green space is associated with mental health and vitality: A cross-sectional study in four european cities', *Health & Place*, 38, pp. 8–15. Available at: https://doi.org/10.1016/j.healthplace.2016.01.003.

Birch, J., Rishbeth, C. and Payne, S.R. (2020) 'Nature doesn't judge you – how urban nature supports young people's mental health and wellbeing in a diverse UK city', *Health and Place*, 62. Available at: https://doi.org/10.1016/j.healthplace.2020.102296.

Boone-Heinonen, J. *et al.* (2010) *Residential self-selection bias in the estimation of built environment effects on physical activity between adolescence and young adulthood*. Available at: http://www.ijbnpa.org/content/7/1/70.

Cao, X., Handy, S.L. and Mokhtarian, P.L. (2006) 'The Influences of the Built Environment and Residential Self-Selection on Pedestrian Behavior: Evidence from Austin, TX', *Transportation*, 33(1), pp. 1–20. Available at: https://doi.org/10.1007/s11116-005-7027-2.

Chin and Wynne W (1998) 'The partial least squares approach to structural equation modeling', *Modern methods for business research*, 295, pp. 295–336.

Cohen, J. (2013) *Statistical Power Analysis for the Behavioral Sciences*. Routledge. Available at: https://doi.org/10.4324/9780203771587.

Duracinsky, M. *et al.* (2007) 'Literature Review of Questionnaires Assessing Vertigo and Dizziness, and Their Impact on Patients' Quality of Life', *Value in Health*, 10(4), pp. 273–284. Available at: https://doi.org/10.1111/j.1524-4733.2007.00182.x.

Fitrinitia, I.S. (2019) 'INTEGRATION OF SPATIAL CHARACTERISTIC TO HEALTH SERVICES FOR IMPROVEMENT OF CHILDREN HEALTH', *International Journal of GEOMATE*, 17(61). Available at: https://doi.org/10.21660/2019.61.8267.

Gruebner, O. *et al.* (2017) 'Cities and Mental Health', *Deutsches Ärzteblatt international* [Preprint]. Available at: https://doi.org/10.3238/arztebl.2017.0121.

Hair, Jr., J.F. *et al.* (2016) 'Identifying and treating unobserved heterogeneity with FIMIX-PLS: part I – method', *European Business Review*, 28(1), pp. 63–76. Available at: https://doi.org/10.1108/EBR-09-2015-0094.

Healthy China Action Promotion Committee (2019) *Healthy China Action (2019-2030), https://www.gov.cn/xinwen/2019-07/15/content_5409694.htm*.

Holmbeck, G.N. and Devine, K.A. (2009) 'Editorial: An Author's Checklist for Measure Development and Validation Manuscripts', *Journal of Pediatric Psychology*, 34(7), pp. 691–696. Available at: https://doi.org/10.1093/jpepsy/jsp046.

Hsu, H.-C. and Bai, C.-H. (2021) 'Social and Built Environments Related to Cognitive Function of Older Adults: A Multi-Level Analysis Study in Taiwan', *International Journal of Environmental Research and Public Health*, 18(6), p. 2820. Available at: https://doi.org/10.3390/ijerph18062820.

Hulland, J. (1999) 'Use of partial least squares (PLS) in strategic management research: a review of four recent studies', *Strategic Management Journal*, 20(2), pp. 195–204. Available at: https://doi.org/10.1002/(SICI)1097-0266(199902)20:2<195::AID-SMJ13>3.0.CO;2-7.

Li Q. (2023) *Analysis of factors influencing China's rare earth trade security based on PLS-SEM model* . Jiangxi university of science and technoligy.

Lu J.Y., Xu J.H. and Sun X. (2024) 'Design and Implementation of Questionnaire Surveys and Their Normative Application in the Field of Library Science', *Library and Information Service*, 68(11), pp. 4–13.

Mikhail, E. *et al.* (2020) 'Questionnaires Assessing the Quality of Life of Ocular Allergy Patients', *The Journal of Allergy and Clinical Immunology: In Practice*, 8(9), pp. 2945–2952. Available at: https://doi.org/10.1016/j.jaip.2020.04.023.

Ministry of health (2000) *Health Japan 21*, *https://www.mhlw.go.jp/www1/topics/kenko21_11/s0.html*.

OpenAI (2023) *ChatGPT*, *https://www.openai.com/chatgpt*.

Rojas-Rueda, D. *et al.* (2019) 'Green spaces and mortality: a systematic review and meta-analysis of cohort studies', *The Lancet Planetary Health*, 3(11), pp. e469–e477. Available at: https://doi.org/10.1016/S2542-5196(19)30215-3.

Tang, J. and Long, Y. (2019) 'Measuring visual quality of street space and its temporal variation: Methodology and its application in the Hutong area in Beijing', *Landscape and Urban Planning*, 191, p. 103436. Available at: https://doi.org/10.1016/j.landurbplan.2018.09.015.

United Nations (2024) *World Population Prospects - Population Division - United Nations*, *URL https://population.un.org/wpp/*.

Wang, Y. *et al.* (2016) 'A review on the effects of physical built environment attributes on enhancing walking and cycling activity levels within residential neighborhoods', *Cities*, 50, pp. 1–15. Available at: https://doi.org/10.1016/j.cities.2015.08.004.

Wang Y.X. (2019) *Research on the influence factors of urban and rural integration development in Xinjiang based on PLS path model*. Xinjiang university of finance & economics.

Wold and Herman (1982) 'Soft modeling: the basic design and some extensions', *Systems under indirect observation, Part II*, 2, pp. 36–37.

World Health Organization (1986) *Creating healthy cities*, *https://www.who.int/activities/creating-healthy-cities*.

Wu Q.X. *et al.* (2023) 'Analysis of factors influencing carbon emissions of urban rail transit projects based on partial least squares structural equation modeling', *Environmental Engineering*, 41(10), pp. 133–140.

Zhang C, Xu Y and Chen P (2007) 'Comparison and application of exploratory factor analysis and confirmatory factor analysis in scale researc', *J. South Med. Univ*, 27(3).

Research Paper

The practical study of inclusive waterway renewal planning:
A case study of West Hongqiao Business District in Shanghai, China

Yidong YU, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, China
Xindan CAO, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, China
Lu LIU, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, China
Xiji JIANG, Xi'an University of Architecture and Technology, China
Xianglei SHI, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, China

Abstract

As the renewal of waterways is regarded as one of the most important strategies for shaping the spatial environments for urban vitality, addressing economic growth and cultural protection, it has obtained increasing attention over the past decade years. However, the waterways' regeneration would influenced by its natural environment and local culture, which consequently cause difficulties in planning and construction of the waterways. Therefore, we offer a framework of 'background analysis-status quo assessment-regeneration strategy' as a response to these issues. The framework is designed to analyse what key factors influence waterways' regeneration and how to derive the natural inclusive goals and social inclusive goals, as well as how to ensure an inclusive collaboration mechanism involving multiple parties at the same time. According to the review of the background and state, we proposed strategies covering operational modes, transportation systems, and culture-tourism initiatives. Finally, we perform practical research in the West Hongqiao Business District in Shanghai to confirm the effectiveness of the framework, which would further ensure the contribution of valuable practical experience while considering the inclusion of preserving the city's culture, history, and communal memory.

Keywords

Inclusive regeneration, Waterway regeneration, Innovative framework

1. Background

Urban waterways often have significant influence and benefit on the socioeconomic context of cities, as they are key physical parts of the eco networks and culture in the cities (Huang and Wang, 2023; Zheng et al., 2022; Song et al., 2022). In recent years, it has been proved that the renewal of waterways has enabled it to be regarded as a key tool for city rebranding, improving urban competitiveness and dwellers' lives (Hein, 2016; Cabau, Hernandez-Lamas and Woltjer, 2021; Fouad et al., 2022; Niu et al., 2023; Dobson, 2021; Qiao et al., 2022; Ding and Wang, 2024). However, there are a number of obstacles, such as the loss of distinctive urban cultures and a lack of community involvement, which led to increasing difficulties in the process of restoring and renovating urban waterways. Furthermore, ensuring that these renewals promote

social inclusion and sustainable development becomes a major challenge. (Zhu and Li, 2024; Kristianova, Gecova and Putrova, 2015; Perera et al., 2022; Piper, 2005). In this case, the United Kingdom has come up with the principles of inclusive design and inclusive regeneration pioneer, which are fundamentally rooted in enhancing the physical environment, balancing the overall interests of the community, and involving multiple participants, thereby shaping a more inclusive and urban landscape (Zhao et al., 2024; Liu et al., 2022; Cattaneo, Giorgi and Ni, 2018; Wang et al., 2023).

In light of these considerations, it is necessary to consider environment and history preservation, and participation from local community members through effective waterway regeneration initiatives, which would combine thorough research and practical experimentation to promote inclusive regeneration. Accordingly, we propose a research framework designed to systematically investigate the practical experiences of inclusive waterway landscape regeneration.

2. Waterway landscape regeneration framework

A framework for waterway landscape regeneration that we constructed is based on the foundation of the theory of inclusive renewal and inclusive design, which is anchored in cultural conservation, waterway space landscape regeneration, and cultural tourism planning (Figure 1).

First of all, we rooted in comprehensive systematic background analysis and evaluation, with the consideration of history and culture, local strategic aim, characteristics, planning regulations and policies, stakeholders' needs, opportunities and potentials, as well as values and visions. This phase, which is regarded as the foundation for final strategic planning, is crucial for obtaining an overall sightseen of the context of the waterways, which could in turn help identify macro-level conditions and opportunities for regeneration.

In the status quo assessment phase, we develop a planning process based on analysis and evaluation, clarifying operational methods and spatial needs that coincide with waterway revitalization. Concurrently, it sets the goal of inclusiveness for the waterway in both natural and social realms based on the principles of natural and social solutions.

In the renewal strategy phase, the research elucidates essential planning and development strategies by addressing current challenges and presenting a focused vision plan. Based on the principle of inclusive design, the research shows approaches in multiple important domains: waterway pathways, leisure areas, landscape improvement, and riverside amenities. These strategies are guided by the goal of natural inclusivity. Additionally, the study proposes approaches centred on social inclusivity, including diversified design, phased implementation, cultural heritage preservation, and behavioural interaction. Ultimately, the study ensures the effective implementation and sustainable development of waterway landscape renewal planning through the construction of an inclusive cooperation mechanism that integrates technical, economic, and institutional dimensions (Figure 1).

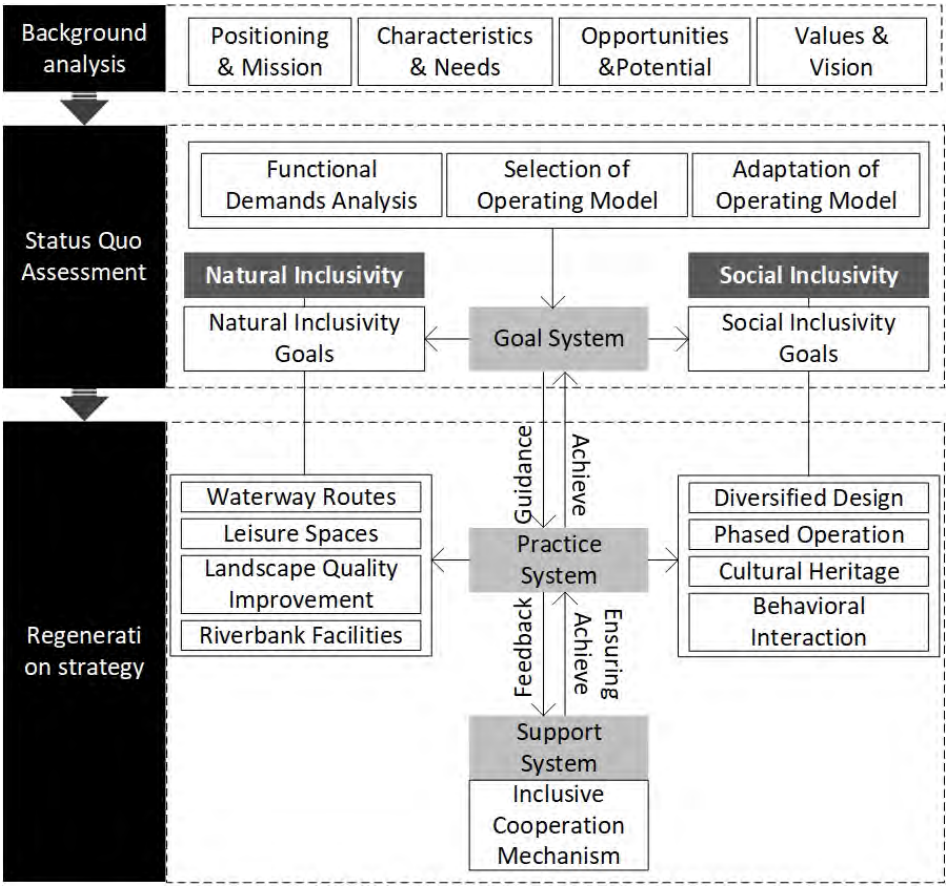


Figure 1. Waterway landscape regeneration framework. Source: Author-drawn.

3. Waterway Landscape Regeneration Planning Practice in Shanghai West Hongqiao Business District

3.1. Background analysis

Located at the heart of the Hongqiao International Central Business District, the Shanghai West Hongqiao Business District serves as a hub for modern service industries, international trade, and corporate headquarters. The area is primarily focused on six key industries, which include convention and exhibition, distribution, headquarters economy, financial, emerging industries, and creative industries. Our research area is about 7.95 km^2 (Figure 2). This research aim is to promote the development of business and upgrade the exhibition industry through the renewal of waterways. Based on a systematic analysis of the background and current situation of Shanghai's West Hongqiao Business District, this study mainly offers an overview of four key dimensions: position and mission, characteristics and needs, opportunities and potential, and value and vision (Figure 3).

Shanghai West Hongqiao Business District is the core functional area of the Hongqiao International Open Hub, which mainly focuses on open communication as its core purpose. Located at the intersection of Shanghai's main urban area and the Yangtze River Delta Green Eco-Integrated Development Demonstration Zone, the area contains famous landmarks for support, such as the National Convention and Exhibition Centre and Panlong Ancient Town, etc.

The characteristics and needs of the West Hongqiao Business District's water system landscape and functional enhancement goals are comprehensively considered in this study. A deeper analysis is conducted on the river network, passenger flow, and business conditions. Despite the district's capacity and convenient long-distance transportation advantages, challenges such as inadequate passenger flow import channels, limited convention and exhibition passenger flow, underdeveloped supporting infrastructure, poor destination connections, insufficient integration between public spaces and business formats, and underutilization of public green spaces by current business formats are identified.

Regarding opportunities and potential, the West Hongqiao Business District in Shanghai have opportunities and potential to develop cultural tourism and regional connections.The area is rich in sources of customers, including business and urban customers brought by international hubs and urban destinations, as well as surrounding residents with the development of housing and living services.

In terms of value and vision, the Shanghai West Hongqiao Business District aims to integrate cultural, sports, business, and tourism resources through characteristic water rings, absorb the flow of convention and commerce hubs (Figure 4-5).

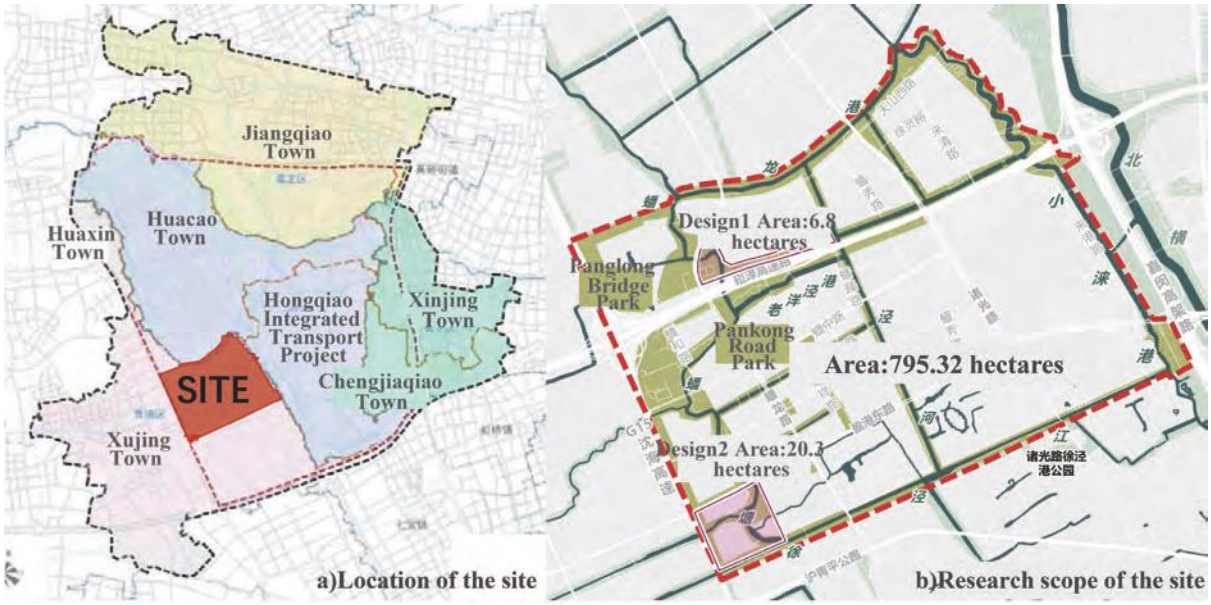


Figure 2. Research Area. Source: Author-drawn.

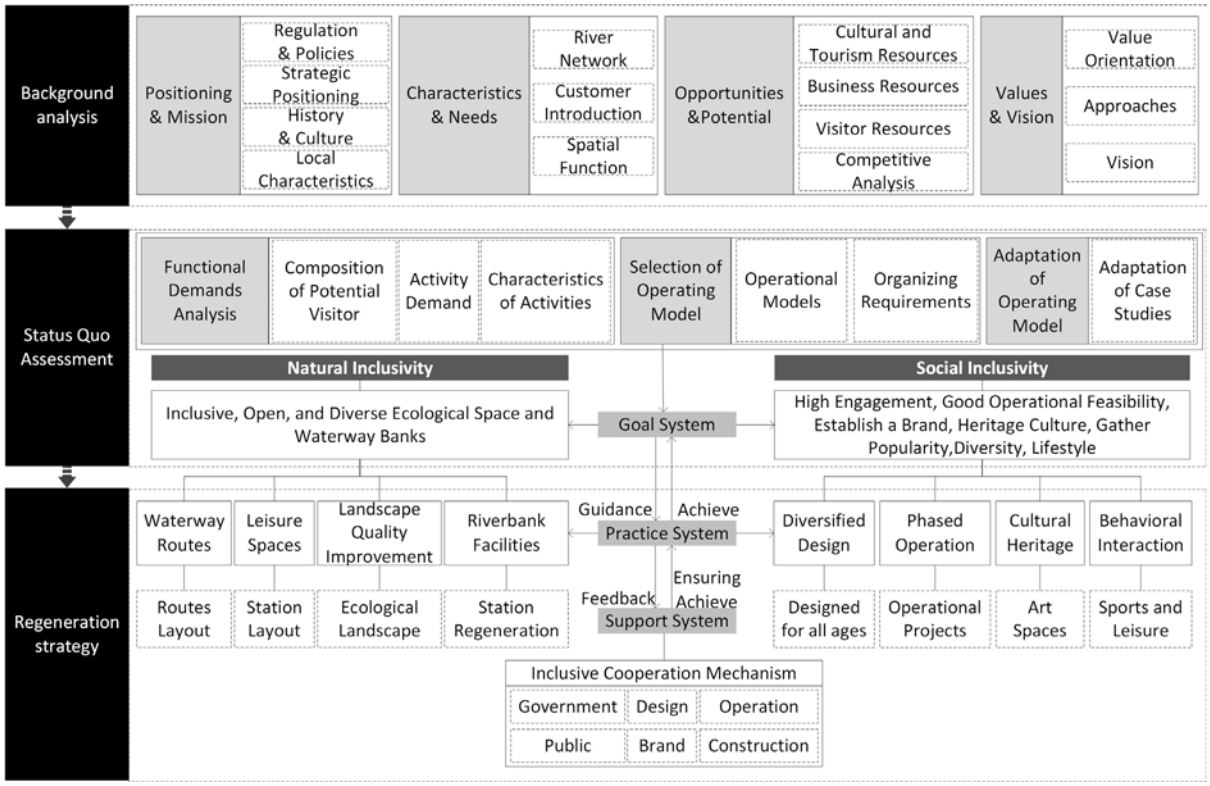


Figure 3. A Practical Framework for Waterway Landscape Renewal Planning in Shanghai's West Hongqiao Business District. Source: Author-drawn.

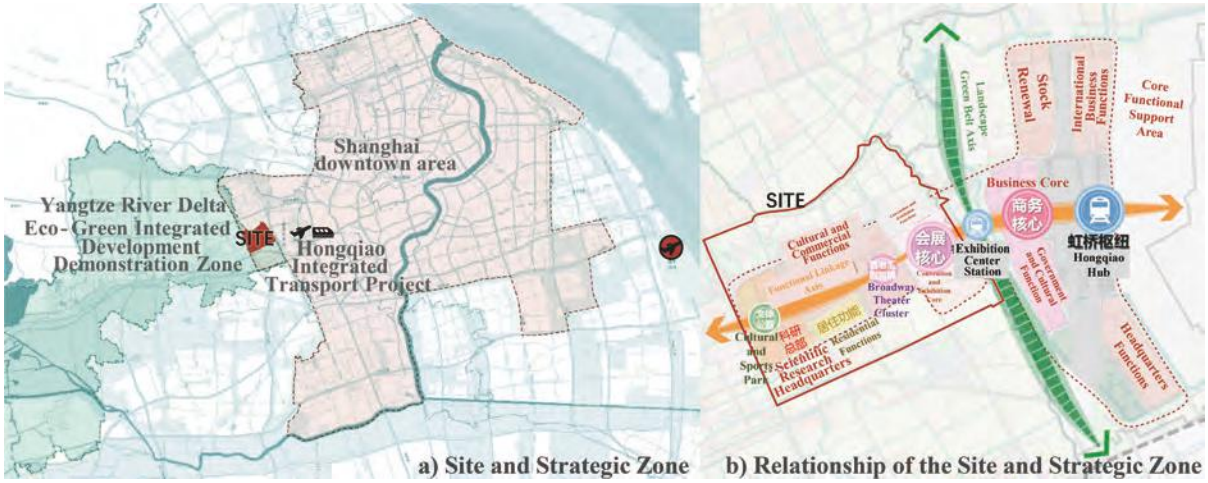


Figure 4. Shanghai West Hongqiao Business District Strategy Map. Source: Author-drawn.

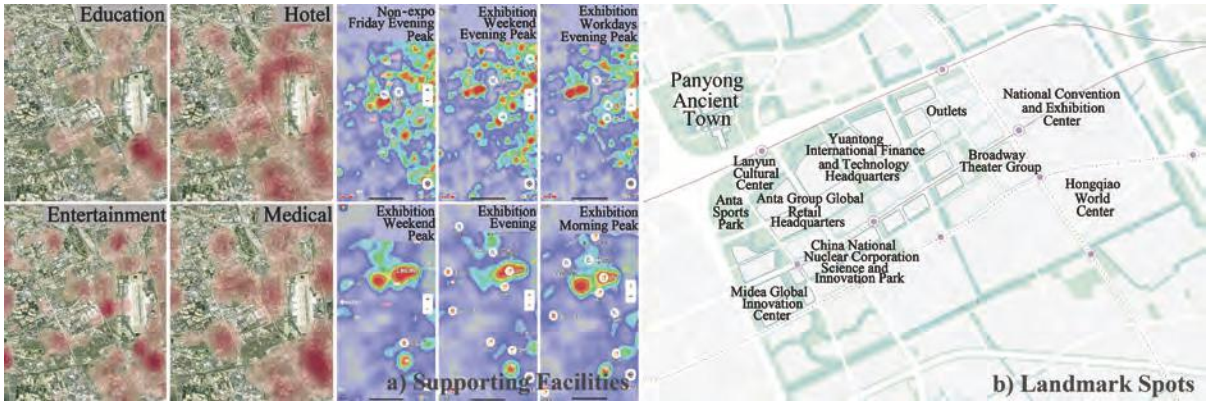


Figure 5. Resources around Shanghai West Hongqiao Business District. Source: Author-drawn.

3.2. Status Quo Assessment

3.2.1. Analysis of functional demands

Inclusive design is regarded as a comprehensive design method, and its task is mainly to think about how to integrate different sort of needs and wildly requirements of service of users without limitation of age and ability of people. The analysis of the components and activity demands of potential users would offer an empirical foundation for inclusive design to enable the planning work for everyone equitably. The analysis results show that the users of the West Hongqiao Business District generally have complex activity needs, including fixed and moving clients (Figures 6-7).

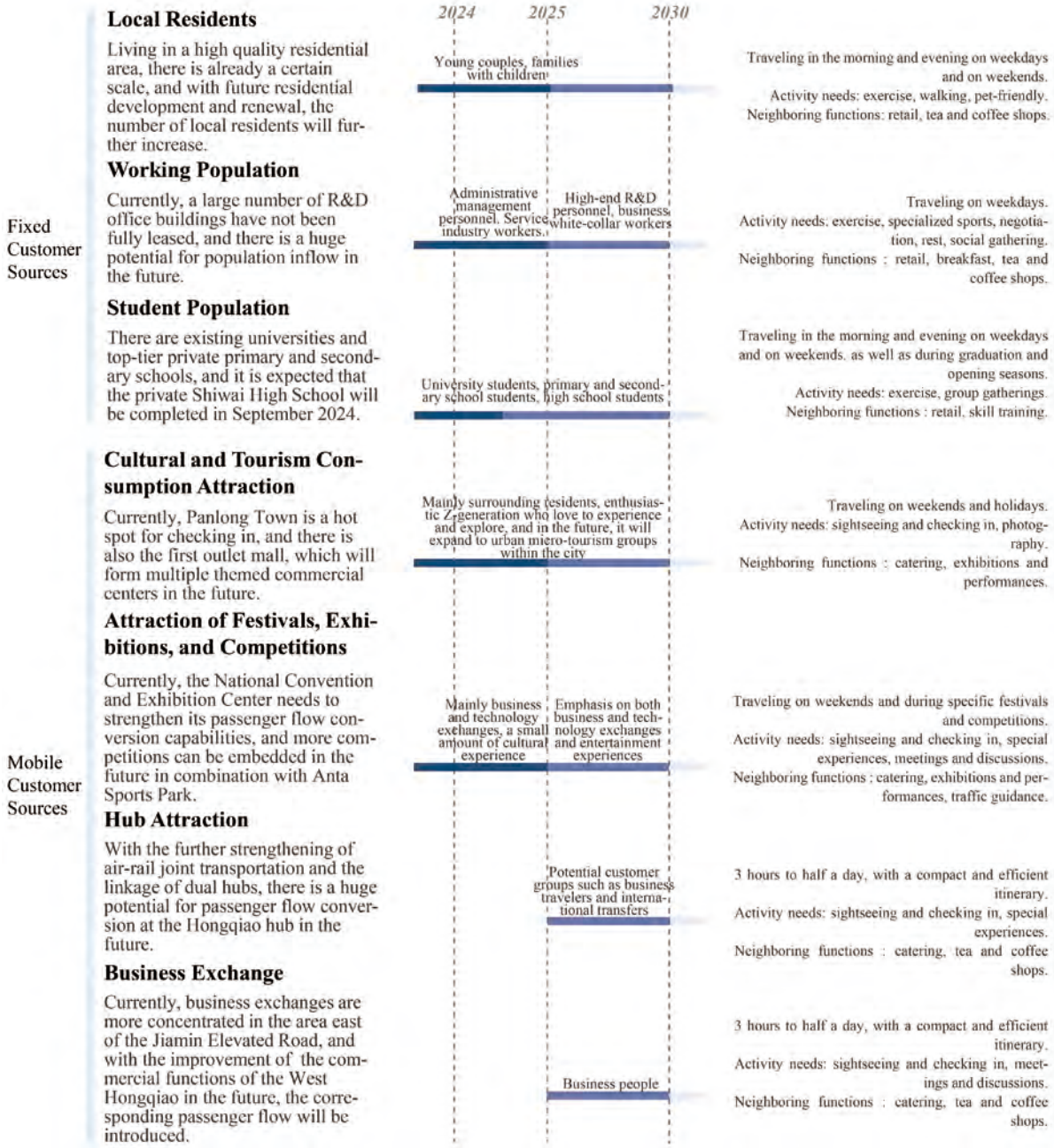


Figure 6. Analysis of the composition of the potential visitor. Source: Author-drawn.

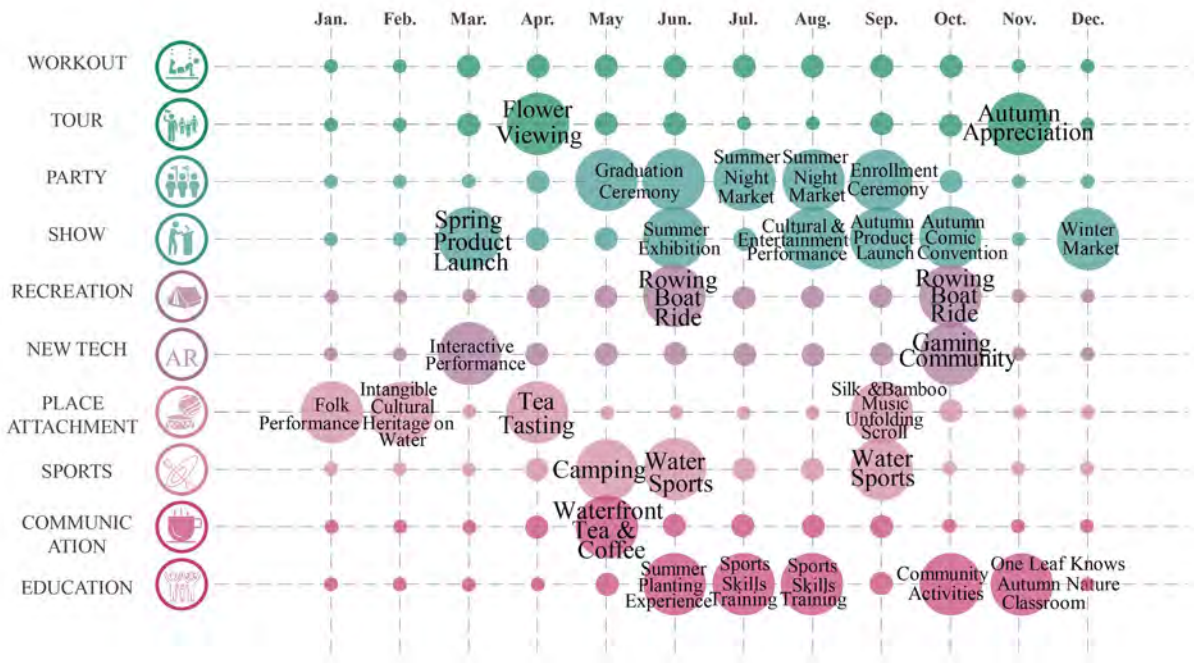


Figure 7. Analysis of the composition of the potential visitor. Source: Author-drawn.

3.2.2. Selection of operating model

There are three types of water sports in the operation mode of the West Hongqiao Water Circle, covering sightseeing tours and feeder transport, each of which has specific carrier requirements and target groups. The water sports mode is mainly operated by water sports clubs, targeting local people, and the water quality must meet the standard of Class III surface water. There are two types of sightseeing boats available, including rowboats and rented powerboats by the hour, that engage in the low-cost operation of cultural and tourism services. The clear sorting out of these operation modes guides the planning and implementation of the West Hongqiao Water Ring.

3.2.3. Adaptation of the operating model

This study analyses the four modes of fitness, which contain target fitness, carrier fitness, positioning fitness and development location fitness, and obtains a final fitness mode. Given the width limitation of the river, the pier is designed to be set up on one side, and ships need to navigate in one direction counterclockwise. Meanwhile, considering the difficulty of retrofitting and the access routes, the vessel design shall meet the requirement of a clear height of no more than 1.3 metres out of the water.

3.2.4. Natural and Social Inclusivity Goals

Based on the results of the above analyses, we derive a natural inclusiveness goal and a social inclusiveness goal for the renewal of the waterways in the West Hongqiao Business District. Its natural inclusiveness goal is to create an open and diversified ecological space and river environment. The goal of social inclusion is to establish a social environment characterized by strong community participation, ease of use, distinctive branding, widespread cultural sharing, social gatherings, and dynamic lifestyles.

3.3. Regeneration Strategy

3.3.1. Natural Inclusive Practices

In the waterway planning for the West Hongqiao area, we provide some measures and inclusive strategies, to solve the problem of environmental accessibility and equity, and to promote the development of cultural and tourism industries. Generally speaking, the nature of the regeneration depends on the inclusive design approach. This approach, involving the design of waterway routes and stations featuring recreational areas and a variety of outdoor activities, enables the development of an efficiently operating waterway system where public resources are equitably distributed.

Regarding the planning of waterway routes, two main routes were designed, covering the featured water land tourist route and the premium water route circuit (Figure 8). In contrast, the premium water route circuit connects Sports Park Station and Midea Station, etc., to achieve differentiated, complementary positions of featured nodes in the area and the extension of the leisure network.

When it comes to designing leisure spaces and transportation hubs, the key points of the design include a central loop of pathways for entertainment, which basically consists of footpaths. In addition, there are eight transportation hubs or water sports facilities across the area, which provide efficient loading services while improving the connectivity of paths, and maximizing the capacity of pedestrian flows.

As for the river facilities and stations, we came up with various actions including river and embankment restoration to improve the ecological capabilities of the waterway and the environmental quality and urban resilience.

Figure 8. West Hongqiao Waterway Regeneration Plan Major Routes and Station Layout. Source: Author-drawn.

3.3.2. Social Inclusive Practices

Two main tours were created (Figure 8). A lot of resources, such as business, cultural, sports and tourism resources, were integrated through the 8-km water ring to build an all-age-friendly leisure network that provides different kinds of experiences for visitors with different needs, such as paddle boarding and flash activities with outdoor brands. As we considered the operation phase and strategy, 2-3 key products were offered to increase the influence of the local brand based on the recent aims (Figure 9).

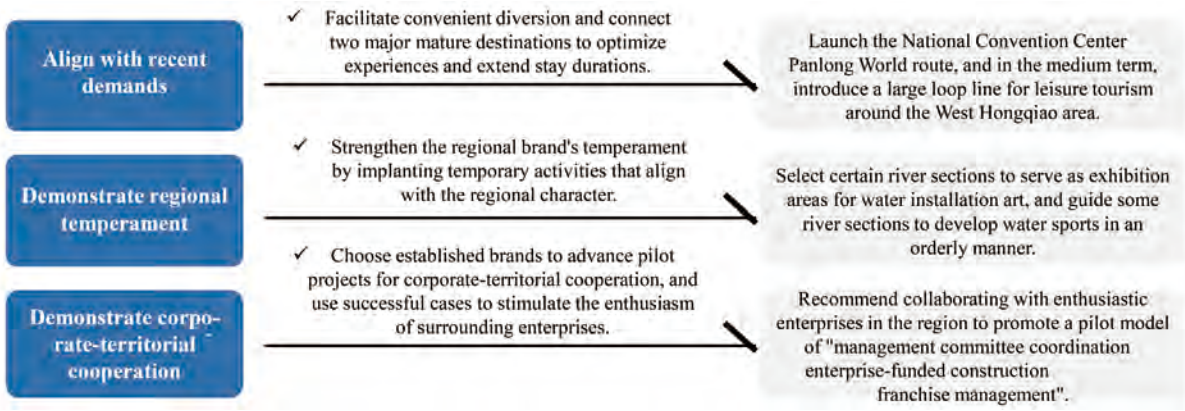


Figure 9. Recent Operations. Source: Author- drawn.

From the perspective of art spaces and cultural heritage, we created an innovative art exhibition area along the river, which offers people a truly unique artistic experience by combining art with spaces. On the one hand, this action could help improve the local brand character; on the other hand, it shows how important it is to have inclusive design in cultural heritage. In sports and leisure, our renewal plan, which is based on inclusive design for promoting a healthy lifestyle and community vitality, combines local characteristics and orderly guides and implements temporary activities for water sports.

3.3.3. Support System

Under the framework of an inclusive cooperation mechanism, the West Hongqiao area, by uniting active enterprises within the region, implements a pilot model of "management committee coordination - enterprise-funded construction - obtaining a franchise" (Figure 10). It aims to choose well-developed brands to promote cooperation between enterprises with local government and the market and inspire other enterprises' participation to promote regional common development.

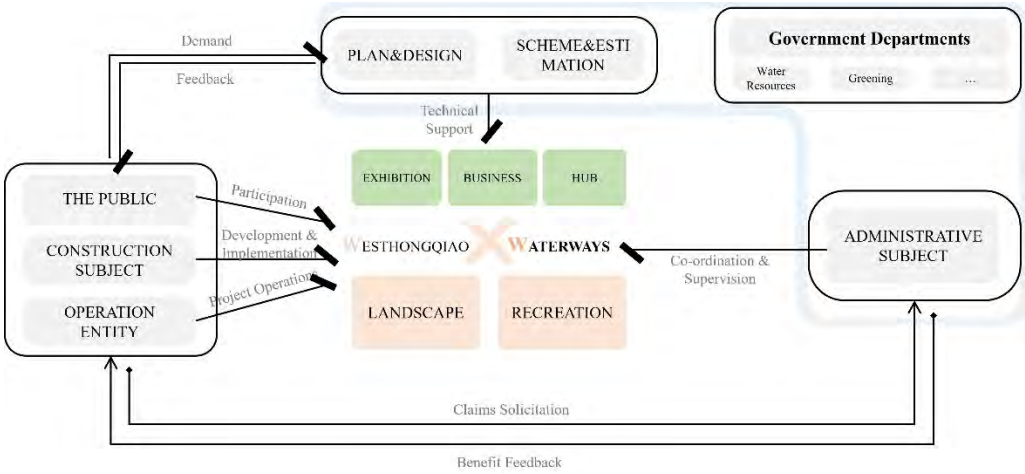


Figure 10. Inclusive Cooperation Mechanism. Source: Author- drawn.

4. Conclusions

This study proposes and verifies a comprehensive research framework for guiding the planning and renewal of urban blue-green spaces, focusing on the renewal of urban waterways. The framework places a strong emphasis on the preservation of cultural heritage and the improvement of water quality, focusing

on the key framework of "background analysis-status quo assessment-regeneration strategy." To illustrate the effectiveness of this approach, we present a detailed case study of the West Hongqiao Business District in Shanghai. Our research highlights the importance of combining natural and social inclusivity in our goals and methods. Improving access and equity in the environment can be achieved by developing a range of varied and interactive ecological areas and riverbank landscapes. In addition, our research suggests opportunities for strategic growth and rejuvenation of urban parks and gardens, with a focus on conserving local traditions and community identity, while also promoting social cohesion and safeguarding the distinctive charm of city living. The collaborative framework we recommend involves various stakeholders to facilitate holistic regional development.

Note: In this study, we used Kimi (Moonshot AI, 2023) as an auxiliary tool, primarily for the compilation and translation of specialized terms, proper noun and proprietary names.

5. References

Cattaneo, T., Giorgi, E. and Ni, M. (2018). Landscape, Architecture and Environmental Regeneration: A Research by Design Approach for Inclusive Tourism in a Rural Village in China. *Sustainability*, 11(1), p.128.

Cabau, B., Hernandez-Lamas, P. and Woltjer, J. (2021). Regent's Canal Cityscape: From Hidden Waterway to Identifying Landmark. *The London Journal*, pp.1–27.

Ding, Z. and Wang, H. (2024). What are the key and catalytic external factors affecting the vitality of urban blue-green space? A case study of Nanjing Main Districts, China. *Ecological Indicators*, 158, pp.111478–111478.

Dobson, J. (2021). Wellbeing and blue-green space in post-pandemic cities: Drivers, debates and departures. *Geography Compass*, 15(10).

Fouad, S.S., Heggy, E., Abotalib, A.Z., Ramah, M., Jomaa, S. and Weilacher, U. (2022). Landscape-based regeneration of the Nile Delta's waterways in support of water conservation and environmental protection. *Ecological Indicators*, 145, p.109660.

Hein, C. (2016). Port cities and urban waterfronts: how localized planning ignores water as a connector. *Wiley Interdisciplinary Reviews: Water*, 3(3), pp.419–438.

Huang, J. and Wang, Y. (2023). Research on Social Service Effectiveness Evaluation for Urban Blue Spaces—A Case Study of the Huangpu River Core Section in Shanghai. *Land*, 12(7), pp.1424–1424.

Kristianova, K., Gecova, K. and Putrova, E. (2015). WATERCOURSE AS CULTURAL HERITAGE IN CONTEMPORARY URBANISM: Preservation approaches from Košice and Prešov in Slovakia. *International Journal of Architectural Research: ArchNet-IJAR*, 9(1), p.122.

Liu, W., Yang, J., Gong, Y. and Cheng, Q. (2022). An Evaluation of Urban Renewal Based on Inclusive Development Theory: The Case of Wuhan, China. *ISPRS international journal of geo-information*, 11(11), pp.563–563.

Moonshot AI (2023) Kimi [Online]. Available at: https://kimi.moonshot.cn/ (Accessed 24 January 2025).

Niu, Y., Jiao, S., Tang, S., Tang, X. and Yin, J. (2023). Evolution Pattern of Blue–Green Space in New Urban Districts and Its Driving Factors: A Case Study of Zhengdong New District in China. *Water*, 15(13), p.2417–2417.

Perera, E.D., Moglia, M., Glackin, S. and Woodcock, I. (2022). The intention-implementation gap for community involvement in urban waterways governance: a scoping review. *Local Environment*, pp.1–23.

Piper, J.M. (2005). Partnership and participation in planning and management of river corridors. *Planning Practice and Research*, 20(1), pp.1–22.

Qiao, Y., Mengjiao, D., Haochen, L., Xizi, T. and Xiaoyan, L. (2022). Research on the Integrated Planning of Blue-Green Space towards Urban-Rural Resilience: Conceptual Framework and Practicable Approach. *Journal of Resources and Ecology*, 13(3).

Song, S., Wang, S., Shi, M., Hu, S. and Xu, D. (2022). Urban blue–green space landscape ecological health assessment based on the integration of pattern, process, function and sustainability. *Scientific Reports*, 12(1).

Wang, W., Watanabe, M., Zhou, D. and Ono, K. (2023). Environmental and Community Regeneration: Exploring Design Approach for Inclusive Tourism Based on Visualization Methods. *Sustainability*, 15(5), pp.4540–4540.

Zhu, Y. and Li, Z. (2024). 'Sharing' as a Critical Framework for Waterfront Heritage Regeneration: A Case Study of Suzhou Creek, Shanghai. *Land*, [online] 13(8), p.1280.

Zhao, Y., Jiang, Z., Yang, Y., Li, C., Dong, C. and Zhao, L. (2024). Research on Child-Friendly Renewal Strategy of Community Public Space From the Perspective of Inclusive Development. *International Review for Spatial Planning and Sustainable Development*, 12(4), pp.4–27.

Zheng, S., Yang, S., Ma, M., Dong, J., Han, B. and Wang, J. (2022). Linking Cultural Ecosystem Service and Urban Ecological-Space Planning for a Sustainable City: Case Study of the Core Areas of Beijing Under the Context of Urban Relieving and Renewal. *SSRN Electronic Journal*.

Research paper

Co-creation for Urban Biodiversity:

The experience of a public participation process in a living lab in Milan, Italy

Eugenio MORELLO, Laboratorio di Simulazione Urbana Fausto Curti, Dastu, Politecnico di Milano, Italy
Israa MAHMOUD*, Laboratorio di Simulazione Urbana Fausto Curti, Dastu, Politecnico di Milano, Italy
Luca LAZZARINI, Laboratorio di Simulazione Urbana Fausto Curti, Dastu, Politecnico di Milano, Italy
Asef AYATOLLAHI, Laboratorio di Simulazione Urbana Fausto Curti, Dastu, Politecnico di Milano, Italy

*Corresponding author: israa.mahmoud@polimi.it

Abstract

This contribution investigates the fine line between engaging citizens on topics related to urban biodiversity and experimenting with co-creation processes in a real living lab setting in Milan, Italy. The participatory process established within the "Laboratorio per la Biodiversità Urbana" (LABU) provided an opportunity to test a novel co-creation methodology, supported by the local municipality's commitment to redesign an area characterized by high urban biodiversity, the Sorelle Mirabal Garden, in the eastern part of the city, currently closed to the public. The process draws on the understanding of the often-invisible relationships between humans and nature embedded in the collective memory of the Garden, aiming to reactivate it as a public space. Testing co-creation methods for enhancing urban biodiversity in a living lab setting has led to significant participant engagement and awareness, fostering recognition of the importance of more-than-human species. It has also enabled the collaborative definition of design solutions that promote inclusivity across different social groups. The measures proposed benefited from the experts' input and the local knowledge provided by citizens. Moreover, the urban living lab approach revealed to be an appropriate environment for managing frictions that originate when jointly addressing the needs of different human and non-human communities within emerging concurrent solutions in the use of space.

Keywords

Urban biodiversity, co-creation, urban regeneration, urban greening, more-than-human, urban planning

1. Introduction: Co-creation for supporting biodiversity in cities

Over the past two decades, awareness has steadily increased across various levels of society about the important role of nature in tackling the environmental and social challenges faced by cities. Urban biodiversity (UB) —

defined as the genetic, species and ecosystem diversity found in urban environments— has become a key focus for urban research and city planning agendas (Secretariat of the Convention on Biological Diversity, 2012; European Commission, 2021; Chan et al., 2021). Despite its multiple benefits provided to inhabitants at individual and community levels (Nilon *et al.*, 2017), the integration of biodiversity in cities faces numerous challenges, particularly in public spaces, where the co-existence of human life and nature demands a shift in societal attitudes. One of the challenges is the social acceptance of nature and wilderness within cities. Individual and social perceptions of biodiversity integration in cities is shaped not only by aesthetic preferences but also by a number of eco-system disservices that animal and plant lives in proximity to human life can generate (e.g., diseases, allergies, physical accidents, maintenance costs, diminished sense of control of spaces, psychological resistances related to the fear of the unknown). In addition, urban biodiversity is not considered a priority on the value scale when deciding how to allocate the budget for urban interventions (Oke *et al.*, 2021; Bulkeley et al, 2022). This significantly limits political commitment and public action. All this often results in forms of resistance by citizens to initiatives aimed at preserving and increasing urban biodiversity. Indeed, implementing biodiversity interventions in cities requires significant resources and will to understand citizens' preferences regarding how they interpret and value urban biodiversity (Schneider et al., 2024). In this vein, several authors (McDonnell, 2007; Cilliers, 2010; Varumo et al., 2022) have highlighted the need to align the cultural and social values of biodiversity with the ecological and economic ones as a way to foster social acceptance and prevent the tensions that often arise from biodiversity initiatives. Varumo et al. (2022) pointed out that, in order to achieve socio-political acceptance, biodiversity initiatives must acknowledge the existing societal norms and values and reconcile the contradictions between the various objectives and interpretations that individuals or groups may assign to biodiversity.

Since few years, the themes of co-creation and public participation oriented towards strengthening natural capital preservation became hot topics in the domain of citizen engagement and local governance (Røiseland, Sørensen and Torfing, 2024), often occurring through an urban living lab setting. As co-creation has been recently used for promoting urban greening and more recently Nature-Based Solutions (NBS), several projects funded by the Horizon 2020 and Horizon Europe research programs showcase on the successes and challenges through which a public participation process go through to create awareness about nature benefits and co-benefits in the urban environment (European Commission, 2023). In this context, the National Biodiversity Future Center (NBFC)[1] initiated a research stream called "Laboratorio per la Biodiversità Urbana" (LABU), which aims to establish a co-creation guidance and ad hoc methodology specifically designed to preserve and enhance urban biodiversity, ultimately striving to research, raise awareness, and achieve a positive impact on nature.
On the one hand, the people's engagement in longer-term urban regeneration processes that include nature and biodiversity aspects generally generate a positive impact on the sense of belonging and increase of attachment to place-based contexts, for instance through urban living labs settings (Nesti, 2018; Xie and Bulkeley, 2020). On the other hand, engagement processes are needed to maintain and support nature itself to thrive in these local contexts and consequently address challenges of climate change and adaptive planning (Galan *et al.*, 2023). Similar co-creation experiences with nature and for nature have highlighted the importance of including local communities and mobilizing place-based knowledge in the process through which ecological restoration is pursued and a wider range of species could be protected (Pineda-Pinto *et al.*, 2024). Such approach should be supported by an adaptive, resilient and novel design process that could be developed and implemented through experimentation and deeply altered by the structure of the shared information flows between locals and municipal authorities (Abson *et al.*, 2017).

[1] NBFC (2022-25) is a research initiative funded by the National Recovery and Resilience Plan as part of the NextGenerationEU program dedicated to the topic of biodiversity conservation, monitoring, and enhancement in the Mediterranean context.

In this article, we explore the experimentation with urban biodiversity in a real living lab setting in Milan, Italy, through the testing of a novel co-creation methodology with the commitment of the local municipality to re-design an area characterized by high urban biodiversity, the Sorelle Mirabal garden located in the neighborhood of Ortica, in the eastern part of the city. Building on several experiences of co-creation practices showcase that this approach requires a paradigm shift when it comes to work with urban nature and nature-based solutions (NBS), as living systems require time and space to thrive. We build on the understanding of the invisible relationships humans and nature have in the collective memory of the Sorelle Mirabal Garden, to reactivate a public garden and currently closed to the public, together with local authorities and community.

This research paper is divided into six sections. After the introduction, the methodological section underpins the approach through which the scientific framework was implemented, and different workshops were held to converge on one design scenario as generated by the living lab participants. Followingly, the case study section showcases the different tools that were explored during the implementation of the process towards reaching a shared consensus for the designed plan. The final sections present the discussion and conclusions drawn from this experience, as well as prospects for replicating the envisioned co-creation process in other urban biodiversity living labs.

2. Methodology: Scientific framework for co-creation for nature and with nature

In this research, a newly established scientific framework for the co-creation process focusing on the themes of urban biodiversity and to be applied in a living lab setting was established. The pathway is divided into three main phases: (1) co-creation planning, (2) co-designing with stakeholders, and (3) co-implementation with citizens and local associations. During the co-creation planning phase (see figure 1) two meetings were held with the municipality officials and responsible associations that helped shape the direction of the co-designing process and its expected outcomes. A simulation of a theory of change on a vision, mission and objectives of the process was carried out with the local co-creation team and several stakeholders, followed by a public event that opened the co-creation process to the public. It is worth noting that the co-monitoring phase is developed in parallel with co-design and co-implementation phases. This parallelization has the potential to better inform the decision-making process when it comes to the specific design solutions that could be developed in place within the living labs. The last phase of the co-creation process focuses on mainstreaming the solutions with local communities, as well as replicating the experience and establishing new living labs around the city or beyond.

In this framework, there is a focus on developing new methods and tools for engaging citizens in the co-design process on the longer term, such as: role playing technique in which citizens empathize with the animal and plant species that inhabit the park for developing awareness on the biodiversity present in the park, and a collaborative workshop for identifying the NBS and design elements to be implemented in the garden. These different methods were established in a guidance document that encompasses also tools such as cards, boards and design charrettes on how to be used and samples for printing.

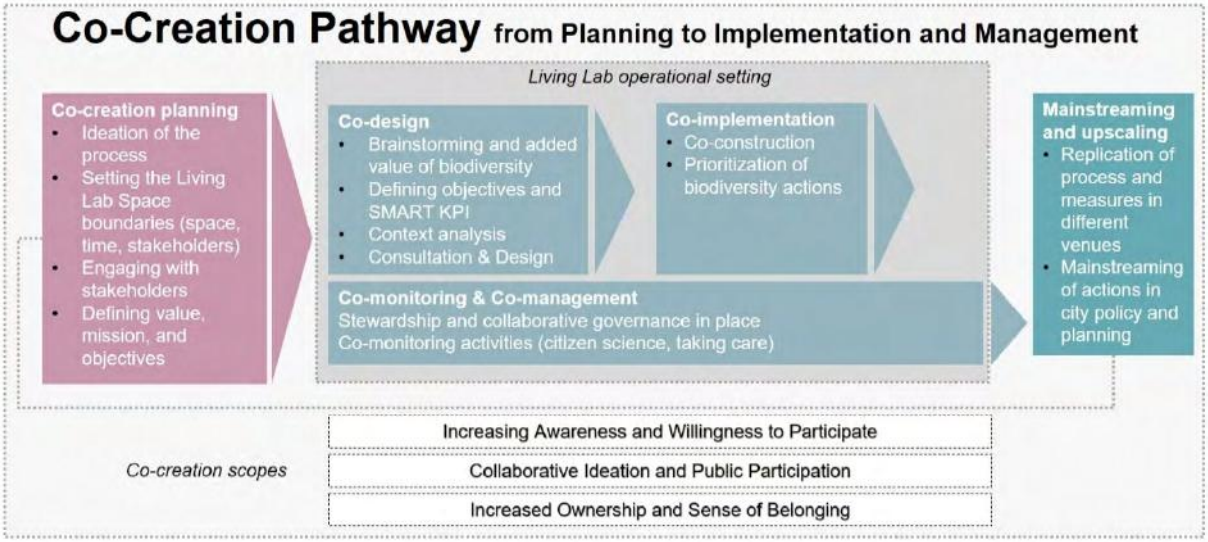


Figure 1. The Co-Creation Pathway organized in four main phases and in a living lab setting, with particular attention to the expected results and scope of the process. Source: the authors.

Regarding Ecosystem Services (ES) cards, a systematic literature review and experts' opinions (using deductive coding) guided the selection of 28 benefits, distributed into three ES categories: provisional, regulating, and cultural. In this step, the emphasis was on the selection of targets' benefits that appear less frequently in public perception. This approach helps to present a comprehensive variety of benefits to participants. A guiding table accompanies all selected benefits, containing the ES class, code, examples of benefits, and the general category.

3. The Application: a living lab for urban biodiversity in Milan

In the first phase of co-creation planning, the municipality of Milan has signed a collaboration agreement with the Politecnico di Milano for co-designing with citizens the Sorelle Mirabal Garden in May 2023, a recently acquired space that was temporarily open for a short period of time more than a year ago and now seeks for a new identity. In this agreement, two different research groups from urban planning and ecology disciplines engage on designing a co-creation plan for involving citizens and local associations in the redesigning of the garden in a way that preserves its past identity, while leveraging urban biodiversity. The project was launched in the beginning of May 2024 and during May and June, three workshops were organized, see figure 2. The different workshops were then followed by a public presentation during the Milano Green Week, an annual event in town dedicated to promoting environmental sustainability, in September 2024 that has put together experts and citizens on the convergence on one desirable designed scenario and permitted a collection of feedback on the criticalities of the park design.

Figure 2. The co-creation pathway articulated in four workshops with citizens, experts and stakeholders. Source: the authors.

LABU Co-design Lab#1 focused on establishing a primary definition of urban biodiversity and its benefits, with particular emphasis on the social values provided by nature. To capture social values connected to nature and urban biodiversity, we used ecosystem services to identify benefits. Ecosystem Services (ES) are benefits people obtain through ecosystems and natural processes that contribute directly or indirectly to sustaining their health and well-being (Daily, 1997; Liquete et al., 2016). Through our review of literature based on each class of ES established by The Common International Classification of Ecosystem Services (CICES) (Haines-Young and Potschin-Young, 2018), we identified a series of values, benefits, and impacts of ES in urban areas that are related to urban biodiversity. Each associated a class of ES (provisional, regulation, and cultural). In the first session, after defining a basic definition of ES to participants, identified values were presented to participants in a set of 28 cards. The cards, divided by color into 3 ES categories, present a simplified benefit or impact of nature on human lives alongside approximate result appearance timeline in years and artificially generated image based on the definition of that impact or benefit. On the card's back, classification information of associated ES (code, section, group, class, and example) was available for further information. Participants in two groups simultaneously discussed the cards, selected their top five benefits, and presented them on the board. Two facilitators assisted throughout these activities, providing information and clarifying terms as needed. By the end of this activity, participants, experts, and facilitators elaborated on the results and selections, and each group expressed their reasoning behind selecting the benefits for the case study context. Among the selected benefits, heat reduction to increase greenery coverage, enhanced local interaction among neighbors, anxiety and depression reduction, and control of disease and sanitary risk is the top selection of participants. The results allow planners to identify ES to focus on during implementation phases and show participants prioritized ES benefits expecting to be present in their neighborhood in the future.

The main objective of LABU Co-design Lab#2 was to acknowledge and value the biodiversity of the garden, guiding participants to identify the needs and trajectories of the species and understand the potential conflicts with humans. To achieve this, participants were asked to engage in a multispecies role-playing game. A set of cards featuring various animal and plant species (both native and invasive), selected with the support of two local experts, was shared during the lab. Most species were chosen based on their actual presence in the habitats of the garden, while others were identified as potential future inhabitants. Each card featured an animal or plant species, showing a picture (downloaded from the Portal of Italian Flora and Fauna) along with the common and

scientific names. Participants were divided into groups of two members and asked to randomly choose two cards, one representing an animal and the other a plant. Two A3 boards illustrating the species' user journeys were also distributed to each group, one representing the daily user journey (24 hours) and the other the yearly user journey (4 seasons). Each A3 board showcases a table with the main row showing, respectively, the 4 seasons and the 24 hours, and the columns outlining five aspects: i) the daily and yearly trajectory, ii) the specific needs of each species, iii) the potential interactions with other species, iv) the possible benefits, and v) the disservices for humans. Participants were asked to discuss collaboratively within their groups and fill out the boards with the relevant information. After 15 minutes of group discussion, all groups presented and shared the outcomes of their role-playing game with the other participants. The discussion also involved two experts who provided feedback and additional insights on the species' user journeys. This allowed for a collaborative learning process, enabling participants to deepen their understanding of the species, and their specific needs in relation to their habitat. During the session, a mediator was responsible for filling out a digital board, taking notes of both the desired and unwanted species that could be considered in the co-design of the multispecies garden.

In the next step, the LABU Co-design Lab#3, the objective was to collaboratively identify the design elements to be implemented in the garden. Thus, a set of cards was prepared featuring a selection of nature-based solutions from available catalogues, along with other types of urban furniture needed for the public use of the garden. The cards were placed on the table, and participants were asked to collaboratively discuss and decide which elements could be introduced into the garden space, in line with the vision, mission, and objectives established during Lab#1.

Following the three abovementioned workshops, Lab#4 focused on discussing preliminary results with public participants, stakeholders, and biodiversity experts. Through this session organized within Milan Green Week in 2024, the initial interventions and location of nature-based solutions were discussed and analyzed in open dialogue with participants. Within this setting citizens communicated their concerns and feedback for current and future stages of the research alongside the dissemination of pre-intervention results from co-monitoring and co-production for raising awareness regarding urban biodiversity and human-nature relations.

4. Findings and Discussion

Several findings could be extrapolated from the co-creation experimentation for urban biodiversity in this case study. Throughout the co-creation planning and co-designing process, several bottlenecks and hindrances have been encountered which slightly affected the project timeline and opening the park to the public. These bottlenecks could be thought as follows:

1) *Co-creating for biodiversity*: The co-creation methodology and tools implemented effectively supported the primary goal of enhancing biodiversity and establishing a multispecies garden. By stepping into the perspectives of other species, participants developed a deeper attachment to biodiversity values and expressed a strong commitment to defending these values by the end of the process. However, the line between raising awareness and subtly nudging or even influencing participants toward biodiversity-friendly solutions may be a fine one.

2) *Political resistance:* the municipal authority had the full capacity to supervise the planning and implementation of desired solutions in the park, which often did not go in line with the strategies and measures selected by citizens. These frictions have risked to slow down the co-design process, since it clearly affected the official approvals needed to proceed to next phases of implementation and the final adoption of solutions.

3) *Citizen engagement* in co-creation processes requires longer time commitment and a special attention to a variety of aspects related to the outcomes of the project without being selfishly biased by the needed versus the expected results. In such complex processes as the case of Sorelle Mirabal Garden,

we have experienced the consistency of attendance from the affectionate group of citizens that had a very long and historical connection with the park and its neighborhood area. Nonetheless, the possibility of including other groups of citizens has been very limited due to the time availability and the lack of territorial connections with larger groups of local associations.

4) *Replicability of the process* is often considered hard to conceive if the funding process is not reliable within the municipality itself, and if the urban biodiversity aspects are not prioritized in the political agenda of the city.

5. Conclusions

Engaging people in the commitment to preserving urban biodiversity poses a significant challenge. Involving them in shared values and decision-making processes can effectively foster support and heighten awareness of the importance of biodiversity planning. In this study, we suggest that a co-creation pathway specifically designed to promote urban biodiversity could offer a promising solution.

Despite the limited timeframe, the envisioned co-creation procedures proved effective in illustrating social-ecological relationships and the benefits of nature to humans. Using Ecosystem Services (ES) as a tool to gauge public perceptions of urban biodiversity allowed for efficient analysis of complex systems, such as cities, and for flexible replication in different contexts with new variables. ES also helps in identifying the appropriate implementation of Nature-Based Solutions (NBS) using ecological tools highlighted by participants.

Acknowledgments

This research has received funding from the Project “National Biodiversity Future Center - NBFC” funded under the National Recovery and Resilience Plan (NRRP), Mission 4 Component 2 Investment 1.4 - Call for tender No. 3138 of 16 December 2021, rectified by Decree n.3175 of 18 December 2021 of Italian Ministry of University and Research funded by the European Union – NextGenerationEU; Project code CN_00000033, Concession Decree No. 1034 of 17 June 2022 adopted by the Italian Ministry of University and Research, CUP, D43C22001250001. We are deeply grateful to Municipality 3 of the City of Milan for their invaluable support in site selection and stakeholder engagement, as well as to the research teams at DAStU and DEIB, Politecnico di Milano, for their ongoing collaboration.

Authorship Credits

Eugenio Morello: Coordination, Conceptualization, Methodology, Writing—original draft, Writing—review and editing. Israa Mahmoud: Conceptualization, Methodology, Writing—original draft, Writing—review and editing. Luca Lazzarini: Methodology, Writing—original draft, Writing—review and editing. Asef Ayatollahi: Methodology, Writing—original draft, Writing—review and editing. All authors have read and agreed to the published version of the manuscript.

6. References

Abson, D.J. *et al.* (2017) ‘Leverage points for sustainability transformation’, *Ambio*, 46(1), pp. 30–39. Available at: https://doi.org/10.1007/s13280-016-0800-y

Bulkeley et al (2022) *Cities and the Transformation of Biodiversity Governance*, *Transforming Biodiversity Governance*. Edited by I.J. Visseren-Hamakers and M.T.J. Kok. Cambridge University Press. Available at: https://doi.org/10.1017/9781108856348

Chan, L., Hillel, O., Werner, P., Holman, N., Coetzee, I., Galt, R., and Elmqvist, T. (2021), *Handbook on the Singapore Index on Cities' Biodiversity (also known as the City Biodiversity Index)*, Montreal: Secretariat of the Convention on Biological Diversity and Singapore: National Parks Board, Singapore, https://www.cbd.int/doc/publications/cbd-ts-98-en.pdf

Cilliers, S. (2010), Social aspects of urban biodiversity. An Overview. In: Müller, N., Werner, P., Kelcey, J.C. (eds.), *Urban Biodiversity and Design*, Hoboken: Blackwell Publishing Ltd, https://doi.org/10.1002/9781444318654.ch4

Daily, G.C. (1997) 'Introduction: What Are Ecosystem Services', in G.C. Daily (ed.) *Nature's Services Societal Dependence On Natural*. 1st edn. Washington D.C.: Island Press, pp. 1–11. https://www.raincoast.org/library/wp-content/uploads/2012/07/Daily_1997_Natures-services-chapter-1.pdf

European Commission (2021), *Biodiversity Strategy for 2030: Bringing nature back into our lives*, available from: https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en (accessed on October 22, 2024).
European Commission (2023) *Guidelines for Co-Creation and Co-Governance of Nature-based Solutions-Insights from EU-funded Projects*. Edited by I. Ferreira, G. Lupp, and I. Mahmoud. Directorate-General for Research and Innovation, Brussels: Publications Office of the European Union. Available at: https://doi.org/10.2777/157060

Galan, J. *et al.* (2023) 'Landscape adaptation to climate change: Local networks, social learning and co-creation processes for adaptive planning', *Global Environmental Change*, 78, p. 102627. Available at: https://doi.org/10.1016/j.gloenvcha.2022.102627

Haines-Young, R. and Potschin-Young, M. (2018) 'Revision of the Common International Classification for Ecosystem Services (CICES V5.1): A Policy Brief', *One Ecosystem*, 3. Available at: https://doi.org/10.3897/oneeco.3.e27108

Liquete, C. *et al.* (2016) 'Perspectives on the link between ecosystem services and biodiversity: The assessment of the nursery function', *Ecological Indicators*, 63, pp. 249–257. Available at: https://doi.org/10.1016/j.ecolind.2015.11.058

McDonnell, M. (2007), Restoring and managing biodiversity in an urbanizing world filled with tensions, *Ecological management and Restoration* 8(2): 83-84, https://doi.org/10.1111/j.1442-8903.2007.00344.x
Nesti, G. (2018) 'Co-production for innovation: The urban living lab experience', *Policy and Society*, 37(3), pp. 310–325. Available at: https://doi.org/10.1080/14494035.2017.1374692

Nilon, C.H. *et al.* (2017) 'Planning for the future of urban biodiversity: A global review of city-scale initiatives', *BioScience*. Oxford University Press, pp. 332–342. Available at: https://doi.org/10.1093/biosci/bix012

Oke, C. *et al.* (2021) 'Cities should respond to the biodiversity extinction crisis', *npj Urban Sustainability*, 1(1), pp. 9–12. Available at: https://doi.org/10.1038/s42949-020-00010-w

Pineda-Pinto, M. *et al.* (2024) 'Leverage points for improving urban biodiversity conservation in the Anthropocene: A novel ecosystem lens for social-ecological transformation', *Environmental Science & Policy*, 162, p. 103926. Available at: https://doi.org/10.1016/j.envsci.2024.103926

Røiseland, Asbjørn., Sørensen, Eva. and Torfing, Jacob. (2024) *Advancing Co-creation in Local Governance*. Edited by A. Røiseland, E. Sørensen, and J. Torfing. Edward Elgar Publishing. Available at: https://doi.org/10.4337/9781802202236

Schneider, A., Neuhuber, T., Zawadzki, W. (2024), Understanding citizens' willingness to contribute to urban greening programs, *Urban Forestry & Urban Greening* 95, 128293, https://doi.org/10.1016/j.ufug.2024.128293

Secretariat of the Convention on Biological Diversity (2012), *Cities and Biodiversity Outlook—Executive Summary*, Montreal. https://www.cbd.int/authorities/doc/cbo-1/cbd-cbo1-summary-en-f-web.pdf

Varumo, L., Kotilainen, J.M., Primmer, E. (2022), Social acceptance of biodiversity offsetting: Motivations and practices in the designing of an emerging mechanism, *Environmental Policy and Governance* 33(3): 301-312, https://doi.org/10.1002/eet.2031
Xie, L. and Bulkeley, H. (2020) 'Nature-based solutions for urban biodiversity governance', *Environmental Science and Policy*, 110(December 2019), pp. 77–87. Available at: https://doi.org/10.1016/j.envsci.2020.04.002

Research Paper

Health-oriented Resilience Evaluation of Village-amid-the-city in Cold Area:A Case study of Harbin, northeastern China

Tingting YU, Harbin Institute of Technology, Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Xu Guo, Harbin Institute of Technology, Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, China

Abstract

According to WHO statistics, from the perspective of global health coverage, villages-amid-the-city, as a special form of urban settlement, are lagging behind in terms of population health and environmental development. Under the impact of the New Crown Epidemic, the ability of community-based settlements to cope with public health events highlights their importance in dealing with health risks. Reducing the health risks of vulnerable groups has become an urgent shortcoming that needs to be filled in order to promote universal health coverage. In order to better understand the level of health-oriented resilience in villages-amid-the-city, a specific framework for analyzing health-oriented resilience indicators in villages-amid-the-city is proposed to reflect the health-oriented resilience drivers affecting villages-amid-the-city and to propose corresponding updated coping strategies to cope with public health risks and to shape livable villages-amid-the-city as places to live. This study takes a typical villages-amid-the-city in Harbin City, Heilongjiang Province, as the research object. Taking the DPSIR model as the theoretical basis and pressure, motivation, state, reaction and impact as the evaluation dimensions of health-oriented resilience, the health-oriented resilience evaluation indexes of villages-amid-the-city are constructed, the health-oriented resilience of six typical villages is calculated by using the composite index method, and the driving factors of the health-oriented resilience of villages-amid-the-city are explored by combining the factor analysis and principal component analysis. In addition, the framework will propose an updated approach for planning decision makers on reducing health risks in villages-amid-the-city. Thus, its policies and practices aimed at improving the environment of cold villages-amid-the-city settlements can be targeted as a tool for implementation.

Keywords

Health-oriented resilience, village-amid-the-city, frame, AHP-BP

1. Introduction

In recent years, global urban public health has been undergoing recovery and reshaping as the shock of the new Crown Pneumonia epidemic came to an end. However, the Global Monitoring Report on Universal Health Coverage 2023 warns that billions of people around the globe are seriously lagging behind on the path to universal health coverage, and that the challenges to global health remain enormous . Inequalities within and between countries persist, with vulnerable groups having lower access to health and related services, facing higher health risks and higher associated mortality rates (Acuti et al., 2020). This is further illustrated by the COVID-19 pandemic, which unevenly affects vulnerable groups versus poorer areas, such as migrants (Alnusairat et al., 2023), ethnic minorities, older people, or those living in deprived neighbourhoods. Villages-amid-the-city, as lagging areas of urban planning, are areas where urban low-income populations are concentrated, but there are a series of problems that threaten the health of human habitats, such as the lack of public services, high security risks (Champlin et al., 2023), and dirty and unkempt environments, which greatly limit the integration of villages-amid-the-city into the development process of globally healthy cities (Mahmood et al., 2022). Health-oriented resilience assessment can provide support for the preparation and defence of villages-amid-the-city before the occurrence of health hazards (Nurmala et al., 2023), response and resistance during the occurrence of health hazards, and self-adaptation and repair after the occurrence of health hazards (Castleden et al, , 2011), and it is an important path to make up for the shortcomings of urban health construction and a necessary link to help the sustainable development of the city, but the relevant research has not yet been carried out widely (Wang et al., 2021).

Health-oriented resilience is the ability to remain healthy in the face of health risks (Panter-Brick 2014). Resilience plays a key role in supporting sustainable lifestyles and promoting health and well-being. Reducing individual behavioural risk factors and improving health-care services are part of improving health-oriented resilience and more critically, addressing human settlements, including buildings, roads, parks, spaces and all other elements constructed or transformed by urban planners (Liu& Jia, 2021). These elements influence the living conditions of residents, the quality of their homes and the community environments in which people interact, and it is these physical and social living conditions that lead to individual behavioural risks (Zhang et al., 2023). In recent years, therefore, building the resilience of human settlements has become an emerging approach to public health emergency preparedness and response, encompassing both individual preparedness and the creation of supportive social environments within living environments to withstand and recover from disasters (Li et al., 2023). Resilient living environments can provide adaptive means of coping with public health risks, thus providing effective safeguards for healthy living.

Research on health-oriented resilience in villages-amid-the-city has three distinct advantages for improving lagging residential environments that host public health. Firstly, the relationship between environmental problems and human health in villages-amid-the-city is analysed using human behaviour as a mediator, and correlates of health-oriented resilience are identified (Jamroni et al., 2021). Second, it examines how to quantitatively evaluate health-oriented resilience in villages-amid-the-city and how to scientifically analyse the drivers (Tan et al., 2021). The third advantage is that renewal strategies for villages-amid-the-city can be proposed based on the health-oriented resilience evaluation (Therrien et al., 2015), and the construction of livable villages can be promoted through appropriate planning and management (Zeng et al., 2022).

In view of this, this study proposes a conceptual framework of health-oriented resilience in villages-amid-the-city from the perspective of health-environmental resilience of villages-amid-the-cityrs. The spatial characteristics of six typical villages-amid-the-city in Harbin City are identified based on field

research, and the health-oriented resilience evaluation model is used to analyse the problems and driving mechanisms, providing theoretical support for choosing the optimal villages-amid-the-city route to promote a livable environment. The objectives of this study are as follows:

(1) This paper will propose a health-oriented villages-amid-the-city resilience evaluation research framework that contains research steps for quantitatively and comprehensively exploring the derivation of resilience indicators for cold villages-amid-the-city.

(2) This paper analyses the interactive mechanism of health-oriented villages-amid-the-city resilience, and constructs an evaluation index system and evaluation method. On this basis, the health-oriented resilience composite index of 12 typical villages-amid-the-city is calculated to further explore the construction of different types of villages-amid-the-city.

(3) This study will propose health-oriented resilience planning strategies and policies for villages-amid-the-city with health dimensions in a hierarchical and categorised manner, which will serve as a reference for health-oriented resilience enhancement of villages-amid-the-city in cold regions.

2. Methods

Through a literature review of Scopus, we provide examples of health-oriented resilience (HR) definitions and focus on methods that assess vulnerability thresholds or give results that can be used for ranking.

2. 1. Definitions of Health-oriented Resilience

When we look at the health-oriented resilience literature in Scopus, there are over hits for the term ‘health-oriented resilience’ in >30 years of publication history. In the last years, there has been an increasing focus on resilience for different health of threats, such as extreme climate events or public health event. In order to distinguish between these concepts, some definitions are presented in Table 1.

Table 1. Several examples of definitions. Source: Review.

Dimensional	Characteristics	Brief description of concept	Author
Special sense dimens-ional	Resilience of public health systems	Physiological and psychological states that arise in complex social contexts combine to determine human adaptive capacity in the face of adversity, change or major risks.	Wulff, K. , 2015
		The resilience of a health system is its ability to absorb, adapt and transform in the face of shocks such as epidemics, natural disasters or major social conflicts, while at the same time requiring that the system maintains its original structures and	Martinez, L. , 2020
General sense dimens-ional	The multidim-ensional resilien-ce of gove-rnance, space,	Resilience is considered a dynamic process of adaptation.	Oke, A. E. , 2020
		It is related to processes and capabilities at the ind-ividual, community and system level	Cheshmehzan

	society and economy with public health as the core.	that result in good health and social outcomes	gi, A. , 2020.

2.2 Data

Harbin is a typical representative of the cold area cities in Northeast China, so it is selected as the research object in this paper.At present, Harbin, as a mega-city, contains a total of 77 villages-amid-the-city in the urban area, involving a land area of 184 square kilometres. However, the relatively poor location and low development potential of Harbin's villages-amid-the-city have made the process of renewal and transformation relatively slow, and problems such as lack of facilities and environmental remediation have become more prominent, posing a threat to the health of the residents of the cold villages-amid-the-city.

In order to ensure the representativeness of the study, six villages-amid-the-city distributed in four different administrative districts were selected for this study, which are as follows:Friendship Village\Deng Jia Village\Hada Village\Fu Shan Village\Hongwei Village and Dong Ming Village (Table 2).

The data used in the research model are mainly from urban geographic data, including Harbin Statistical Yearbook, Harbin Regional Statistical Bulletin, and Harbin Regional Environmental Condition Bulletin. It also contains some meteorological data, which comes from the China Air Quality Online Monitoring and Analysis Platform (https: //www. aqi research. cn/) website.

Table 2. Several examples of definitions. (source: self-drawn by the author)

Friendship Village	Deng Jia Village	Fu Shan Village
Hongwei Village	Hada Village	Dong Ming Village

2. 3 Theoretical Basis of Health-oriented Resilience Evaluation

Based on the literature review of existing empirical studies, this paper summarises four types of theoretical frameworks(Table 3) for resilience assessment that are currently frequently used in the field of urban resilience research as categorical dimensions for indicator screening.

Table 3. Four types of theoretical frameworks for resilience assessment. (source: self-drawn by the author)

Urban Resilience Assessment Models	Model Features
PSR Model	It allows for the integration of urban disaster resilience and response processes. The division of this process into stress, state and response corresponds exactly to the three resilience processes of disaster resistance, disaster absorption and system recovery(Das et al., 2020).
PEOPLES Model	Different quantitative evaluation indicators were used to evaluate the resilience of the system in terms of seven dimensions: population, environmental and ecological governmental organisation, physical infrastructure, lifestyle and community management, economic development, and social and cultural capital, Evaluate community-wide resilience in terms of three dimensions: recovery time, function and strength(Cimellaro et al., 2016)
CRAM Model	A five-dimensional model (21 items) has been developed through statistical and cluster analysis of relevant indicators of the economic, social and building infrastructure of the current community to obtain the gap between the recovery time of the current facilities and the expected design recovery time, which allows for the resilience evaluation of the current community(Mukhopadhyay et al., 2019).

DPSIR Model	The DPSIR model is a conceptual model of a widely used system of evaluation indicators in environmental systems, developed as a system of indicators for measuring the environment and sustainable development, which looks at human-environmental system interactions from a systems analysis perspective. The model divides the evaluation indicators that characterise a natural system into five modules: Driving forces, Pressure, State, Impact and Responses. (Mukhopadhyay et al., 2019)

3. Results and Discussion

3. 1. Index Screening

We summarized and reviewed the past empirical literature through a process that involved rigorous literature search, screening and extraction. In this paper, journal articles published between January 2015 and March 2023 were searched in three databases, including Medline, Web of Science and CNKI.

3. 2. Construction of Assessment Framework

The DPSIR model(Figure 1) is a conceptual model for the evaluation of indicator systems, which was developed in 1993 by the European Environment Agency through a modification of the PSR model. The basic meaning of the model is: system driving force (Driving) leads to pressure (Pressure), the pressure forces the system to change certain state (State), Changes in state have effects on the system, and these effects cause humans to react (Response) either directly or indirectly.

It is enduring resilience oriented towards physical health promotion, which focuses not only on the outcomes of resilience at work (i.e., absorptive, adaptive and transformative capacities), but also requires governance capacities at the community or village level to respond to emergencies. These operational dimensions are interrelated and together characterize resilience management in health-oriented resilience.

Figure 1. The DPSIR model. (source: self-drawn by the author)

"Response (R)" is organized into five dimensions. It is extended and optimized based on the PSR and DSR models, and can be analyzed from the dimension of the whole system with the intrinsic connection between activity, economic, social and environmental factors. In this study, the DPSIR model was introduced to assess the resilience of community habitat. The model uses five levels and 12 indicators (Table 4). In the model constructed in this paper, drivers (D) exert pressure (P) on the environment, leading to changes in the state of the environment (S). This further affects human activities and health (I). Villages-amid-the-city 's environments can respond to the feedback of drivers and pressure (R) through measures such as renewal, and Figure 1 represents the DPSIR model of the CR assessment system. The DPSIR model represents:"Driving forces (D)", "Pressure (P)", "State (S)", "Impact (I)", tates, and impacts (R) to promote healthy villages-amid-the-city development.

Based on the content of previous studies and empirical cases, this study screened to identify key indicators adapted to urban villages in each level of criteria.

Drivers (D) are the elements that drive dynamic change in the environmental regeneration and improvement of villages-amid-the-city. Selected indicators include population vulnerability, density of population, density of building, income level. They refect built environmrnt, population. These drivers influence stressors, state factors, and response factors, and affect the physical activity and health-related lifestyle habits of the population.

Pressure (P) refers to factors that have an inhibiting effect on maintaining or restoring the health status of residents in villages-amid-the-city. They include indicators that reflect environmental pressure and pollution such as CO2 emissions, PM2. They reflect the environmental pressure and pollution of pollution

faced by the urban village. They affect state and response factors and influence residents' outdoor activities.

State (S) represents the current condition of the environment that is subject to drivers and pressures that can be used for physical activity by urban village residents. Indicators such as the density of roads, bus stops and subways, coverage of convenient commercial services, and land use structure reflect the state of the environment and typical problems in urban villages. These factors are influenced by drivers and pressures, and also influence other factors and responses. For example, road density may lead to congestion and traffic problems. This would be detrimental to residents' outward mobility..

Impact (I) refers to the results of various types of environmental factors in villages-amid-the-city that act on human health activities. For example, indicators such as residents' fitness awareness and occupational health risks reflect the status of physical activity resources in the village. These indicators directly affect residents' health activities. This is because more connected roads and more sports facilities will provide more exercise opportunities for residents in villages-amid-the-city.

Response (R) indicators are behavioral feedback given by urban village residents to the natural, built and social environments. Indicators such as green space density, health insurance coverage and quality of volunteer service refect residents'responses and preferences related to health activities. And the following indicators (Table 4) were finally obtained from the literature review.

Table 4. The evaluation index of health-oriented resilience. (source: self-drawn by the author)

Criterion layer	Index layer	Description of indicators
Drivers (D)	D1 Population vulnerability	Proportion of children under 7 years of age and elderly people over 65years of age
	D2 Density of population	The statisticians from the Haerbin Statistical Yearbook
	D3 Density of building	Sum of base area of buildings in villages-amid-the-city/construction land area of villages-amid-the-city
Pressure (P)	P1 Number of refuse collection points	Field research statistics
	P2 AQI	The statisticians from the China Air Quality Online Monitoring
State (S)	S1 Density of food places	Distribution density of catering facilities in villages-amid-the-city
	S2 Density of convenient commercial services	Distribution density of commercial facilities in villages-amid-the-city
Impact (I)	I1 Residents fitness awareness	Resident self-assessment questionnaire
	I2 Per capita sports area	Field research statistics
Response (R)	R1 Green density	Green space area/total villages-amid-the-city site area
	R2 Health insurance coverage	Resident self-assessment questionnaire

3. 3. Data analysis model

In this paper, the AHP-BP method is used to calculate each health-oriented elasticity index factor. This method effectively avoids the shortcomings of the hierarchical analysis method, which is highly subjective. At the same time, the neural network works by simulating the human brain, which can learn autonomously like human beings and has functions such as nonlinear transformation, which can effectively exclude randomness and subjectivity, and is an innovation to the traditional evaluation method. The AHP-BP model is as follows (Figure 2).

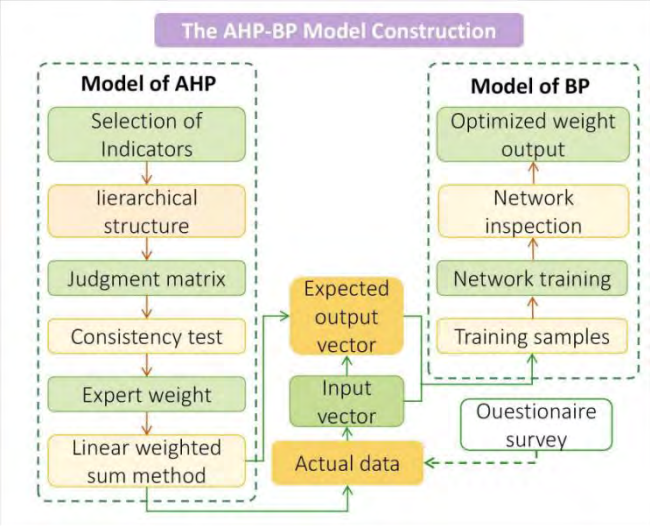


Figure2. The AHP-BP model. (source: self-drawn by the author)

3. 4. The Calculation of Health-oriented Resilience

EpiData 3. 0 software was used to enter the data and establish the database. SPSS 21. 0 software was used to analyse the data, describing the health-oriented resilience level of each dimension of health-oriented resilience in each villages-amid-the-city with mean and standard deviation, and Matlab software to construct the BP neural network model and calculate the evaluation value.

Firstly, the villages-amid-the-city health evaluation index system is analysed at each level based on analytic horizontal process. Then repeatedly train the network to make it have associative memory and prediction ability. The topology of BP neural network is shown in Figure 3[i], the basic idea is to adjust the weights and thresholds of the network to minimise the sum of squares of the errors of the network's output layer, so that the output value is as close as possible to the target value, the specific process is as follows.

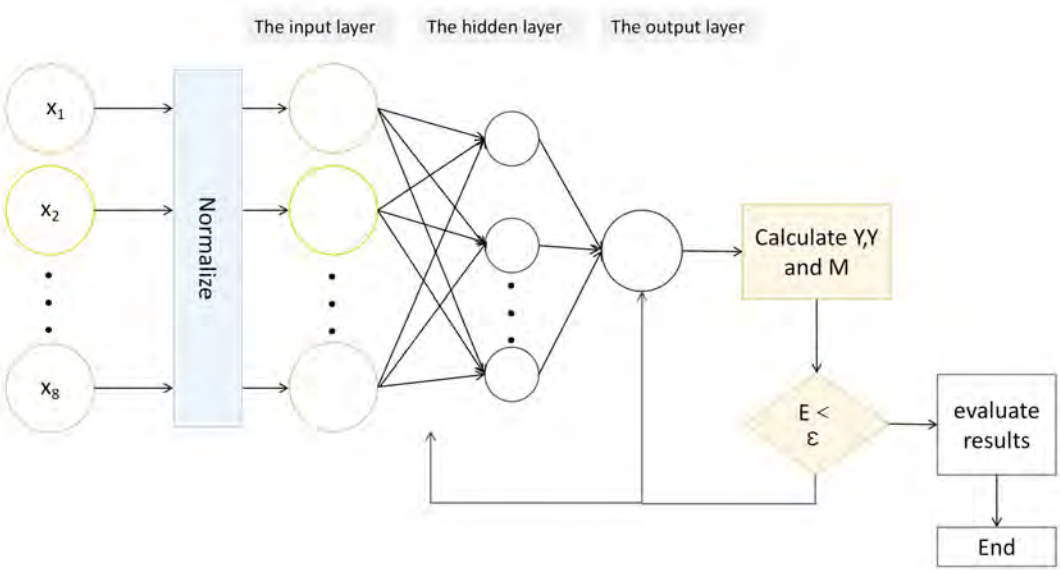


Figure3. BP neural network topology diagram.

(i) Initialise the weights and thresholds of the network. Use ω_{ij} to denote the connection weights from the input layer to the implicit layer, ω_{jk} to denote the weights from the implicit layer to the output layer, θ_i to denote the implicit layer threshold, and θ_k to denote the output layer threshold.

(ii) Input learning samples, calculate the output value of each layer. X_i represents learning samples, i=1, 2, ... , n, n is the number of input layers. z_j represents the output value of each node of the implicit layer, f is the implicit layer excitation function, and the function chosen in this paper is f(x)=1/[1+e^(-x)], which is calculated as follows:

$$z_j = \int\left(\sum_{i=1}^{n}\omega_{ij}x_i - \theta_j\right), j = 1,2,\cdots,l \text{ (} l \text{ is the number of implicit layer nodes)}$$

Y_k denotes the output layer node output value, which is calculated as follows:

$$Y_k = \sum_{j=1}^{l}\omega_{jk}z_j - \theta_k, k = 1,2\cdots,l \text{ (} l \text{ is the number of output layer nodes)}$$

In this case, the formula for calculating the number of nodes in the implicit layer is $l < \sqrt{(m+n)} + a$ (m is the number of output nodes, n is the number of input nodes, and a is a constant between 0 and 10). In this study, 11 indicators were used as input layers. The comprehensive evaluation of health-oriented resilience of villages-amid-the-city is used as the output layer, therefore, the input node is 11, the output node is 1, and the range of values of the neurons in the implicit layer is calculated according to the above implicit layer calculation formula as [6-16], after continuous attempts, it was determined that the number of neurons in the hidden layer was taken as 10 this time by the trial-and-error method.

(iii) Thresholds are updated by calculating relative errors and correction weights.

According to the learning continuously calculate the error MSE, and compare with the expected error accuracy, if the actual calculated error is within the acceptable range, then the learning is finished, otherwise return to step (ii) to adjust the neuron and threshold according to the rules for further learning,

until it meets the specified error, accuracy, or number of training times. Simulate the neural network model by training samples, and input 6 sample villages-amid-the-city data into the simulated network model to verify the simulation (Table 5).

Table 5. The health-oriented resilience level of 6 sample villages-amid-the-city.

Health-oriented Resilience Level	Village-amid-the-city	Score	Description of resilience Level
Very Low	Deng Jia village	7. 45	flat terrain, good ecological environ-ment, rare facilities, complete culture, poor economy,dilapidated buildings
Low	Dong Ming village	7. 89	Certain ecological resource,and transformation, generic building landscape, faint buildings
Moderate	Hong Wei village	8. 37	incomplete environment and building transformation, low vitality, simple industry structure,incomplete facilities
High	Fu Shan village	8. 72	adequate infrastructure and environmental improvement, lost custom culture, poor agricultural economy,strong construction,
Serious	Ha Da village	9. 13	complete facilities and environmental improvement, damaged buildings, diversity product and affluent life,diverse culture
	Friendship village	9. 26	

3. 5 Discussion

The villages-amid-the-city in Harbin have relatively large differences in their health-oriented resilience due to their different demographics, development levels, and built environment conditions. By studying the resilience characteristics of six typical villages-amid-the-city in Harbin, this paper finds that the following characteristics exist in the health-oriented resilience of three types of typical villages-amid-the-city:

Ha Da village and Friendship village have a low density of buildings, a high level of health awareness among the residents, and the villages reflect a correspondingly high level of health. There are relatively few refuse sites and low levels of greenery in Deng Jia village and Dong Ming village, with a high level of coverage of food and drink establishments. Correspondingly, the two villages have relatively low levels of health-oriented resilience on the ground. The level of health-oriented resilience in the Hong Wei village is moderate, with no significantly relevant indicators of health-oriented resilience.

Due to social differentiation, villages-amid-the-city are vastly different from traditional settlements in terms of composition, employment structure, and social relationships, and the level of health resilience in villages-amid-the-city has become a key aspect that needs to be improved in order to cope with public health risks. UN-Habitat reminds that although population density does not directly affect the spread of epidemics, this study finds that overcrowded housing, insufficient living services, and lack of open space in villages-amid-the-city not only reduce health resilience, but also reflect serious health equity conflicts, which is a key target for the renewal of villages-amid-the-city at present.

4. Conclusion

Increased levels of health resilience in urban villages are key to advancing sustainable urban spatial environments in all countries, as well as an effective guarantee of global health equity. The impact of urban village living environments on residents' health has increasingly become a common focus of urban planning, geography and preventive medicine research. Only by clarifying the more core health resilience indicators in urban village living environments can we more accurately provide effective and sustainable coping strategies for the renewal of healthy urban villages. In this paper, we investigated the health resilience characteristics of different urban villages under special climatic backgrounds using six typical urban villages in China's severe cold regions as test sites, and revealed the characteristics of the built environments of urban villages with different levels of health resilience. This can provide a reference for future urban villages to implement regeneration actions with health as the goal.

However, the number of subjects in this study is limited, and it is only of high reference significance for urban village regeneration under severe cold climate. The applicability of this study to urban villages in other climates needs to be further explored.In addition, the study showed that the level of health resilience in urban villages was not significantly related to the number of waste stations in the environment, which is different from the findings of previous studies(Wilson et al., 2018) and requires further empirical evidence.

5. Acknowledgements

This research was funded by National Natural Science Foundation of China (grant no. 52208053, 52278056), the 66th China Postdoctoral Science Foundation (Project No. 2019M661284).

6. References

Acuti, D. , Bellucci, M. and Manetti, G. (2020) Company disclosures concerning the resilience of cities from the Sustainable Development Goals (SDGs) perspective. Cities, 99.

Alnusairat, S. , Abu Qadourah, J. and Khattab, R. (2023) Assessing the future city post COVID-19: linking the SDGs, health, resilience, and psychological impact. Sustainability, 15(1), p. 811.

Castleden, M. , McKee, M. , Murray, V. and Leonardi, G. (2011) Resilience thinking in health protection. Journal of public health, 33(3), pp. 369-377.

Cimellaro, G. P. , Renschler, C. , Reinhorn, A. M. and Arendt, L. (2016) PEOPLES: a framework for evaluating resilience. Journal of Structural Engineering, 142(10), p. 04016063.

Cheshmehzangi, A. (2020) Reflection on early lessons for urban resilience and public health enhancement during the COVID-19. Health, 12(10), p. 1390.

Champlin, C. , Sirenko, M. and Comes, T. (2023) Measuring social resilience in cities: An exploratory spatio-temporal analysis of activity routines in urban spaces during Covid-19. Cities, 135, p. 104220.

Das, S. , Pradhan, B. , Shit, P. K. and Alamri, A. M. (2020) Assessment of wetland ecosystem health using the pressure–state–response (PSR) model: A case study of mursidabad district of West Bengal (India). Sustainability, 12(15), p. 5932.

Jamroni, M. , Sukesi, K. , Yuliati, Y. and Purnomo, M. (2021) Village community resilience in handling the COVID-19 pandemic. Multicultural education, 7(6), pp. 155-170.

Liu, R. and Jia, Y. (2021) Resilience and circularity: revisiting the role of villages-amid-the-city in rural-urban migration in Beijing, China. Land, 10(12), p. 1284.

Li, Q. , Yu, C. , Chen, N. , Guo, P. and Liu, Y. (2023) Study on the Resilience Enhancement and Renewal Strategy of Traditional Village Public Space in the Post-Epidemic Era: A Study Considering Cuanxia Village in China as an Illustration. In New Energy and Future Energy Systems (pp. 9-26). IOS Press.

Mukhopadhyay, A. , Chatterjee, S. , Bagchi, K. K. , Kirs, P. J. and Shukla, G. K. (2019) Cyber risk assessment and mitigation (CRAM) framework using logit and probit models for cyber insurance. Information Systems Frontiers, 21, pp. 997-1018.

Martinez, L. , Leon, E. , Al Youssef, S. and Katrina Karaan, A. (2020) Strengthening the health lens in urban resilience frameworks. Cities & health, 4(2), pp. 229-236.

Mahmood, S. S. , Hasan, M. Z. , Hasan, A. R. , Rabbani, M. G. , Begum, F. , Yousuf, T. B. , Hanifi, S. M. A. , Reidpath, D. D. and Rasheed, S. (2022) Health system impact of COVID-19 on urban slum population of Bangladesh: a mixed-method rapid assessment study. BMJ open, 12(2), p. e057402.

Narasimhan, M. , Karna, P. , Ojo, O. , Perera, D. and Gilmore, K. (2024) Self-care interventions and universal health coverage. Bulletin of the World Health Organization, 102(2), p. 140.

Nurmala, V. F. , Panjaitan, B. S. P. and Subiyanto, A. (2023) May. The importance of village resilience assessment in village based programs to support regional resilience. In IOP Conference Series: Earth and Environmental Science (Vol. 1173, No. 1, p. 012059). IOP Publishing.

Panter-Brick, C. (2014) Health, risk, and resilience: Interdisciplinary concepts and applications. Annual Review of Anthropology, 43(1), pp. 431-448.

Tan, X. , Song, Y. and Liu, T. (2021) Resilience, vulnerability and adaptability: A qualitative study of COVID-19 lockdown experiences in two Henan villages, China. PLoS One, 16(2), p. e0247383.

Zeng, X. , Yu, Y. , Yang, S. , Lv, Y. and Sarker, M. N. I. (2022) Urban resilience for urban sustainability: Concepts, dimensions, and perspectives. Sustainability, 14(5), p. 2481.

Oke, A. E. , Aghimien, D. O. , Akinradewo, O. I. and Aigbavboa, C. O. (2020) Improving resilience of cities through smart city drivers. Construction economics and building, 20(2), pp. 45-64.

Therrien, M. C. , Tanguay, G. A. and Beauregard-Guérin, I. (2015) Fundamental determinants of urban resilience: A search for indicators applied to public health crisis. Resilience, 3(1), pp. 18-39.

Wang, C. , Dong, X. , Zhang, Y. and Luo, Y. (2021) Community resilience governance on public health crisis in China. International Journal of Environmental Research and Public Health, 18(4), p. 2123.

Wilson, G.A., Hu, Z. and Rahman, S. (2018) Community resilience in rural China: the case of Hu Village, Sichuan Province. Journal of rural studies, 60, pp.130-140.

Research Paper

Exploration of the Active Aging Renewal Model in Double-Aging Communities

from the Perspective of Sense of Place

Danyang JING, Beijing Forestry University, China

Abstract

Chinese communities are currently facing the dual challenges of aging infrastructure and an aging population. Many renewal projects for "double-aging communities" often prioritize modern and intelligent design methods, as well as standardized elderly facilities and services, while neglecting the emotional needs and creative participation of older adults. This has deepened the stereotype of elderly individuals as a "passive and disadvantaged group," rendering them mere "observers" and "burdens" within the community. As a result, the sense of place among older adults has weakened, leading to social isolation and a decline in community cohesion.

This study focuses on the "Neighbouring Courtyard" renovation project in Silicon Valley Pioneer Community, located in Xisanqi Street, Haidian District, Beijing, completed in 2023. Initially built in 1996, approximately 20% of the community's population is now over 60, significantly exceeding the United Nations' 10% threshold for entering an aging society. Prior to the renovation, the community faced issues such as outdated environmental facilities, weak community culture, and low resident participation. The project deviates from traditional community renewal methods, embracing a positive aging approach that effectively addresses the emotional and spiritual needs of elderly residents, thereby enhancing community cohesion.

This research aims to analyse design strategies and methods corresponding to the sense of place needs of older adults within community renewal efforts. It seeks to explore models of inclusive development and the preservation of community memory through active aging.

Employing qualitative research methods, this study collected data on older adults' perceptions and suggestions regarding community renewal through site observations, surveys, and in-depth interviews. A total of five field explorations were conducted, yielding 132 valid survey responses and in-depth interviews with 20 elderly residents. The research gathered insights into the emotional identity development, design preferences, social participation, and interactions of older adults within the community from the perspective of sense of place, followed by detailed analysis.

The findings reveal that, due to changes in life circumstances such as retirement and children's independence, older residents have more time to engage in community life and express stronger emotional attachments to their community compared to younger age groups. They possess valuable social experiences and hold a deeper understanding of community development, desiring to actively participate in various stages of community building and activities. The project fully respects the opinions and needs of older adults by employing a co-creation model, fostering a multi-layered courtyard structure that integrates essential living, neighbourly interaction, and health services. Interactive installations and cultural elements that reflect the memories of the older generation, such as a smile collection station and phenology exhibition area, were

incorporated to stimulate their enthusiasm and creativity.

These innovative designs enhance older adults' sense of place and belonging, effectively deepening emotional connections within the community. This research illustrates a model of positive aging renewal for double-aging communities from the perspective of sense of place. It recommends challenging the bias that views aging and older adults as wholly negative factors, advocating for active aging strategies in the renovation of aging communities to better meet the sense of place needs of older populations and encourage their active role in inclusive community development.

Keywords

Double-aging Communities, Positive Aging, Community Renewal, Sense of Place Theory

1. Introduction

Population aging is a global phenomenon that is increasingly affecting all regions of the world(Harper, 2014). It is projected that by 2050, 16% of the global population will be over 65 years old, with 80% of elderly individuals living in low- and middle-income countries(Worid Population Prospects 2024). China currently has the largest elderly population in the world and is undergoing rapid aging (National Bureau of Statistics). As of 2023, over 21% of China's population is aged 60 and above, and over 15% is aged 65 and above. It is expected that by around 2050, the elderly population in China will peak at 487 million, accounting for 34.9% of the total population (National Bureau of Statistics). This aging rate significantly exceeds the global average, posing substantial challenges associated with high levels of aging(Chen *et al.*, 2022).

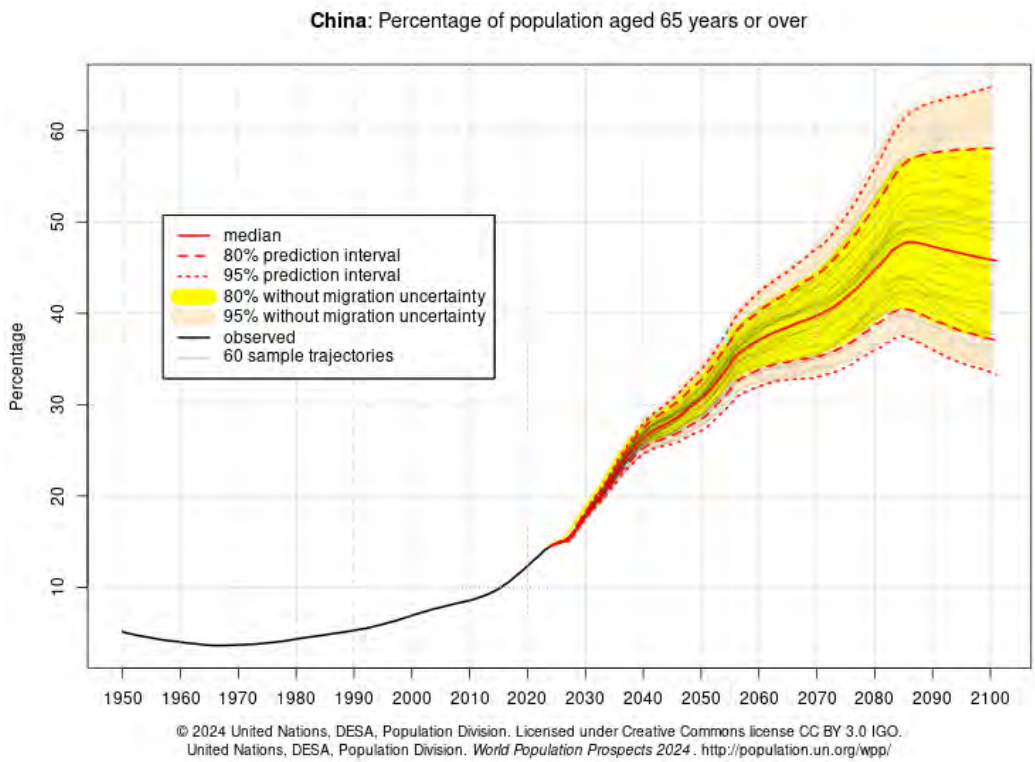


Figure 1. China:Percentage of population aged 65 years or over. Source: Worid Population Prospects 2024.

As the elderly population continues to grow, older adults often face challenges such as health decline and difficulties in adapting to technology(Partridge, Deelen and Slagboom, 2018). With the acceleration of social change and rapid urban development, the living conditions of older individuals have become increasingly precarious. Social structures and policies frequently fail to fully recognize the potential of the elderly, who are often defined as consumers of resources rather than contributors (Georgios, 2023). This perspective marginalizes their social roles, pushing them further toward social exclusion (Burholt et al., 2020). Such negative views not only limit opportunities for elderly participation in society but also exacerbate feelings of social isolation and reduce their quality of life, undermining social equity and cohesion (Niedzwiedz *et al.*, 2016). Therefore, addressing how to improve the age-friendly social system, create livable environments for older adults, dismantle stereotypes and age discrimination, and encourage active social participation among the elderly is an urgent issue that needs to be considered (Swift *et al.*, 2017; Levy, Lytle and Macdonald, 2022).

Influenced by shifts in social identity and activity capacity, most older adults conduct their primary daily activities within their communities. As the fundamental unit of social governance in China, communities serve as essential spaces for the well-being of the elderly. Therefore, the transformation of communities to be more age-friendly is urgently needed(Tang, 2015).

Currently, most urban communities in China were established in the 1980s and 1990s, and they generally suffer from insufficient and aging public spaces and infrastructure, as well as a lack of thoughtful landscape design(Wei, 2012). Coupled with an aging homeowner demographic and a significant increase in the elderly population, many old communities overlap with aging communities, resulting in a “double-aging” characteristic marked by both population aging and infrastructure decline (Chen *et al.*, 2022). Within these double-aging communities, the needs of older adults for public leisure spaces and emotional connections to their communities are often unmet, presenting unique challenges and opportunities for community development, governance, and urban renewal (Yang *et al.*, 2023).

2. Literature Review

2.1. International Positive Aging Initiatives

In recent years, the concept of age-friendly cities has gained increasing attention (Torku, Chan and Yung, 2021). Various international organizations have proposed numerous initiatives and practices aimed at addressing the challenges of global population aging. In 2015, the United Nations adopted the 2030 Sustainable Development Goals (SDGs), emphasizing the needs of older adults in areas such as social security, health services, and equal opportunities. Since 2015, the Organisation for Economic Co-operation and Development (OECD) has advocated for policy innovations in aging societies, promoting employment support for older adults, lifelong learning, and reforms to pension systems. In 2011, the European Union launched the European Innovative Partnership for Active and Healthy Ageing (EIP-AHA) initiative. The goal of this initiative is to promote the community application of smart health technologies for the elderly, while promoting interaction between different age groups and strengthening community support systems. The World Health Organization (WHO) initiated the Age-Friendly Cities and Communities program in 2007, focusing on creating age-friendly environments across eight dimensions: infrastructure, transportation, housing, and social participation, among others. The International Federation on Aging (IFA) has long been dedicated to global elderly welfare and health initiatives, addressing social isolation through multi-stakeholder collaboration and advocating for global pension policy reforms. The shared goal of these organizations is to create a safer, healthier, and more inclusive environment for positive aging through

technological innovation, policy reform, and social inclusion, ensuring that older adults can play active roles in society(*Global age-friendly cities: a guide*, n.d.).

As the fundamental unit of Chinese society and the primary activity space for older adults, communities have become important pilot sites for positive aging practices in China(Wang, 2024). To address the double-aging challenges in communities, China has implemented a series of policies and practical measures. The "14th Five-Year Plan for National Aging Development and Pension Service System" (2021) proposes the age-friendly renovation of old communities, including the installation of barrier-free facilities and elevators to enhance the convenience of life for older adults (Yang *et al.*, 2023) (National Development and Reform Commission, 2021). The "Guidelines for the Construction of Age-Friendly Communities (Trial)" (2021) outlines specific construction requirements related to spatial layout and activity spaces (Ministry of Housing and Urban-Rural Development, 2021). Simultaneously, the government aims to improve community service efficiency through grassroots governance and smart platforms, encouraging older adults to participate in community development, supporting senior service stations, and integrating medical and elderly care services to ensure health management and rehabilitation care (Ministry of Civil Affairs, 2022).

2.2. Positive Aging Practices

Traditional age-friendly models primarily focus on providing necessary living support and services for older adults, such as housing modifications and improved transportation accessibility, ensuring that they can live safely and comfortably in familiar environments(Yang and Wang, 2024). Currently, age-friendly renovations in China mainly emphasize improving the living conditions and meeting the physiological needs of older adults, with a focus on enhancing residents' quality of life and the overall development of cities(Li, 2024). These approaches often employ standardized and uniform design techniques for elderly care services and facilities, concentrating on material improvements in the external environment and physical care for older adults(Jiao, 2024). However, there is often a lack of substantial communication regarding residents' grassroots needs, especially for older adults, who are often viewed as a "vulnerable group needing care." Their emotional needs and active participation are frequently overlooked, leading them to become passive observers in community development or even viewed as "negative factors." This results in weakened interpersonal relationships and a lack of emotional connection to the community, hindering the establishment of a positive cultural ecosystem within the community(Georgios, 2023; Yang *et al.*, 2023).

As we all know, with the development of society, the problem of population aging is becoming more and more serious. As a result, the existing community pension model has been unable to meet the diverse needs of the elderly. In this context, the concept of "active aging" has received more and more attention worldwide. The core objective of this concept is to create a healthy and active living environment for older persons, which covers physical health, social participation and cultural activities(McNeil-Gauthier, Milot and Levasseur, 2024).

The strategy of "active aging" progressive significance is that it not only focus on the elderly's health, more emphasis on the importance of social participation for old age. As for the specific measures to promote active aging, many scholars have conducted research. Fitzgerald and Caro (Fitzgerald and Caro, 2014), believe that the successful implementation of active aging policies must fully consider the characteristics of the local level and adapt to local conditions to meet the different needs of the elderly. (Aldrich and Meyer, 2015) also mentioned that social capital and support networks in communities are critical to driving active aging. In addition, a large number of studies have shown that increased social activities and community involvement have a significant impact on improving mental health and life satisfaction in older adults (Bertelli-Costa and Neri, 2021). (Smith *et al.*, 2023) note that the development of inclusive

community policies and services not only promotes community harmony, but also enhances the sense of belonging and well-being of older adults. Care should be taken to listen to the voices of older people during the community renewal process to ensure that their needs and expectations are reflected (Chen *et al.*, 2022).

So to speak, in addition to a healthy body, the elderly of cultural memory, social interactions, and participate in community construction demand gradually increased. Community renewal model based on active aging is particularly important in this context. In order to achieve this goal, it is necessary to understand the intrinsic link between the spiritual needs of older residents and their living environment (Ma *et al.*, 2021).

This study introduced the theory of "sense of place", to expand community research Angle of view from the physical space to social interaction. Through multi-dimensional analysis, the interaction and connection among individual emotional attachment, community development and social cohesion are discussed. It provides a comprehensive perspective on the design of "dual aging" communities and can further help develop effective aging strategies.The framework also provides valuable insights for policy-makin(Yang *et al.*, 2023).

3. Research Area and Methodology

3.1. Research Area

The study focused on the "Silicon Valley Pioneer Community". The community was established in 2023 and is located in Jiancai Dongli, Xisanqi Street, Haidian District, Beijing. The community was built in 1996 and has a high proportion of elderly residents, with those aged 65 and above making up 17% of the total population—significantly exceeding the 7% threshold, thus qualifying as a typical double-aging community. In 2022-2023, the "Neighbouring Courtyard" community space renewal project was initiated, covering approximately 2,000 square meters and aimed at creating age-friendly spaces. The project is divided into three parts: A:Compassionate Unity Courtyard :Carry out community compassion work; B:Integrated Activity Square : Accommodate diverse community activities; C:All-Age Shared Court: Promote all-age interaction. This project serves as an excellent case study for research on positive aging community development in China.

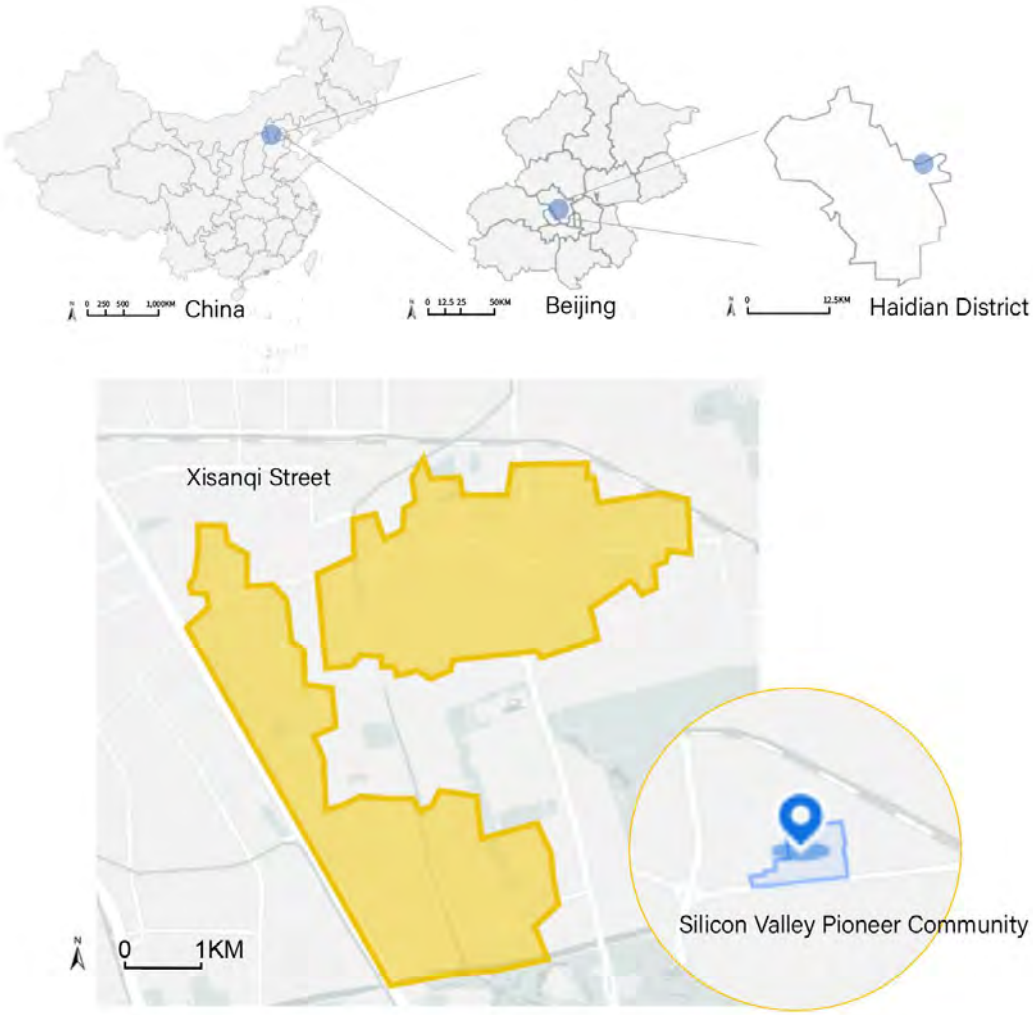


Figure 2. Research Project Location and Scope. Source: Author's Own Drawing.

3.2 Research Methodology

This study employs qualitative research methods, utilizing on-site observations, questionnaires, and in-depth interviews to collect data on elderly residents' perceptions and suggestions regarding community renewal. From the perspective of older adults' sense of place, the study analyses the positive aging design techniques and actual effects in community renewal.

The interview guide includes three main aspects:(1)Facility Use and Dependence: Exploring the extent to which elderly residents use and depend on community facilities and services, understanding the impact of post-renovation amenities on daily life convenience and satisfaction.(2)Cultural Integration and Emotional Connection: Investigating elderly residents' sense of belonging and emotional ties within the community, including whether the community meets their emotional belonging needs and how the community environment and neighbour relationships influence emotional attachment.(3)Impact of Community Activities: Examining how community activities affect elderly individuals' self-worth and their participation frequency and interest in social and cultural activities, exploring the relationship between their initiative and community interaction.

From October 2023 to September 2024, five on-site surveys were conducted in the Xisanqi community, targeting elderly individuals aged 50 and above who have lived in the community long-term and possess

the ability to understand and communicate effectively. This ensures a comprehensive reflection of their feedback and expectations regarding community renovation and living conditions. A total of 132 valid questionnaires were collected, and 20 elderly residents who have lived in the community for over five years were selected for in-depth interviews. Data on the development and transformation of emotional identity in community life, design styles and functions of living environments, social participation, and interaction experiences and perspectives were collected and coded using NVivo.

	Questionnaire item	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Place Dependence	1. I need the facilities and services here	5	4	3	2	1
	2. Living here is very safe and convenient	5	4	3	2	1
	3. The living environment provided here makes me feel secure and comfortable	5	4	3	2	1
Place Identity	1. I appreciate the environment and service facilities here	5	4	3	2	1
	2. This place embodies the spirit and culture that I relate to	5	4	3	2	1
	3. I feel like I'm part of a community here	5	4	3	2	1
Place Attachment	1. I feel a deep emotional connection to the community here	5	4	3	2	1
	2. I love staying here, the people and the atmosphere make me feel very close	5	4	3	2	1
	3. I can feel my worth here. This place means a lot to me	5	4	3	2	1

Figure 3. Place Attachment Scale. Source: Author's Own Drawing.

4. Research Results and Discussion

4.1 Meeting Basic Needs of the Elderly is the Foundation for Establishing Place Dependence

The Silicon Valley Pioneer Community originally included convenient facilities such as a supermarket, barbershop, dry cleaner, and community health service station. However, the overall commercial atmosphere is weak, and basic infrastructure like roads is deteriorating. The public spaces are inefficient, lacking outdoor recreational facilities. Over 2,000 square meters of building space have long been idle, negatively impacting the living environment and failing to meet residents' diverse cultural and daily life needs.

Survey results indicate that Zone C scored the highest in terms of facility completeness and comfort, particularly excelling in the indicators of "necessary facilities," "safety and convenience," and "environmental comfort." In contrast, Zone A suffers from insufficient facilities, leading to lower usage frequency and shorter stay times for seniors. As one interviewee noted, *"A doesn't have a lot of facilities, so I don't spend a lot of time here." (Interviewee 15, 62-year-old, Male)*. Improvements in lighting conditions in Zone B have enhanced nighttime safety, encouraging more seniors to participate in evening outdoor activities. One participant remarked, "There is a row of lights in B, and we all like to do activities here at night because it is not easy to fall when we can see the road clearly." (Interviewee 5, 55-year-old, Female).

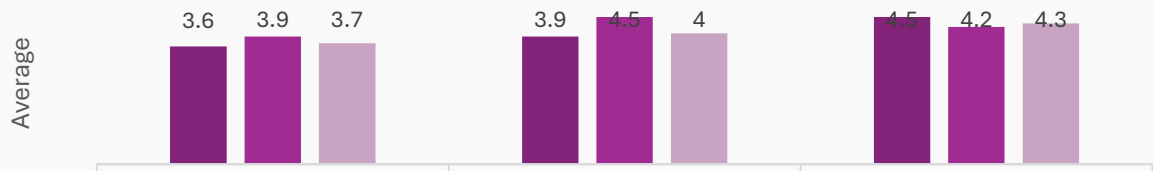
Adequate living service facilities and activity spaces significantly contribute to seniors' sense of place attachment. Compared to common facilities, designs that consider the real, daily needs of elderly residents

receive more favorable reviews. For instance, many elderly residents face challenges in meal preparation, and over half of the interviewees indicated that a "central kitchen" providing meals effectively resolves their difficulties, becoming an indispensable part of their community life. One 68-year-old retired empty-nester stated:

> *"My kids are away, and I can't cook at my age. I eat in the central kitchen in C almost every day. I go to other parts of the neighborhood when I need to, but not often."*
>
> *(Interviewee 12, 68-year-old, Female)*

In summary, comprehensive facilities not only enhance seniors' convenience and safety but also increase their reliance on the community. Meeting the specific needs of the elderly through targeted facilities is a fundamental means and basis for promoting active aging.

Figure 4. Project Real Scene. Source: Author's Own Photography.



	A	B	C
Q1	3.6	3.9	4.5
Q2	3.9	4.5	4.2
Q3	3.7	4	4.3

Figure 5. Place dependent average score. Source: Author's Own Drawing.

4.2 The Impact of Cultural Elements on Place Identity among the Elderly

At the level of place identity, improvements in the overall environment significantly enhance seniors' sense of belonging and fondness for the community. Survey results indicate that most seniors appreciate the enhancements in the community environment and believe that the increase in service facilities has improved their convenience of living. Many seniors express that after the environmental upgrades, they not only enjoy visiting the community themselves but also frequently invite old friends to join them. One interviewee remarked, *"After the renewal of the community, the environment became much better. I not only came here by myself but also often asked my old friends to come here to play." (Interviewee 9, 57-year-old, Female)*. This demonstrates that environmental improvements play a positive role in fostering social interaction and community participation among seniors.

Moreover, among the various elements of community space, cultural carriers hold significant importance (Borer, 2006), and seniors show a strong interest in the cultural aspects of their community. They believe that these cultural elements reflect a spirit relevant to them and enhance the cultural atmosphere. For instance, seasonal poetry engraved on the ground and concentric knots have become important visual symbols for seniors to express their community identity. As one resident described, *"The design of seasonal*

poems engraved on the floor tiles enhances the cultural atmosphere of B. But I prefer the concentric knot on the C ground because it reminds me of activities with everyone." (Interviewee 19, 66-year-old, Male).

Incorporating community culture is crucial for enhancing seniors' sense of identity and belonging. These cultural designs not only elevate the aesthetic value of the community but also strengthen seniors' sense of place identity, further promoting their active aging. Additionally, 83% of respondents indicated that the cultural elements contributed to their sense of community integration, with one stating, *"My picture on the wall here makes me feel like I'm part of this community." (Interviewee 15, 68-year-old, Male)*. Cultural designs related to seniors' life experiences can more effectively evoke their community memories and foster a sense of belonging compared to generic cultural designs.

Figure 6. Cultural Element Paving. Source: Author's Own Photography.

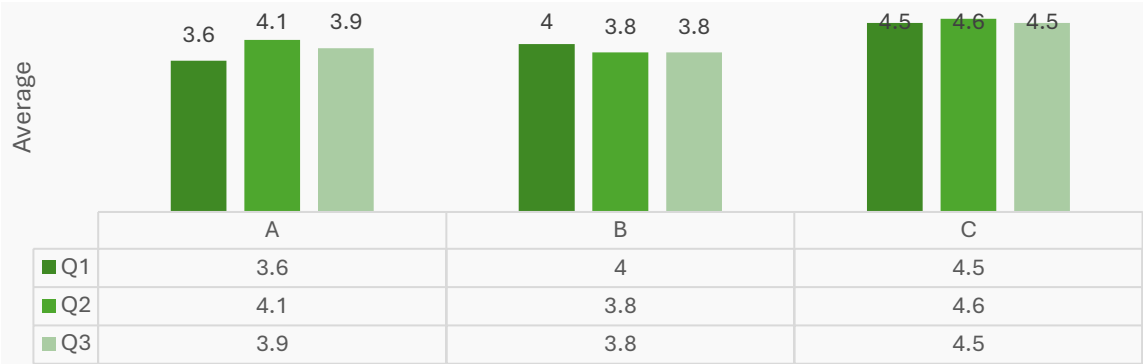


Figure 7. Place Identity average score. Source: Author's Own Drawing.

4.3 The Role of Community Renewal in Fostering Place Attachment among the Elderly

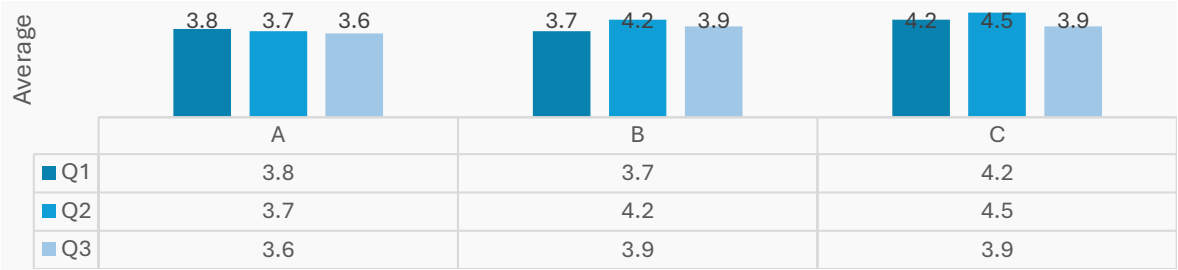
Place attachment represents a higher level of place sense and is often the most challenging to cultivate. Currently, many communities overlook the emotional needs and creative participation of the elderly, often viewing them as "passive and outdated vulnerable groups," leading them to become "bystanders" and "burdens" within the community(Boudiny, 2013).

During the research, it became evident that being valued and having opportunities to participate in community spaces significantly enhance elderly residents' place attachment. If the community can facilitate and guide active participation, or even organize collective actions among residents, it can help them develop a deeper sense of place attachment (Rollero and De Piccoli, 2010).

In the Jian Cai Dong li community, the primary mode of community renewal is led by Party building, gradually developing resident-led initiatives. This grassroots social development explores a new governance model of "collective discussion," which, compared to top-down approaches, better meets residents' diverse usage needs and improves the efficiency of renovations, based on the behavioural characteristics and usage habits of the residents(Yang *et al.*, 2023). Many daily sports activities and

volunteer organizations in the community are primarily led by elderly individuals, who express a strong sense of responsibility toward their community and a desire to contribute further to its development. As one participant noted: *"Our opinions were solicited in the early stages of the design of the project, and I also joined the community volunteer organization. I feel that I have contributed to the construction of the community, and I hope that there will be more activities for us elderly people to participate in in the future." (interviewee 8, 59-year-old, Male)*. This indicates that being valued and having participation opportunities in community spaces can enhance the elderly's place attachment. If the community promotes and guides active involvement, it can help the elderly develop a deeper connection to their place.

Figure 8. Photos of Activities for the Elderly. Source: Government News.



	A	B	C
Q1	3.8	3.7	4.2
Q2	3.7	4.2	4.5
Q3	3.6	3.9	3.9

Figure 9. Place Attachment average score. Source: Author's Own Drawing.

In summary, based on sense of place theory, community renewal strategies that incorporate functional, cultural, and social participation elements can effectively promote active aging. Empowering the elderly and leveraging their advantages in time, energy, and social experience contribute to creating more inclusive and thriving communities.

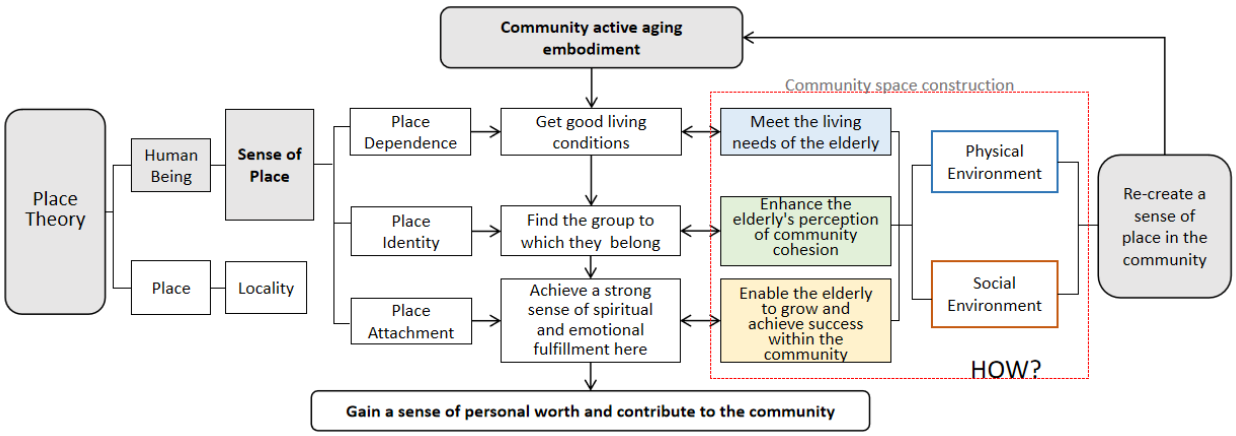


Figure 10. The sense of place promotes the active aging mechanism of the double-aging community score. Source: Author's Own Drawing.

5. Conclusion and Recommendations

This research project fully respects the opinions and needs of the elderly, employing a model of co-design, co-construction, and collaborative governance, alongside innovative workshops. It has created a multi-layered elder-friendly community structure that encompasses basic living needs, cultural education, and neighborly interactions, integrating interactive devices that are easy for the elderly to engage with, as well as elements that reflect the memories of the older generation, such as a smile photo wall. These innovations stimulate the enthusiasm and creativity of the elderly, enhancing their sense of place and deepening emotional connections within the community, embodying an active aging renewal model for double-aging communities from the perspective of sense of place.

The research reveals that the potential of the elderly in community development is often underestimated. As they enter old age, residents experience lifestyle changes due to retirement and their children starting families, resulting in more leisure time compared to other age groups. This enables them to engage more deeply in community life and fosters a stronger emotional attachment and enthusiasm for community involvement. Additionally, the elderly possess rich social experiences and a comprehensive understanding of community development, driving their desire to play a more active role in community building and activities, contributing to the recreation of social value.

The study recommends improving community facilities to meet the basic needs of the elderly, incorporating cultural elements to enhance the community atmosphere, and breaking the bias that views the elderly and aging as entirely negative factors. It advocates for the adoption of active aging renewal methods in old community renovation projects, aiming to better meet the sense of place needs of the elderly and promote their positive roles in inclusive community development. Furthermore, it encourages the promotion of bottom-up community renewal and governance models.

Community renewal based on field sense theory can significantly enhance the sense of dependence, identity and belonging of the elderly on the community, thereby enhancing the cohesion of the community, supporting active aging and sustainable development, and encouraging the elderly to participate in community construction, and allowing the elderly to find emotional satisfaction in their own environment while contributing to the development of the community by improving living conditions and integrating cultural elements. Empower seniors with greater roles and responsibilities to help build a more vibrant community. In summary, the sense-based approach to community renewal provides an effective strategy for age-friendly community development and provides valuable insights to address the "double-growth" challenge in an aging society.

6. References

Aldrich, D.P. and Meyer, M.A. (2015) ‘Social Capital and Community Resilience’, *American Behavioral Scientist*, 59(2), pp. 254–269. Available at: https://doi.org/10.1177/0002764214550299.

Bertelli-Costa, T. and Neri, A.L. (2021) ‘Life satisfaction and participation among community-dwelling older adults: Data from the FIBRA study’, *Journal of Health Psychology*, 26(11), pp. 1860–1871. Available at: https://doi.org/10.1177/1359105319893020.

Borer, M.I. (2006) ‘The Location of Culture: The Urban Culturalist Perspective’, *City & Community*, 5(2), pp. 173–197. Available at: https://doi.org/10.1111/j.1540-6040.2006.00168.x.

Boudiny, K. (2013) ‘“Active ageing”: from empty rhetoric to effective policy tool’, *Ageing & Society*, 33(6), pp. 1077–1098. Available at: https://doi.org/10.1017/S0144686X1200030X.

Chen, Xinxin *et al.* (2022) 'The path to healthy ageing in China: a Peking University-Lancet Commission', *Lancet (London, England)*, 400(10367), pp. 1967–2006. Available at: https://doi.org/10.1016/S0140-6736(22)01546-X.

Fitzgerald, K.G. and Caro, F.G. (2014) 'An Overview of Age-Friendly Cities and Communities Around the World', *Journal of Aging & Social Policy*, 26(1–2), pp. 1–18. Available at: https://doi.org/10.1080/08959420.2014.860786.

Georgios, C. (2023) 'Social innovation in rural governance: A comparative case study across the marginalised rural EU', *Journal of Rural Studies* [Preprint].

Global age-friendly cities: a guide (no date). Available at: https://www.who.int/publications/i/item/9789241547307 (Accessed: 2 September 2024).

Harper, S. (2014) 'Economic and social implications of aging societies', *Science*, 346(6209), pp. 587–591. Available at: https://doi.org/10.1126/science.1254405.

Levy, S.R., Lytle, A. and Macdonald, J. (2022) 'The worldwide ageism crisis', *Journal of Social Issues*, 78(4), pp. 743–768. Available at: https://doi.org/10.1111/josi.12568.

Ma, X. *et al.* (2021) 'How to design comfortable open spaces for the elderly? Implications of their thermal perceptions in an urban park', *Science of The Total Environment*, 768, p. 144985. Available at: https://doi.org/10.1016/j.scitotenv.2021.144985.

McNeil-Gauthier, A.-L., Milot, D.-M. and Levasseur, M. (2024) 'How environments can promote active aging: results from a case study of two municipalities in Quebec, Canada', *Canadian Journal of Public Health*, 115(1), pp. 117–131. Available at: https://doi.org/10.17269/s41997-023-00806-0.

Niedzwiedz, C.L. *et al.* (2016) 'The relationship between wealth and loneliness among older people across Europe: Is social participation protective?', *Preventive Medicine*, 91, pp. 24–31. Available at: https://doi.org/10.1016/j.ypmed.2016.07.016.

Partridge, L., Deelen, J. and Slagboom, P.E. (2018) 'Facing up to the global challenges of ageing', *Nature*, 561(7721), pp. 45–56. Available at: https://doi.org/10.1038/s41586-018-0457-8.

Rollero, C. and De Piccoli, N. (2010) 'Place attachment, identification and environment perception: An empirical study', *Journal of Environmental Psychology*, 30(2), pp. 198–205. Available at: https://doi.org/10.1016/j.jenvp.2009.12.003.

Smith, M.L. *et al.* (2023) 'Societal- and community-level strategies to improve social connectedness among older adults', *Frontiers in Public Health*, 11. Available at: https://doi.org/10.3389/fpubh.2023.1176895.

Swift, H.J. *et al.* (2017) 'The Risks of Ageism Model: How Ageism and Negative Attitudes toward Age Can Be a Barrier to Active Aging', *Social Issues and Policy Review*, 11(1), pp. 195–231. Available at: https://doi.org/10.1111/sipr.12031.

Tang, B. (2015) "Non-rural, Non-Urban" : Community Governance in Urban Villages in China, *The China Quarterly*, 223, pp. 724–744. Available at: https://doi.org/10.1017/S0305741015000843.

Torku, A., Chan, A.P.C. and Yung, E.H.K. (2021) 'Age-friendly cities and communities: a review and future directions', *Ageing & Society*, 41(10), pp. 2242–2279. Available at: https://doi.org/10.1017/S0144686X20000239.

Wei, Y.H.D. (2012) 'Restructuring for growth in urban China: Transitional institutions, urban development, and spatial transformation', *Habitat International*, 36(3), pp. 396–405. Available at: https://doi.org/10.1016/j.habitatint.2011.12.023.

'World Population Ageing 2023: Challenges and opportunities of population ageing in the least developed countries' (no date).

Yang, N. and Wang, B. (2024) 'Research on the Age-Friendly Transformation of Old Residential Communities', *International Journal of Engineering and Technology*, 16(2), pp. 80–86. Available at: https://doi.org/10.7763/IJET.2024.V16.1259.

Li Yan (2024) A study on adaptive aging reconstruction strategies of old residential areas under the background of active aging. Master. North China University of Technology. Available at: https://doi.org/10.26926/d.cnki.gbfgu.2024.000329.

Yang Xiaolin et al. (2023) A study on the relationship between residents' spontaneous construction behavior and public space elements in Shuanglao Community: A case study of Zhuguang Community in Guangzhou, Urban Development, 30(11), pp. 1–8.

Jiao Yiwen (2024) Research on improving China's community home care Service system in the New Era. PhD. Jilin University. Available at: https://doi.org/10.27162/d.cnki.gjlin.2023.007616.

Wang Yongmei Z.S. (2024) "An Analysis of the Effects of Pilot policies on the Reform of Home and Community Elderly Care Services in China", Population Research,48(3), p. 81.

Research Paper

Achieving Environmental Justice for Disadvantaged Communities in Industrial Recession Urban Areas

Wenqian Niu, Cornell University, China

Abstract

Urban areas dealing with industrial decline often face problems like empty land, polluted environments, and broken social connections. This study looks at Cleveland's St. Clair-Superior neighborhood as an example of how industrial changes have created unequal access to resources. To promote equity in urban planning, the research focuses on reducing the extra challenges faced by underserved communities and improving the lives of local residents. Using tools like GIS mapping, fieldwork, and input from the community, the study explores ways to increase green spaces, reuse empty lots, and preserve cultural identity. The findings highlight the need for a well-rounded approach that includes environmental, social, and cultural factors. The suggested solutions show how planning with equity in mind can help transform struggling neighborhoods into strong, connected communities. This model can guide other cities facing similar issues.

Keywords

Environmental Justice, Urban planning, Industrial recession, Spatial inequity, Community engagement

1. Introduction

Urban spaces are changing as industries shift, impacting communities that depend on them. The recession of heavy industries has left vacant sites, altered populations, and disrupted social and economic structures in many cities (Hegerty, 2019). This calls for redesign for the urban planning to address decay, underused land, and demographic changes (Bertolini, 2011). Environmental Justice offers the principle for ensuring everyone has access to safe, healthy environments. Environmental Justice focuses on improving conditions in disadvantaged areas by enhancing environmental quality, reducing health disparities, and fostering social ties (Agyeman et al., 2016) .

Cleveland's St. Clair-Superior neighbourhood, affected by industrial recession, exemplifies the need for Environmental Justice-oriented interventions. This community faces issues such as vacant land, pollution, and limited green space ("ST. VITUS CHURCH | Encyclopedia of Cleveland History | Case Western Reserve University," 2020). Through spatial analysis, field studies, and community input, this research suggests ways to improve access, repurpose vacant areas, and support cultural renewal. These strategies aim to create healthier, more inclusive urban spaces, offering a model for other cities facing similar problems.

2. Literature Review

2.1. The Impacts of Industrial Shifts and Recession on Urban Environments

Urban spaces are undergoing transformative shifts due to evolving economic and industrial demands,

resulting in notable changes to the spaces on which communities depend for livelihoods. With the departure of heavy industries from urban areas, industrial sites are left vacant, populations shift, and the social and economic fabric of cities deteriorates (Pottie-Sherman, 2020) . These transformations, especially in post-industrial cities, underscore an urgent need for restructured spatial and environmental planning to address issues like urban decay, underutilization of land, and population migration and change (High, 2003).

In the United States, many industrial-based cities such as Detroit—historically driven by automobile and metal industries—have confronted these challenges since the 1950s (Hegerty, 2019). Economic recession and industry shift alongside crises like the subprime mortgage collapse, have accelerated population decline, unemployment, and an increase in violent crime rates, particularly in cities within the Northeastern and Midwestern U.S. The exodus of highly educated, high-income residents, combined with an influx of diverse demographic groups, has created complex spatial challenges, intensifying social tensions, unemployment, and economic disparity. The economic and social changes caused by industrial decline highlight the urgent need for urban planning strategies to deal with its unintended effects. This is especially true for cities facing industrial recession. A major result of these changes is the increase in vacant land and abandoned buildings. These contribute to fragmented urban spaces, social isolation, and health problems. As Garvin (2013) points out, empty lots can harm both mental and physical health. They lower neighborhood morale, weaken community ties, attract crime, and make areas less safe. This is also the root of the issues facing cities in the industrial recession. (Pottie-Sherman, 2020)
This change in land use often places a heavier burden on disadvantaged neighborhoods. It increases environmental inequalities by reducing the quality of resources and adding social stress. Long et al. (2018) note that abandoned industrial sites often leave behind pollutants. These harm vulnerable communities the most and limit access to safe and healthy public spaces. These are the real challenges that cities in industrial decline are facing today.

2.2. Environmental Justice in Industrial Recession Area

Environmental Justice (EJ) can be regarded as a field that draws from and integrates theory and practice in a mutually informing dialogue, environmental justice can be understood as a form of social *praxis* (Prilleltensky, 2001). Principles for Environmental Justice emphasize the right of all individuals to equitable access to safe, healthy environments, regardless of race or socioeconomic status. The origins of the Environmental Justice movement, such as the 1982 protests in Warren County, North Carolina, (GAO, 1983) highlight a longstanding struggle against environmental discrimination. In this case, 414 activists were arrested while protesting the placement of a toxic waste facility in a predominantly Black and low-income community, sparking national conversations on the need for environmental equity. (McGurty 2007) As Environmental Justice principles gained momentum in the 1980s and 1990s, the movement expanded from opposing environmental burdens to advocating for equal access to environmental benefits like green spaces, clean air, and safe housing infrastructure. (Morello-Frosch et al. 2002)

Over the years, the scope of Environmental Justice has broadened, increasingly overlapping with sustainability goals to improve quality of life within a holistic framework. (Choi et al.,2020) Environmental Justice advocates argue that access to a healthy, fulfilling life should be available to all, highlighting the need for resources that empower individuals to make meaningful life choices with happiness, safety and the sense of belonging. (Sze and London, 2008)This evolving focus incorporates Environmental Justice principles into sustainable urban planning, underscoring that environmental protection should be accompanied by equitable distribution of environmental assets and resources, targeted for the long-term development. Today, the Environmental Justice movement supports the creation of green spaces, access

to recreational areas, and environmental protections that allow all residents, including marginalized groups, to benefit from a higher quality of life. (Rawls,1958),

For industrial recession cities, incorporating Environmental Justice into urban planning has driven efforts to re-envision and repurpose vacant and deteriorating spaces through innovative regeneration projects. By revitalizing neglected areas and enhancing green spaces, cities can mitigate environmental hazards and bolster social equity. Cities like Detroit have embraced Environmental Justice principles by converting former industrial land into productive agricultural zones, thereby fostering economic growth and improving environmental quality. (Schilling and Logan, 2008) These conversions serve as a model for creating spaces that promote community well-being while addressing the historical imbalances that have disproportionately impacted disadvantaged neighbourhoods. Integrating Environmental Justice into urban planning represents a comprehensive approach to rectifying inequities and achieving sustainability, aiming to create healthier, more inclusive urban environments.

The integration of Environmental Justice within urban planning reflects a shift toward using spatial and environmental strategies to redress inequities in industrial recession cities. By advancing initiatives that prioritize equitable distribution of urban resources and sustainable growth, cities can enhance quality of life and ensure all residents can benefit from safe, accessible, and vibrant public spaces.

2.3. St. Clair-Superior in Cleveland

Cleveland is a typical example as the industrial recession city. It is a major city located in northeastern Ohio, U.S., rests on the southern shore of Lake Erie. As a prime example of the industrial decline affecting many Midwestern cities, Cleveland’s location along a river and lakeshore fostered its development into a significant commercial and industrial hub during the late 19th century, attracting large waves of immigrants and experiencing robust population growth. However, by the 1960s, Cleveland's economy began to slow as manufacturing declined, and suburbanization trends gained momentum. This shift was further exacerbated by the restructuring of key industries, notably the steel and automotive sectors, leading to substantial job losses within Cleveland and the surrounding region. The industrial transformation left a lasting impact on urban land use, contributing to industrial pollution and complicating the equitable distribution of environmental resources. (Council, 2020)

St. Clair-Superior, a historic and well-known neighborhood on Cleveland's East Side, is bounded by E. 30th Street to the west and Martin Luther King Jr. Drive to the east. Known as one of Cleveland’s oldest and most culturally diverse neighborhoods, St. Clair-Superior has retained much of its Polish and Slovenian cultural heritage while welcoming newcomers from various parts of the world. Initially, the community was predominantly composed of white residents of Eastern European descent. However, notable demographic shifts in the 1990s and 2000s transformed the neighborhood, and by 2020, approximately 75.6% of the residents identified as African American, 18.8% as white, and 5.8% as Hispanic. (“St Clair-Superior neighborhood in Cleveland, Ohio (OH), 44103, 44108 subdivision profile - real estate, apartments, condos, homes, community, population, jobs, income, streets,” n.d.)

Despite this cultural vibrancy, St. Clair-Superior faces significant environmental and infrastructural challenges. Heavy industry and manufacturing plants were initially concentrated along the railroad tracks and high-capacity transportation roads lay on the north of St. Clair Avenue, a legacy of Cleveland’s industrial expansion. However, with the impact of industrial decline, many of these former industrial sites and associated land in St. Clair-Superior have become vacant or severely underutilized. Such kind of vacant and gap zone also became a kind of block to the access of other functional spaces. Access to natural resources and recreational spaces remains limited due to infrastructural barriers, such as Interstate 90 and major

railroad tracks, which restrict access to Lake Erie, Gordon Park, and even nearby Rockefeller Park. Consequently, St. Clair-Superior experiences significant environmental resource inequities, as evidenced by poor infrastructure, unplanned vacant land, and limited access to public open spaces. These disparities result in lower health outcomes and diminished economic value for the area. Additionally, high levels of vacant land can foster the rate for violent crime, and restricted access to green spaces has adverse impacts on residents' physical and mental health. Such poorer reputation, in fact, inhibits economic development in the community. reinforcing the notion of environmental inequity within this community.

Figure 1. Mapping_ Location of St. Clair-Superior . Source: *Author's own work*.

The current situation of irrational categorization and inequity of environmental resources is faced by most disadvantaged communities in cities in industrial decline. Therefore, equality and environmental justice are expected by these communities. The primary goal is to explore how environmental resource inequities manifest in disadvantaged communities in industrial recession urban areas and to identify their causes. Using the St. Clair-Superior neighbourhood as a case study to propose planning strategies that achieve environmental justice in these areas.

3. Methodology

This study incorporates three primary methodologies for data collection and analysis: (1) Mapping and GIS tools were utilized to evaluate current land use patterns and transportation networks. Spatial data from the Cleveland Planning Commission was leveraged to analyze roadway accessibility for motorized, bicycle, and pedestrian pathways, as well as to examine the accessibility and distribution of public green spaces in comparison to other neighbourhoods; (2) Field investigations were conducted to update data on existing vacant lots and document residents' experiences walking through the neighbourhood. Using an Image-Walk method allowed for observing and recording visual impressions of specific spatial environments, revealing underlying issues in spatial planning and design; and (3) A focus group was organized to facilitate direct communication with residents, capturing valuable insights on hidden spatial use issues and unaddressed community needs. These discussions, along with co-design workshop, provided residents an

opportunity to raise relevant issues, needs, and suggestions, while semi-structured interviews further captured the diversity of resident perspectives. This research approach enables the development of comprehensive and inclusive urban planning strategies aimed at achieving environmental justice for neighbourhoods affected by industrial decline.

4. Results

4.1. Spatial Analysis of Infrastructural Barriers

The analysis of GIS data in Cleveland's St. Clair-Superior neighbourhood underscores how significant infrastructural barriers create stark inequalities in access to environmental resources, with specific spatial limitations preventing residents from fully utilizing the green spaces that surround their community. To the south, a railroad physically separates the neighbourhood from the southern public green spaces, such as Rockefeller Park, which is a major source of green space and recreational opportunity. The north side is similarly restricted, as Interstate 90 cuts off access to the Lakefront zone, including popular destinations like Gordon Park, the Lakefront Nature Preserve, and the soon-to-be-developed Cheers public green space. These major infrastructural barriers contribute to a broader sense of disconnection and limit residents' opportunities to engage with nature (see Figure 2). Additionally, pedestrian infrastructure within the neighbourhood remains highly fragmented and restricted, characterized by narrow sidewalks hemmed in by busy motor vehicle lanes, fractured pathways, and the steep topography of the area, which further complicates accessibility. Combined, these conditions create an environment that is not only physically but also socially limiting, resulting in a disjointed urban landscape that impacts residents' quality of life and restricts their access to nearby environmental resources (see Figure 3). (Bullard and Johnson 1997; Cohen and Hobson 2004)

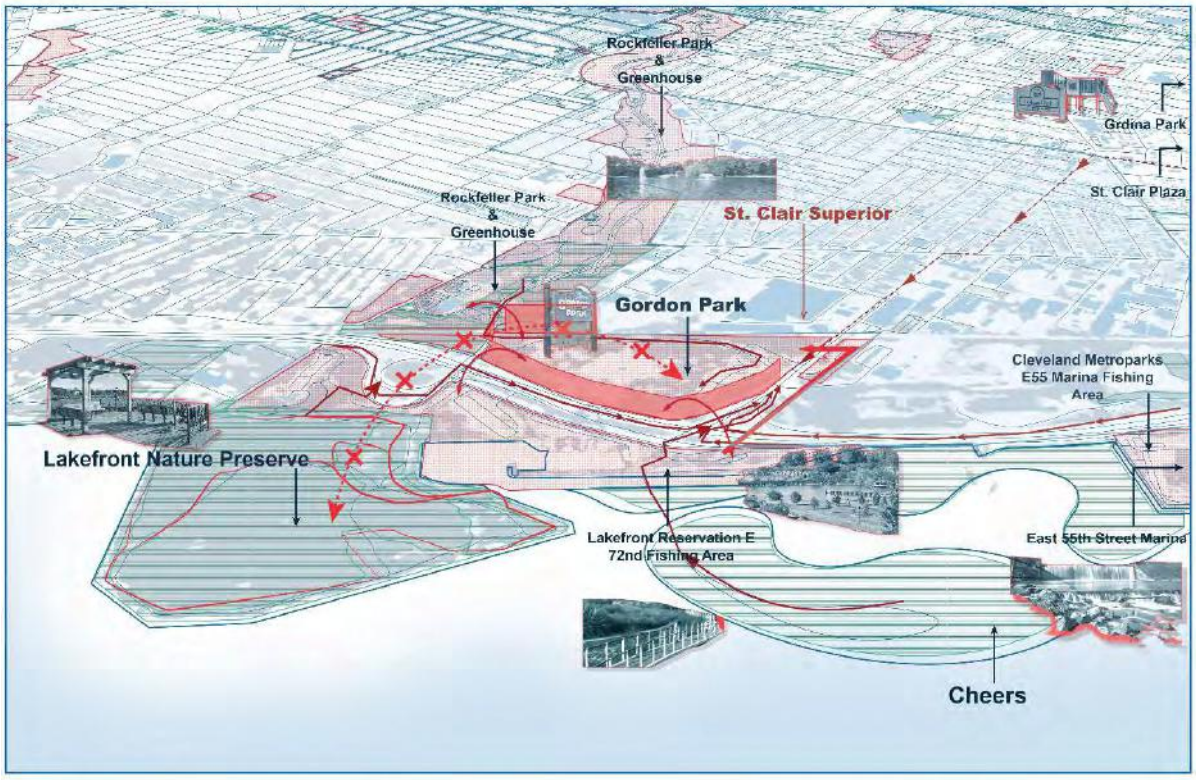


Figure 2. Analysis of Accessibility to Public Green Spaces . Source: *Author's own work*.

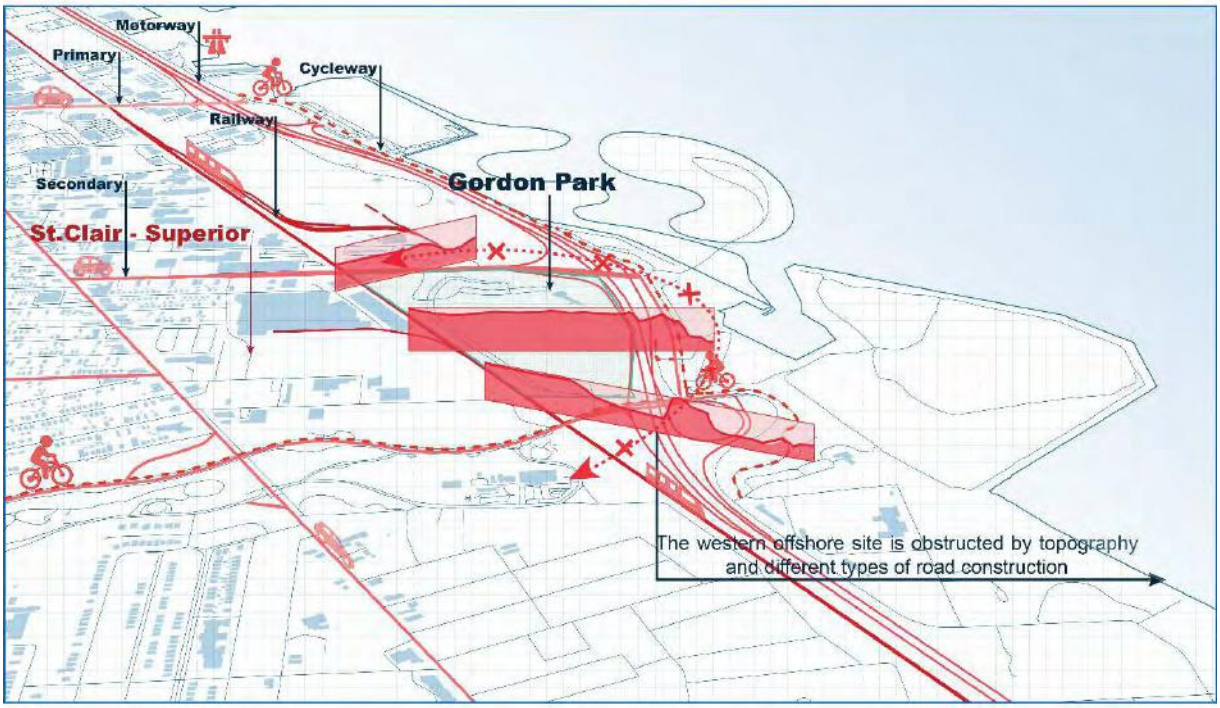


Figure 3. Analysis of Transportation. Source: *Author's own work*.

4.2. Social and Environmental Impacts Under Vacant Spaces

Field investigations, through both observational analysis and image-based assessments, provide a deeper insight into social and environmental challenges in the St. Clair-Superior neighbourhood, revealing how these issues affect community cohesion, public safety, and overall livability. Observations reveal visible signs of neglect in the neighborhood. Broken utilities, damaged public spaces, poorly maintained streetlights, and overgrown plants make the area feel unsafe and rundown. Vacant lots are scattered across residential areas, often sitting between houses, without any management. These empty spaces create gaps in the community and make people feel isolated. Many of these lots are overgrown and not taken care of. Their location near homes and limited visibility can lead to physical and emotional risks. This place, actually became hotspots for crime, adding to the neighborhood's unsafe reputation. Residents have shared concerns about safety and trust in their surroundings. Some parents or local residents here often avoid using outdoor spaces or letting their children play outside because they feel uneasy and unsafe. One mother shared that her fear for her child's safety prevents her from allowing outdoor, unsupervised play with worries about the risks from unfamiliar surroundings and neighbours, citing concerns about neighbourhood kidnappings and the limited visibility that the fractured urban layout provides. This environment stifles potential for organic social cohesion and limits daily interactions, resulting in a weakened sense of community trust and shared identity.

Figure 4. Analysis of Transportation. Source: *Author's own work*.

4.3. Cultural Needs and Community Feedback

The analysis of community dynamics, captured through interviews and a co-design workshop with local residents, emphasizes the need for cultural expression, identity-building, and a sense of belonging within the neighbourhood. Residents expressed frustration over the absence of public art, particularly murals, which are iconic in other Cleveland neighbourhoods and serve as vibrant expressions of local identity. Cleveland's mural culture, known for narrating local histories and fostering neighbourhood pride, is conspicuously absent in St. Clair-Superior, depriving residents of a visual and cultural link to their city, compared with the street views in the Downtown area. Residents expressed a strong desire for communal activities and public spaces that reflect their diverse social and cultural backgrounds, imagining a neighbourhood that not only meets their functional needs but also resonates with cultural meaning. One resident said,

'Although I know we don't have the financial support to turn our neighbourhood into a glamorous,

upscale community, I still want to have art and culture so that I can still be connected to this city.'

（Resident A）

The lack of accessible public art in the neighbourhood is not only a missed opportunity for aesthetic enhancement but also a barrier to establishing a cohesive neighbourhood identity that resonates with the broader Cleveland community, reinforcing a sense of disconnection.

5. Discussion

Based on these findings, a comprehensive strategy is proposed to address St. Clair-Superior's spatial, social, and cultural needs, focusing on improving accessibility, enhancing community safety, and fostering cultural revitalization within the neighbourhood, targeting for achieving Environmental Justice for this area.

5.1. Proposed Strategies for Accessibility and Effective Connection

The first critical component of this strategy involves improving access to green spaces through strategic infrastructural developments. Constructing underpasses beneath the railroad and flyovers across Interstate 90 would create direct links to major green spaces, such as Rockefeller Park, Gordon Park, the Lakefront Nature Reserve, and the upcoming Cheers public green space. These infrastructural enhancements would be designed with pedestrian safety and comfort in mind, incorporating adequate lighting, clear sightlines, and well-maintained paths to ensure usability for residents of all ages. Within the neighborhood, a network of pedestrian paths should be created to improve connectivity in both east-west and north-south directions, making it easier to get around the district and other public space Redesigned sidewalks - wider, well-lit and separated from traffic lanes - would create safer, more welcoming streetscapes for pedestrians, cyclists and children. Improved pedestrian infrastructure would encourage outdoor activities, promote physical and mental health and provide safer play opportunities for children, contributing to the well-being and engagement of the whole community.

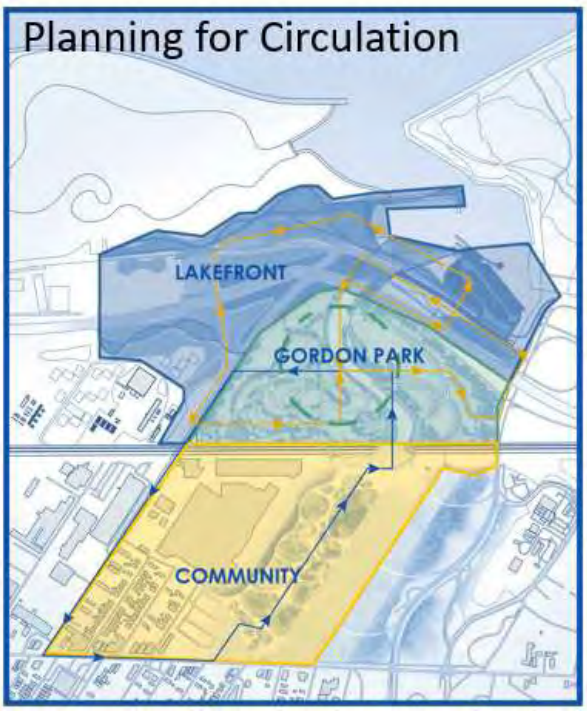


Figure 5. Proposed Planning Strategies. Source: ***Author's own work***

5.2. Vacant Land Repurposing and Public Activities Revitalization

The second key element of this plan is to transform the vacant lots of St. Clair-Superior into active community spaces. These spaces could include playgrounds, mini or small farms, gardens or outdoor theaters. This change would solve several problems at once. It would make the area safer by eliminating the unsafe elements and feeling at the places where crime can occur to help residents feel more secure. These spaces would also enable people to meet, chat and take part in shared activities. They would bring together people of all ages and backgrounds from different cultures and races. These community spaces would give people a place to connect and feel like they belong, which could make the neighborhood look better and improve its reputation. Adding art to these spaces could draw visitors and make the area more adaptive and attractive, helping the local economy.

5.3. Cultural Identity Through Public Art

The last part of this plan is to bring cultural identity to the neighborhood through public art, especially murals. This would let St. Clair-Superior residents connect with the city's culture and feel proud and take pride of their community. Regular mural events, where local artists and residents create art and painting in mural showing the neighborhood's historical and cultural background, could strengthen ties with Cleveland itself. These projects would help residents share their stories through art, bringing people together and building pride in their neighborhood. Murals and other public art would make the area more attractive, serve as symbols of strength, and give residents a shared sense of identity. These events would help people form closer bonds and preserve the neighborhood's heritage.

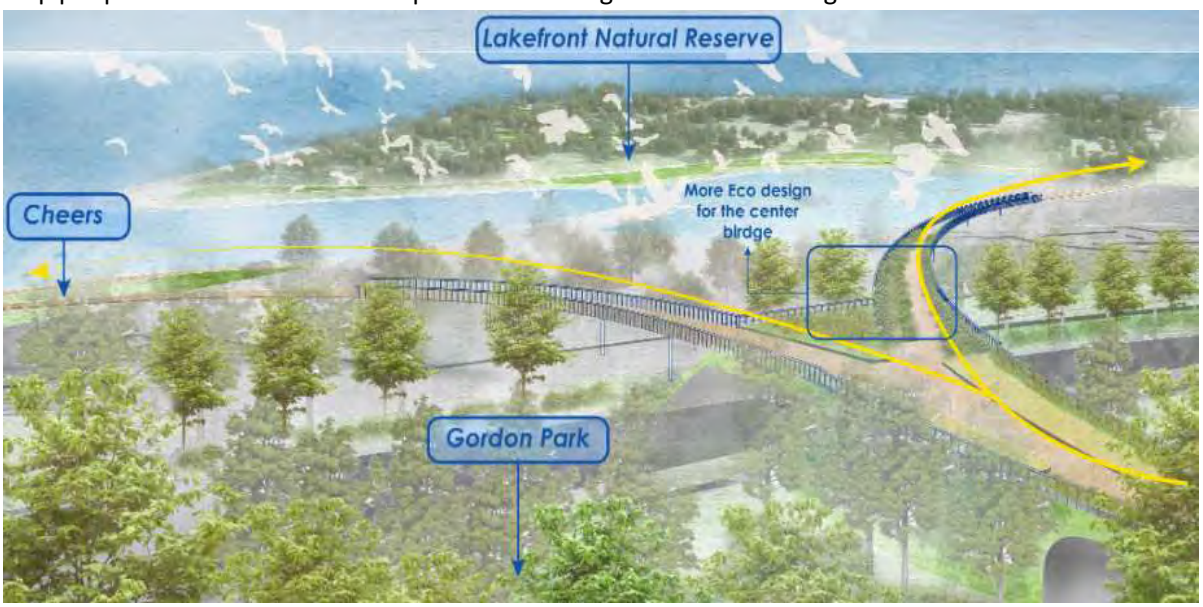


Figure 6. Perspective for Connectivity. Source: ***Author's own work***

Figure7. Planning Strategies. Source: ***Author's own work***

5. Conclusion

Cleveland's St. Clair-Superior neighborhood provides important lessons and vital guidance for cities dealing with industrial recession. Planning for equity and inclusion in these areas means more than improving green spaces or upgrading environmental resources with the connections among them. Besides, it also needs to consider and design the social, cultural, and emotional aspects that shape how residents interact with their surroundings and how then identify themselves. St. Clair-Superior, with its long history and challenges, shows how careful urban planning can fix uneven development, build stronger community ties, and protect the cultural and racial identity of disadvantaged groups.

For the field of regional planning, the St. Clair-Superior example highlights the importance of involving the community through engagement and co-design. These methods let residents share their needs and ideas, making them active contributors in shaping their neighborhood. This approach builds a sense of belonging, increases community ownership, and makes plans more effective by addressing the area's specific social and cultural needs. Work in neighborhoods like St. Clair-Superior shows that resources like parks, recreational spaces, and easy access to transportation are essential for improving public health, helping local economies, and supporting community well-being.

The St. Clair-Superior model offers a practical approach for other neighborhoods facing similar challenges. Reusing vacant spaces, focusing on sustainable redevelopment, and involving residents in design can address issues like disconnection, safety concerns, and the loss of cultural identity. Cleveland's efforts show how environmental justice can guide urban planning to create spaces that meet basic needs while supporting social connections, cultural expression, and emotional well-being.

4. References

Agyeman, J., Schlosberg, D., Craven, L. and Matthews, C., 2016. Trends and directions in environmental justice: From inequity to everyday life, community, and just sustainabilities. *Annual Review of Environment and Resources*, 41, pp.321–340. https://doi.org/10.1146/annurev-environ-110615-090052

Bertolini, L., Wenban-Smith, A., Robiglio, M., Williams, B., van der Kooij, E. and Bertolini, L., 2011a. Planning and the recession. *Planning Theory & Practice*, 12(4), pp.429–451. https://doi.org/10.1080/14649357.2011.617499

Bertolini, L., Wenban-Smith, A., Robiglio, M., Williams, B., van der Kooij, E. and Bertolini, L., 2011b. Planning and the recession. *Planning Theory & Practice*, 12(4), pp.429–451. https://doi.org/10.1080/14649357.2011.617499

Charles, C., n.d. *Assessing the impact of the Great Recession on the Rust Belt states: A policy analysis*.

Connolly, P., n.d. *Activating vacant spaces: An art and environmental justice project - assessment in Cleveland, Ohio's Slavic Village neighborhood*.

Council, O.E., 2020. Organizations launch Cleveland Comprehensive Environmental Policy Platform. *Ohio Environmental Council*. Available at: https://theoec.org/clevelandenviropolicyplatform/ [Accessed 28 October 2024].

Feindt, P.H. and Cowell, R., 2010. The recession, environmental policy and ecological modernization – What's new about the Green New Deal? *International Planning Studies*, 15(2), pp.191–211. https://doi.org/10.1080/13563475.2010.509474

From XS to XL urban nature: Examining access to different types of green space using a 'Just Sustainabilities' framework, n.d. Available at: https://www.mdpi.com/2071-1050/12/17/6998 [Accessed 28 October 2024].

Garvin, E.C., Cannuscio, C.C. and Branas, C.C., 2013. Greening vacant lots to reduce violent crime: A randomized controlled trial. *Injury Prevention*, 19(3), pp.198–203. https://doi.org/10.1136/injuryprev-2012-040439

Hegerty, S.W., 2019. The Rust Belt, the Sunbelt, and the concentration of poverty within large U.S. cities. *Review of Regional Studies*, 49. https://doi.org/10.52324/001c.11161

Hendricks, M.D. and Van Zandt, S., 2021. Unequal protection revisited: Planning for environmental justice, hazard vulnerability, and critical infrastructure in communities of color. *Environmental Justice*, 14(2), pp.87–97. https://doi.org/10.1089/env.2020.0054

High, S., 2003. *Industrial sunset: The making of North America's Rust Belt, 1969-1984*. Toronto: University of Toronto Press.

Israel, B.A., Eng, E., Schulz, A.J. and Parker, E.A., 2005. *Methods in community-based participatory research for health*. San Francisco: John Wiley & Sons.

Kenny, J., 2020. Economic conditions and support for the prioritization of environmental protection during the Great Recession. *Environmental Politics*, 29(5), pp.937–958. https://doi.org/10.1080/09644016.2019.1680074

Kneebone, E. and Garr, E., 2009. *The landscape of recession*.

Knoble, C. and Yu, D., 2023. Environmental justice: An evolving concept in a dynamic era. *Sustainable Development*, 31(5), pp.2091–2108. https://doi.org/10.1002/sd.2519

Long, M.A., Lynch, M.J. and Stretesky, P.B., 2018. The Great Recession, the treadmill of production and ecological disorganization: Did the recession decrease toxic releases across US states, 2005–2014? *Ecological Economics*, 146, pp.184–192. https://doi.org/10.1016/j.ecolecon.2017.10.022

McGurty, E., 2007. *Transforming environmentalism: Warren County, PCBs, and the origins of environmental justice*. New Brunswick, NJ: Rutgers University Press.

Pottie-Sherman, Y., 2020. Rust and reinvention: Im/migration and urban change in the American Rust Belt. *Geography Compass*, 14(10), p.e12482. https://doi.org/10.1111/gec3.12482

Prilleltensky, I., 2001. Value-based praxis in community psychology: Moving toward social justice and social action. *American Journal of Community Psychology*, 29(5), pp.747–778. https://doi.org/10.1023/A:1010417201918

Schilling, J. and Logan, J., 2008. Greening the Rust Belt: A green infrastructure model for right-sizing America's shrinking cities. *Journal of the American Planning Association*, 74(4), pp.451–466. https://doi.org/10.1080/01944360802354956

The Office, 1992. *Siting of hazardous waste landfills and their correlation with racial and economic status of surrounding communities: Report*.

St Clair-Superior neighborhood in Cleveland, Ohio (OH), 44103, 44108 subdivision profile - real estate, apartments, condos, homes, community, population, jobs, income, streets, n.d. Available at: https://www.city-data.com/neighborhood/St-Clair-Superior-Cleveland-OH.html [Accessed 28 October 2024].

ST. VITUS CHURCH | Encyclopedia of Cleveland History | Case Western Reserve University, 2020. Available at: https://case.edu/ech/articles/s/st-vitus-church [Accessed 28 October 2024].

Sze, J. and London, J.K., 2008. Environmental justice at the crossroads. *Sociology Compass*, 2(4), pp.1331–1354. https://doi.org/10.1111/j.1751-9020.2008.00131.x

Takeo, E., n.d. *People and plants in a Rust Belt city: A critical analysis of urban agriculture in Cleveland, Ohio using a sustainable development framework*.

Case Study Report

Streets for People

Pathways of Change from India's Smart Cities

Gargi, ROY, Senior Urban Planner, India

Abstract

In 2020, when Covid-19 brought cities around the globe to a halt, citizens across India took to walking and cycling not just to exercise, but to access essentials and services. Leveraging this opportunity, the Smart Cities Mission launched two national initiatives—the Streets4People and India Cycles4Change Challenges—to inspire Indian cities to work with their citizens and urban practitioners to create inclusive, walking and cycling-friendly streets.

To date, over 1700 projects on sustainable mobility and streetscape are considered under the Mission, including over 2500 km of Smart Streets with universal accessibility and designated pedestrian paths, and over 570 km of cycle tracks. 15 cities have adopted the Health Streets Policy, and 9 cities are working towards its implementation. 19 city municipalities have prepared 3 years action plans with network plans for scaling up walking and cycling transformation. To increase the uptake of cycling, cities have also deployed public bicycle-sharing systems with over 10,000 bicycles and launched several awareness campaigns such as Cycle to Work. With support from the central government of India and the Smart Cities Mission, Indian cities have achieved a dramatic transformation of their streets. This case study report aims to capture the transformative journey of these streetscape projects from Indian cities to provide learnings for other developing cities to scale up this transformation nationwide. This case study, first, defines the concept of people-friendly streets in the Indian context and then establishes how Indian Smart Cities initiated behavioral change people-centric initiatives and campaigns to generate awareness of cycling and walking, which later became the drivers of change for the transformative journey of Indian streets. Thirdly, it deep dives into the transformative journey of three streetscape projects from three Indian Smart Cities — Bhubaneswar, New Town Kolkata, and Indore. All these streets are categorized respectively, under three broad categories Transit Streets, Neighbourhood Street, and Market Street, to provide a holistic landscape of the streetscape projects across Indian cities. Thirdly, the case study further focuses on the institutionalization of future projects by following six pillars of change for the scale-up of streetscape projects' journey in India. Lastly, this case study provides a list of financial recommendations that have helped cities unlock potential funding opportunities to transform their streets.

Keywords

Transit streets, Healthy Streets, Neighbourhood streets, Streets for people

1. Setting the Context

1.1. Introduction

For the last few decades, economic growth and urbanization have gone hand in hand in Indian cities. Cities have been expanding rapidly as more people move to cities in search of opportunities, in turn increasing the need for efficient urban mobility. Our streets and public transport systems have not expanded and improved at the same pace, leading to existing infrastructure in Indian cities getting overwhelmed. This has led to a rapidly increasing dependency on personal motor vehicles resulting in ever-widening roads and massive flyovers gradually taking over our cities. The increasing trends of motorization has contributed to several issues that are making streets extremely unsafe for pedestrians and cyclists. Traditionally, streets in India are more than just a means of mobility. They act as vibrant public spaces that facilitate the livelihoods of people. The ongoing infrastructure projects are prioritizing the fast movement of motorized transport leading to streets as vehicle-friendly spaces. In order to reverse this trend, many Indian cities have taken steps by designing people-friendly streets that prioritize walkability, cyclability and promote the use of public transport. This step has been further enhanced through support from national-level initiatives such as the Smart Cities Mission of India.

Figure 1. Race Course Road, Coimbatore Smart City. Source: Smart Cities Mission, India

1.1. Smart Cities Mission's role in transforming streetscapes across India

Since its launch in 2015, the Smart Cities Mission has emphasized the need for networks of safe, inclusive, accessible, and liveable streets as a strong foundation on which smart cities can grow. The Mission developed guidelines for the design of Healthy Streets to support the creation of safe walking and cycling infrastructure. In 2020, as Covid-19 brought our cities to a halt, citizens across India took to walking and cycling not just to exercise, but also to access essentials and services. Leveraging this opportunity, the Smart Cities Mission launched two national initiatives—the Streets4People and India Cycles4Change Challenges—to inspire Indian cities to work with their citizens and urban practitioners to create walking and cycling-friendly streets.

Over 1700 Smart Mobility projects have been implemented under the Mission including over 2500 km of Smart Streets with universal accessibility and designated pedestrian paths, and over 570 km of cycle tracks. 15 cities have adopted the Health Streets Policy and 9 cities are working towards its implementation. 19 cities have prepared 3-year action plans with network plans for scaling up walking and cycling transformation. To increase the uptake of cycling, cities have also deployed public bicycle-sharing systems with over 10,000 bicycles and launched several awareness campaigns such as Cycle to Work. With support from the Mission, cities across the country have been able to achieve dramatic transformations of their streets. This report provides the learnings from the implemented projects to provide inspiration and valuable lessons for other cities across the country to scale up this transformation nationwide. This report provides detailed of best-practice examples that decision-makers, city engineers, urban practitioners, academicians, and local citizen champions can use to advocate for nationwide scale-up. For this purpose, the report categorizes streets into 3 broad typologies and by setting three examples, it deep dives into the detailed transformation journey.

Figure 2. Linear Garden Street, Pimpri Chinchwad Smart City. Source: Streets for People, Pathways of change from India's Smart Cities, India

2. India’s Urban Streetscape

2.1. Streetscape Typologies

To provide a menu card of the proven good practices of Smart Streets and Roads across several Smart Streets., this report primarily categorizes India’s urban streets into 3 broad typologies, and they are as follows-

Figure 3. Figure below showcase 3 broad typologies of India's Urban Streets. Source: Smart Cities Mission, India

Transit Streets

These streets are mostly arterial or sub-arterial streets connecting major parts of the city. With a mix of land uses along them, these streets are typically designed for easy movement of high volume of vehicles. These streets have lower pedestrian volumes compared to vehicles. However, these streets present an opportunity to improve these for everyone using them and can ensure better safety.

Neighborhood Streets

These are mostly collector or local streets within or connecting neighbourhoods. With predominantly residential land use along them, these streets see short trips for a variety of activities school trips, grocery shopping. and other recreational activities. These streets typically accommodate all kinds of transport modes, and all the users share the street space. These need to be designed to ensure the right balance of street space for all modes

Market & Commercial Streets

These streets serve as destinations with mostly commercial activity along both sides. These streets see bustling pedestrian activity and require wide footpaths to account for the volume of pedestrians.

3. Transformative journey in different typologies of streets

3.1. Streetscape Typologies

3.1.1. Overview of the Project

Smart Janpath Road is one of the busiest roads in the Bhubaneswar Smart City. The Smart Janpath road is 5.8 km long and is a visionary project of the Smart city. The project caters to pedestrians and cyclists with designated pathways, public plazas, and improved pedestrian crossings. The success of the project lied in its community-friendly approach, that helped transforming the road into a pedestrian and cyclist- friendly haven.

Category: Arterial Street	Length:5.8 km	Total cost: ₹ 79.57 Cr.
RoW 60m	Duration of the project: Oct 2017- Feb 2022 (4 years 8 months)	Nodal Authority: Bhubaneswar Smart City Limited
Implementing Partners:	M/S EGIS India Consulting, M/S IBI India Limited, M/S Ernst and Young	

Table 1. Overview of the Project Smart Janpath of Bhubaneswar Smart City

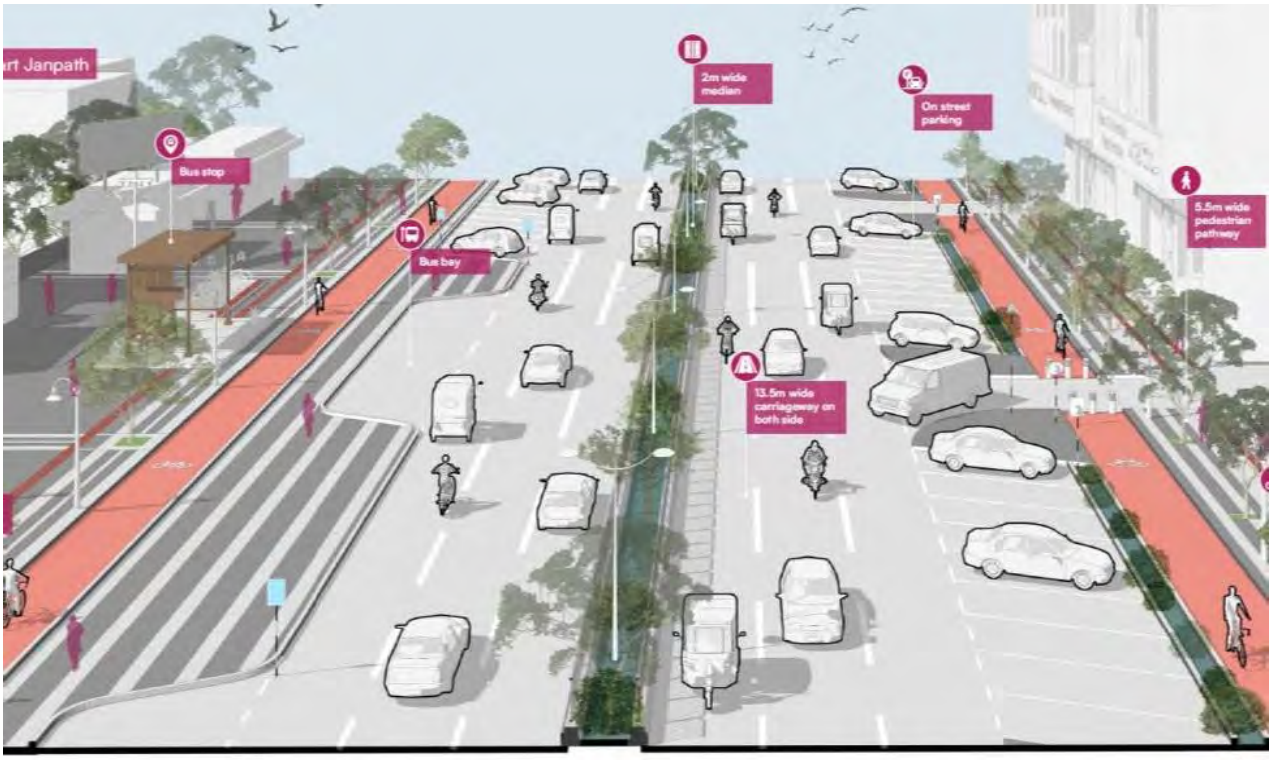


Figure 4. Overview and cross-section of Smart Janpath, Bhubaneswar. Source: Streets for People, Pathways of change from India's Smart Cities

3.1.2. Design Highlights of the project

- Dedicated footpaths, cycle tracks, on-street parking, vending zones, and bus stops incorporated with public amenities are the key features of the s design.
- All the utilities are consolidated underground. Further, several traffic-calming measures, including the rumble strips, zebra crossings, and bollards are integrated into the street design to regulate the pedestrian and bicycle movement.
- Placemaking initiatives have transformed the street edge into inclusive public places integrated with public amenities like seating, street lighting, dustbins etc.
- Pre-stressed concrete, stamped concrete and sand aggregate are used for the footpath, cycle track, and landscape elements respectively.

Figure 5. Design elements in Smar Janpath, Bhubaneswar Smart City. Source: Streets for People, Pathways of change from India's Smart Cities, India

3.1.3. Project Journey

The following table illustrates the key steps undertaken during the project.

Key Steps	Actions taken under each step			
Step 01: Laying the Foundation	The city has institutionalized a Street Vending Policy to organize and manager street vendors.			
	Healthy Streets Policy	Healthy Streets Cell	Parking Policy	Street Design Guidelines
	✓	X	✓	✓
Step 02: Building the team's muscles	Selected city engineers visited the street design projects in Pune and shared their observations with the team members enabling a peer-to-peer learning for the entire team.			
	Site Visits		✓	
	Capacity building workshop		✓	
Step 03: Doing things together	Stakeholder engagement All the stakeholders (including RWA, business owners, residents, NGO representing transgender community) were engaged throughout the project duration through stakeholder consultations. field visits on a regular basis for redressal and resolution of legal issues. Further, officials from Bhubaneswar Municipal Corporation, Bhubaneswar Development Authority, Public Works, Water Resources, Energy, Housing and Urban Development Department, Government of Odisha and communication agencies like BSNL, AIRTEL, TATA etc. were taken on board during the planning and decision-making process.			
	Public Engagement		Tactical Trial	
	✓		✓	
	Media engagement Media was engaged for the outreach and to generate awareness about stakeholder consultation sessions.			
	24x7 Redressal Team 24x7 tracking and redressal of issues was ensured through WhatsApp groups and on-ground staff from the Bhubaneswar Municipal Corporation. The city officials received daily updates.			
Step 04: Monitoring, learning and improving	Monitoring Two dedicated teams ensure proper enforcement in the area. They discourage mobile vendors, ensure symmetrical arrangements of vending kiosks, oversee proper parking of vehicles in assigned spaces, and tow vehicles. Moreover, the officials of Bhubaneswar Smart City were also entrusted with supervision duties in the Smart Janpath to monitor the same.			
	CCTV Surveillance CCTV surveillance near bus stops focuses on people waiting as well as passengers boarding and de-boarding the buses to ensure safety.			
	Operations and maintenance The project contractor has been assigned a contract of four years for O&M of the street. Sanitation and street lighting is being managed by the Bhubaneswar Municipal Corporation.			

Table 2. Overall project journey

Figure 6. Construction phase and laying of underground pipes. Source: Streets for People, Pathways of change from India's Smart Cities, India

3.1.4. Challenges

- Encroachment by vendors: Initially the roads were encroached on by street vendors. There was major pushback from these vendors and from local people, however, this issue was resolved through several stakeholder engagements.
- Laying of underground utilities: Relocating underground utilities along the smart road. Through efficient engineered mechanism and stakeholder consultation with the officials from Bhubaneswar Development Authority, Public Works, Water Resources, Energy, Housing and Urban Development Department, Government of Odisha, this issue was resolved.
- Pushbacks from Citizens: Citizens filed cases in the court as they felt the design was not contextual. This was mitigated through a participatory approach, where citizens were invited for workshops to provide feedback to the design consultants that satisfy the citizen's needs.

3.1.5. Outcomes

- Inclusive space: The project incorporated all-inclusive vibrant public spaces with dynamic public plazas to foster a sense of community.
- Reclaimed space: The project reclaimed 60000 sq m of space for pedestrians and cyclist.
- Boosting local businesses: The project has boosted the local economy by establishing 1,000+ business on one side of the road and 100+ residential plots on the other side.

3.1.6. Scaling Up the Transformation

The Bhubaneswar Development Authority has launched the Urban Regeneration through Bhubaneswar Streets (URBS) Project to enhance the city's liveability. This multipronged approach with Street Design Guidelines forming an integral part, will set the framework for the urban regeneration of streets and public spaces in Bhubaneswar.

In 2021, after the implementation of Smart Janpath the Street Design Guidelines and standards for Bhubaneswar was prepared to design the roads where space is allocated to safely balance the needs of all road users including pedestrians, cyclists, transit, and motorists. In a nutshell, the guideline provided a step- by step approach formulating a COMPLETE STREET. The following diagram shows the typical road section of the complete streets.

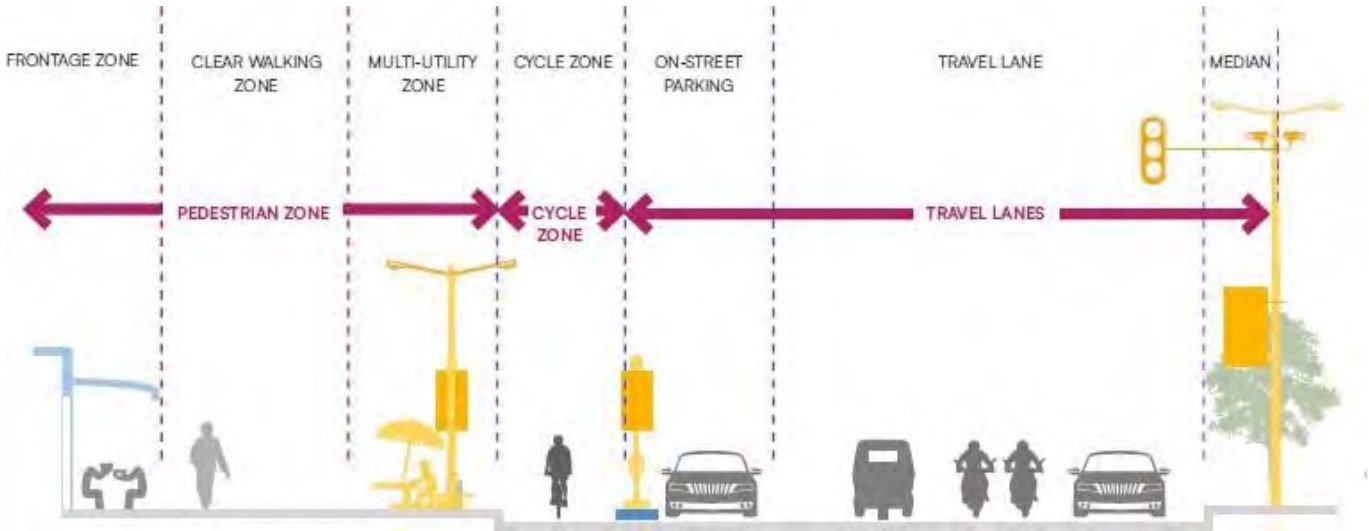


Figure 7. Typical cross-section of future streets of Smart Janpath, Bhubaneswar Smart City. Source: Streets for People, Pathways of change from India's Smart Cities, India

3.2. Case study on Neighbourhood Streets: Street 106, New Town Kolkata

3.2.1. Overview of the Project

Street 106, situated at the core of New Town Kolkata Smart City, despite regular footfall was rendered lifeless during evenings. As part of the Smart Cities Mission's initiative – Street4People Challenge, the project was conceived and aimed to introduce new engaging activities, such as a food truck park, to activate the street during late hours.

Category: Sub-Arterial Street	Length:0.2 km	Total cost:₹5.2 Cr.
RoW 46m	Duration of the project: Oct 2021- Jun 2022 (8 months)	Nodal Authority: New Town Kolkata Development Authority (NTKDA)
Implementing Partners:	City Level Advisory Forum (CLAF), Malabi Makur & Associates, M.M Enterprise (Contractor)	

Table 3. Overview of the project of Street 106 of New Town Kolkata Smart City

Figure 8. Overview and the cross-section of Street 106 of New Town Kolkata Smart City. Source: Author

3.2.2. Design Highlights

- The project conceptualization initiated with a design competition to crowdsource ideas. An integral part of the selected design was the efficient traffic circulation for converting Street 106 into a pedestrian-friendly zone.
- The carriageway is refurbished, and vibrant paints are used to demarcate the pedestrianized stretch. Footpath abutting the carriageway is converted into children's play zone with outdoor play equipment. A segregated cycle track is also created along the street length.
- The service lane is converted into a food truck zone, integrated with necessary amenities like seating spaces, to popularize the street and keep it active in the late evening hours.
- A permanent dais is integrated in the street design to offer a platform for performances during public events. NTK radio is an active contributor to the space.

Figure 9. Design highlights of the project. Source: Streets for People, Pathways of change from India's Smart Cities, India

3.2.3. Project Journey

Key Steps	Actions taken under each step			
Step 01: Laying the Foundation	The city formed the Non-Motorised Transport or NMT cell which is now part of the New Town Kolkata Green Smart City Corporation Ltd. The city also developed Street design guidelines which was followed during the implementation of other streets in New Town Kolkata.			
	Healthy Streets Policy	Healthy Streets Cell	Parking Policy	Street Design Guidelines
	✓	✓	X	✓
Step 02: Building the team's muscles	Online & offline Juries Local experts were involved in the competition juries to share contextual suggestions on the designs submitted by the participants.			
	Site Visits	X		
	Capacity building workshop	✓		
	Walking audits It was organized with the participants of the design competition to ensure that they are aware of the on-ground situations.			
Step 03: Doing things together	Design Competition Crowd sourcing ideas through a design competition helped in ensuring community engagement.			
	Stakeholder engagement Weekly citizen grievance meetings were organised for each action area where city officials, including engineers, CEO, and the chairman of ULB, interacted with citizens, NGO, shopkeepers' association, transgender community, women association, to resolve their issues. This led to a smooth implementation as people started trusting the grievance redressal system. All the stakeholders were engaged throughout the project period through mutual consultation, filed visit for redressal and resolving legal issues on continuous basis.			
	Public Engagement	Tactical Trial		
	✓	✓		
	Traffic management The city authority of New Town Kolkata along with the Bidhanagar Police Commissionerate played an important role in working out an alternative traffic circulation plan, for pedestrianizing Street 106.			
Step 04: Monitoring, learning and improving	Monitoring The project was regularly monitored by the engineering section of the West Bengal Housing Infrastructure Corporation (WBHIDCO) and the NMT Cell of New Town Kolkata. Moreover, the project was also periodically monitored by the Board of Directors of NKGSCCL and the City Level Advisory Forum through weekly review meetings.			

	Newly implemented Foodtruck Policy The city authority developed a food truck policy where registered commercial vehicles can be licensed to run food trucks in this zone. The street design included a dedicated space for accommodating up to 20 food trucks. The revenue generated from the rentals provided by food trucks is directed to the general fund of city authority, which takes care of the operations & maintenance of the space.

Table 4. Step-by-step project of journey of the project. Source: Street for People Pathways of Change from India's Smart Cities

Figure 10. Public participation during the implementation of the project

3.2.4. Challenges

- Resistance from the citizens: At the initial stage, there was major pushbacks by the citizens on the street's pedestrianization approach. However, this was eased through series of regular stakeholder consultation with the citizens and decision makers. During the implementation stage, a dedicated parking bay was incorporated at the redesigned service lane for food trucks to ensure smooth traffic and pedestrian circulation.
- Traffic management: During the implementation stage, there was vehicular traffic movement issue. To mitigate this challenge, alternate routes were provided, to ensure the easy implementation of the pedestrianization of Street 106.

3.2.5. Outcomes

- Revenue generation: The revenue generated from the rentals provided by food trucks is directed to the general fund of NKDA, which takes care of the operations & maintenance of the space. Presently, the operating food trucks generate around 1 lakh revenue (on weekdays). The revenue figures substantially increase to over 2 lakhs on weekends when the place is bustling with people and activities.
- Increase in footfall: On weekdays, the site records a footfall of around 250 – 300 persons per day which increases manifold during the weekends 1000 – 1500 persons per day.
- Reclaimed space: 1275 sq m of space was reclaimed for pedestrians and cyclists.
- Enhanced Air Quality: Post implementation of this project here has been a 1.86% improvement in
- AQI index, and 28.83% reduction in PM 10 AVG (µg/m³) in New Town Kolkata.
- Change in Design Thinking: The success of the Streets4Peopple Challenge as seen at the Street 106, led the city to take up another Happy Street which is currently being executed. Tactical trials, initiated during project implementation, are now part of the system for all street projects in NTK.

3.2.6. Scaling-up the transformation

New Town Kolkata's 3-year Action Plan aims to implement traffic-calmed streets in 5 neighbourhoods/wards after testing solutions through tactical methods. New Town Kolkata Smart City aims to double the Healthy Streets Network and has planned the implementation in 3 phases. The City also aims to implement parking management in 2 model neighbourhoods and initiate an impact assessment of all the completed streets in the New Town Kolkata Smart City. The city also aims to host regular Healthy Streets campaigns to build awareness.

3.2. Case study on Market Streets: Chappan Dukan, Indore Smart City

3.3.1. Overview of the Project

Apart from being a smart city, Indore is considered the food hub of central India, and Chappan Dukan (56 Shops) is considered one of the significant projects of Indore Smart City that aligns with the ethos of Indore's culture. Chappan Dukan is a 200-metre-long series of shops serving delectable delicacies that are famous in Indore. Situated in the center of the city, this food street is served as one of the major tourist destinations. Before revamping, the street was in haphazard condition without any on-street parking and public amenities for the visitors. The street used to be a 30m wide motorized road, which was converted into a pedestrian-friendly street. The Indore Smart City ensured a democratic design and implementation process through continual citizen engagement.

The design and implementation process employed in the redevelopment of Chappan Dukan can and should be replicated in all urban projects, specifically similar street markets in India. Indore's first-ever street to be designated as a vehicle-free zone.

Category: Local Street	Length:0.2 km	Total cost: ₹ 5 Cr.
RoW 30m	Duration of the project: Oct 2019 - Mar 2020 (4 months)	Nodal Authority: Indore Smart City Limited (ISCL)
Implementing Partners:	Indore Municipal Corporation, Indore Smart City Development Limited, 56 Dukan Association, Jila Prasharan, 9 Squares Consultants, AVi Enterprises.	
Award and recognition:	Clean Street Food Hub 2021, ISAC Award – Built Environment 2022, Smart Solution Award – 2022.	

Table 5. Overview of the Indoor Smart City's Chappan Dukan Street

Figure 11. Indore's Chappan Dukan Street transformed from a vehicular road into a vehicle-free zone. Source: Smart Cities Mission, India

3.3.2. Design Highlights

- The design incorporated various theme-based seating areas, that included congregation spaces, semi-open enclosures, and open-area theater seating. Green shaded spaces were created for pedestrians. Street corners were expanded for the pedestrian areas and furnished with benches, improving user experience.

- Additional street furniture such as LED lights, designer pavement spaces, lush plantations, and greenery were incorporated for enhanced visual appeal. Security and monitoring were controlled by the newly installed CCTV cameras.

3.3.3. Project Journey

The following diagram showcases the different steps of the project.

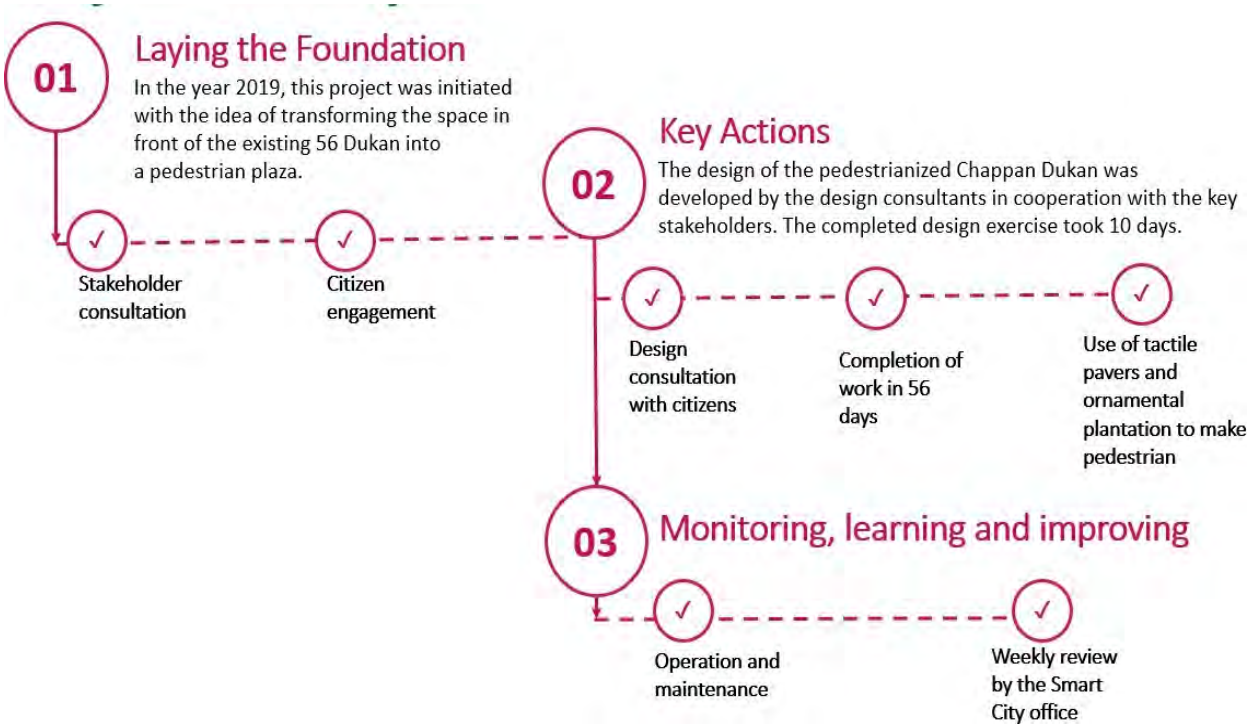


Figure 12. Project Journey of the Chappan Dukan project. Source: Author

3.3.4. Challenges

- One of the key challenges faced by the authority in developing 56 dukan was on boarding shop keepers as the development work was going to affect their business and convincing the shopkeepers to revamp the façade of the shops at their own expense.
- The shops were open throughout, hence it was difficult to manage footfall of around 7000 people every day with the ongoing work.
- With efficient coordination between ISCL and consultants and the contractors, the project was timely implemented.

3.3.5. Outcomes

- Increase in footfall: The area has seen a huge increase in footfall from 6,000 to 15,000 per day.
- Revenue generation: The revenue from Chappan Dukan is around 40% of the annual Rs. 5000 crores turnover from food markets in the city.
- Reclaimed space: 4050 sq m of space was reclaimed for pedestrians.

4. Scaling up: 6 Pillars of Change to Create Healthy Streets

As observed in the above-mentioned case studies, it is worth mentioning that cities have taken conscious steps towards sustainable urban development and creating people centric streets. However, the transformative journey encountered several common challenges. These challenges were overwhelming. By identifying these challenges, many cities have adopted innovative strategies to implement more successful and impactful street transformation projects.

As seen before, several smart cities and many other Indian cities have set a benchmark for creating people friendly urban spaces through conscious urban planning, effective community engagement and sufficient resource allocation.

This part of the report delves into the six pillars of change that enabled several Indian cities to create impactful Healthy Streets.

Laying the Foundation: Policies, Plans & Guidelines:

Cities have realized that a strong foundation and necessary reforms are crucial to implement visionary policies that ensure the resilience of street transformation initiatives. These reforms include:

- Developing Healthy Street Policies & Design Guidelines
- Walking & Cycling Network Plans with 3-Year Action Plans
- Establishing Healthy Streets Design Cell and Apex Committee
-

Sourcing the Funds: Budgeting and Financing for Healthy Street:

Planning finances and identifying sustainable funding sources are key elements in ensuring the long-term success of Healthy Streets initiatives. Further, cities should also assign budgets for maintenance works that include retrofitting curbs, ramps, and pedestrian crossings for existing developed roads.

Hiring a Team of competent practitioners- Designers, Contractors, and Project Managers:

This approach helped to attract several top-tier design talents such as team of urban designers, projects managers and contractors, allowing them to bring creative solutions and innovative ideas to the table.

Building the Team's Muscle:

Cities appointed dedicated staff members with specialized training to conduct capacity building training and workshops to implement street design. This investment on city officials and city leaders was a crucial factor in enabling cities to transform their vision into reality.

Community Engagement:

The importance of citizen engagement in the decision-making process was recognized by the cities. For the successful implementation of people friendly streets, citizen engagement was crucial as it helped to foster a sense of ownership among the citizens.

Impact assessment, monitoring and improvement:

Several assessment frameworks are developed by cities to measure the impact of the projects on people. These frameworks helped the cities to evaluate the benefits of the healthy streets' projects. Visible benefits from the implemented project are evaluated with the hep of the regular feedback from the citizens. This citizen-centric approach facilitated in impact assessment of the implemented project and gather insights to shape future projects.

5. Ways to Fund and Finance Healthy Streets

Apart from adopting the six pillars of change, cities need to find innovative ways to fund and finance healthy streets. In India, most cities or states are highly dependent on the central-level funding, and thus many cities mostly rely on central-level missions or budgets to fund the project at the city level.

Thus, this ending section of the report recommends ways to fund and finance scaling up healthy streets.

a) National or State level funds:

These are one-time/recurring large-scale budget allocations for capital investments on urban infrastructure/sustainable mobility interventions from the national- or state governments. To optimize on these funds, cities could package Healthy Streets projects to improve three key urban infrastructure challenges - mobility, utility, and liveability.

Examples of National-level funds in India:

- Smart Cities Mission Fund
- National Clean Air Programme Fund (NCAP)
- Nirbhaya Fund
- Gati Sakthi Scheme

Examples of State-level funds in India:

- Urban Road Infrastructure Fund (Tamil Nadu)
- City Infrastructure Development Fund (Assam)
- Urban Infrastructure Fund (Maharashtra)

b) Healthy Streets funds:

Set up a Healthy Streets Fund as part of your city's annual budget. Prioritize recurring funding allocation for roads and related amenities, from your city's own tax revenue or partly redirect funds from the state department for road construction. In the long-term, set up a Healthy Streets Cell/Department with dedicated internal capacity to implement high-quality infrastructure.

c) Grants from development Agencies:

Grants from development agencies are generally available and allocated to a limited number of cities or projects with focused goals.

d) Opportunities from global development sector:

Other than grants routed through the national/state departments, various global development agencies also offer opportunities for capacity building and technical support through direct 'call for proposals'.

e) Revenue from Travel demands Management (TDM):

Progressive TDM policies should be based on incentivizing sustainable mobility, as much as disincentivizing polluting private modes.

f) Land Value Capture (LVC) Mechanisms:

It can promote inclusive and equitable urban development, by accounting the increase in property value due to public infrastructure, levying relative charges, and reinvesting them for high-quality public infrastructure.

g) Contributions from non-governmental partners:

This reduces the dependency on city budgets for small-scale neighbourhood-level interventions. This also provides the opportunity for catalysing community-driven transformation.

h) Market-based financing Mechanisms:

Market-based tools will help cities increase and diversify own-source revenues. It gives direct access to capital market and avoid unplanned growth or deficient infrastructure supply.

i) Low- or zero-interest loans (Soft loans):

It could help in increasing the capital investments for resilient urban infrastructure. This also opens up opportunities to collaboratively work with Development Banks and tap into international expertise.

6. References

Smart Cities Mission and ITDP, Govt. of India. (2024) *Streets for People: Pathways of Change from India's Smart Cities*. 1st edn. New Delhi: Ministry of Housing and Urban Affairs.

Karssenberg, H., Laven, J., Glaser, M. and van 't Hoff, J. (2016) *The City at Eye Level*. 2nd edn. Delft: Eburon Academic Publishers.

Sim, D. (2019) *Soft City: Building Density for Everyday Life*. 1st edn. Copenhagen: Gehl Architects.

Villadsen, K., Gehl, J. and Svarre, B. (2021) *Shanghai Riverfront Evaluation*. 1st edn. Copenhagen: Island Press.

Vaidya, H., Sharma, A. and Singh, R. (2022) *Transforming Urban Landscape in India, A compendium of 75 public spaces*. 1st edn. New Delhi: National Institute of Urban Affairs (NIUA), India.

Vaidya, H., Sharma, A. and Singh, R. (2023) *Good Practices in Climate Action, A City Climate Alliance*. 1st edn. New Delhi: National Institute of Urban Affairs (NIUA), India.

Whyte, W.H. (1980) *Good Practices in Climate Action, A City Climate Alliance*. 8th edn. New York: Project of Public Places.

Global Designing Cities Initiative. (2016) *Global Street Design Guide*. 1st edn. New York City: Island Press.

Global Designing Cities Initiative. (2020) *Streets for Pandemic Response and Recovery*. 1st edn. New York City: Island Press.

ITDP. (2021) *Adopting the Healthy Streets Policy*. 1st edn. New Delhi: Ministry of Housing and Urban Affairs.

ITDP. (2022) *Three-year Healthy Streets Action Plan Guide*. 1st edn. New Delhi: Ministry of Housing and Urban Affairs.

ITDP. (2022) *Open Streets Campaign Guide*. 1st edn. New Delhi: Ministry of Housing and Urban Affairs.

ITDP. (2022) *Walking Audit Guide*. 1st edn. New Delhi: Ministry of Housing and Urban Affairs.

ITDP. (2022) *Handlebar Survey Guide*. 1st edn. New Delhi: Ministry of Housing and Urban Affairs.

ITDP. (2021) *Design Competition Template*. 1st edn. New Delhi: Ministry of Housing and Urban Affairs.

ITDP. (2021) *Urban Street Design Guidelines*. 1st edn. Chennai.

Delhi Development Authority. (2006) *The National Urban Transport Policy*. 1st edn. New Delhi: Govt. of Delhi.

Biswas, A., Sharma, R. and Singh, P. (2019) *The Sponge Handbook*. 1st edn. Chennai: Cities fit for Climate Change.

Case Study Report

Rebuilding Villages and Empowering Rural Communities through Sai Kung Hoi Arts Festival

Sarah MUI, One Bite Design Studio, Hong Kong
Alan CHEUNG, One Bite Design Studio, Hong Kong
Stephanie CHEUNG, One Bite Design Studio, Hong Kong

Abstract

Sai Kung Hoi Arts Festival (SKHAF) is a three-year cultural initiative in Hong Kong, organised by the Hong Kong Tourism Commission and curated by One Bite Design Studio (onebite) from 2022 to 2024. The festival is held in Sai Kung, an urban outlying town known for its geological formations, beaches, islands, mountains, and fishing villages. As the festival's curator, onebite brings together artists and rural heritage to create in-situ storytelling pieces, on top of cultural programmes that reimagine the unknown and long-forgotten customs and rituals of four outlying islands, each boasting their distinct history. The festival places local communities at the centre, from collecting oral history as a passive engagement to being a decision-maker and co-designing visitor experience. This process hugely empowers and prepares them for future community mobilisation, development, and building — all essential for rebuilding the dilapidated villages. This approach of partnering with local communities and turning cultural heritage into new tourism products for place branding and rural revitalisation is unprecedented in the city. SKHAF can potentially become a policy driver for many abandoned villages in the city and surrounding area. It could serve as a new community development and rural revitalisation model in a densely populated financial city.

Keywords

Rural Revitalisation, Cultural Heritage, Community Development, Arts Festival

1. Problem addressed

Whilst a metropolitan, 60% of Hong Kong is still covered in green and blue, with many fishing and farming villages once bustling in the countryside. With the city turning into secondary industrial production and serving as an entrepot from the 1960s onwards, and since the 1990s and 2000s, evolving rapidly into a well-known financial and services hub, villages have thus gradually lost their population to the city's economic hubs (Cairns, 2024). Children moved to the city for education and adults moved for a better future of upward mobility. This coincided with the wave of migration before the 1997 handover from the British to the Chinese, many villagers moved to Germany, Belgium, the United Kingdom, the Netherlands, and alike. Rural villages have not found new ways of survival in this new era of city development; there are few, if not a complete lack of economic activities, lack of upgrades in infrastructure, and most of them remain remote and difficult to reach. It is a common perception that villages are backwards and difficult to live in. Slowly, villages became dilapidated, losing most of their population, with only a few elderlies staying behind. Many villages have become deserted and abandoned.

Unfortunately, rural heritage has long been overlooked in Hong Kong. While there have been recent efforts to revitalise intangible cultural heritage, little has been done to revitalise rural villages that are on the outskirts of urban areas. There is a limited identity for these long-forgotten villages, descendants feel detached from the area, and many have no reasons to go back, let alone a sense of ownership, agency and responsibility towards the future of villages. Having drastically lost their populations, the important memories, customs and traditions of villages are also fading as the only returning and remaining elders age; it is critical to act now to preserve the precious intangible cultural heritage (Law and Kong, 2018).

Sai Kung Hoi Arts Festival (SKHAF) is a three-year cultural initiative that brings together artists and rural cultural heritage to celebrate long-forgotten rituals and practices of the fishing villages and islands of Hakka in the area of Sai Kung. SKHAF takes place on the islands of Yim Tin Tsai, Sharp Island, Kau Sai Chau and High Island, mostly situated within the area of the Hong Kong UNESCO Global Geopark, consisting of sites and landscapes that boast ecological significance, in addition to cultural and historical importance. In the process of curating and organising the festival, local communities are empowered to rebuild the fading villages and traditions. SKHAF aims to rebuild a sense of identity for these villages, a sense of ownership among senior villagers, and encourage younger generations to come back and instil a sense of hope and possibilities in them by creating a new future for the tourism economy.

2. Project context

Locally, a strong and diverse policy context, directly and indirectly, creates a supportive policy environment for the creation of the SKHAF project and its sustainable development. Rural village revitalisation sits within the focus of various bureau-level directions. The establishment of a new Countryside Conservation Office in 2018 focuses on countryside revitalisation and ecological conservation with an earmarked funding of HK$1 billion, within which, a Countryside Conservation Funding Scheme was set up to allocate half of the funding for local communities, NGOs and academia to support related preservation and research projects. Alongside efforts in conservation, infrastructure upgrades have also been enlisted in policies. The Pier Improvement Programme by the Civil Engineering and Development Department was initiated in 2017, the plan is to renovate or construct 23 piers in rural areas and outlying islands in two phases, covering SKHAF's Yim Yin Tsai, Kau Sai Chau and High Island. The programme intends to "enhance the accessibility to scenic and natural heritage attractions and support the development of green tourism while fulfilling the basic needs of the local villagers who rely on boats as their major transport mode and the operational needs of fishermen" (Civil Engineering and Development Department, 2023), synergising with SKHAF's direction of village and tourism development.

Given the intense international and regional competition in the financial sector, diversification of economic activities has long been an important imperative in Hong Kong. The government has introduced many initiatives to strengthen other sectors, such as technology and innovation, logistics, as well as the tourism sector. As early as 2017, the government decided to "develop high value-added tourism, eco-tourism, cultural, heritage and creative tourism, etc. so as to attract tourists with different interests to visit and spend in Hong Kong" (Office of the Chief Executive, 2017). The need to boost tourism offerings is particularly dire after COVID-19, with the city seeing a huge drop in tourist numbers. As of 2024, international tourist recovery is still at 60% of the average in the five-year period between 2015 and 2019 (Leung, 2024). and tourists lamenting the city's lack of options and fading attractiveness. Tourists are now looking for more in-depth and local experiences, venturing to non-conventional sites, creating favourable conditions for SKHAF.

Meanwhile, internationally and within Asia, there is increasing interest in successful case studies of art festivals. Notably, the Echigo-Tsumari Art Triennial and Setouchi International Art Triennale in Japan both take place in rural communities, they have shown how in-situ art in collaboration with local communities could rebuild villages by driving significant local and international tourism and more importantly, encouraging younger citizens to move back to remote areas and alleviate the problem of depopulation and dilapidation (Kitagawa, 2014; Akimoto, 2019).

3. Project approach

The project approach of SKHAF can be explained via the adapted framework of sense of place (Fig. 1). Adapted from Ellery and Ellery (2019), and Ellery, Ellery and Borkowsky (2020) the framework integrated Arnstein's Ladder of Citizen Participation and the impact on one's sense of place[source]. The diagram illustrates the progression of an individual's positive connection to a place across the Ladder of Citizen Participation, advancing from "non-participation" and "tokenism" to "degrees of citizen power" through deeper involvement in "community-driven placemaking" rather than "externally imposed placemaking." SKHAF designed and adopted a gradual approach over the three years of operation to engage with the local community and build their sense of place.

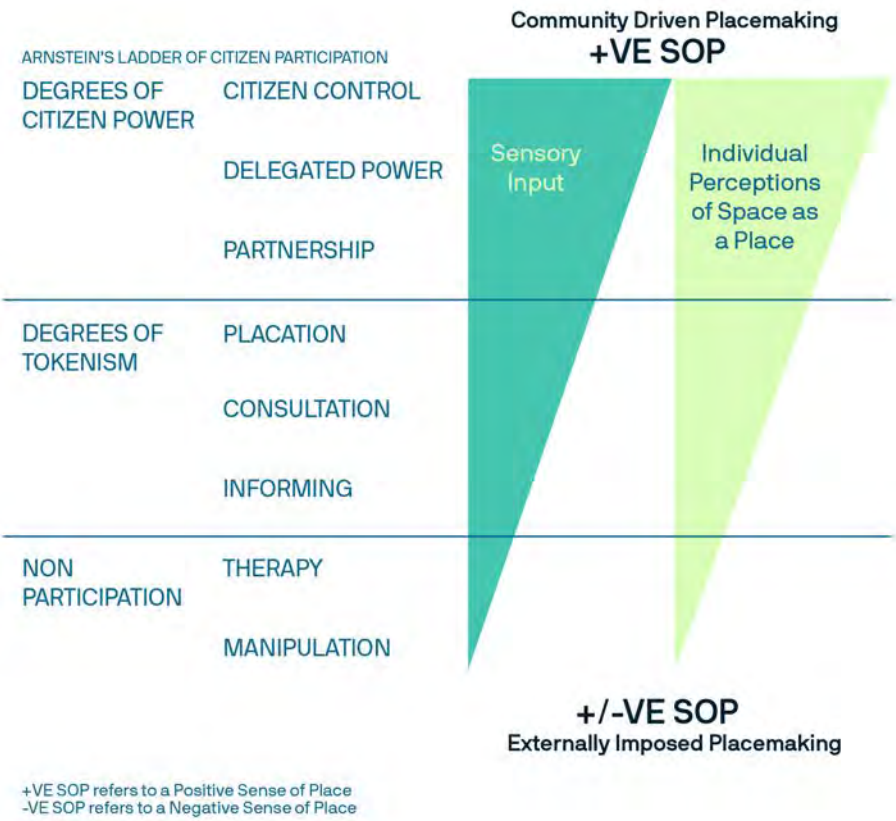


Figure 1. Framework integrating Arstein's Ladder of Citizen Participation and concept of sense of place, developed by Ellery et al., redrawn by authors.

3.1. Informing and consultation

The first point of contact for the SKHAF team was the various village chiefs of the standing villages. The team arranged formal meetings to inform the chiefs of the festivals and consulted the chiefs to connect with the right stakeholders for background research of the area regarding their culture, customs, and heritage. The team was able to consult village committees, local NGOs, key representatives and active villagers via the introduction of chiefs, and conducted interviews to collect stories. The team also organised experiential learning activities for the artists to experience first-hand the uniqueness of the place. This process was more passive and one-way as the team was starting to get to know the places and the people.

As the relationships with the villagers progressed, we organised one-on-one meetings, casual tea and meal gatherings, and bonding events outside of festival seasons to nurture trust and maintain engagement with the local communities (Fig. 2). For example, both the team and villagers explored the geopark and participated in fishing trips. These gatherings strengthened connections and provided villagers, particularly younger generations who started coming back, with opportunities to connect during these friendly gatherings.

Figure 2. First encounter with Yim Tin Tsai villagers and artists in the first year (Photo by Tai Ngai Lung)

3.2. Placation

At the beginning of the festival, the team alone decided on the selection of artists and artworks. Starting from the second year, an open call for artists was added, and villagers took on the new shared responsibility to decide on the artists and the placement locations of the artwork. The team served as the intermediary between artists and relevant village stakeholders to foster collaboration and knowledge exchange. For instance, “Sails” by Inkgo Lam (Fig. 3) is a bamboo installation imitating the sails of a fishing boat and its

journey. The very idea of the piece was a collaborative and iterative process between Inkgo and the villagers, evolving from windmills symbolising luck to sails.

Figure 3. "Sails" by Inkgo Lam was a collaborative iterative effort with the fishermen (Photo by Jeremy Cheung).

3.3. Partnership

The second year saw a new shared planning and decision-making opportunity with the villagers, as they co-designed and helped with hosting festival programmes. Experiences such as dragon boat (Fig. 4), fishing net weaving (Fig. 5), sea urchin harvesting (Fig. 6) and traditional food preparation (Fig. 7) showcased to public participants their proud heritage and an innovative collaborative approach that placed the villagers at the heart of the festival. Additionally, a team of Village Ambassadors was formed, connecting cross-generations of villagers to share their life stories and memories of the villages with the public. These are significantly more in-depth interactions as compared to the first stage of story collection during festival preparation. At this stage, villagers have become essential partners that help design and shape the festival experiences.

Figure 4. Co-designing public experiences with villagers to showcase traditions (Photo by Tai Ngai Lung)..

Figure 5. Partnerships with villagers allowed a deeper storytelling and a new role for young and old villagers (Photo by Kaho Ho).

Figure 6. Sea urchin harvesting was a rare experience for many public participants (Photo by Tai Ngai Lung).

Figure 7. Traditional food preparation gave a reason for young and old villagers to gather and present their culture (Photo by Tai Ngai Lung).

The notion of community was a core question to ask at SKHAF. The team intended to expand the definition of community, creating a common thread that brings outsiders to the villages, especially those without any residents. A new community perhaps could include outsiders who are art and nature lovers, festival ambassadors, and kai-to ferry owners, as well as the wider Sai Kung community and stakeholders, so that the islands are not a standalone existence, but a connection with the city. A celebration night is always organised to connect this community and create new shared memories (Fig. 8).

Figure 8. The annual celebration night was an opportunity to connect all stakeholders of SKHAF and create new shared memories (Photo by Tai Ngai Lung).

4. Project results

Over the past two years, SKHAF welcomed over 140,000 local and international tourists, involving over 30 local and international artist groups, 80 programme partners and 100 villagers. Such is a first-of-its-kind in Hong Kong, proving the tourism possibilities and successfully rebranding the villages and islands as tourism attractions through the art festival, resulting in attractive and novel tourism products and experiences (Fig. 9).

Figure 9. SKHAF has turned the islands into popular attractions and proved the tourism possibilities of rural cultural heritage (Photo by Kaho Ho).

The impacts on the community level take place on different levels, as illustrated with the VASK (values, attitude, skills, knowledge) model. On value, there is a significantly improved sense of belonging, ownership and responsibility instilled in the villagers and the various local stakeholders. The younger generation, in particular, has become more proactive and can now envision different roles they can play in the future development of the villages. There is a strong sense of pride, a stark contrast from the old perception of how rural area is backwards. Villagers have also become much more open-minded to arts and culture, and other new initiatives. In the beginning, villagers were very detached and dismissive, not understanding the relevance and value of the festival. Recently, with a young descendant selected as one of the participating artists, many villagers expressed their pride in him and proactively initiated conversations with this young villager, fostering intergenerational conversations that seldom took place. On a broader scale, villages in the area are composed of Hakka and fishermen villagers, who were not amicable in the past. The festival plays a significant role in bringing these villagers together and contributing to the greater goal collectively, mending past contentions.

Moreover, villagers have gained valuable skills that are vastly different from their work skills and exposure to fishing and farming. Via SKHAF, they learnt about and gained hands-on experiences in tour guiding, storytelling, designing and hosting experiences for diverse public audiences, and dealing with tourists, artists, designers and government officials. In terms of knowledge, not only did the villagers have a completely new encounter with the tourism market, its product offerings and landscape, but the team also helped the area unveil important historical assets. Throughout the process of curating the festival, hidden tangible and intangible heritage assets and history are uncovered, these are previously unknown and undocumented. Villagers now possess a lot more information about their homes and collective history.

In tangible terms, SKHAF has brought long-awaited physical infrastructure and public services improvement to the area. Roads, pavement and paths leading to artworks are improved, especially regarding its

accessibility. The festival also opened up underutilised and abandoned semi-public spaces in the villages and leveraged them as an interesting backdrop for the artwork. For example, “Rhythmic LANE” by Napp Studio & Architects and Fragrant Village made use of the abandoned basketball court of the former Leung Shuen Wa Public School (Fig. 10), and “Dear Sea” by Niko Leung transformed the worn-out Sha Kiu Tsuen Village Office into a new gathering space for villagers (Fig. 11). Such opening up of public spaces unleashed an important imagination of the future activation of more open spaces for communal and visitor use in the future. More importantly, the restoration of Kaito (small ferry) routes for Kau Sai Chau and High Island is an important milestone for the area (Fig. 12). Some of the islands have lost the provision of public ferry routes due to the lack of demand, making them inaccessible. The service resumption came with government and industry support, and the Kaito also operates out of the festival, during weekends and public holidays. Villagers hugely welcome this resumption, those who have moved out now can come back more often.

With the influx of tourists and interest in the area, the villagers realised they could better mobilise support and garner justification for further amenities improvement from relevant government departments, e.g. to improve WiFi and telecommunication networks and enhance accessibility. This combination of tangible improvements creates new possibilities for these islands and makes moving back to the islands a possible choice.

Figure 10. "Rhythmic LANE" reopened the abadoned basketcall court of the village public school (Photo by Carlo Yuen).

Figure 11. "Dear Sea" opened the doors of former Sha Kiu Tsuen Village Office (Photo by Jeremy Cheung).

Figure 12. Restoration of the Kaito services is a significant milestone for the villages (Photo by Kaho Ho).

5. Broader project impacts

The broader impacts and implications of the project come in three-fold, impacting the government administration and policies, institutions and city branding. On the policy-making level, SKHAF has become a major policy, mentioned in the Policy Address and often by government officials. Given the overwhelmingly positive responses, the project and its model perhaps could serve as a pivotal policy catalyst for numerous derelict villages within the urban and peri-urban landscape in Hong Kong. SKHAF is one-of-its-kind in how it turns local cultural heritage into site-specific artwork in rural areas, as well as

working with local communities and building significant relationships with them during the process. This could bring insights into integrating community development, participation and empowerment, and rural revitalisation while satisfying the policy directives in economy diversification and tourism development. This project also shifts slightly how the government administration supports a large-scale arts festival situated in a rural setting while involving multiple government agencies. For example, some artworks are placed within the boundaries of country parks, which conventionally hold strict rules - rarity for the Agriculture, Fisheries and Conservation Department to allow such a happening. SKHAF is also one of few government-funded projects that allow merchandise-selling, allowing tourists to bring a piece of Sai Kung back to their home countries.

The project has sparked huge interest locally and on the international level. Various institutions have begun taking SKHAF as a research object in the fields of rural revitalisation, environmental sustainability, arts management and more. Given the lack of similar cases in Hong Kong and the region, SKHAF serves as an important case and provides valuable information and insights into this set-up in a cosmopolitan setting. Lastly, SKHAF has greatly enhanced international awareness of Hong Kong's nature, its rural beauty and deep-rooted cultural heritage, shaping a new kind of city branding.

6. References

Akimoto, Y. (2019). *Naoshima Project*. Translated by S.X. Lin. Taiwan: Faces Publishing Ltd.

Cairns, R. (2024). *In Hong Kong, abandoned villages have been reclaimed by nature | CNN*. [online] CNN. Available at: https://edition.cnn.com/2024/02/13/style/hong-kong-abandoned-villages-stefan-irvine-photographer-hnk/index.html [Accessed 29 Oct. 2024].

Civil Engineering and Development Department (2023). *Topics in Focus - Pier Improvement Programme (PIP)*. [online] www.cedd.gov.hk. Available at: https://www.cedd.gov.hk/eng/topics-in-focus/index-id-32.html [Accessed 29 Oct. 2024].

Ellery, P.J. and Ellery, J. (2019). Strengthening Community Sense of Place through Placemaking. *Urban Planning*, 4(2), pp.237–248. doi:https://doi.org/10.17645/up.v4i2.2004.

Ellery, P.J., Ellery, J. and Borkowsky, M. (2020). Toward a Theoretical Understanding of Placemaking. *International Journal of Community Well-Being*, 4. doi:https://doi.org/10.1007/s42413-020-00078-3.

Kitagawa, F. (2014). *Echigo-Tsumari Art Triennale Concept Book*. Translated by L.L. Zhang. Taiwan: Yuan-Liou Publishing Co., Ltd.

Law, W. and Kong, H. (2018). *Vivifying Lai Chi Wo : sustainable Lai Chi Wo Programme four year review and outlook*. Hong Kong: Policy For Sustainability Lab, Faculty Of Social Sciences, The University Of Hong Kong.

Leung, H. (2024). *Hong Kong struggles to win back long-haul tourists amid fewer flights and travel warnings*. [online] Hong Kong Free Press HKFP. Available at: https://hongkongfp.com/2024/04/07/hong-kong-struggles-to-win-back-long-haul-tourists-amid-fewer-flights-and-travel-warnings/.

Office of the Chief Executive (2017). *Chapter 3 Diversified Economy, Better Jobs*. [online] *The Chief Executive's 2017 Policy Address*. Available at: https://www.policyaddress.gov.hk/2017/eng/pdf/Agenda_Ch3.pdf [Accessed 29 Oct. 2024].

Case Study Report

Urban Regeneration and Small-Town Revitalisation, Tools for redressing spatial injustices

A case Study of eMaxesibeni Town, Eastern Cape, South Africa

Pilisiwe. Z MASIBA, University of Johannesburg, South Africa. pili.masiba@gmail.com
Sandla MASINYANE, Umzimvubu Local Municipality, South Africa. lmasinyane@gmail.com
Thulisile. N MPHAMBUKELI, University of Johannesburg, South Africa. tmphambukeli@uj.ac.za

Abstract

In recent times, urban regeneration and small-town revitalisation have been a buzzing topic in South African urban planning. The National Development Plan of 2013 (vision 2030) strives to eliminate poverty and inequalities in South Africa by placing people at the centre of development. The NDP 2013 states that South Africa needs an economy which is inclusive, and dynamic and where the fruits of the growth shall be shared equitably amongst South Africans (South African Government, 2013). Urban regeneration and small-town revitalisation are some of the tools which are used by the provincial government to redress inequalities of the past while improving service delivery through improved access to basic services. Local governments are responsible for implementing these projects to transform the economies and social space of small towns through the funding received from the national treasury. Urban regeneration refers to the vision and action which leads to compacting urban problems, bringing about improved sustainable economies, environments and social conditions in an area that has been subjected to change. The purpose of urban regeneration is to come up with strategies for the promotion of local economic development. Its main objectives are aimed at reducing unemployment and poverty by finding spatial initiatives which can generate employment and economic activities and thus boost investor confidence in an area. The main goal of small towns' revitalisation is to redress the socio-economic decline of small rural towns by assisting local municipalities in improving basic service delivery. Small rural towns are faced with the challenges of declining economic activities due to the migration of people moving from these towns to cities and these rural towns are left to deteriorate. The goal of small towns revitalisation is achieved through five strategic objectives which are implemented to reach the end goal. This paper focuses on the principles, processes and themes of urban regeneration and how these can be applied to small towns such as eMaxesibeni to redress the spatial and socio-economic inequalities. Secondly, discuss the five goals of small towns' revitalisation and how they can assist in reversing the socio-economic decline of small towns. The paper consists of three sections which are the review of the existing literature, spatial data analysis of the study area and the regeneration and revitalisation projects implemented in eMaxesibeni town.

Keywords

Urban regeneration, small town revitalisation, Spatial injustice

1. Introduction

In recent years urban regeneration and small-town regeneration strategies in post-colonial and post-apartheid South Africa have been used to redress past spatial injustices and promote sustainable development in rural towns facing socio-economic decline. The initiatives aim to revitalise rural towns with declining economies and decaying towns by focusing on improvements in infrastructure and socioeconomic revitalisation. Spatial injustice is the uneven distribution of services, resources and economic opportunities across different geographic regions (Setianto and Gamal, 2021). This unequal distribution manifests in the marginalisation of rural towns, segregated urban centres and communities with inadequate basic services resulting in socio-economic consequences.

The legacy of colonialism, apartheid spatial planning and post-apartheid planning systems in the South African context has further perpetuated segregation between the wealthy and the poor, uneven provision of resources and development between regions. In South African history rural areas and towns were perceived as reserves for cheap labour for industrialising and mining major cities posing great challenges in urban and regional planning (Bundy, 2020).The small towns revitalisation and urban regeneration initiatives are tools used by the South African government to redress the past spatial injustices by reversing the socio-economic decline of rural communities and towns by making them more vibrant, sustainable and inclusive.

Urban regeneration and small-town revitalisation is a complex system that focuses on transforming urban landscapes to address social, environmental and economic issues. Urban regeneration approaches within the field of urban planning aim at revitalising urban spaces which are underused, decaying and neglected to restore their economic value and make them more vibrant (Tallon, 2020). It is used as a tool to modernise districts and neighbourhoods to align with the needs of the current generation without compromising the needs of future generations. The approach is grounded on the restructuring of current land uses, provision of basic services, improvement of existing infrastructure and inclusion of public-private partnerships thus ensuring the inclusivity of affected stakeholders and sustainability (Cysek-Pawlak and Pabich, 2021).

In contrast bad urban regeneration approaches can lead to poor economic performance further perpetuate social inequalities and hinder sustainable urban development hence it is important to have an in-depth understanding of the concept and its consequences (Tallon, 2020). Bad effects of urban regeneration are mostly experienced where local policies and strategies do not have the aspect of community engagements and public participation of stakeholders. Urban regeneration strategies generally affect the poor of the

poorest as the projects are completed, land uses change, housing and land values tend to escalate and residents are forced to relocate from their neighbourhoods.

For the government to achieve this goal it needs to pursue five strategic objectives which include, improved urban planning and public infrastructure, improved local economic benefits, promoting focused, coherent and integrated intervention packages in selected towns and lastly having a deeper knowledge base on the design and delivery of effective small-town revitalization programmes. This requires local governments to adopt policies which will take into account the unique characteristics of the area. The eMaxesibeni small town's urban regeneration project presents an opportunity to explore how the initiatives can be used as a means to address spatial injustices. This case study could inform theory and policy related to addressing spatial injustice across different geographies and can act as a model for planners advocating for equal distribution of resources, sustainable development and inclusivity in small towns and urban regeneration approaches.

2. Background and context of the project

2.1. Urban Regeneration and Small Town Revitalisation of EmaXesibeni Town

Umzimvubu Local Municipality undertook to implement prepared the Small Town Revitalization funded by the Office of The Premier, Province of the Eastern Cape. The office of the premier secured funding from National Treasury over three years to assist selected municipalities with small-town revitalization projects as part of redressing inequality of the past while improving service delivery through improved access to basic services. The comprehensive business plan identified interventions to improve small towns and focus areas. The overall goal of the small-town development programme is to reverse the socio-economic decline of small towns by supporting municipalities in improving basic services provision in the small towns.

This goal is to be achieved through pursuing the four strategic objectives:

1. Improved urban planning and public infrastructure
2. Improving local economic benefits
3. Promoting focused, coherent and integrated intervention packages in selected towns
4. Deeper knowledge base on the design and delivery of effective small-town revitalization programmes.

Umzimvubu Local Municipality submitted the following projects for funding from Office of The Premier as part of the Small-Town Revitalization Programme:

1. Upgrading of eMaxesibeni Cemetery
2. Upgrading of eMaxesibeni Town Streets
3. Development of eMaxesibeni Transportation Hub

2.2 Project locality

eMaxesibeni town is one of the small rural towns of Umzimvubu Local Municipality. The municipality falls under Alfred Nzo District Municipality in the Eastern Cape province of South Africa which has been declared by President Cyril Ramaphosa as one of the poorest districts in the country. The two towns eMaxesibeni and KwaBhaca are administrative centres in the Umzimvubu Local Municipality and they are recognised as primary economic nodes as per the Municipal Spatial Development Framework. The project area comprises of eMaxesibeni Town. The locality of the project area eMaxesibeni (previously known as Mount Ayliff) is presented in Figure 1.

The land uses within the town of Mount Ayliff are predominantly commercial and residential, some parts of the town on the outskirts are being utilised for industrial purposes but some of the land uses are illegal and do not comply Land Use scheme which is the town planning legislation used for the development of eMaxesibeni Town. The Umzimvubu Integrated Development Plan (2023/2024) estimates that of that 95% of the population of the municipality reside in rural spaces with the rest (5%) in the two urban centres of KwaBhaca (15 444 people) and eMaxesibeni (6 618). The 6,618 people are the direct beneficiaries of the urban regeneration and small towns revitalisation project.

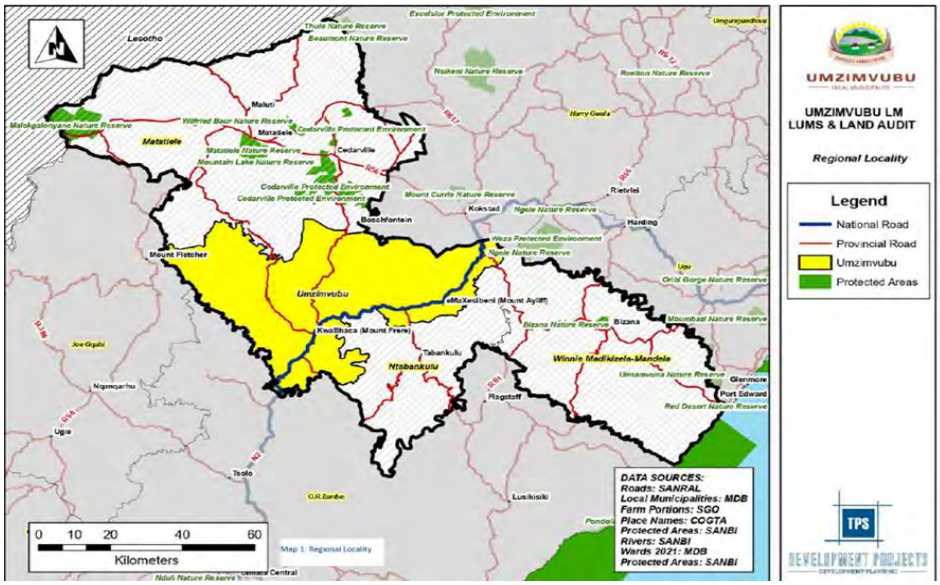


Figure 1: Locality map of eMaxesibeni Town, Source: Umzimvubu Local Municipality STR proposal

3. Project Implementation and Impact

3.1 Upgrading of eMaxesibeni Town Streets and Walkways

The project entailed upgrading the general landscape along Main Street and the adjoining Streets, modernisation of intersections and street furniture. The total length of roadway upgraded is 1.6km. The upgrading of the streets included concrete block paving of sidewalk areas from the edge of the road carriageway to adjacent boundary fence or commercial building veranda, installation of new concrete kerbs and stormwater drainage channels, and installation of PVC pipe sleeve for optical fibre service cables and construction of traffic circles at two four-way intersections in Main Streets. The roadway of all streets identified for the upgrade is currently surfaced with asphalt and walkways paved ensuring mobility and walkability of the town.

Figure 2: Upgrading of eMaxesibeni streets and walkways. Source: Own Compilation

3.2. Construction Of eMaxesibeni Transportation Hub

The site identified for the transport Hub is located within the eMaxesibeni Town in Ward 28 of Umzimvubu Local Municipality. The site is located approximately 260m from the core activity area of the eMaxesibeni Central Business District. The entire site was a greenfield before the construction. The site development included the construction of formal hawker stalls, workshops for mechanics, and bus and taxi ranks. This project is expected to boost the local economy of the town as it provides over 100 formal trading spaces for small businesses.

Figure 3: eMaxesibeni transportion Hub: Source own compilation

3.3 Upgrading of eMaxesibeni Cemetery

EmaXesibeni Cemetery is located at coordinates 30o 48’ 31’’ (S) and 29o 22’ 31’’ (E). The nearest town to the project site is eMaxesibeni (Mount Ayliff), within which the project is located and is approximately 1km (drive distance) from the eMaxesibeni CBD. EmaXesibeni Cemetery covers an area of 40 100 square metres (4 hectares) and only 2 000 square metres (0.2 hectares) or 5% is used. There are no public building amenities at the cemetery. The scope of the project included building structures and road works including stormwater drainage channels. The buildings proposed for the upgrade of the cemetery included a Guardhouse and Ablution Block. Due to budget limitations, the construction of the Administration Block has been placed on hold but has already been incorporated in the project design and design drawings.

The civil works proposed for the upgrade of the cemetery included surfacing of the main external access road, re-construction and gravelling of an auxiliary gravel access road, provision of external parking, reconfigurationnd rehabilitation of existing concrete block paved internal driveways and provision of stormwater drainage control channels

Figure 4: Upgrading of eMaxasibeni Cemetery. Source: Own Compilation.

4. Future proposal and recommendations

Addressing past spatial injustices in eMaxesibeni Town through the use of tools such as small-town revitalisation and urban regeneration initiatives presents a framework for sustainable socio-economic development within urban planning. Key proposals incorporate, community hubs that are multifunctional in terms of integrating social services such as access to basic education, health care systems, economic opportunities and social spaces. This approach improves the accessibility of social services and reduces the dependency of eMaxesibeni town on larger cities like Kokstad, Margate and Port Shepstone. The over-reliance on neighbouring major cities has largely contributed to the economic decline of small rural towns like eMaxesibeni.

Furthermore, the introduction of mixed-use zones in the CBD and the promotion of affordable housing closer to commercial activities will reduce spatial segregation and thereby encourage socioeconomic diversity in the town. It is proposed that the municipality consider improving public transportation infrastructure that will link the eMaxesibeni town with the surrounding communities it serves. Additionally, it is proposed that the municipality integrate digital and smart technologies such as GIS-Based tools to assist in decision-making for future urban development and monitoring of spatial disparities within the area. Improvements in the agricultural sector and local economic development within the municipality are still required because this is the primary economic sector which will contribute to the economic growth of the town. These proposals and recommendations focus on restructuring eMaxesibeni town's urban landscape and ensuring that the town is more sustainable, resilient, efficient and inclusive.

5. References

Bundy, C., 2020. Poverty and Inequality in South Africa: A History, in: Oxford Research Encyclopedia of African History. Oxford University Press. https://doi.org/10.1093/acrefore/9780190277734.013.659

Cysek-Pawlak, M.M., Pabich, M., 2021. Walkability – the New Urbanism principle for urban regeneration. J. Urban. Int. Res. Placemaking Urban Sustain. 14, 409–433. https://doi.org/10.1080/17549175.2020.1834435

Liao, Z., Liu, M., 2023. Critical barriers and countermeasures to urban regeneration from the stakeholder perspective: a literature review. Front. Sustain. Cities 5, 1115648. https://doi.org/10.3389/frsc.2023.1115648

Mthiyane, D.B., Wissink, H., Chiwawa, N., 2022. The impact of rural–urban migration in South Africa: A case of KwaDukuza municipality. J. Local Gov. Res. Innov. 3. https://doi.org/10.4102/jolgri.v3i0.56

Setianto, M.A.S., Gamal, A., 2021. Spatial justice in the distribution of public services. IOP Conf. Ser. Earth Environ. Sci. 673, 012024. https://doi.org/10.1088/1755-1315/673/1/012024

Shmaryahu-Yeshurun, Y., 2024. Gentrifiers of Color: Class Inequalities in Ethnic/Racial Neighborhood Displacement. J. Am. Plann. Assoc. 90, 434–451. https://doi.org/10.1080/01944363.2023.2251981

Tallon, A., 2020. Urban Regeneration in the UK, 3rd ed. Routledge, Third edition. | Abingdon, Oxon ; New York, NY : Routledge, 2021. https://doi.org/10.4324/9781351030304

Research Paper

Research on Rural Revitalization Planning from the Perspective of Youth Friendship

-- Taking Nuanshui Town as an Example

PENG Siwei, Southeast University, China
WANG Xingping, Southeast University, China

Abstract

Against the backdrop of a long-standing urban-rural dual system oriented towards urban growth, the issue of rural decline has become increasingly prominent. Coordinating urban-rural relations through rural revitalization to achieve Chinese-style modernization has emerged as a crucial topic in contemporary China. As China's urbanization process advances, production factors such as land and capital continue to flow into cities, leading to a sustained outflow of rural population. Insufficient talent pool, structural imbalance, low quality, and aging have become common phenomena in rural areas. In particular, the loss of young talent stands out as the most pressing issue in rural development, attracting increasing attention from institutions and scholars alike. Based on this, the study takes a youth-friendly perspective as its entry point, using Nuanshui Town as a typical case, and proposes a "4+9+N" development framework to support youth development through innovation, entrepreneurship, growth, and cultural support. The aim is to establish a long-term mechanism for youth participation in rural revitalization. This research holds positive significance for enriching the theoretical framework of rural revitalization planning and for practicing rural revitalization planning from the perspective of youth development.

Keywords

Youth Friendship; Rural revitalization; Nuanshui Town; Sustainable development

1. Introduction

In the context of the long-term urban-rural dual system oriented towards urban growth, the issue of rural decline has become increasingly prominent. Coordinating urban-rural relations through rural revitalization to achieve Chinese-style modernization has become an important issue in China today. With the advancement of China's urbanization process, production factors such as land and capital continue to flood into cities, causing a continuous outflow of rural population. Insufficient talent, structural imbalance, low quality, and aging have become common phenomena in rural areas. In particular, the loss of young talents has become the most prominent issue in rural construction, which is attracting more and more attention from institutions and scholars. However, current research on rural revitalization in the planning academic community mainly focuses on areas such as land supply, financial security, and industrial development.

Research on how to attract young talents to return to their hometowns to start businesses through planning, thereby promoting rural revitalization, is still blank. It ignores that young talents may become the main force of rural revitalization and the sustained, universal, and proactive driving force for urban-rural integration.

2. Literature review

In 1965, the United Nations General Assembly adopted the first global youth policy, the "Declaration on the Promotion among Youth of the Ideals of Peace, Mutual Respect, and Understanding between Nations." This was followed by the adoption of several related documents, including the "World Programme of Action for Youth to the Year 2000 and beyond" (1995), the "Lisbon Declaration on Youth Policies and Programs" (1998), and the "Bucharest Youth Action Plan" (1998). The "UNDP Youth Strategy 2014-2017" was the first to emphasize the strategic importance of "enhancing youth empowerment for sustainable development," highlighting the crucial role and transformative power of youth in urban development, which has since attracted widespread attention from various sectors. Notably, after 2000, many cities worldwide explicitly adopted youth-friendliness as a strategic direction, actively creating an urban environment that prioritizes youth development. Vancouver's "Youth-Friendly City Strategy 2006" aimed to establish "a resilient, safe, capable, and livable city," while Brisbane incorporated youth-friendly city development as part of its "Youth Strategy 2014-2019," envisioning "young people becoming healthy, valuable, resilient, and confident citizens who actively contribute to a better Brisbane."

Scholars have also demonstrated significant interest in the development and construction of youth-friendly cities, conducting extensive research in this area. Hyojin Nam and Seok In Nam (2018) analyzed South Korea's child-friendly city policies based on six key elements: objectives, forms of welfare and services, eligibility rules, management and delivery, financing, and interaction. This research provided institutional improvement suggestions for cities interested in joining the UNICEF Child-Friendly Cities Initiative. Aboma Motuma, Thomas Syre, and Gudina Egata (2016) conducted empirical studies on youth-friendly services in Ethiopian towns. Zheng Degao, Yan Yan, and Liao Hang (2022) evaluated the level of youth-friendliness in 55 key cities in China, offering insights for systematically advancing youth development-oriented cities. However, most research has concentrated on urban youth development, with relatively little exploration into promoting rural youth development and integrating it with rural revitalization.

This study, which draws from the view of youth and the nature of rural revitalization, investigates the significance of and mechanism of planning in order to encourage the youth to participate in rural revitalisation, and it is based on the view that rural revitalisation planning is done from a young perspective and that, in order to support and enrich the theoretical framework of rural revitalisation planning, it will be helpful to assist the formulation of relevant policy.

3. Methods

This study adopts research methods such as case study and field research, taking Nuanshui Town as a typical case to explore rural revitalization planning strategies from a youth-friendly perspective. It delves into the role and mechanism of planning in guiding youth participation in rural revitalization. In addition, to increase the readability of this paper, the AI tool (Wenxin Yiyan) was utilized in the section on translation, proofreading, and polishing.

3.1 Case Study Method

This study takes Zhungeer Banner in Inner Mongolia as a typical case and adopts a youth-friendly perspective as the entry point to conduct an in-depth analysis of the issues and challenges present in rural revitalization planning. It clarifies a reasonable path for planning to guide youth participation in rural revitalization and attempts to propose a long-term mechanism for planning and fostering youth involvement in rural revitalization.

3.2 Field visits, interviews, and meetings

This study employs the field research method, conducting in-depth interviews with the government of Nuanshui Town and villagers from various villages, and carrying out on-site inspections of the actual development situations of these villages. It assesses the rural development of Nuanshui Town from different dimensions including population, society, economy, and environment, with a focus on youth development. This assessment provides support for proposing a long-term mechanism for planning and fostering youth involvement in rural revitalization.

4. Case study: Nuanshui Town

4.1 The Development Background of Rural Revitalization in Nuanshui Town

Nuanshui Town is located in the western part of Zhungeer Banner, Inner Mongolia Autonomous Region, China, and in the central part of the important coal mine source area in western Inner Mongolia Autonomous Region and northern Shaanxi province. It is a typical resource-based area. Nuanshui Town is a severely exposed area of arsenic sandstone, and this special geological condition is one of the main factors leading to soil erosion and Yellow River flood disasters in China. In response to this, since 2009, Nuanshui Town has been identified by the Chinese government as a pilot town for the construction of an ecological natural restoration area. Ecological migration work is carried out in units of entire communities or natural villages, aiming to restore the ecological environment. As of the end of 2021, the vegetation coverage of the entire town has reached more than 85%, indicating that ecological management has achieved certain results. However, the basic underdeveloped situation of Nuanshui Town has not been fundamentally changed, and some prominent issues such as the separation of people and production and the separation

of people and land have not been resolved. The severe loss of young talents, the lack of living security for villagers who have left the village, and the lack of effective utilization and development of relevant ecological resources by talents in the village have become the main problems facing the development of Nuanshui Town.

By 2022, Nuanshui Town had a permanent population of 6,857, with 3,149 youth aged 14 to 35 accounting for 45.9% of the total. Accelerating its modernization amidst ecological migration, Nuanshui Town faces a notable decrease in its permanent population, accompanied by prominent issues of person-household separation and person-land separation. Youth, as the primary force in the employed and mobile populations, are increasingly concentrating in Xuejiawan Town, the core area of Zhungeer Banner, exacerbating the trend of population outflow from Nuanshui Town. In terms of youth population proportion, the four administrative villages of Changhansu, Deshengyouliang, Nuanshui, and Yushuhao have significantly higher youth populations than the town average.

Although Nuanshui's youth enjoy a solid foundation for development, there are still issues that require attention: The enthusiasm of youth to participate in rural revitalization and engage in entrepreneurship and innovation needs further stimulation. Policies and social environments that encourage youth entrepreneurship and innovation must be continuously optimized. Pressures related to housing, social integration, external communication, and social security persist for youth to a certain extent. The social mechanisms for coordinating youth development work need further improvement, and greater synergy is required to promote youth development.

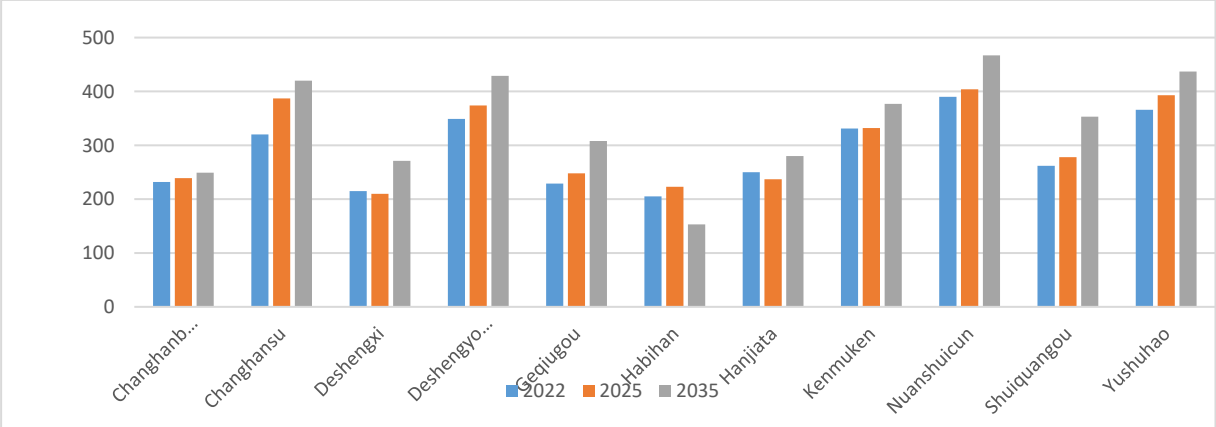


Figure 1: Statistical Analysis of Youth Population Changes in Each Village of Nuanshui Town (2022 -2035). Data source: Provided by the Nuanshui Town Government.

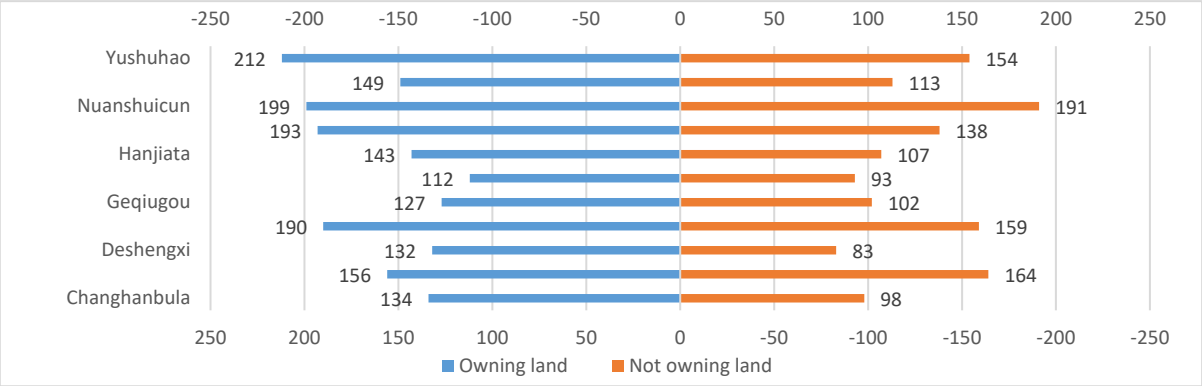


Figure 2: Statistics on Whether Youth in Each Village of the Nuanshui Town Have Farmland in 2022. Data source: Provided by the Nuanshui Town Government.

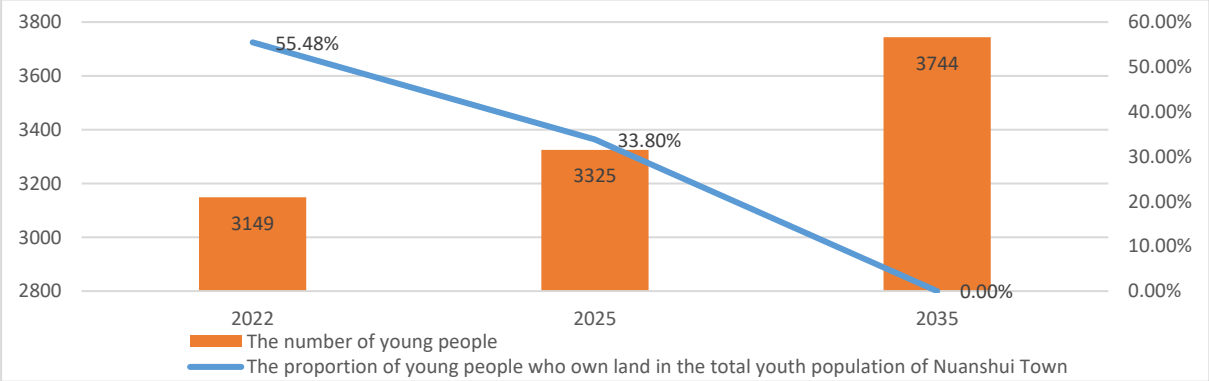


Figure 3: Statistical Analysis of Changes in the Youth Population and the Proportion of Land-Owning Youth in Nuanshui Town (2022-2035). Data source: Provided by the Nuanshui Town Government.

Focusing on the overall economic and social development goals of Ordos, Zhungeer Banner, and Nuanshui Town, as well as the relevant requirements for youth development work, and taking into account the actual situation of youth development across the town, the following development goals have been established: By 2025, a policy system and working mechanism tailored to Nuanshui Town's economic development and conducive to youth development will be basically established, with an application to pilot a national youth development-oriented town. By 2035, the policy system, working system, and guarantee system for youth development will be further improved, achieving an organic integration of high-quality development for both youth and Nuanshui Town. A national youth development-oriented town with unique Nuanshui characteristics will be established.

Nuanshui Town should leverage its Rural Revitalization Workstation as a platform, centering on the development needs of "youth entrepreneurship participation in the advancement of rural revitalization" and "youth social participation in the revitalization of rural culture". By utilizing functions such as innovation and entrepreneurship platforms, internship and practice bases, rights and interests' protection, rural cultural development, and supporting policy systems, the town should actively introduce resources from universities and colleges to gather resources for educational internships and training, employment and entrepreneurship guidance, and youth volunteer services. At the same time, it should actively provide

supporting measures such as housing and career development for youth, education and childcare, dating and friendship, as well as healthcare and pension services, to guide youth in engaging in internships, practices, training, as well as entrepreneurship, innovation, and creative work.

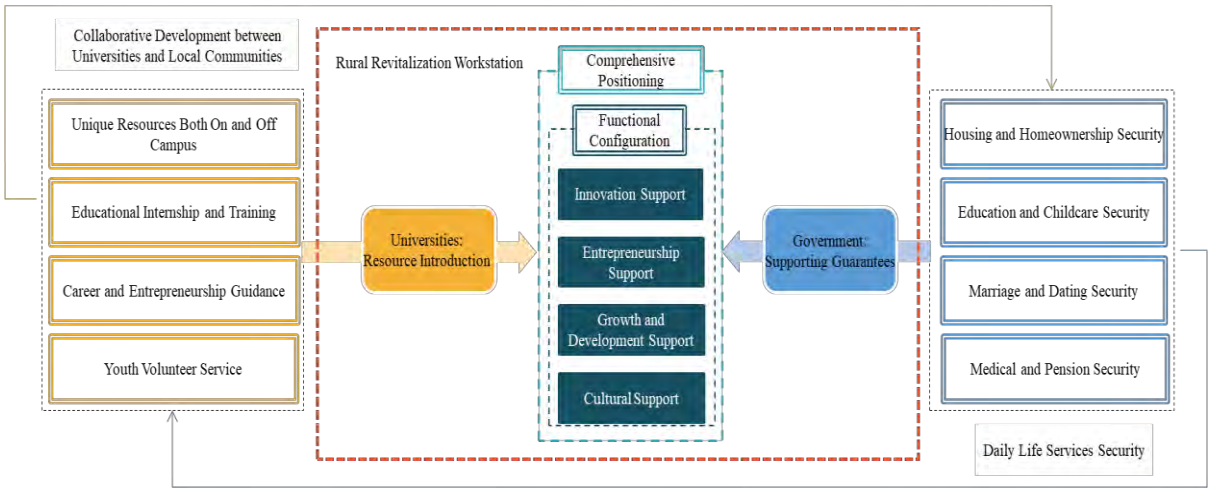


Figure 4: Working Mechanism of the Rural Revitalization Workstation in Nuanshui Town. Image Source: Self-drawn

4.2 Practice Path for Rural Revitalization Planning from the Perspective of Youth Friendship

Promote four major projects, implement nine plans, and introduce N youth development policies to construct a systematic, pragmatic, and inclusive "4+9+N" youth work system, optimize the environment for youth growth, and promote comprehensive youth development.

1) Innovation Support

Promote the further improvement of the youth entrepreneurship service system, significantly enhancing the vitality of entrepreneurial innovation. Strengthen the coordination and integration of employment and entrepreneurship policies with economic policies such as industry, finance and taxation, and financial policies, as well as social policies related to talent, education, and social security. Implement a new agricultural assistance program, encouraging youth participation in the construction of local government-village collective-joint venture systems, fostering rural youth leaders in achieving prosperity, modern youth farm (forestry) owners, and agricultural professional managers, and strengthening support services for returning youth entrepreneurs. Launch a science and technology innovation leadership program, attracting talents and intelligence according to the needs of the fruit and forestry industry base in Nuanshui Town, ensuring that externally recruited talents can come and stay. Implement a cultural creativity post program, establishing youth cultural posts relying on rural revitalization workstations, supporting the construction of the Nuanshui Town cultural brand in the new era, and participating in the protection of Nuanshui Town cultural relics. Optimize talent security and retention environments, streamline entrepreneurial procedures, improve talent incentive mechanisms, increase financial support for innovative talents and entrepreneurial

teams, and establish a comprehensive distribution and incentive mechanism dominated by performance and market forces, including human capital and technology as equity stakes. Provide high-standard talent security services for youth in Nuanshui Town, offering various living guarantees to eligible college graduates. Leverage various media and platforms to promote youth employment and entrepreneurship support policies and typical figures in multiple forms and directions, fostering a favorable atmosphere for youth innovation and entrepreneurship.

2) Entrepreneurship Support

Promote a more diversified range of employment services for youth, a more comprehensive service system, more adequate protection of youth employment rights, and more flexible employment support policies. Strengthen employment-first policies, improve the public employment service system, and advance the informatization of youth employment services, providing young people with diversified services such as career guidance, job recommendations, and employment assistance. Implement talent training and practical training programs, based on the needs of industrial development, to enhance the cultivation of new-type professional farmers, rural practical talent training, and vocational skills training. Actively cultivate and apply for a batch of employment internship and apprenticeship bases. Implement employment promotion and internship plans, organize recruitment activities for young talents, carry out centralized investigation and resolution of labor disputes involving young workers, and improve the employment support system for urban and rural employment-challenged individuals. Actively implement subsidies and incentive policies such as guaranteed loans for entrepreneurship, interest subsidies, and subsidies for public welfare positions to promote employment and entrepreneurship, facilitating full employment for key groups such as college graduates, veterans, children of low-income farmers, rural junior and senior high school graduates who have not continued to higher education, unemployed youth, and young people with disabilities. Implement scientific, educational, and popular science practice plans, focusing on distinctive geological resources, and in combination with ongoing scientific research projects at universities, deeply promote the integration of science education, popular science, and cultural tourism. Improve mechanisms for protecting the employment and labor rights and interests of young people, and intensify efforts in labor protection supervision and law enforcement, labor and personnel dispute mediation and arbitration, and safety production supervision and inspection.

3) Growth and Development Support

Efforts should be made to fully implement laws, regulations, and policies related to the development of young people. This includes thoroughly enforcing the laws on the protection of minors, the prevention of juvenile delinquency, and other legal regulations concerning the rights and interests of young people in areas such as education, health, employment, entrepreneurship, and social security. Enforcement inspections should be intensified to effectively safeguard the healthy growth and social security of young people, as well as their legal rights and interests. It is crucial to stay informed about the development of youth and to analyze their current conditions, promoting the resolution of practical difficulties and pressing issues faced by young people. Combining legal education and publicity with legal services, we should

encourage the active participation of youth social organizations and social workers in youth affairs to protect the rights and interests of young people. Special attention should be given to vulnerable youth groups, such as those in difficult circumstances, migrant youth workers in cities, and their underage children, to ensure their care and rights protection. There should be a strong crackdown on actions that infringe upon the legal rights and interests of young people, including severe penalties for crimes such as trafficking, sexual assault, abandonment, and abuse of minors. Comprehensive law enforcement in the online sphere should be strengthened to severely punish all types of online crimes involving young people. Implement public welfare actions for family education and organize diverse summer camp activities to encourage youth to pursue education, enhance the educational level of young farmers, improve lifelong learning systems, and promote the integration and connection of vocational education with general education, academic education with non-academic education, and pre-employment education with post-employment education. Innovate in the selection, training, evaluation, appointment, and incentive mechanisms for young talent to provide a larger platform and more opportunities for various young talents. Strengthen social assistance for young people, offering poverty relief, medical aid, rights protection, educational grants, employment training, and psychological counseling to young people from families in difficulty who are orphaned, ill, wayward, out of school, unemployed, or unsupervised.

4) Cultural Support

Continuously expand the ranks of young cultural talents and focus on strengthening the creation of cultural masterpieces. Improve and perfect the public cultural service system, enhance the participation of young people in cultural activities, and continuously promote the construction of cultural warmth and the development of the cultural industry and undertakings for young people. Support young people in participating in social practice and public welfare services, highlight the role of young social organizations, attract and encourage young people to widely participate in various social services, steadily cultivate a backbone force of young volunteer services, and promote young people's deep participation in community governance. Guide young people to participate orderly in political life and public affairs, encourage young people to participate in grassroots mass self-governance in urban and rural areas, actively guide young people to participate in public affairs of cities and communities, regularly hold warm water youth interviews and youth representative forums, understand the main difficulties and problems faced by young people, provide feasible help, and enhance the sense of belonging among young people. Enrich young people's cultural activities, vigorously promote the display and exchange of excellent traditional culture and arts, guide young people to actively participate in the protection of cultural heritage, the revitalization of traditional crafts, and the inheritance of folk literature and art, lead the network culture, and improve the supply and dissemination capabilities of excellent network cultural products. Improve the cultural service system for young people, timely grasp the dynamic changes in the cultural needs, concepts, and trends of young people, guide and instruct young people's cultural practices, encourage and support various cultural units to carry out cultural activities and provide cultural services for young people for free or at a low cost, and enhance the service functions for the young people's group. Enhance the exchange and integration of

different young people's groups, and enhance the political identification and social participation of groups such as new generation of migrant workers, young entrepreneurs, backbone of young social organizations, young new media practitioners, and young freelance professionals.

5. Conclusion

The future belongs to the youth, and hope is vested in them. This study takes Nuanshui Town as an example to explore rural revitalization planning from a youth-friendly perspective. Under the long-term urban growth orientation, rural areas are facing issues such as population outflow, talent shortage, and aging, especially the loss of young talent, which has become a key bottleneck for rural development. As a typical resource-based area, Nuanshui Town has achieved certain successes in ecological restoration, but the loss of young talent and the effective utilization of ecological resources remain the main challenges it faces.

The study believes that the planning academia should pay more attention to how to attract young talent to return to their hometowns for entrepreneurship and innovation to promote rural revitalization. Young talent is not only the main force of rural revitalization but also an important force in promoting urban-rural integration. Starting from a youth-friendly perspective, this study deeply analyzes the problems and challenges in rural revitalization planning and proposes planning pathways and long-term mechanisms to guide youth participation.

Through empirical research on Nuanshui Town, this study has put forward a series of targeted strategic recommendations aimed at building a planning system that can attract young talent and promote their participation in rural development. These recommendations include providing guarantees for living services, improving educational and medical conditions, and optimizing housing and employment environments, in order to create a more youth-friendly living environment in rural areas.

The conclusion points out that youth-friendly rural revitalization planning can not only enrich and improve the existing theoretical system but also provide strong support for policy-making. It has important practical significance for achieving sustainable rural development and coordinating urban-rural relations. The implementation of these strategies can effectively promote the return of young talent, stimulate the innovative vitality of rural areas, and promote the in-depth implementation of the rural revitalization strategy.

6. References

Xiang, Y.P. (2021). Research on the Internal Mechanism and Dynamic Mechanism of Rural Tourism Driving Rural Revitalization. Hunan Social Sciences, (02), 41-47.

Zhu, D.Q., & Shi, X.J. (2021). Technical Logic and Value Orientation of Vocational Education Serving Rural Revitalization. China Educational Technology, (01), 41-49.

Tang, H.T., & Li, S.N. (2020). E-commerce, Poverty Eradication, and Rural Revitalization: Roles and Paths. Journal of Guangdong University of Finance and Economics, 35(06), 65-77.

Xu, W.X., Li, L., Zhou, J.P., et al. (2020). Dynamic Evolution and Driving Mechanism of Coupling Coordination between Rural Revitalization and New Urbanization. Journal of Natural Resources, 35(09), 2044-2062.

Motuma, A., Syre, T., Egata, G. et al. (2016). Utilization of youth friendly services and associated factors among youth in Harar town, east Ethiopia: a mixed method study. BMC Health Serv Res 16, 272. https://doi.org/10.1186/s12913-016-1513-4

SONG,, JONGMOO; Yoo, Jeanie. (2024). Analysis of types of Youth-friendly spaces. YOUTH FACILITIES AND ENVIRONMENT. 22(2): 24-31. DOI10.55063/KIYFE.2024.22.2.3

Young-Hee Lee, Mi-Na Lee. (2014). A Study on the Development of Indicators for the Youth- Friendly Community. Journal of Korean Council for Children & Rights. 18(4): 575-600

Kegler, MC ; Oman, RF ; Vesely, SK ; McLeroy, KR; Aspy, CB ; Rodine, S ; Marshall, LD.(2005). Relationships among youth assets and neighborhood and community resources. HEALTH EDUCATION & BEHAVIOR. 32(3): 380-397. DOI10.1177/1090198104272334

Kusumawardani, E; Septiarti, SW. (2019). Youth involvement: Empowerment effort through child-friendly village program. MASYARAKAT KEBUDAYAAN DAN POLITIK. 32(2): 209-216

Geary, RS; Gómez-Olivé, FX; Kahn, K; Tollman, S; Norris, SA.(2014). Barriers to and facilitators of the provision of a youth-friendly health services programme in rural South Africa. BMC HEALTH SERVICES RESEARCH. 14:259. DOI10.1186/1472-6963-14-259

Littman, DM. (2024). Practices and settings which promote a psychological sense of community among young people who experience social marginalization: A scoping review. CHILDREN AND YOUTH SERVICES REVIEW. 161: 107620. DOI10.1016/j.childyouth.2024.107620

Kim, HeeJoo; Seo, Jeong A.(2020). A Case Study of ChildÂ·Youth Friendly Cities Development. The Journal of the Korea Contents Association. 20(3): 584-599. DOI10.5392/JKCA.2020.20.03.584

Zhu, F. (2018). Research on Policy Innovation of Youth-Friendly Cities in "New First-Tier Cities" [J]. China Youth Study, (06), 78-85. DOI: 10.19633/j.cnki.11-2579/d.2018.0094.

Zhu, F., Zhang, J., & Yi, Y. (2019). Causes of the Rise, Evaluation Strategies, and Lessons from Youth-Friendly Cities in Developed Countries [J]. Journal of Youth Studies, 2(71-80).

Yan, Z. (2022). Theoretical Connotation, Functional Characteristics, and Index System Construction of Youth-Friendly Cities [J]. China Youth Study, (05), 5-12. DOI: 10.19633/j.cnki.11-2579/d.2022.0066.

Zhu, F., & Shan, Y. (2018). Human-Centered New Urbanization and Youth Development in the New Era [J]. Youth Development Forum, 28(04), 3-17.

Duan, Z., Meng, X., & Hao, W. (2023). Research on the Construction Path of Youth-Friendly Cities from the Perspective of Talent Ecological Environment: Based on Fuzzy Set Qualitative Comparative Analysis [J]. Human Resource Development of China, 40(04), 107-122. DOI: 10.16471/j.cnki.11-2822/c.2023.4.008.

Zheng, D., Yan, Y., Liao, H., et al. (2022). Research on Urban Planning and Construction Evaluation from the Perspective of Youth Development [J]. Urban Planning Forum, (S2), 33-39. DOI: 10.16361/j.upf.202208005

Xu, H., Hua, C., & Li, Y. (2022). Construction of Youth Development-Oriented Cities: Research on the Planning Path for Social Vitality Regeneration in Old Communities [J]. Urban Planning Forum, 3, 96-101.

Li, J., & Chai, M. (2022). Research on the Construction of Youth Innovation-Oriented Cities and Index System: Based on the Practical Exploration in Guangzhou [J]. Youth Exploration, 2, 69-79.

Liao, Q., Zhang, M., He, G., et al. (2022). Evaluation of Urban Policy Environment for Promoting Youth Development [J]. China Youth Study, 5, 13-20.

Chen, Y. (2022). New Talent Policies in Non-First-Tier Cities and the Realization of Population Agglomeration Vision [J]. Jiangxi Social Sciences, 42(4), 196-205.

Zhou, Y. (2020). Demographic Characteristics and Formation Reasons of China's "Post-90s" Generation [J]. China Youth Study, 11, 43-51.

"Wenxin Yiyan" AI Tool. (n.d.). Used for translation, proofreading, and polishing in this paper. Retrieved from https://yiyan.baidu.com/chat/Njg1MjgzMTg4OjQ4NTYwMDIzMTI= January 29, 2025

Case Study Report

Traditional to Contemporary: Study on Inheritance and Transformation of Chinese Covered Bridge Culture Heritage from a Spatial Connectivity Perspective

Xijia SUN, Southeast University, China
Xiangfeng LI, Southeast University, China
Rui HOU, Tsinghua University, China

Abstract

In both historical and contemporary contexts, most Bridges exist independently as part of transportation and landscape systems, rather than as components of urban and rural environments. However, the ancient Chinese covered Bridges from the very beginning demonstrated a wisdom of connection rather than isolation. As a carrier integrating multiple spatial elements such as place, scene, person and object, the corridor bridge not only reflects the history, culture and spirit of the designer and user, but also presents new forms and meanings by absorbing the development of society, technology and art.
This paper examines the similarities and differences in form and function between contemporary covered Bridges and traditional Chinese covered Bridges in integrating urban and rural spatial pattern. In addition, from the perspective of spatial connectivity, this paper analyzes the inheritance and transformation of the cultural heritage of traditional covered Bridges by contemporary covered Bridges through case studies, providing insights for urban renewal and the design of covered Bridges structure and space.

Keywords

Covered bridge, Legacy, Connectivity, Regeneration

1. Starting: The Differences Between Contemporary and Covered Bridges

1.1. Two types of contemporary bridges

Urbanization-driven construction is spreading across the globe. In both historical and contemporary contexts, most bridges exist independently in transportation and landscape systems, not just as components of urban and rural living environments.

For example, the Golden Gate Bridge in San Francisco, and the BP Bridge (Pedestrian Bridge) in Millennium Park, respectively, exhibit two purposes of use, one is a bridge for traffic and traffic, and the other is for landscape or scenery.

From this perspective, architecture is seen as a distinct object with a clear boundary, drawing a line from the land and posing a risk of alienation from the environment (Hensel, M., 2021).

1.2. Background: The Chinese covered bridges

However, China's covered bridges have a long history, and from the very beginning showed a sense of connection rather than isolation, which has had a wide influence in East Asia. As a carrier integrating multiple spatial elements such as land, landscape, people and objects, covered bridges not only reflect the spirit of history and culture, builders and users, but also absorb the development of society, technology and art, presenting new forms and meanings (Bi, S., 2003).

This photo shows one of the oldest existing wooden Bridges in China, called Zhiqing Bridge, built during the Ming Dynasty, 1470 to be exact, in Fujian Province. The bridge is intricately designed and exquisitely crafted, with Spaces for rest and shrines inside, and features caissons and supports. It is made entirely of mortise and tenon joints, without a single nail, and its decoration is very beautiful (Dai, Z.J, 2012). This combination is very rare in existing covered bridges.

Figure 1. One of the oldest existing wooden covered bridges in China. Source: Chinese National Geography.

This paper focuses on traditional and contemporary covered bridges. Through case studies and comparisons, it can be found that in the past decade, contemporary covered bridges inherited and developed many aspects of traditional covered bridges, including their connection, forms, and functions. This provides new insights and ideas for future planning and design.

2. Approach: 4 Main Characteristics of Chinese Covered Bridge

A bridge is a structure built over water or in the air to facilitate passage. With the development of technology and art, Chinese bridges evolved into beam bridges, arch bridges, suspension bridges and other types (Jiang, Y., 2010). Different forms emerged, such as covered bridges with pavilions on their decks. On both sides of the bridge there are auxiliary buildings such as gatehouses and archways.

The covered bridges studied here are broadly bridges with buildings or corridors and pavilions on their decks, representing a combination of architecture and bridge engineering (Liu, Y., 2022).

Traditional Chinese covered bridges in Fujian, Zhejiang, Hunan, Guangxi, and Anhui Provinces in China, for example, were born in the complex terrain to meet traffic and daily needs. Over time, a unique theoretical system has been formed in terms of location, layout, function, and form.

This can be summarized into 4 main characteristics: Regional Integration, Functional Versatility, Formal Structure, and Sense of place.

2.1. Regional integration

The most primitive bridges were built to overcome the challenge of crossing land gaps. The construction of a bridge first requires determination of the exact positions of the abutments and the direction, which is crucial for its durability and stability of the bridge. Ancient China developed theories about site selection and layout, which can be called Feng Shui.

In Chinese Feng Shui theory, the ideal settlement area for water to enter is called a "Shui Kou (water gap)," and is usually located at mountain bends, between two mountains, or surrounded by streams(Zhu, Y.C., 2015). Most of the covered bridges are built in Shui Kou space of towns and villages, which defines the entrance and is an important passage.

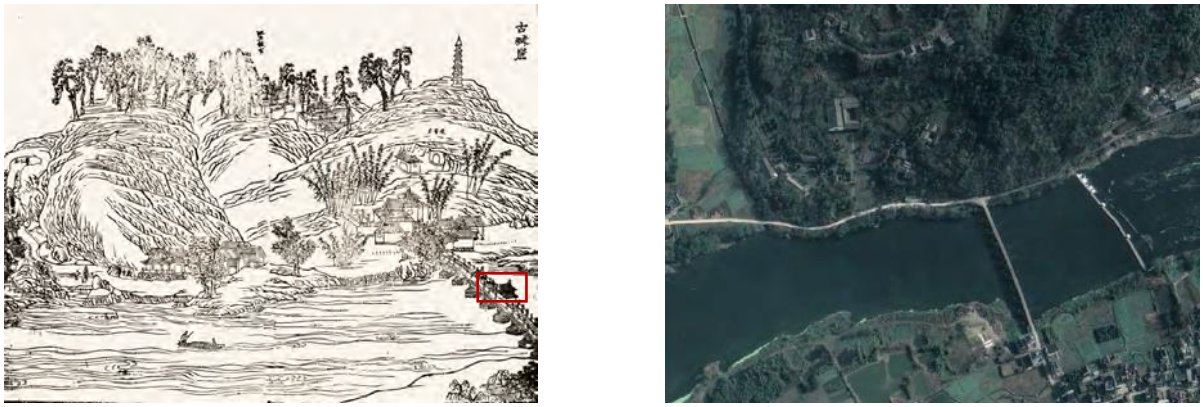


Figure 2. Drawing of Shui Kou of Ancient Rock City(left) and satellite image(right).

Source: Woodcut from the Xuning County Annals, Qing dynasty(left); Google map(right).

Figure 2 shows a woodcut published during the reign of Kangxi in the Qing dynasty. It depicts “Shui Kou” of Ancient Rock City, located along the Heng River, one of the important waterway of ancient Huizhou.

It also shows a stone bridge with a pavilion connecting the north and south coasts and integrating various elements of the ancient city and village in a "natural order."

2.2. Functional versatility

Chinese traditional covered bridges show versatility, combining practical, cultural, and spiritual elements. In ancient Huizhou city, covered bridge at Shui Kou space has many functions such as flood control, fire protection, sacrifice, entertainment, defence, trade and so on. Of all these functions, defence and surveillance are particularly important.

The Shui Kou often overlaps with the village entrances, or is located at the traffic artery. Their planning usually integrates the topography and landscape, connecting pavilions, buildings, towers, archways, to create spatial structure that mix points, lines, and surface (Zhu, Y.C., 2013). Covered bridges are the key elements of these flow lines.

As shown in figure 3, this is a drawing of the Fangxi Shui Kou of Xu Village, and the section from GaoYang Covered Bridge to the Wuma Archway presents a linear space. The stone beach beside the Fangxi Stream forms a flat space. Further ahead, there are two node spaces. Beyond this is the open Wuma Archway, which creates a

layered spatial sequence at the entrance to the village. It also enhances the sense of territory and privacy (Wang, Y., 2020).

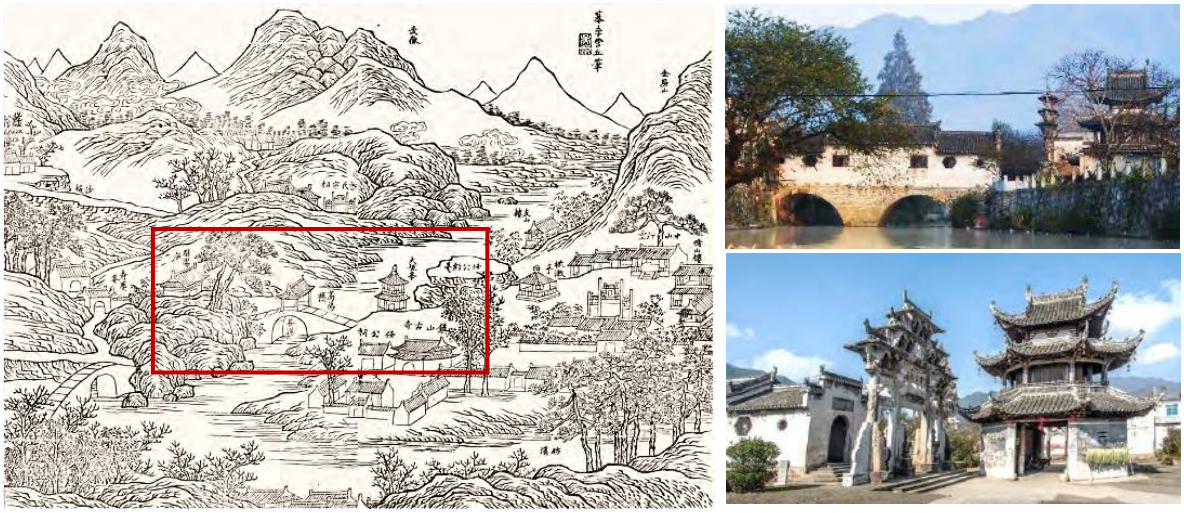


Figure 3. Drawing(left) and photos(right) of Shui Kou of Fangxi in Xu Village. Source: From the Internet.

In the overall layout of many historical towns in Fujian and Anhui provinces, the Shui Kou space is often regarded as the "gateway" or entrance of the village. The distance between the Shui Kou and the ancient village is related to the geographical location and size of the village. Taking ancient villages in Huizhou, Anhui province as an example, the Shui Kou space was usually kept at a certain distance from the main residential areas and adjustments accordingly. There are two types: for smaller villages or towns, the Shui Kou serves as entrance to the village. For larger villages or villages do not pass through the water system, the Shui Kou and the village entrance are separated and there is a certain distance between the two (Wang, Y. 2020). The Shui Kou space is generally organized by multistorey buildings, as a monitoring and preventive measure, but also a buffer against external aggression, and plays a vital role in the organization and hierarchy of the region.

2.3. Formal construction

Traditional Chinese wooden bridges and buildings have a common origin. Compared to other types of buildings, bridges clearly demonstrate their structural systems and mechanical relationships, conveying an unique sense of strength, stability, and craftsmanship. They are buildings that take into account location, functional requirements and other factors, resulting in an integrated approach to structural design and form shaping (Ma, H., 2006). The common structural forms of covered bridges include beam bridges and arch bridges.

Take Yanzi Bridge in Anhua, Hunan Province (FIG. 4) as an example, it is a representative wooden beam covered bridge in traditional Chinese architecture (Xie, L.,2023). Its construction system can be summarized into four parts: piers, spans, decks, and bridge houses, showing distinct structural and regional characteristics (Jiang, Y.,2010).

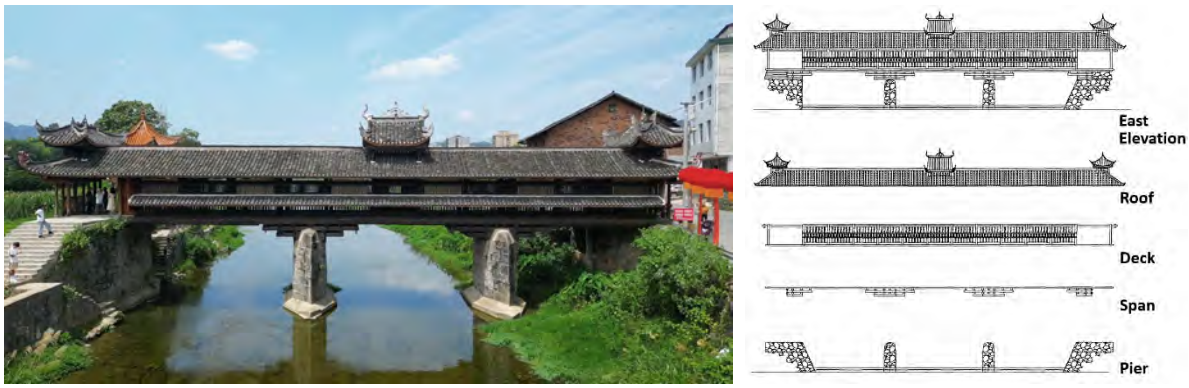


Figure 4. Photo and east elevation of Yanzi Bridge in Hunan Province, China.

Source: Jiang, Y., (2010) Architecture and Cultural Studies of Chinese Covered Bridge. Hunan: Central South University.

Traditional Chinese covered bridges combine local materials with traditional timber construction techniques. Contemporary covered bridges also adopt advanced modern construction techniques in terms of form, structure, and materials.

2.4. Sense of place

Traditional Chinese covered bridges play a vital role in connecting regions, landscapes, and communities, establishing a unique aesthetic paradigm, and many contemporary covered bridge cases have inherited this feature, fostering a sense of place and enriching the vitality of the area.

As shown in Figure 5, the selection of the village site follows the principle of being near the mountains and by the river to ensure safety and liveability. The village is situated in a small basin that is elongated east to west and narrow north to south, giving it a ship-like shape. The village is situated in a small basin that stretches from the east to west and is narrow from north to south, giving it the shape of a boat. The entrance to the village (also known as Shui Kou) is located on the west side of the village, and the terrain is narrow and winding (figure 6). A covered bridge directly spans the pond, transforming the narrow linear space of the water gap into an open planar space. To the east, structures such as arches continue the central axis and connect with the village(Wang, W., 2006). The whole water gap area presents rich spatial hierarchy.

Figure 5. Historical document(left) and satellite image(right) of Xidi village. Source: From the Internet.

Figure 6. Historical document(left) and photo (right) of Shui Kou in Xidi village. Source: From the Internet.

Such village site selection and entrance route planning not only ensure the safety of the village, but also create a narrative aesthetic, so that the village becomes a natural organic whole. The water gap where the covered bridge is located is the prelude to the spatial sequence of the village.

It is also worth noting that the four features of the covered bridges do not exist independently. Instead, these features are integrated into the bridges according to changes in geographical environment, climate conditions, folk culture, and socio-economic background. Therefore, these features can coexist within a covered bridge.

3. Result: Inheritance and Transformation

3.1. Planning case

In contemporary Chinese village renewal and planning, there are many examples of inheriting and carrying forward the traditional village Feng Shui layout. For example, Shangping Village in Sanming, Fujian Province, a traditional Chinese village and a historic and cultural village in Fujian Province (FIG. 7), dates back to the Song Dynasty (about 800 years ago), and its current layout remains intact, with two streams encircling the village and converging at the village entrance to form an important node known as the Shui Kou. There are also some protected cultural relics in the village, such as the study hall and ancestral temple.

Given the size of the village, renewal efforts are often focuses on specific key nodes. The architect He Wei adopted this method and selected the key nodes such as the Shui Kou village entrance, Yangjia Study Hall, and ancestral temple to carry out the revitalization of Shangping Village.

One of the most critical areas is the village entrance (Shui Kou), where villagers worship their ancestors and deities. Ancestral temple, family temple, and pavilion and other buildings constitute the basic features of the Shui Kou area. The planner and architect chose to maintain the original layout by rebuilding a new covered bridge at the site of the village entrance, relocating the statues to its original location. Covered bridge has become a symbolic spiritual landmark, guiding villagers home at night and playing a defensive and supervisory role (He, W., 2019).

This approach to planning and design respects the connection between the village and its geographic, historical, cultural, and social environments. No matter in traditional towns or rural areas, covered bridge is not only a kind of transportation facility; it embodies multiple functions and values, is an important medium to activate the whole region, and also an important medium to establish China's traditional urban and rural environmental aesthetics paradigm.

Figure 7. Shangping Village Regeneration, planed and designed by He Wei. Source: www.gooood.cn.

3.2. Architectural design practices

In the design practice of contemporary Chinese covered bridges, there are many excellent examples that consider the environmental connectivity and versatility of these structures. A notable example is the Bridge School (FIG. 8), which won the Aga Khan Award for Architecture in 2010. Located between two Tulou in the center of Xiashi Village, Fujian Province, the project aims to resolve the historical enmity between the two clans living in the two Tulou, who once maintained separated by a ditch (Li, X.D., 2017).

The architect chose this location, connecting the two sides with a bridge with a small school. To facilitate communication, the design combines teaching spaces with the bridge's transportation function, including two classrooms for a Hope Elementary School. In addition, the bridge serves as a multifunctional space to provide diverse public services for local residents and children, including classrooms, a library, a stage, shops, and areas for holding public events (Li, X.D., 2014).

Figure 8. Photos(left) and layout(right) of the Bridge School. Source: Li Xiaodong Atelier.

Another example is the Yusuhara Wooden Bridge Museum (FIG. 9), designed by Japanese architect Kengo Kuma.

The Yusuhara Wooden Bridge Museum, separated by a cliff and a road, connects a hotel and a spa run by the town. The museum functions not only as the flyover between the two facilities, but also as accommodations, work and exhibition rooms to meet the artist's residency program, thus connecting the world's cultures. (Kuma, K., 2015).

Kengo Kuma said they adopted an unique cantilever bridge design, a traditional technique that references cantilever structures commonly used in Chinese and Japanese architecture (Sun, T., 2023). The structure was created by using laminated wood pieces of small cross-section and gradually extending the bridge a little at a time from both ends by using many overlapping members.

The bridge is like a huge Dougong, similar in structure to traditional Chinese covered bridges, including elements such as roof, deck, span, and piers. However, it also utilizes modern materials such as reinforced concrete and steel frames (Ai, S.H., 2016).

In the overall layout, the principle of the bridge's settlement is similar to that of Shui Kou covered bridge. The museum is not near the main road but is located on a bend in the road at the foot on the hill. It connects the shortest distance at the mountain pass. The bridge follows the terrain at the foot of the mountain like an arch, leading people into the village.

Figure 9. Photos and section of the Yusuhara Wooden Bridge Museum. Source: Kengo Kuma & Associates.

4. Border impact: From Tradition to the Contemporary and Into the Future

Today, although many towns no longer need to defend themselves against invaders as they did in ancient times, the functions of the Shui Kou have changed. New functions, forms and structures have been developed to meet the need of residents. However, this long-standing approach to planning and design has become ingrained in the Chinese concept of the ideal living space. The covered bridge and Shui Kou integrate the space of a town or a village, define safe areas and boundaries, acknowledge the daily and the diversity of space, pay attention to human life in the environment, and create an intentional place that connects people's living spaces with ideals. This creates a special approach in planning (FIG. 10).

Especially in the context of China's rural revitalization, villages renewal should give priority to the local material and cultural characteristics, pay attention to the protection and promotion of these characteristics, so as to promote social and spatial equity and justice. Many urban planners and architects have taken note of this and

have incorporated elements of traditional heritage and contemporary technology into their work to breathe new life into the future development of ruban and rural areas. (Shi, Y.G., 2019) (Li, B., 2021).

Figure 10. Photos of Yangmeizhou bridge (left), Jishou art museum (middle) and the bridge at the entrance of Tangshan Quarry park (right). Source: From the Internet

It can be believed that this wisdom of connecting rather than separating will always exist in the lives of those who discover, design, build, and use covered bridges, and will be deeply imprinted in their culture and thinking, waiting for planning and design practice and time to create further forms and meaning.

5. References

Hensel, M., Wang, P.Y., Liu, Y.G. and Li, M. (2021) 'Integration of Architecture and Environment The Distinctive Traits of Embedded Architectures', *Architectural Journal*, (12), p15-19.

Bi, S. and Zhao, C. (2003) 'The special significance of Zhejiang and Fujian wooden arcade covered bridge in human settlement culture', *Southeast Culture*, (07),p51-56.

Dai, Z.J. (2012) 'Research on the morphology and culture of Fujian covered bridges', *South Architecture*, (06), p8-12.

Zhu, Y.C. (2015) 'On Lounge Bridge of Shuikou Gardens in Huizhou', *Chinese Landscape Architecture*, 31(05), p111-114.

Ma, H. (2006) A Study on Design Theroies of Traditonal Chinese Garden-bridge. Beijing: Beijing Forestry University.

Wang, Y.(2020) 'Environmental Prevention Function of Water Gap Space Of Huizhou Ancient Villages and its Enlightenment on Security', *City Planning Review*. 44(03), p93-101.

Liu, J. (2024) 'Chinese corridor bridge planning, construction and its artistic value', Cultural Relics World, (01), p7-9.

Liu, Y. (2022) 'The Challenge of Span: Constructional Thoughts of Historical Timber Structure in China and Europe', *Architecutral Journal*, (04), p36-43.

Jiang, Y. (2010) Architecture and Cultural Studies of Chinese Covered Bridge. Changsha: Central South University.

Xie, L. *et al.* (2024) 'Investigation of an Ancient Wooden Cantilever Covered Bridge in China: Construction Form and Mechanical Properties', *Structural Engineering International*, p1–6.

Xie, L., He, X., Hu, Y., Wei, X., and Shen, L. (2023). 'Wooden cantilever covered bridges in Anhua, China,' *BioResources,* 18(2), p4182-4194.

Wang, W. (2024) 'Xidi Village in Yi County—Modern Interpretation of Intangible Heritage & Settlement Space', *Anhui Architecture*, (01), p9-10+14.

He, W. (2019) 'Reflections and enlightenment on the revitalization planning of Shangping Ancient Village', *Open Times*, (04), p2+225.

Li, X.D., Chen, J.S. and Li, Y. (2017) 'Pinghe County, Fujian Province Qiling countryside stone village bridge bookstore', *Development of Small Cities & Towns*, (10), p68-69.

Li, X.D. (2014) 'Bridge School, Xiashi Village, Fujian, China, 2009', *World Architecture*, (09), p54-63.

Kengo Kuma & Associates. (2015) 'Yusuhara Wooden Bridge Museum', *World Architecture Review*, 30(03), p13-15.

Sun, T., Li, L.Z. and Kong, Y.H. (2023) 'The Path of Reconstruction of Traditional Woodworking: The Construction Logic and Formal Expression of Kengo Kuma's Yusuhara Wooden Bridge Museum', *The Architect*, (04), p64-72.

Ai, S.H. and Liu, Z.(2016) 'Light Wooden Bridge Museum —— Analysis Of Yusuhara Wooden Bridge Museum', *Architecture and Culture*, (07), p87-89.

Shi, Y.G. (2019) 'Constructing Meanings Through Meaningful Construction——A Study of Yung ho Zhang's Jishou Art Museum', *Architectural Journal,* (11), p46-49.

Li, B., Tang, P. and Li, H.J. (2021) 'Digital Chain： A Bridge Between Generative Design & Precision Construction', *Architecture Technique*, 27(04), p46-61.

Research Paper

Revisiting the notion of urban blight in the context of Global South

A discursive approach

Barnali CHAKRABORTY, Indian Institute of Technology, Kharagpur, India

Priyanka DEY, Indian Institute of Technology, Kharagpur, India

Abstract

Cities across the world are experiencing rapid transformations driven by urbanisation and demographic shifts. The presence of urban blight impacts the functionality and sociability of urban areas, diminishing community wellbeing and quality of life. Traditional policies of urban blight often struggle to address its multifaceted impacts due to the ambiguity associated with the terminology. This research aims to explore the concept of blight and elucidate the criteria that characterise urban blight in the context of the Global South. By adopting an integrated research method, comprising systematic literature reviews, expert opinion surveys, relative to identified distribution analysis, and grey relational analysis, the research provides a contextualised understanding of the phenomenon. The research broadens the nuanced understanding of blight by incorporating subjective and objective attributes, addressing the physical, functional, environmental, economic, psychological, and social aspects. The comprehensive perspective outlined in this research will facilitate a more place-based and sustainable approach to blight remediation.

Keywords

Urban blight, Global South, Grey Relation, RIDIT, Social Decline

1. Introduction

The 21st century cities are undergoing rapid demographic, economic, and spatial transformations, triggered by rapid urbanisation and the resulting mass migration of people from the rural hinterlands (OECD and European Commission, 2020; United Nations, 2018). The natural ageing of urban infrastructures coupled with constrained resources has led to the occurrence of urban blight in many cities across the world (Darling, 1943; Breger, 1967). Urban blight profoundly affects community wellbeing and quality of life as its presence contributes to functional, social, and economic depreciation (Pinto *et al.*, 2021). The conceptual evolution of blight has been explored in various historical theories on cities and urban growth. According to the theories on classification of cities, as propounded by Lewis Mumford (1938), Griffith Taylor (1949), J.M. Houston (1953), and M.R.G. Conzen (2004), every city goes through several stages of development, reaches a point of stagnation, and subsequently begins to decline, leading to urban blight and decay. The physical manifestation of blight was first reported during the Industrial Revolution era, when neighbourhoods housing the industrial workers in congested and substandard quarters with frequent outbreaks of diseases were considered blighted (Breger, 1967; Linehan, 2000). Subsequently, the post-industrial decline and the resulting fall of economies, outflow of

people, and housing abandonment were included under the broad realm of urban blight (Schilling *et al.*, 2015). This dynamic and malleable nature of the phenomenon often hinders policy formulation to manage urban blight and effectively address the place-based demands of the affected areas. Presently, there is a lack of clarity among the urban administrations of different nations as to what exactly constitutes blight. This ambiguity complicates a united attempt to eradicate the menace of blight, where we encounter certain areas that are successfully at the forefront of this struggle, whereas other areas have been left crippled by this issue. An overarching global characterisation of blight may misrepresent the region-specific realities of blight in cities of the Global South. Urban practitioners in the Global South often adopt the ways and techniques of the Global North while dealing with urban blight. Completely undermining the stark contrast in the demands of the Global North and the Global South, due to differences in socio-economic growth trajectories, administrative structures, and governance models (Myers, 2021), often leads to disastrous outcomes. Therefore, this research aims to elucidate the criteria that characterise urban blight in the cities of Global South. Identifying the primary, secondary, and tertiary criteria that characterise urban blight will help clarify and refine the definition of the term *urban blight* in the context of the Global South, providing a more grounded approach for blight remediation in these cities. A mixed-method approach was adopted to capture the multifaceted nature of urban blight and provide a nuanced understanding by incorporating both subjective and objective attributes of the phenomenon. A systematic literature review was conducted using the PRISMA method, following which content analysis and reflexive thematic coding were employed to analyse the selected documents. The extracted indicators of blight were evaluated by a panel of 15 experts and relative to identified distribution analysis (RIDIT) and grey relational analysis (GRA) were employed for interpreting the expert opinions.

Blight evaluation studies so far have predominantly focused on the physical aspects of the phenomenon manifested in the form of degraded and dilapidated built environments (Athens *et al.*, 2020). This research provides a fresh perspective by incorporating the social, economic, and environmental aspects of urban blight in addition to the physical and spatial aspects. The findings of this research can be instrumental in highlighting the complex underpinnings of urban blight, enabling a sensitive approach to address and alleviate blight. The remainder of the study has been structured as follows: Section 2 presents a brief background of the existing literature. Section 3 explains the methodology of the research, followed by section 4, which presents the result and discusses the research outcome. Section 5 presents the final inferences and conclusion of the research.

2. Background

The term *urban blight* was first put forward by Philip V.I. Darling in 1943, demarcating it as an area with inadequate and substandard living conditions, lacking sufficient open space, natural light, and ventilation (Darling, 1943; Lousada *et al.*, 2021). Due to urbanisation induced pressures and its growing impacts on quality of life and urban liveability, original inhabitants in old city cores often move to peripheral areas in search of better quality of life, leading to housing abandonment and vacancy (Ferreira *et al.*, 2018; Pinto *et al.*, 2023; Chakraborty and Dey, 2024b). Mass scale abandonment and vacancy results in the formation of urban blight, characterised by physical degradation and depreciation in the socio-functional aspects of the affected areas (Maghelal *et al.*, 2014; Sun *et al.*, 2019; Pinto *et al.*, 2021). The negative externalities of blight result in reduced property values, deterioration of public health, increased crime and anti-social activities, unemployment, etc., contributing to poor living conditions and further depreciation of real estate values (Pritchett, 2003; Donnelly, 2008; Brueckner and Helsley, 2011; Hoffman, 2012). If left unaddressed, urban blight can negatively impact a nation's economy and GDP in the long run due to its

substantial effects on the real estate market. As such, urban blight management has been gaining attention of late.

However, previous literature has noted that the differing definitions of blight pose challenges for operationalising the concept (Athens *et al.*, 2020). The subjective nature of the phenomenon often leads to disagreement over the meaning of the term, hindering evidence-based policy formulations. This contesting notion of blight has led to significant challenges in effectively defining and addressing it across different spatial and socio-economical contexts (Breger, 1967; Weaver, 2013). Eminent domains, local authorities, and redevelopment agencies enjoy the tacit and ambiguous declaration of blight, which enables them to procure areas for demolition and redevelopment solely based on visible signs of decay or subjective perceptions related to health and safety concerns (Gordon, 2008). The lack of a standard definition for objectively evaluating urban blight increases the risk of authorities capitalising on this opportunity to redevelop blighted areas merely to serve personal or corporate agendas (Weaver, 2013; Cook and Sutherland, 2015). Such ad-hoc and top-down approaches risk driving adverse outcomes like displacement and gentrification, thereby further marginalising the communities these interventions aim to support. Additionally, these challenges may also hinder the development of actionable plans for comprehensive blight management.

Studies on urban blight tend to focus on one or two aspects of the phenomenon at a time, mostly from the perspective of public health issues or socio-economic impacts, thereby often overlooking the integrated managerial approach that the phenomenon demands. Therefore, bridging this gap necessitates a more unified conceptualisation that incorporates the multifaceted aspect of blight. Thus, this research aims to refine the concept of blight, providing a more contextualised understanding of the phenomenon by focusing on the Global South. Integrating the functional, environmental, economic, psychological, and social underpinnings of blight, this research attempts to reflect the complex realities of the blighted urban areas, contributing to a more nuanced and inclusive understanding of the phenomenon. As majority of the existing studies on blight have predominantly focused on the Global North, this study will help advance the extant literature by considering the Global South as the focus of the research. The findings of this research will help pave the way for sustainable and inclusive management of blight, aligning diverse goals of different stakeholders with the ground realities of affected communities.

3. Methodology

The methodology of the research was divided into three parts: data collection, collation and analysis. In the first step, a systematic literature review was conducted following the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) method. The documents considered for the review were extracted from the Scopus database, as it returned a larger bibliographic collection compared to other databases. The keywords used for the search were "*urban blight*", "*urban decay*", "*urban degradation*", "*urban deterioration*", and "*urban obliteration*". These terms are regarded as synonyms and are often used interchangeably within the research community. The database search returned a result containing 594 documents. 460 documents were retained in the *level 1* screening by refining the search to include only peer-reviewed articles published in English between 1990 and 2022. Documents within the research areas of social science, environmental science, engineering, and multidisciplinary studies were retained in *level 1* screening. The titles, abstracts, keywords, and relevance of the published manuscript were manually assessed in *level 2,* based on which 242 documents were retained for the final level of screening. Finally, 60 documents that presented a detailed discourse on urban blight were selected in *level 3*. These selected documents were analysed to extract the indicators of urban blight

using reflexive thematic coding following the steps mentioned in the data collation stage (Figure 1). A total of 72 indicators were extracted following five rounds of coding iteration until redundancy. Based on inductive interpretation and shared commonality of the indicators, they were grouped under six categories, namely *physical, functional, environmental, economical, psychological,* and *social*.

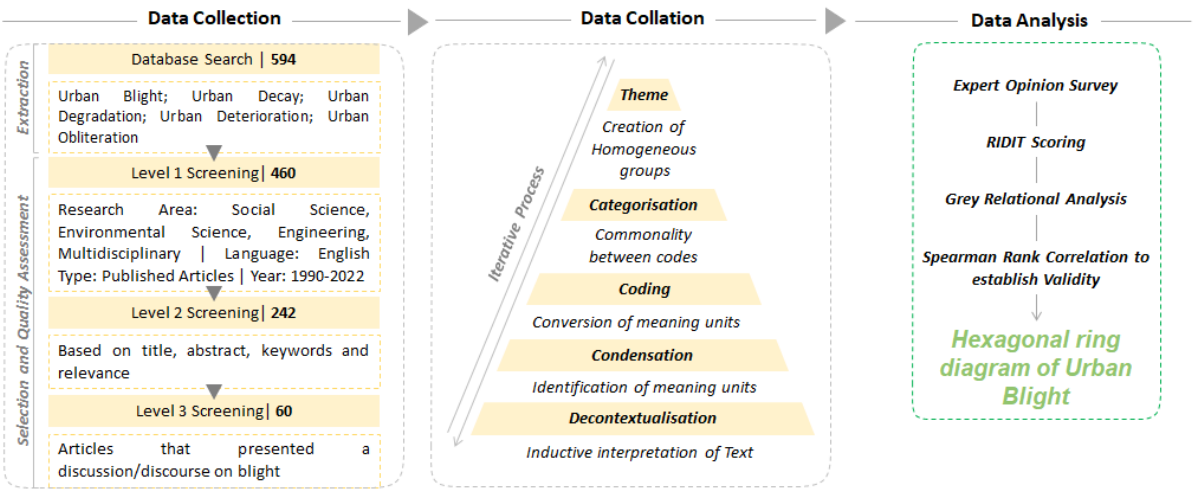


Figure 1. Research Methodology. Source: Authors

Next, online expert opinion surveys were conducted to validate the selection of indicators. A panel of 15 national and international experts working in the Global South was invited to participate in the online surveys. A five-point likert scale was used by the experts to rate their level of agreement on whether the concerned indicators are defining characteristics of urban blight in the context of the Global South. A total of 44 indicators were retained for the subsequent stages of analysis. The sole objective of conducting the systematic literature review was to ensure that diverse perspectives on urban blight could be captured, which was then refined to address the present context of this research by employing the expert opinion surveys. The collated data from the expert opinion survey was subsequently analysed and interpreted using the *relative to identified distribution analysis* (RIDIT) and *grey relational analysis* (GRA).

3.1. Relative to identified distribution analysis (RIDIT)

The RIDIT analysis is a statistical method for analysing ordinal scale likert scale data without any assumption regarding the distribution of the dataset (Mandal and Dey, 2022). RIDIT analysis can be conducted on a relatively small amount of data. This analysis is useful in determining the priority of indicators in multi-attribute or multi-criteria decision-making studies based on the assigned satisfaction or dissatisfactions against each indicator. The mean RIDIT values for each indicator were computed on the basis of the level of importance and satisfaction assigned by the experts using the following steps:

(i) The frequency f_j for each point on the likert scale was calculated based on the received expert responses, where $j=1,\ldots,n$ represents a point on the considered rating scale.

(ii) The midpoint F_j was calculated for all the points considered in the rating scale. For the first point, the midpoint was given by $F_1 = \frac{1}{2} f_j$ and midpoint for every subsequent point was calculated as:

$$F_j = \frac{1}{2} f_j + \sum_{k=1}^{j-1} f_k$$

where $j=2,\ldots,n$

(iii) The RIDIT R_j for all the rating scale points was calculated as:

$$R_j = \frac{F_j}{N}$$

where *j=1,….,n* and *N* was the sum of total number of responses collected for each indicator.

(iv) The RIDIT value r_{ij} for all the rating scale points for an indicator was calculated as:

$$r_{ij} = \frac{R_j \times \pi_{ij}}{\pi_i}$$

where *i=1,….,p* and π_{ij} was the frequency of any defined rating scale point *j* for any indicator *I,* and π_i was the frequency aggregation for the ith indicator observed across all the rating scale points as given by:

$$\pi_i = \sum_{k=1}^{n} \pi_{ik}$$

(v) The mean RIDIT ρ_i was calculated for all the indicators *i* as:

$$\rho_i = \sum_{k=1}^{n} r_{ik}$$

(vi) Finally, to check the validity of the results, the *Kruskal-Wallis* statistics was calculated as:

$$W = 12 \sum_{i=1}^{p} \pi_i (\rho_i - 0.5)^2$$

3.2. Grey Relational Analysis

Grey relational analysis is used to evaluate the correlation or similarities between indicators based on their pattern of variation (Kuo, Yang and Huang, 2008). It does not have any strict assumptions regarding the distribution of the dataset and can be used as an alternative to probabilistic and statistical methods. Like RIDIT analysis, grey relational analysis can be conducted on a small sample size. In this study, the grey relations between the indicators were computed as follows:

(i) First, a reference data series x_0 was generated as:

$$x_0 = (d_{01}, d_{02}, \dots, d_{0m})$$

where, *m*=number of respondents and the reference series represent the most favoured responses.

(ii) The comparison data series x_i was given by:

$$x_i = (d_{i1}, d_{i2}, \dots, d_{im})$$

where, *i=1,…,k* and *k* was the number of scale items.

(iii) The difference between the reference and comparison series was calculated as:

$$\Delta_i = (|d_{01} - d_{i1}|, |d_{02} - d_{i2}|, \dots\dots, |d_{0m} - d_{im}|)$$

(iv) The global maximum and minimum values of the difference data series were calculated as:

$$\Delta_{max} = \max_{\forall i}(max\ \Delta_i)$$

$$\Delta_{min} = \min_{\forall i}(min\ \Delta_i)$$

(v) The grey relation coefficient was given by:

$$\theta_i(j) = \frac{\Delta_{min} + \omega\Delta_{max}}{\Delta_i(j) + \omega\Delta_{max}}$$

where, $\Delta_i(j)$ was the jth value in the difference data series and ω was the coefficient value, which was considered as 0.5 for this study.

(vi) Finally, the grey relation grade for the ith scale item was given by:

$$\Gamma_i = \frac{1}{m}\sum_{n=1}^{m} \theta_i\,(n)$$

4. Results and Discussions

The responses collected from the expert opinion surveys were analysed using the RIDIT and GRA methods. The findings of the analysis have been presented in Figure 2. The priority ranks of the indicators were determined based on the RIDIT values, which were then compared with the values obtained from the grey relational analysis to check for differences in the ranking of the indicators. A low value of mean RIDIT score is preferred over a higher one, as it indicates a reduced likelihood of being associated with negative propensity. The findings from the RIDIT analysis revealed that the experts assigned greater importance to *abandoned buildings*, followed by *violence and crime*, *decline in public health*, *degraded building conditions*, *improper waste disposal, litter and garbage on streets*, *drug trafficking and substance abuse*, *social unrest*, *structural construction left incomplete for years*, *substandard and unsanitary living conditions,* and *newly constructed buildings left unoccupied for years*. The *Kruskal-Wallis Test* (W) returned a value of 120.598, which is significantly higher than the *chi sq.* value of 59.304 for a degree of freedom of 43 at 95% confidence level, indicating that the expert views on the indicators were dissimilar in one way or another.

The results from the grey relational analysis gave similar priority ranks for the indicators, as shown in Figure 2. According to the GRA results, the top ten relevant indicators were found to be *decline in public health*, *abandoned buildings*, *violence and crime*, *social unrest*, *drug trafficking and substance abuse*, *improper waste disposal, litter and garbage on the streets*, *degraded building conditions*, *substandard and unsanitary living conditions*, *structural construction left incomplete for years,* and *newly constructed buildings left unoccupied for years*. This indicates that physical and social factors take precedence as the most important indicators of blight in the Global South. These indicators under the *physical*, *social*, *functional,* and *environmental* categories received the highest priority from the experts regarding their relevance as characteristics of urban blight in the context of the Global South cities. To test the statistical validity of the analysed results, *Spearman's rank correlation* test was carried out. The correlation between the ranking of the indicators using RIDIT analysis and grey relational analysis was found to be 0.985 at 95% confidence level. This proved the statistical validity of the indicators' ranks, signifying that the ranks derived from the RIDIT analysis and grey relational analysis were statistically similar, thus establishing the reliability of the research findings. Figure 3 presents a spider graph illustrating the correlation between the RIDIT ranks and grey relational ranks of the indicators.

Characteristics of Urban Blight		Scoring		Ranking	
		RIDIT	GRA	RIDIT	GRA
Physical	**Abandoned buildings**	**0.3059**	**0.7949**	**1**	**2**
	Vacant plots/land parcels	0.6746	0.4854	40	40
	Degraded building conditions	**0.3260**	**0.7786**	**4**	**7**
	Presence of demolished buildings	0.5003	0.6231	23	27
	Structural construction left incomplete for years	**0.3665**	**0.7595**	**8**	**9**
	Newly constructed buildings left unoccupied for years	**0.3793**	**0.7500**	**10**	**10**
	Substandard and unsanitary living conditions	**0.3707**	**0.7684**	**9**	**8**
	Structures made of makeshift materials	0.6928	0.4823	42	41
	Graffiti	0.7803	0.4156	44	44
	Overgrown vegetation and weeds	0.5867	0.5660	32	33
	High building density marked by overcrowding and congestion	0.6669	0.4997	38	38
	Abandoned vehicles on the streets or automobile junkyards	0.3870	0.7119	11	12
	Poor visual appearance	0.4599	0.6687	19	19
Functional	**Decline in public health**	**0.3249**	**0.8119**	**3**	**1**
	Nonconformity with building codes/byelaws/land use	0.6857	0.4901	41	39
	Poor road infrastructure, narrow streets and footpaths in despair	0.5067	0.6143	26	30
	Parking problems	0.6745	0.4779	39	42
	Inadequate and poor infrastructural services	0.4398	0.6976	17	14.5
Environmental	Environmental contamination or presence of pollutants	0.4186	0.7143	12	11
	Degraded outdoor/open public areas	0.4392	0.6976	16	16
	Improper waste disposal, litter and garbage on the streets	**0.3383**	**0.7806**	**5**	**6**
	Air pollution and poor air quality	0.5989	0.5707	34	32
	Proliferation of pests and animals in the streets	0.5390	0.6065	31	31
Economical	High rate of mortgage foreclosure	0.5004	0.6330	24	24
	High number of rented properties	0.7784	0.4357	43	43
	Low per capita income	0.5202	0.6378	28.5	22
	Low property values	0.4668	0.6803	20	18
	Tax delinquency	0.4938	0.6211	22	28
	High rate of unemployment	0.4933	0.6500	21	20
Psychological	Feeling of exclusion or marginalization	0.4192	0.7048	13	13
	Less sense of community	0.5936	0.5612	33	34
	Contested notion of safety and security	0.4479	0.6476	18	21
	Poor reputation or social stigmatization of neighborhood	0.4198	0.6976	14	14.5
Social	Antisocial behavior and immoral activities	0.5260	0.6310	30	25
	Conflicting land ownership	0.6401	0.5231	36	36
	Socio-economic segregation	0.5132	0.6262	27	26
	Lack of civism	0.5202	0.6163	28.5	29
	Lack of public participation	0.6665	0.5180	37	37
	Lack of social cohesion	0.6207	0.5446	35	35
	Vandalism	0.4204	0.6925	15	17
	Drug trafficking and substance abuse	**0.3388**	**0.7810**	**6.5**	**5**
	Violence and crime	**0.3188**	**0.7929**	**2**	**3**
	Social unrest	**0.3388**	**0.7810**	**6.5**	**4**
	Population exodus	0.5008	0.6333	25	23

Figure 2. Results of the RIDIT and GRA analysis. Source: Authors

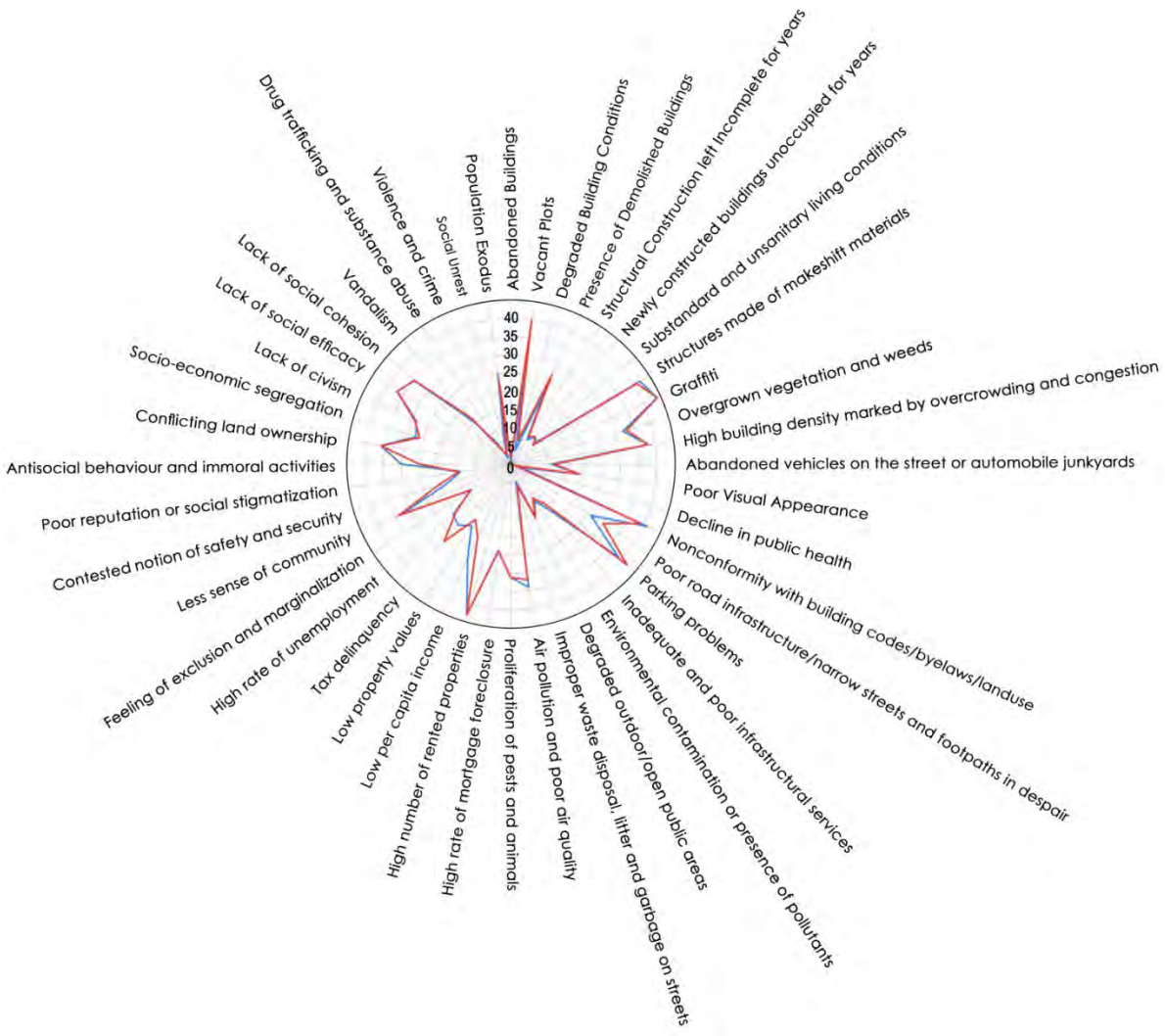


Figure 3. Correlation between the RIDIT and GRA ranks. Source: Authors

Contrary to the commonly held notion of blight as a synonym for physical degradation, the results from the expert opinion surveys, RIDIT and grey relational analysis underscored the crucial role of social factors, like *violence and crime*, *social unrest*, and *drug trafficking and substance abuse,* in developing a comprehensive understanding of urban blight. Indicators like *vacant plots*, *graffiti,* etc. did not gain enough consensus regarding their relevance as characteristics of blight in the Global South. This difference in the broad notion of blight in the Global North and the Global South cities can be attributed to the fact that cities in the Global North experienced blight as an effect of rapid industrialisation and the post-industrial decline. As previously mentioned, cities in the Global North encountered significant migration during the Industrial Revolution, with migrants living in overcrowded housing and workers' apartments. Subsequently, the congested living quarters, coupled with their unsanitary and substandard living conditions with limited or negligible lighting and ventilation, were termed as *urban blight*. Similarly, the post-industrial economic stagnation, declining population due to loss of job opportunities, and the resulting housing abandonment and vacancy also started getting associated with the concepts of urban blight (Chakraborty and Dey, 2024a). Majority of the current literature on blight emerging from the Global North still adheres to this conceptualisation of blight. However, in the Global South, urban blight often results from rapid and unplanned urbanisation and physical dilapidation due to natural ageing of building structures. Many of the cities in the Global South are still operating with physical infrastructures

that date back to the colonial era, resulting in inadequacies in meeting the needs of the growing population. In the absence of adequate infrastructure, the neighbourhoods often encounter improper garbage disposal, poor street conditions, pest infestation, poor hygiene, etc., contributing to decline in public health and overall quality of life. Figure 4 illustrates the relevance of the indicators in three different tiers that best define the notion of urban blight in the context of the Global South. Finally, the following statement was proposed to better elucidate urban blight in the context of the Global South:

Urban blight *is characterised by the presence of abandoned buildings and structures in deplorable conditions. These areas experience improper waste disposal and litter and garbage on the streets, leading to substandard and unsanitary living conditions and a decline in public health. Blighted areas are additionally prone to incidences of violence, crime, drug trafficking, and substance abuse, thereby contributing to social unrest.*

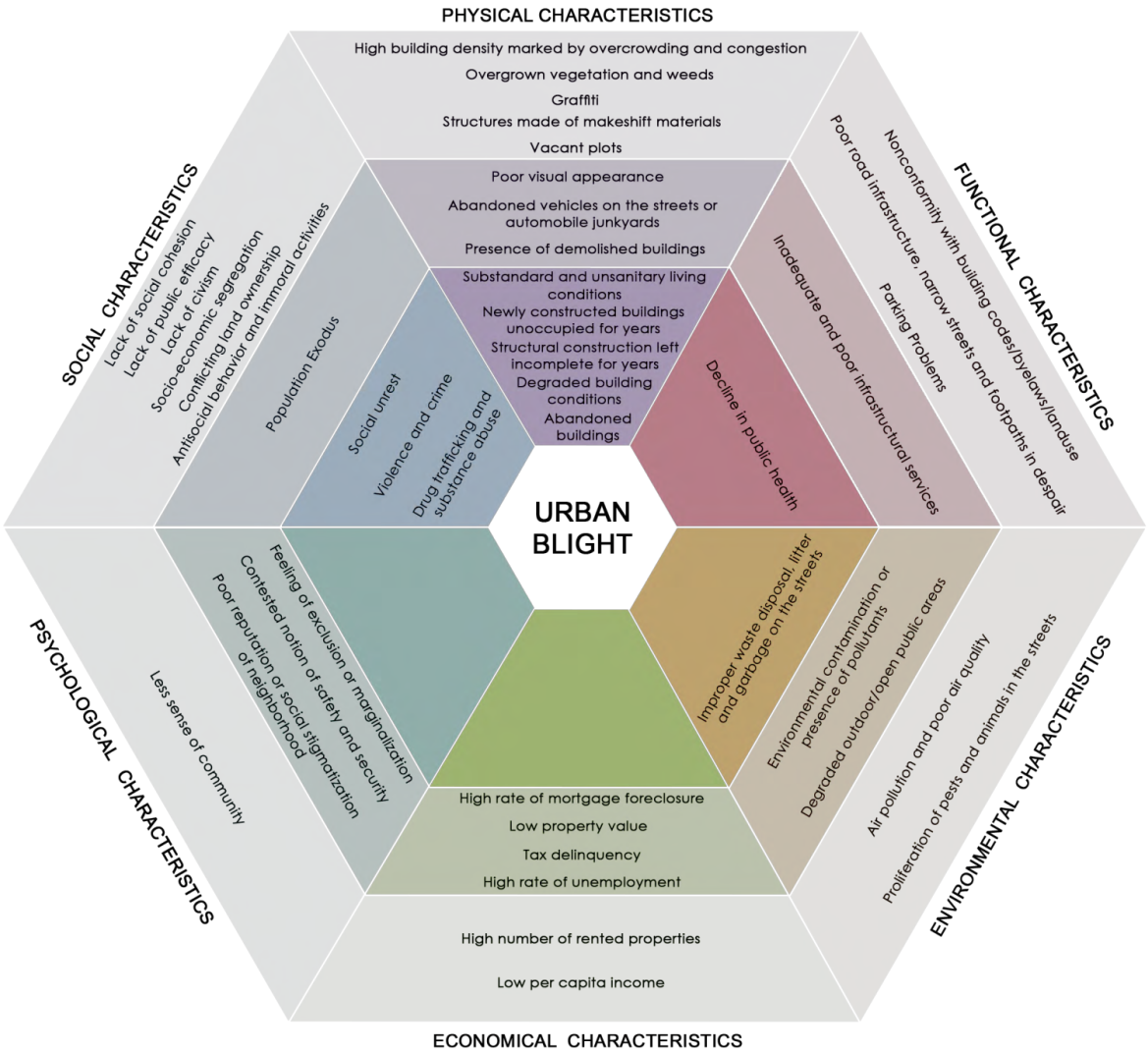


Figure 4. Hexagonal ring diagram demarcating the blight characteristics. Source: Authors

5. Conclusions

Urban blight has become a pressing global concern, intensified by rapid urbanisation and overexploitation of ageing infrastructure and depleting resources. There is a distinct gap in defining blight effectively. This ambiguity associated with blight has resulted in poorly conceived policies and initiatives that fail to address the place-based needs of the affected areas and their inhabitants. An overarching global characterisation of blight may undermine the region-specific aspects of blight in cities of the Global South. At present, most of the blight remediation initiatives are initiated solely based on the presence of properties with visual signs of blight, while completely ignoring the social, cultural, economic, and environmental underpinnings of the phenomenon. Consequently, such top-down approaches tend to address the issue in a fragmented manner, often inducing cascading negative effects like gentrification, economic restructuring, high real estate prices in the redeveloped areas, affordability issues, etc. Contemporary blight identification and analysis is tacit in nature. Therefore, by recognising the pressing need for a regionally sensitive understanding of urban blight, this research attempted to explore the notion of blight in the context of the Global South. By re-evaluating the conventional definitions of blight, mostly emerging from the Global North, this research puts forward a nuanced conceptualisation of urban blight that integrates the unique characteristics of the phenomenon in the Global South. Employing PRISMA analysis and expert opinion surveys, this research incorporated the functional, environmental, economic, psychological, and social attributes of blight in addition to the traditionally considered physical attributes.

This research advocates for the contextualisation of this complex phenomenon of urban blight, moving away from the *one size fits all* approach of blight management. This integrated approach of the research provides comprehensive insights into the phenomenon. By broadening the discourse on blight, this research offers valuable guidance for urban practitioners to develop sustainable and inclusive urban blight interventions that respect the spatial and socio-cultural fabrics of the affected areas. This refined understanding of urban blight in the context of the Global South, comprising both subjective and objective attributes, encourages a participatory approach of blight management, fostering a path towards sustainability and inclusivity.

6. Acknowledgement

We thank the Indian Institute of Technology, Kharagpur, and the Ministry of Education, Government of India, for providing assistance for this research under the Prime Minister's Research Fellowship Scheme.

7. Reference

Athens, J. *et al.* (2020) 'Using 311 data to develop an algorithm to identify urban blight for public health improvement', *PLoS ONE*, 15(7 July), pp. 1–11. doi: 10.1371/journal.pone.0235227.

Breger, G. E. (1967) 'The Concept and Causes of Urban Blight', *Land Economics*, 43(4), pp. 369–376. doi: https://doi.org/10.2307/3145542.

Brueckner, J. K. and Helsley, R. W. (2011) 'Sprawl and blight', *Journal of Urban Economics*, 69(2), pp. 205–213. doi: 10.1016/j.jue.2010.09.003.

Chakraborty, B. and Dey, P. (2024a) 'A Composite Urban Blight Identification and Evaluation Index (CUBIE): A Systems-Driven Approach Based on Empirical Evidence from Kolkata, India', *Social Indicators Research*. doi: 10.1007/s11205-024-03494-6.

Chakraborty, B. and Dey, P. (2024b) 'Spatial characterisation of blighted urban areas using space syntax analysis: the case of historic city centre of Kolkata, India', *GeoJournal*, 89(5), p. 231. doi: 10.1007/s10708-024-

11221-4.

Conzen, M. R. G. (2004) *Thinking about urban form*. Edited by M. R. G. Conzen and P. Lang. New York: Oxford.

Cook, M. E. and Sutherland, M. K. (2015) 'A shared information resource to fight urban blight: Challenges and opportunities in New York state', *ACM International Conference Proceeding Series*, 27-30-May-, pp. 283–288. doi: 10.1145/2757401.2757432.

Darling, P. V. I. (1943) 'Some Notes on Blighted Areas', *Journal of the American Planning Association*, 9(1), pp. 9–18. doi: 10.1080/01944364308979041.

Dey, P. and Mandal, K. (2024) 'Socio-economic vulnerability assessment of culturally unique ethnic communities using RIDIT scoring: a case of Rann of Kutch, India', *GeoJournal*, 89(5), p. 232. doi: 10.1007/s10708-024-11233-0.

Donnelly, P. G. (2008) 'Urban Decline', *Sociology, Anthropology and Social Work Faculty Publications*, 27. doi: 10.4324/9780203796542.

Ferreira, F. A. F. *et al.* (2018) 'A prioritisation index for blight intervention strategies in residential real estate', *Journal of the Operational Research Society*, 69(8), pp. 1269–1285. doi: 10.1080/01605682.2017.1390535.

Gordon, C. (2008) *Mapping Decline*. University of Pennsylvania Press. doi: 10.9783/9780812291506.

Hoffman, J. (2012) 'Raze the dead: Urban blight, private universities, and the path towards revitalization', *University of Pittsburgh Law Review*, 74(1), pp. 85–105. doi: 10.5195/lawreview.2012.192.

Houston, J. M. (1953) *A Social Geography of Europe - James Macintosh Houston - Google Books*. Duckworth.

Kuo, Y., Yang, T. and Huang, G.-W. (2008) 'The use of grey relational analysis in solving multiple attribute decision-making problems', *Computers & Industrial Engineering*, 55(1), pp. 80–93. doi: 10.1016/j.cie.2007.12.002.

Linehan, D. (2000) 'An archaeology of dereliction: poetics and policy in the governing of depressed industrial districts in interwar England and Wales', *Journal of Historical Geography*, 26(1), pp. 99–113. doi: 10.1006/jhge.1999.0166.

Lousada, A. L. D. *et al.* (2021) 'A sociotechnical approach to causes of urban blight using fuzzy cognitive mapping and system dynamics', *Cities*, 108. doi: 10.1016/j.cities.2020.102963.

Maghelal, P. *et al.* (2014) 'Assessing blight and its economic impacts: A case study of Dallas, TX', *WIT Transactions on Ecology and the Environment*, 181(May), pp. 187–200. doi: 10.2495/EID140161.

Mandal, K. and Dey, P. (2022) 'Coastal vulnerability analysis and RIDIT scoring of socio-economic vulnerability indicators – A case of Jagatsinghpur, Odisha', *International Journal of Disaster Risk Reduction*, 79, p. 103143. doi: 10.1016/j.ijdrr.2022.103143.

Mumford, L. (1938) *The Culture of Cities*. Harcourt Brace Jovanovich.

Myers, G. (2021) 'Urbanisation in the Global South', in *Urban Ecology in the Global South*, pp. 27–49. doi: 10.1007/978-3-030-67650-6_2.

OECD and European Commission (2020) *Cities in the World*. OECD (OECD Urban Studies). doi: 10.1787/d0efcbda-en.

Pinto, A. M. F. *et al.* (2021) 'Analyzing blight impacts on urban areas: A multi-criteria approach', *Land Use Policy*, 108. doi: 10.1016/j.landusepol.2021.105661.

Pinto, B. M. B. *et al.* (2023) 'Analyzing causes of urban blight using cognitive mapping and DEMATEL', *Annals of Operations Research*, 325(2), pp. 1083–1110. doi: 10.1007/s10479-022-04614-6.

Pritchett, W. (2003) 'The "Public Menace" of Blight: Urban Renewal and the Private Uses of Eminent Domain', *Yale Law & Policy Review*, 21(1), p. 2.

Schilling, J. *et al.* (2015) *Charting the multiple meaning of blight: A national literature review on addressing the community impacts of blighted properties*. Available at: https://doi.org/10.13140/rg.2.1.2417.8960.

Sun, W. *et al.* (2019) 'Neighborhood blight indices, impacts on property values and blight resolution alternatives', *Journal of Real Estate Research*, 41(4), pp. 555–603. doi: 10.22300/0896-5803.41.4.555.

Taylor, G. (1949) *Urban Geography: A Study of Site, Evolution, Patern and Classification in Villages, Towns and Cities*. Routledge. doi: 10.4324/9780203716250.

UNO (2018) *World Urbanization Prospects*, *Demographic Research*. Available at: https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf.

Weaver, R. C. (2013) 'Re-framing the urban blight problem with trans-disciplinary insights from ecological economics', *Ecological Economics*, 90, pp. 168–176. doi: 10.1016/j.ecolecon.2013.03.009.

Research Paper

An Initial Exploration of Progressive Cultural Industry Cluster Models in Historical Districts from the Perspective of Catalysts:

Taking Feng Yuan Street-Liwan Lake District in Liwan District, Guangzhou as an Example

Dongxin Lian, South China University of Technology, China

Shifu Wang, South China University of Technology, China

Abstract

After more than 30 years of urbanisation, China's urban development path is changing from the traditional pursuit of single high-speed growth to the pursuit of high-quality spatial quality improvement. Most of the historic districts, which are the heritage and memory of the city, have lost their original cultural authenticity during the last round of urbanisation.There are such practical dilemmas as lowering the quality of the districts, serious gentrification and degradation of the living environment. After studying the existing models in China, and taking into account the development of the Feng Yuan Street-Liwan Lake Historic District in Liwan District, Guangzhou, and based on the cultural catalyst effect of the district, it is found that the progressive cultural industry cluster mode of business optimization is conducive to the development of the historic district, thus promoting the vitality of the district and improving its quality. On this basis, we explore the relevant institutional supply and guarantee mechanism to further construct a new mode of industrial development in the historic district.

Keywords

Business model, Optimisation strategy, Historic district, Cultural catalyst, Progressive regeneration, Cultural conservation

1. Introduction

1.1. Theoretical Review and Practical Frontiers of Cultural Catalysts

As early as the 1960s, American urbanist Jane Jacobs proposed the importance of culture in urban development, with a particular emphasis on the cultural characteristics of historic districts (Jane Jacobs,1961). Following a series of practical applications, countries such as the United States, the United Kingdom, and Germany expanded their understanding of culture to a two-way interaction between theory and practice, recognizing culture as valuable capital that can promote regional and local development (Juliet Davis,2009; Izadi Mohammad Saeed. et al.,2018; Shemirani Seyed Majid Mofidi et al.,2021). Conversely, the cultural experience brought by cultural capital in historic cities can generate new concepts for urban development, emphasizing the spiritual and emotional connections between

people and the environment, as well as deeper psychological needs and aesthetic activities such as a sense of direction and belonging. Since the 1970s, the United States initiated urban regeneration movements driven by cultural policies, achieving notable successes in projects such as the redevelopment of the Inner Harbor areas in Pittsburgh and Baltimore, leading Western countries to gradually consider cultural catalysts as a significant driving force for urban development and old city renewal.

In the 1980s, the term "urban catalyst" first appeared in the work of American architects Wayne Attoe and Donn Logan, American Urban Architecture: Catalysts in the Design of Cities, where it was noted that "new elements can be introduced strategically to activate existing elements within the city without changing their essential attributes. Once activated, these elements also bring along the forms, characteristics, and quality of the introduced elements, creating a chain reaction (Ashima Krishna,2016)." This illustrates the crucial role that catalysts play in urban renewal and development. Catalysts can be physical forms, such as buildings or landscape features, or intangible forms, such as unique cultural traits or artistic activities（Espindola, E. ,2022; Izadi, M. S et al.,2021）. In the context of historic preservation and urban renewal, an urban catalyst refers to any element that can improve the urban environment. However, not all urban elements can serve as catalysts; instead, elements that align with local characteristics and history should be selected, achieving comprehensive regional vitality through the method of embedding, thereby promoting harmonious development of the city and its neighboring areas (Miles, S., & Paddison, R.,2005; Beck D,2019).

In contrast, China introduced this theory in the 1990s. Although research on catalytic theory has been relatively recent, insights have been gained from international experiences about the importance of culture in revitalizing historic districts (Kim, G. K.,2006). Based on Wayne Attoe's theory of urban catalysts, further exploration of the types and characteristics of catalysts has led to the conclusion that "point catalysts" are the most moderate approach for intervening in urban design in historic districts. They have minimal impact on the surrounding environment, making them an effective means of historical district renewal (Table1).

Table 1. Cultural catalytic form

Cultural catalytic form	Catalyst Characteristics Diagram	Feature description
Dot-shaped		Transformation and Renewal of a Point Space in Historical and Cultural District
Current		Characterized by point connection or original linear space series, connection
Surface		The Renewal and Transformation of the Area Space of the Districtand the Surrounding Area Radiated by the Cultural Catalyst Effect

Source: Author drawing.

As for the selection of specific catalysts, through the industrialisation experiments on the intangible cultural heritage, cultural symbols, cultural characteristics and other elements present in the historic districts, it has been concluded that the revival of cultural businesses is conducive to the enhancement of the overall quality of the districts and the reshaping of their vitality (Krishna, A. ,2016; Bohannon, C. L. ,2004). In

addition to reaching a consensus on the importance of local culture, local residents, the government and developers, as pluralistic subjects, need to pay attention to the long-term interests of cultural capital for the city and the district , adhere to rational urban renewal concepts, and ensure the balance of interests of all parties through the corresponding policies and plans, which is the system and management requirements for the maintenance of cultural catalysts in the later stage (Figure 1).

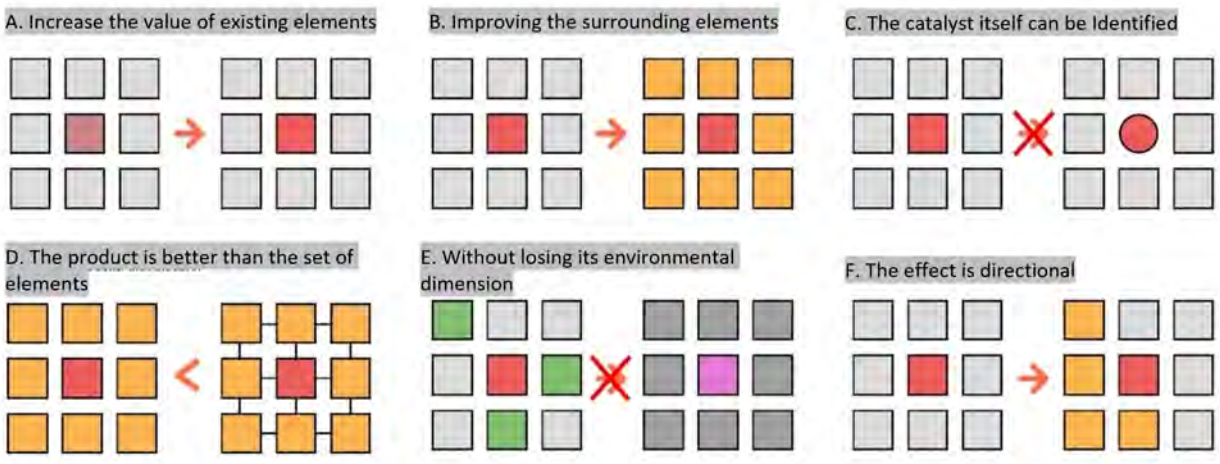


Figure 1. The Utility of Cultural Catalysts in the Renewal of Historic Districts. Source: Author drawing.

1.2. Renewal and Development Patterns of Historic and Cultural districts in China

The integrated real estate development model is led by real estate developers, who utilize substantial capital to relocate all original residents for large-scale intensive development (Overmeyer, K., & Misselwitz, P. ,2011). This model mainly involves either the complete functional replacement of historical buildings or uniform high-density industrialized development to redevelop historic districts. However, this real estate-driven approach to renewal comes at the cost of sacrificing the original residents' lifestyle, forcibly embedding new industries and functions to meet modern needs. In the pursuit of maximum profit, developers often neglect the preservation and transmission of historical culture, and the excessive promotion of modern lifestyles leads to the disappearance of traditional ways of life. This, in turn, results in changes to the social structure of the district, triggers localized social conflicts, and, in some cases, leads to excessive gentrification.

Compared to the unified planning, redevelopment, and construction approach of the integrated real estate development model, this approach places greater emphasis on organic renewal, focusing on the appropriate preservation of the district's traditional lifestyle and cultural context. It adopts suitable scales and a moderate, gradual approach to progressively invigorate the district. This model is particularly favored in China, with its advantage being that it centers on the original residents of the district while balancing the exploration and utilization of the district's historical culture. Under the premise of preserving the original neighborhood lifestyle, diversified and flexible commercial development can be carried out. On one hand, this ensures that the historical culture and human customs of the district are well preserved; on the other hand, differentiated revitalization methods can be chosen based on the characteristics of different types of districts, using a "phased and segmented" approach to select appropriate revitalization measures. However, this model faces challenges such as difficulty in sustaining long-term funding for preservation and high technical requirements for conservation. Therefore, it is necessary to encourage and expand multi-party participation, involving the government, experts, and all sectors of society.

Under government leadership, both government and private capital participate in the comprehensive "commercialized" restoration and protection of historic districts, quickly acquiring funds for renovation through large-scale commercial investments. Besides restoring historical buildings, this approach also emphasizes converting residential functions into commercial ones. Unlike the integrated real estate development model, this approach involves phased renewal of the district under government direction.

The commercialized model has advantages such as quick short-term results and high investment intensity, and it is often used in historic districts originally dominated by commercial functions. However, it cannot be ignored that excessive commercialization can severely erode the traditional atmosphere and cultural environment of historic districts. Some districts may also find it difficult to create a commercial atmosphere due to geographical and environmental reasons, which could result in further damage to districts that have already undergone commercialization (Table2).

Table 2. Comparison of Business Development Models in Historic Districts in China

	Real Estate Development	**Progressive development**	**Commercial development**
Extent of land concessions	All leased land	Small number of sites offered for sale d for sale	Part of the sites offered for sale
Degree of commercial exploitation	strong	feeble	strong
Participation in the main body of the transformation	real estate developer	Residents, governments, social organizations	Government and enterprise
Relocation of aboriginal people	Relocation of all Aboriginal people	A small number of residents negotiated relocation	Some residents moved after consultation
Investable capital sustainability	strong	feeble	strong
Protection development mode	Preservation of the core building and its surroundings alteration of its internal functions	Retain most of the buildings for restoration and remediation	Preservation of the architectural heritage, restoration of the exterior and complex utilisation of the interior functions
Cases	Shanghai Xintiandi, Guangzhou Xinyi Hall	Suzhou Pingjiang Road	Hangzhou Qinghefang, Guangzhou Shangxiangjiu

Source: Compiled by the author from information.

2. The Importance of Progressively Introducing Cultural Catalysts in Developing Historic Districts

No matter what kind of development mode is used, it cannot be denied that business development is an effective way to protect and revitalise historic districts (Schreiber, F., Fokdal, J., & Ley, A. ,2023). In the context of China's planning from incremental to stock, from the rough to the pursuit of high-quality and refined development, the government will spend more energy into the campaign to improve the quality of

historic districts, at this time, the district industry needs to shoulder the burden of supplying funds for the repair of old buildings in the districts, improvement of the human habitat, the shaping of the cultural brand, and other special actions.

The model of progressive industrial clusters. The progressive industrial cluster model is different from the traditional industrial park model, aiming to build an industrial cluster 'without walls'(Fan, X. ,2020), which is reflected in the openness and accessibility of the historical and cultural district, and even more so in the openness of the operation and management system of the industry. Through government-led, multi-party participation and gradual development, 'point by point' gradually introduce cultural industry-based industries, while taking into account the retention of a certain amount of traditional industries, paying attention to the diversity and characteristics of the overall industry, and aiming to stimulate the new vitality of the historical district（Figure. 2）.

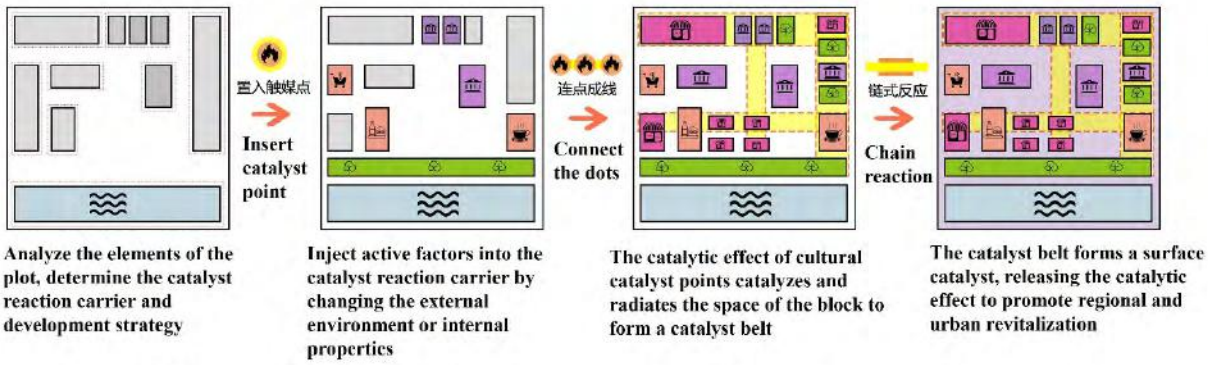


Figure 2. Principles of Progressive Culture Industry Cluster Role. Source: Author drawing.

Cultural Clusters Promote the Quality and Vitality of district. The concept of industrial cluster originated from Mike Porter's 'Competitive Advantage of Nations' in 1990, who emphasised that the core of industrial cluster lies in the spatial concentration of industries, which is conducive to lowering the operating costs of enterprises, and that the complementary supply chain formed by industrial clustering can promote the scale effect and influence of industries within a certain range. For historic districts, because of their unique historical space, they have the advantageous conditions for nurturing cultural industries, and encouraging the aggregation of cultural industries not only enriches their cultural connotations, but also promotes the functional remodelling of the space with new vitality (Kangcai, N. I. E. & Xuehong, Z. H. O. U. ,2019). In addition, spontaneous complementarity and healthy market competition between similar businesses can better promote the overall quality of the district 's businesses.

3. Case study: Feng Yuan Road-Liwan Lake Historic District Liwan, Guangzhou

3.1. Special resources

The Liwan Lake-Fung Yuen Street Historical district is located in the Xiguan area of Liwan（Figure. 3）, Guangzhou, and is divided into two pieces: Liwan Lake and Feng Yuen Street. The core protection scope of Liwan Lake is based on the property boundary of Liwan Lake Park: it contains Laiwan Chung and Renwei Temple and Panshi Restaurant; Fungyuan Street is a mixed commercial and residential historical district that takes into account the commercial and residential functions, mainly based on the densely populated areas of cultural relics and historical buildings in Xiguan Dajia Community and Longjin West Road Riding Street. The history dates back as far as the Southern Han Dynasty (2,300 years ago) as the emperor's backyard, and

most of the current neighbourhood has the architectural pattern and texture of the Ming and Qing dynasties (around 300 years).

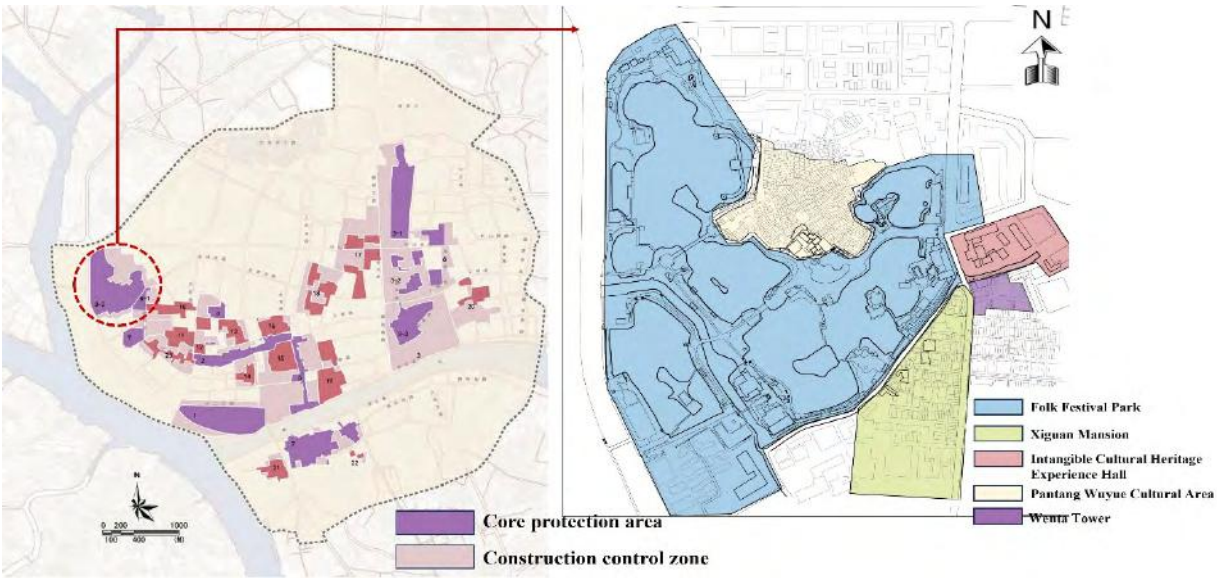


Figure 3. Location Analysis of Feng Yuan Street - Liwan Lake Historical and Cultural Quarter. Source: Author drawing.

It is one of the 26 historical districts delineated in the Protection Plan for Famous Historical and Cultural Cities of Guangzhou with a larger scope. Within the area, there is a collection of iconic tangible cultural landscapes such as Liwan Lake Park, Fengyuan Street, Lychee Bay Chung, the Man Tower, Renwei Temple, Xiguan Daiya, the Riding Floor Street, Lingnan Gardens, and intangible cultural heritage such as Cantonese Opera, Cantonese Cuisine, and traditional handicrafts. As the district is located in the old city of Guangzhou, it is surrounded by many historical districts such as Enning Road, Changhua Street, Baoyuan Road, etc., which have different styles and spatial characteristics, making it a spatial space with a strong historical flavour of the 'old Guangzhou' and Lingnan culture（Table. 3）.

Generally speaking, the district is famous for its man-made built environment pattern and style centred on Liwan Lake, which is fsormed by the combination of the gardens and public houses surrounding the lake and the two traditional texture areas of Xiguan traditional city and Xijiao traditional village. Among them, Feng Yuan Street retains the traditional Xiguan Dajia residential buildings, and Pantang Village is the only remaining complete Ming and Qing Dynasty water village settlement in the historical city that retains the old historical pattern, street texture and cultural features. In addition, the district is also home to many intangible cultural heritages of Guangzhou, with a variety of activities such as traditional folklore, opera and fine arts, making it one of the few places in the Guangdong-Hong Kong-Macao Greater Bay Area that carries the Cantonese culture（Figure. 4）.

Table 3. Catalogue of tangible and intangible cultural heritage

Typology	**Tangible culture elements**
Architectural style	Xiguan Daiya (bamboo house), Liang Ancestral Hall (three courtyards), Chen Lianbo Public Hall (Western architecture), Haisan Xiankuan (Lingnan garden), Longjin Road Cavalcade Street, Panshi Restaurant (Lingnan garden-style architecture), Liwan Grand Theatre, Wenta.
Architectural elements	Brick carvings, grey sculptures, Teochew wood carvings, barred doors, Manchurian windows, clear water brick walls, wok walls, hemp stone streets,

	etc.
natural resources	Lai Wan Lake, Lingnan Garden, Lai Chi Wan Chung and others
Landscape resources	Lingnan Bonsai, Yingde Stacked Stone, Lingnan Gardening, Lingnan Landscaping, etc.
Typology	**Intangible cultural heritage**
traditional music and opera	Cantonese music, Cantonese operas, eight-note gongs and drums
traditional theatre	Lingnan Puppetry Performing Arts, Cantonese Opera
traditional art	Guangzhou marquise carving, Canton embroidery, ivory carving, Guangzhou wood carving, Guangzhou jade carving, paper-cutting
Chinese traditional medicine	Lingnan Tian Moxibustion, Lingnan Fire Needle Therapy, Cai Zhi Lin, Jing Xiu Tang, Xiguan Zheng Bone

Source: Compiled by the author from information.

Figure 4. Historic District Site Photos. Source: Baidu website.

3.2. Methodology

Compared with the rich cultural precipitation, the overall distribution of the business environment in the Liwan Lake-Fung Yuen Street Historic District is fragmented, and there are many types of business but lack of regional cultural characteristics. According to the existing business can be referred to Kim, G. K. (2006)said that the business of the historic district is divided into three major types: general consumption, cultural enterprise, and cultural industries（Table 4） , general consumption refers to the business of for-profit nature that is not very related to the cultural characteristics of the district, including catering and general shops, etc.; the cultural undertakings are the non-profit business that the public can freely visit the culture of the regional characteristics, including museums and exhibition halls, etc.; the cultural industry refers to the business that fits into the cultural characteristics of the historic district, and the business that has the cultural characteristics of the region. Cultural industries refer to those businesses that fit the cultural characteristics of the historic district, or those businesses that have been retained by the public through the long evolution of the district, including old shops, exhibition venues, and so on. According to the field research, the overall general consumption industry is as high as 58%, while the real cultural industry with special characteristics only accounts for 37%（Figure. 5）. Selecting Pantang Road, the most central commercial street in the historic district, and Shanghai Xintiandi North Lane on Pingjiang Road in Suzhou for horizontal comparison and calculation found that the index of its industry diversity is on the low side, and there is room for further improvement.

Table 4. Classification of Cultural Businesses

Typology	**concrete content**
general consumption	Cafes, Stores, Catering
cultural enterprise	Museums, art galleries, exhibition halls
Cultural industries	Intangible crafts、cultural and creative、Cultural trails, national parks

Source: Compiled by the author from information.

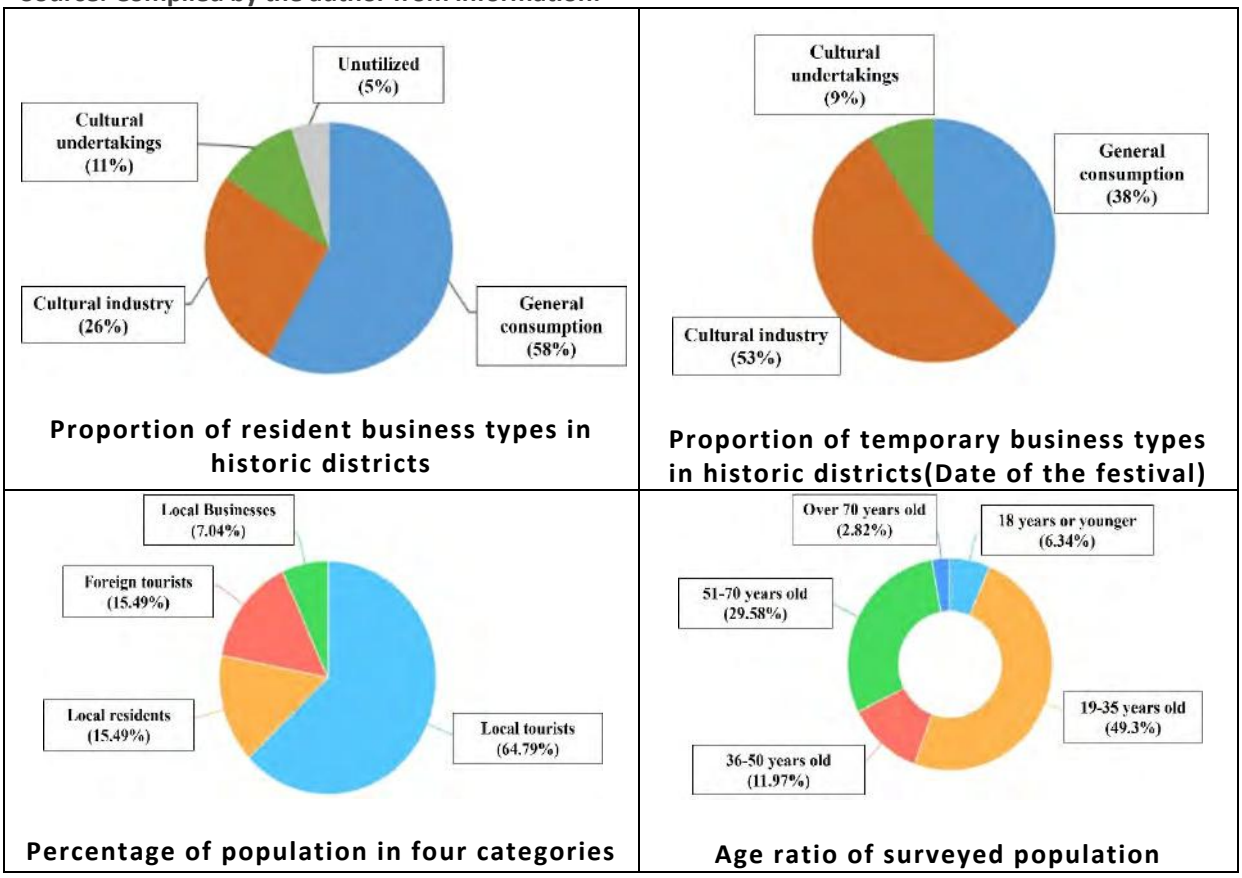


Figure 5. Basic information on survey respondents in the Quarter. Source: Author's drawing.

Questionnaire surveys of user groups often provide a more realistic picture of the overall imagery of a historic district and the perceptual experience needs that different groups expect to have in the district. This design is based on a survey of the perceptual imagery of four groups of people: local residents, local tourists, foreign tourists, and local merchants(350 questionnaires were distributed, of which 345 were valid, with a 98 % recovery rate).

3.3. Findings

Nearly 90% of the respondents were positive about the historical and cultural characteristics of the district, saying that they could feel the local culture of Xiguan in Guangzhou, especially after the micro-renovation of Pantang Wuyao, which resulted in the addition of a rich and diverse range of cultural and creative shops, non-heritage workshops and other forms of business. However, more than 58% of people still do not know the folk culture and anecdotes of celebrities in the district, and visitors' perception of the history and culture of the district comes more from the old shops (53%) or the activities of local residents in the park (26%). In the evaluation of the district 's businesses, 79% of the people have a high level of satisfaction with the district d's businesses, believing that they are able to show the characteristics of the district and satisfy the needs of consumption better. However, people's expectations for the district mainly stem from the desire to increase the number of cultural industries such as non-heritage cultural experiences, old-fashioned restaurants and small cultural and creative shops（Figure. 6）.

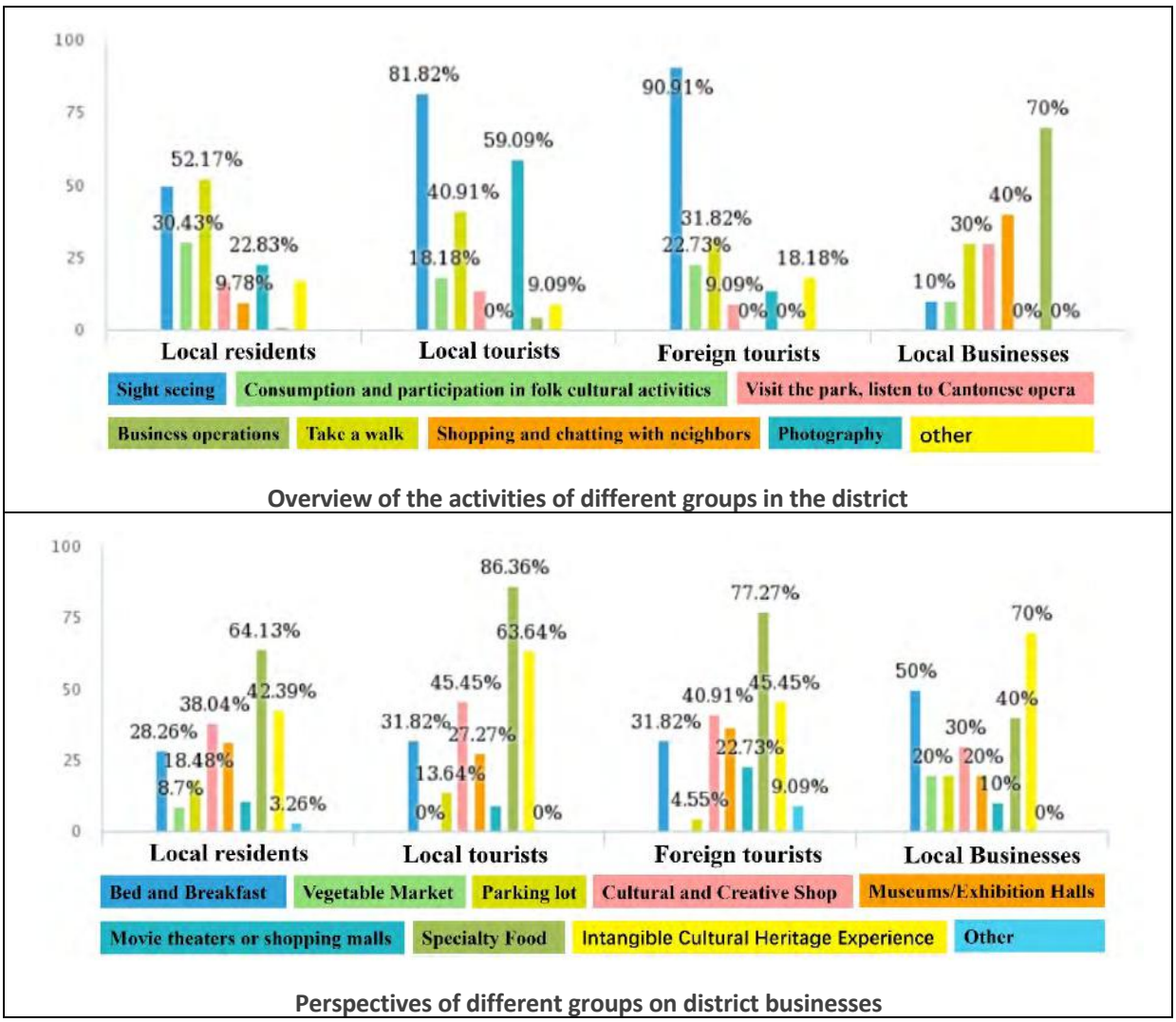


Figure 6. Descriptive statistics of questionnaire results. Source: Author's drawing.

There is a lack of business diversity in this district, especially in the cultural business and cultural industries that display the culture of the district and represent the regional characteristics, and the existing businesses are mainly catering and retailing. From the group survey, we can see that for the aborigines, they hope that the district can have a more convenient living consumption business, and can provide a certain hair salon, food market and other businesses. Most of the tourists are satisfied with the Xiguan local cultural style shown in the district, but less satisfied with the culture that can be felt in its business. It can be seen that the existing business is mostly to meet the tourists to use as the main body, lack of attention to the needs of the aborigines and local merchants.

4. Conclusion and discussion

The core of cultural industry clusters is to focus on the use of cultural catalysts. Different cultural catalyst spaces, such as spaces for traditional festivals and cultural exhibitions (Zhao, Congyu. ,2018), can be explored through the revitalisation of original folk activities in historical and cultural districts, and the presentation of the lifestyle of the indigenous people and anecdotes of famous people in the districts. Particular attention will be paid to the shaping of cultural brands such as Panxi Restaurant and Kaiji Desserts, as well as the planning and promotion of folk cultures such as the Brushstroke Ceremony and

the Water Flower Market, and non-heritage cultural experience activities such as Cantonese Opera, Canton Embroidery and Canton Colour. The activation of intangible cultural elements through tangible means can increase the cultural capital and at the same time add a cultural atmosphere to the historical and cultural district. In the building of cultural industry clusters, it pays attention to the use of gradual catalysing forms, and builds a catalysing system of 'connecting lines with points, forming a network with lines, and linking up into surfaces. Firstly, the activation of important cultural nodes in the block is the main focus, combined with the linear spatial catalysts of the Riding Floor Street and the Style Street, to form the catalyst effect within the block, and gradually build the industry cluster（Figure. 7）.

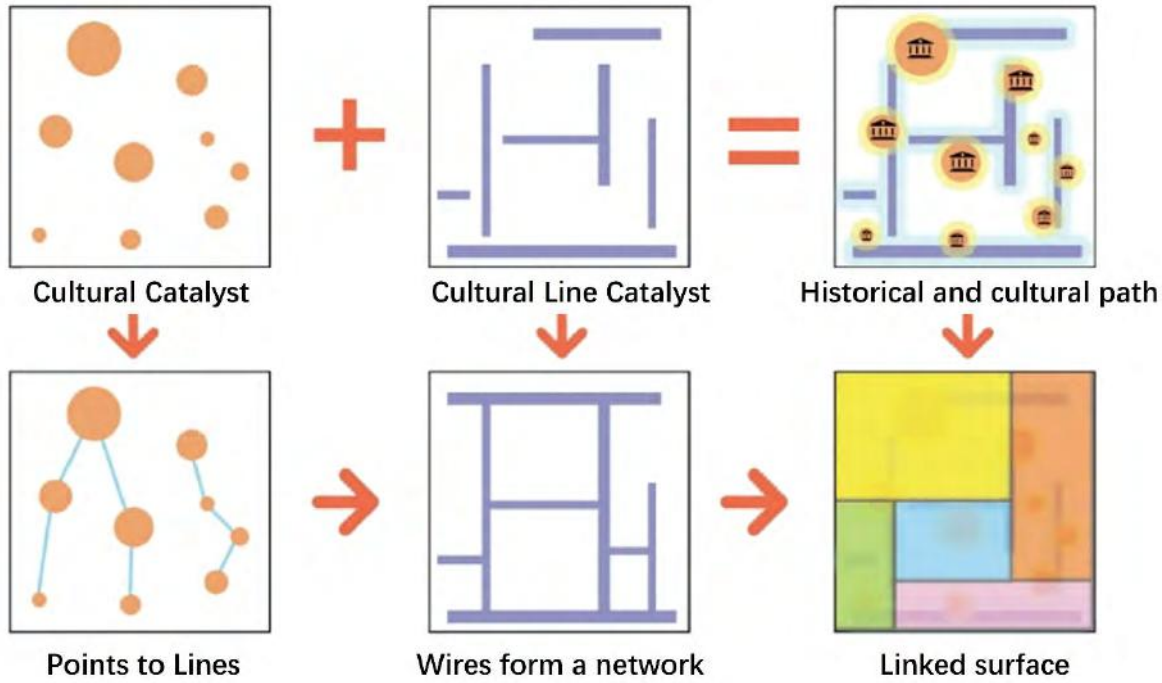


Figure 7. Progressive Cultural Catalyst System Construction. Source: Author's drawing.

In the process of cultural industry cluster development, we should pay attention to the respect and preservation of the traditional life of the aborigines, not only to maintain the interests of the residents, but also to encourage the residents to show their own way of life in the historical and cultural district s, and to run the business forms with the characteristics of the district (Wang, S. F. ,2018). At the same time, the discovery of the district culture and historical memory to the use of optimization and renewal of business needs to be introduced gradually, for the cultural industry and the branding of old brands is also a gradual process. More importantly, it is important not to neglect the later management and maintenance of the business, as well as the establishment of the business access, optimisation and operation system（Figure. 8）.

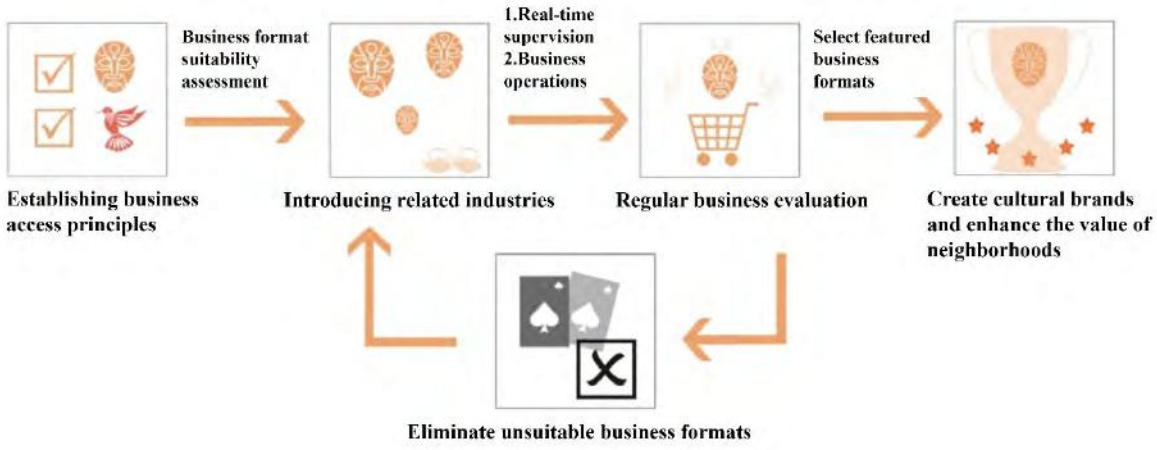


Figure 8. Progressive business optimisation system. Source: Author's drawing.

5. References

AITANI, K., ARIMA, T（2017）. Urban Catalyst: Regeneration of Downtown Area Through Community Development.

Bohannon, C. L. (2004). The urban catalyst concept (Doctoral dissertation, Virginia Tech).

Beck, D., Brooks, S. (2019). Social enterprise and the development of cultural heritage assets as catalysts for urban placemaking. In New Metropolitan Perspectives: Local Knowledge and Innovation Dynamics Towards Territory Attractiveness Through the Implementation of Horizon/E2020/Agenda2030–Volume 2 (pp. 308-315). Springer International Publishing.

Block, T., Paredis, E. (2013). Urban development projects catalyst for sustainable transformations: The need for entrepreneurial political leadership. Journal of Cleaner Production, 50, 181-188.

Camhis, M., & Fox, S. (1992). The European Community as a catalyst for European urban networks. Ekistics, 4-6.

Davis, J . (2009). Urban catalysts in theory and practice. Architectural Research Quarterly, 13(3-4), 295-306.

Espindola, E. (2022). Historic District Transformation: A Study into How Historic District Designations Can be a Reactants or Catalysts for Change in Three Neighborhoods in San Antonio, Texas (Master's thesis, The University of Texas at San Antonio).

Fan, X. (2020). Research on the Reconstruction and Reuse of Historic Blocks from the Perspective of Urban Catalysts: Taking a Historical District of Foshan as an Example. In The 2nd International Conference on Architecture: Heritage, Traditions and Innovations (AHTI 2020) (pp. 449-455). Atlantis Press.

Hammes-Schiffer, S. (2017). Catalysts by design: The power of theory. Accounts of chemical research, 50(3), 561-566.

Horelli, L. M., Sadoway, D. (2014). Community informatics in cities: New catalysts for urban change. Journal of Community Informatics, 10(3).

Izadi, M. S., Moshaver, M. K., Sajjadzadeh, H., & Tavassoli, M. (2018). Locating urban catalyst projects in inefficient urban textures with the regeneration approach: A case study on Tehran. Journal of History Culture and Art Research, 7(3), 136-151.

Jacobs, J. (1992). The death and life of great American cities. 1961. New York: Vintage, 321(325), 9783839413272-099.

Krishna, A. (2016). The catalysts for Urban conservation in Indian cities: Economics, politics, and public advocacy in Lucknow. Journal of the American Planning Association, 82(2), 204-207.

Kim, G. K. (2006). The 'Catalyst Effect' of Urban Design. Planner, 22(10), 1.

Kristo, S., Dhiamandi, J. (2016). Urban Catalyst as the tool for public space transformation. In 1st International Scientific Conference On Professional Sciences (Vol. 1, pp. 45-53). Universiteti" Aleksandër Moisiu" Durrës.

Kim, J. (2009). Urban design as a catalyst for advancing architectural education. Enquiry The ARCC Journal for Architectural Research, 6(1).

Kangcai, N. I. E., Xuehong, Z. H. O. U. (2019). Renewal Design of Marketplace Culture Spaces in Traditional Blocks Based on Catalyst Theory: A Case Study of Pengzhen Town in Shuangliu District of Chengdu. Journal of Landscape Research, 11(4).

Ma, Yu. (2017). Research on commercial suitability of historical and cultural districts based on cognitive evaluation (Doctoral dissertation, Chongqing: Chongqing University).

Miles, S., Paddison, R. (2005). Introduction: The rise and rise of culture-led urban regeneration. Urban studies, 42(5-6), 833-839.

Overmeyer, K., Misselwitz, P. (2011). Urban catalyst: Strategies for temporary use. P. Oswalt (Ed.). Basel: Birkhäuser.

Shemirani, S. M. M., Alalhesabi, M., Zolfigol, S. (2021). A comparative study of catalyst projects in urban centres: Imam Square in Hamedan. In IOP Conference Series: Materials Science and Engineering (Vol. 1067, No. 1, p. 012072). IOP Publishing.

Setioko, B., Kusumaning Wardhani, M., Woro Murtini, T. (2018). Urban Catalyst Element Impact on the Pattern of Spatial Distribution in Semarang City Border Area. International Journal of Engineering and Technology, 7(02).

Schreiber, F., Fokdal, J., Ley, A. (2023). A Catalyst for Innovation? A Conceptual Framework for Analyzing the Potential of Urban Experiments to Transform Urban Planning Practices. Planning Theory & Practice, 24(2), 224-241.

Wang, N. (2022). Research on the Design of Old Building Reconstruction from the Perspective of Urban Catalyst Theory. World Scientific Research Journal, 8(9), 214-220.

Wang, S. F. (2018). Reflections on the Comprehensive Value and Conservation Revitalisation of Historic Cities. Journal of Urban Planning, No.241(01), 10-11.

Zhao, Congyu. (2018). A study on the renewal strategy of historic districts under the perspective of 'humanistic catalyst'-The example of Shichahai area in Beijing. Beauty and Age: City (12), 5.

Research Paper

Spatio-temporal effects of urban rail transport on residential prices around stations

A case study of Harbin Line 1

Rong, G, Harbin Institute of Technology, China

Jin, Y, Harbin Institute of Technology, China

Xingjian, L, Tianjin General Institute of Urban Planning and Design Co., China

Abstract

With the vigorous development of rail transit in China, the impact of urban rail transit on the price of land along its routes has attracted widespread attention, including the price of residential houses, office buildings, and commercial buildings. Exploring its spatio-temporal effects helps to predict the impact of new rail transit in the future as well as to help the government formulate reasonable house price regulation and urban land use policies. This paper measures the spillover effect of Harbin rail transit, taking Harbin Line 1 as an example, and explores the spatial and temporal effects of urban rail transit on residential prices within 2 km of the station by comparing the 2013, 2018, and 2024 year periods from the pre-construction period to the completion of the operation of the urban rail transit. The results show that the prices along the urban rail transit lines are affected by a combination of factors such as location, neighbourhood and architecture, among which, the urban rail transit has a significant value-added effect on the prices of the residences along the lines.The price of each industry shows different degrees of decreasing with the increase of the distance from the railway transport. Rail transit has significant market segmentation effects on the prices of businesses along the line, and the radius of influence of the central city market is larger than that of the non-central city market. Urban rail transport has a positive impact on the prices of businesses along the route during both the initial operational and construction periods, with the construction period having a significantly higher impact on residential prices than the initial operational period.

Keywords

Railway stations, Residential property price, Spatio-temporal effect , Harbin

1. Introduction

Since the State Council issued the Guiding Opinions on Priority Development of Public Transport in Cities, public transport has gradually taken a leading position in urban transport and become a strategic focus of urban transport. As China's urbanisation construction process continues to accelerate, the city's infrastructure facilities are becoming more and more perfect, and the transport system has ushered in new challenges. On the one hand, urban rail transit system can greatly reduce traffic pressure, on the other hand, it can also improve the space utilisation rate, optimise the space layout, and play a vital role in promoting the process of environmentally friendly and conservation-oriented cities(Li X 2022). ‘Land preparation along rail transit lines, public transport oriented integrated development, and last kilometre construction have become the key tasks of many cities during the 14th Five-Year Plan period. The last kilometre construction has become one of the priorities of many cities during the ‘14th Five-Year Plan’ period(Huang Cuncun,Wang Xiaowen and Li Linna 2021).

Taking Harbin's residential market in 2024 as a reference, there is a disparity in the value of properties adjacent to metro lines, with prices in some areas exceeding 40,000 yuan per square metre while in others they are as low as 0.1 million yuan per square metre, and there are even high-grade residential areas where the average price is 40 times that of low-grade residential areas. There is an inevitable logic behind such differences in property prices, but excessive price differences may lead to the misuse of metro resources and problems such as unbalanced urban development, monopolisation of educational resources and social stratification(Teng Li, Zhong Chujie and Cai Di 2022) . In the face of limited urban construction funds and spatial resources, there is an urgent need for in-depth analyses of the metro's impact on residential prices, and for research into how to effectively regulate premiums in order to enhance the social and economic benefits of urban metros(Zheng Siqi,et al.2014).

2. Research Case and Methodology

2.1. Case Study

Harbin is a prefecture-level city under the jurisdiction of Heilongjiang Province, the capital of the province, a sub-provincial city, a megacity, the core city of the Harbin-Changchun urban agglomeration, an important central city in Northeast China and an important manufacturing base of the country, as determined by the State Council. Harbin Metro Line 1 is the first metro line to be built and operated in Harbin, Heilongjiang Province, China, and the first alpine-resistant metro line in China, which was opened on 26 September 2013 for operation. The line is roughly north-south direction, starting from Harbin East Station in the north, through the Daowai District, Nangang District, Xiangfang District, Pingfang District and other areas, and ending in the south of Xinjiang Street Station, 23 stations along the line, the line length of 26.27 kilometres. The line was started in September 2008, in 2013 opened for operation. Based on the metro construction, it is studied every five years starting from 2013.

The impact of urban rail transport on residential prices is generally limited to a certain range. Relevant studies show that the impact of rail transport on residential prices is weak when the distance from the station is more than 2 km(Qu Shijin et al 2018). Therefore, taking into account domestic and international experience, the study scope is defined as the area within a 2 km radius of the stations along Harbin Metro Line 1. Taking Harbin Metro Line 1 as an example, the study explores the spatial and temporal effects of urban rail transit on residential prices within 2 km of the stations from the pre-construction to the completion of the operation process (Bao Shanju, Lu Lin 2018).

2.2. Research methodology

Characteristic Price Model, is argued that property consists of a number of unique attributes and that the value of property depends on the overall utility derived from these attributes(Zhou Xinxin et al. 2020). By analysing the price composition of property commodities and revealing the value embedded in each attribute, the attribute factors in property price fluctuations are disentangled while maintaining the property attributes unchanged, so that the impact of attribute changes can be excluded one by one from the overall price changes, and ultimately, the price changes can be purely driven by the relationship between supply and demand. Common types of property value models include linear, logarithmic and semi-logarithmic(HURST N B, WEST S E. 2014). After repeated trials, the best-performing semi-logarithmic attribute value model is adopted in this study to explore the impact of urban metro on residential prices in time and space(Forouhar A.2016).

2.3. Data sources

Through data crawling, we obtained 16,077 POI points in the Golder map of Harbin city and 16,077 sample data related to the residences in Harbin city from 2013 to 2024. According to the date of

residential information published on the website as the basis of time division, the residential houses are divided into 3 periods, i.e. the early operation period, the construction period, and the maturity period. The data is mainly obtained from the China Residential Price Quotation Platform, supplemented by real estate websites such as Anjuke, Chain Home and Housing World. Residential prices are all per square metre. The geographic location information of POI landmarks such as residences, hospitals, parks, schools, etc. is captured from Gaode map to build a spatial database(as shown in the figure1 to3).

Figure 1. Price of dwellings within the 2km buffer zone of rail stations, 2013. Source: Author's own drawing.

Figure 2. Price of dwellings within the 2km buffer zone of rail stations, 2018. Source: Author's own drawing.

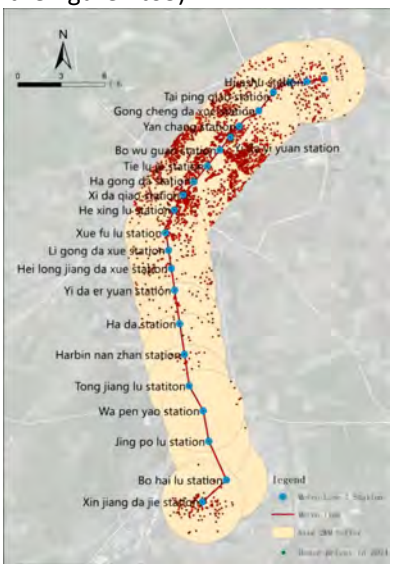


Figure 3. Price of dwellings within the 2km buffer zone of rail stations, 2024. Source: Author's own drawing.

Explore the value-added model of the residential market around rail transit stations. In-depth analysis of the impact of geographic location, architectural attributes, environmental construction and other factors on residential prices, and combining these factors with actual transaction prices, comparing the overall level of the study area, and dividing price levels (LIANG X J et al. 2018). To study how different indicator factors act on the premium effect of the residential market around the rail transit stations and their influence (as shown in the table1).

Table 1 Selection and assignment methods for housing price influencing variables Source: Literature Integration

Category indicators		Unit	Method of assignment of indicators
Dependent variable	*Y*	Yuan/m2	2 km around the rail transit station The average price of each residential quarter within the scope
Location traffic	*X1*	m	Straight-line distance from residential quarter to nearest rail transit station
	X2	m	Distance from residential quarter to CBD (take the nearest residential quarter to Harbin International Financial City CBD, Haxi Railway Station CBD and Hadong New District CBD)
	X3	Strip	Number of bus lines within 500m around residential quarters
Architectural features	*X4*	Actual value assignment	Floor area ratio of residential quarters
	X5	a	House construction time (difference between the opening year of residential subdivisions and 2024)

	X6	Actual value assignment	Greening rate of residential quarters
	X7	Dummy variable	1 km around residential quarter If there are primary schools in it, it is 1, and if there are no primary schools, it is 0.
	X8	Dummy variable	1 km around residential quarter If there are secondary schools within it, it is 1, if there are no secondary schools, it is 0
	X9	Dummy variable	1 km around residential quarter If there are high schools in it, it will be 1, if there are no high schools in it, it will be 0
Environment Construction	*X10*	Dummy variable	1 km around residential quarter If there are hospitals in it, it is 1, if there are no hospitals in it, it is 0
	X11	Dummy variable	1 km around residential quarter If there is a shopping mall inside, it is 1, if there is no shopping mall inside, it is 0
	X12	Dummy variable	1 km around residential quarter If there is a park inside, it is 1, if there is no park inside, it is 0
	X13	Dummy variable	1 km around residential quarter If there is a stadium inside, it is 1, if there is no stadium, it is 0
	X14	Dummy variable	1 km around residential quarter If there is a museum inside, it is 1, if there is no museum, it is 0

3. Analysis of results

3.1. Spatial distribution pattern of residential prices

Through the ArcGIS 10.8 version of the software to draw the Harbin underground line 1 around the distribution of residential market prices, observation of the image can be found, residential prices in the construction of rail transit at different stages of the geographic north-south axis presents an 'inverted U' distribution characteristics, that is, the centre of the region prices are higher, the two sides of the lower, especially the southern region of the lowest prices. The southern region has the lowest price. In order to explore the spatial distribution characteristics of residential prices near urban rail transit stations, we calculated the average residential prices of each station and drew a line chart of residential prices according to the order of stations from north to south(as shown in the figure4).

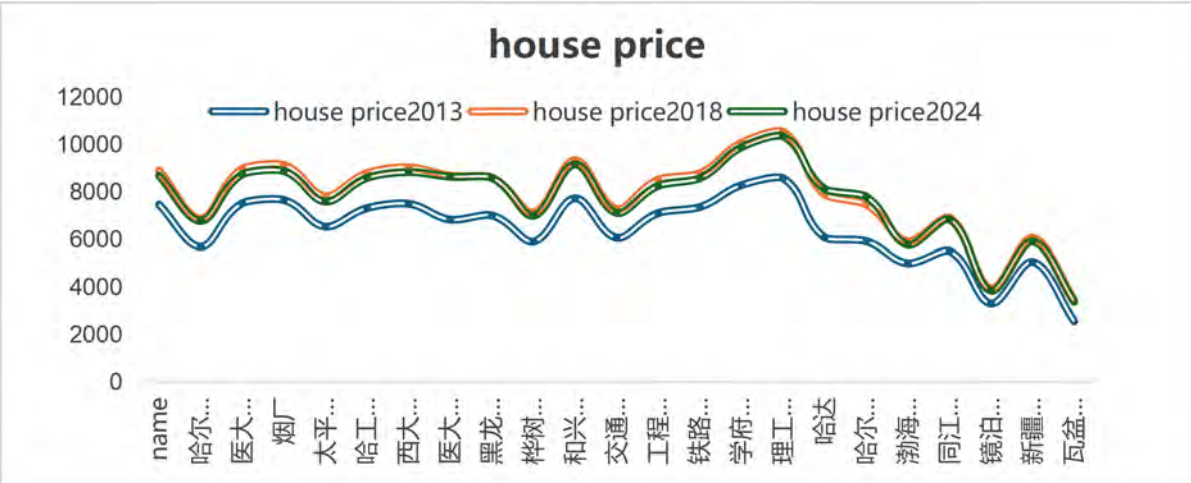


Figure 4 Trends in average housel prices around the site, 2013, 2018 and 2024

Source: Author's own drawing.

Along Harbin Metro Line 1, the spatial distribution of residential prices exhibits a single-centre characteristic, with the highest price point located at the Polytechnic University station in the city centre

zone. From this centre outwards, residential prices gradually decrease as the distance from the central business district increases(as shown in the figure5 to 7).

Figure 5. Average price of dwellings within the 2km buffer zone of rail stations, 2013. Source: Author's own drawing.

Figure 6. Average price of dwellings within the 2km buffer zone of rail stations, 2018. Source: Author's own drawing.

Figure 7. Average price of dwellings within the 2km buffer zone of rail stations, 2024. Source: Author's own drawing.

3.2 Identification of price spatial distribution characteristics

Using the residential value prediction model to analyse the distribution of house prices, the regression analysis of the model shows that the significance of the F-value test is lower than 0.001, and the R^2 coefficient reaches 0.775, which indicates that the model fits well; the distance between the residential area and the metro station and the city centre has a significant decreasing negative premium effect on the house prices. Factors such as building age, medical facilities, and shopping centres show significant linear negative premium effects on house prices; and factors such as the number of bus lines, green coverage, and leisure parks have significant linear positive premium effects on house prices(as shown in the table2).

Table 2 Regression results of the model Source: Author's own drawing.

Variable	Coefficient	Variable	Coefficient
InX1	-0.034*	*X8*	0.012
InX2	-0.651**	*X9*	0.137**
X3	0.339**	*X10*	-0.359**
InX4	0.193	*X11*	-0.035*
X5	-0.058*	*X12*	0.083**
X6	0. 263**	*X13*	-0.045
X7	0.008	*X14*	-0. 126**

Note: ** and * indicate significant at the 1 per cent and 5 per cent levels, respectively.

3.3 Temporal effects of urban rail transport on residential prices along the route

Early stages of urban rail transport planning and operation (2013):House prices in the four administrative regions traversed by the line are generally on an upward trend, and residential prices in the area covered by the metro are generally in line with average regional house price conditions.

Urban rail construction period (2018): Nangang District and Xiangfang District residential prices in the underground radiation area began to exceed the regional average; in contrast, Pingfang District and Daowai District residential prices are generally higher than the underground neighbourhood. The reason for this is that Nangang District and Xiangfang District is located in the old city of Harbin, industrial concentration, rapid economic development.

Urban rail maturity (2024): Average house prices in all regions as well as prices of homes in metro-affected areas hit record highs, with prices of homes in metro-affected areas increasing by 16% to 32% compared to the early stages of construction. In Nangang and Xiangfang districts, the price of residences around the metro line increased due to the opening of the metro, exceeding the regional average house price.

A quantitative study of the role of urban construction of rail transit on the market value of neighbouring residences at various stages was conducted by applying the time dummy variable in the characteristic price model. It was found that the initial construction phase of rail transit and its operational phase had a significant positive contribution to the market value of neighbouring residences (as shown in the table). This suggests that the construction of rail transport makes a significant positive contribution to enhancing the value of homes along the route, and that the positive contribution to home prices is more pronounced during its formal operational phase than during the construction phase. The opening of the railway significantly improves the accessibility of the route, which in turn brings a positive price increase effect to the residential market(as shown in the table3).

Table 3 results of hedonic price models with different distance intervals Source: Author's own drawing.

Model	Dependent variable			
	Within 0.5 km from the subway	0.5 -1 km from subway	1-1.5 km from the subway	1.5-2 km from subway
Initial stage of rail transit construction	0.555*	0.563*	0.419*	0.456*
Rail transit operation period	0.774*	0.764*	0.624*	0.714*

Note: ** and * indicate significant at the 1 per cent and 5 per cent levels, respectively.

4. Conclusion and discussion

Taking the residential areas along Harbin Metro Line 1 as a case study, the study explores the mechanism of urban rail transport on residential market price, and also examines the spatial and temporal impacts on residential price at different stages of rail transport construction. The research findings are as follows:

The spatial impact of rail transit on residential prices is analysed using a characteristic price model, which shows that the price of residences near the Polytechnic University Station of Metro Line 1 reaches the highest level, and then declines drastically towards the south, while the price of residences towards the

north does not fluctuate much. There is a significant negative correlation between residential price points and the distance to the rail station, with the most significant price reductions occurring in the range of 0 to 0.5km, and the effect of the rail transit on residential price points becoming weaker after more than 2km. In addition, the impact of rail access on residential price points varies by location, with non-city centres affected to a greater but lesser extent than city centres.

The analysis of the factors affecting the price of homes along the rail transit line through the characteristic price model and regression method shows that a total of 14 factors have a significant impact on the price of homes, and the rail transit has a significant effect on the price of homes, and this effect is closely related to the distance of the homes from the station as well as the period of construction of the rail transit.

The analysis of the temporal impact of rail transport on residential price shows that from the early stage of construction to the mature period of operation, rail transport has always had a positive impact on residential price along the line. After taking macroeconomic factors into account, the opening of rail transport still has a significant impact on residential price appreciation.

This study only analyses the residential price level, and future research can be expanded to compare the spatial and temporal effects of different real estate types, such as commercial and industrial, in order to enrich the research results.

5. References

Pilgram C A, West S E. (2018)'The effect of light rail on residential property values in Minneapolis', *Minneso-ta. Regional Science and Urban Economics,*69(12),p1-10.

Song Z, Cao M, Han T, et al. (2019)' Public transport accessibility and housing value uplift: Evidence from the Docklands light railway in London', *Case Studies on Transport Policy*, 7(3), p607-616

Seo K, Golub A, Kuby M.(2014) 'Combined impacts of highways and light rail transit on residential property values: A spatial hedonic price model for Phoenix, Arizona', *Journal of Transport Geography*, 41(8),p53-62

Li X, and Love P E D. (2022)' Procuring Urban Rail Transit Infrastructure by Integrating Land Value Capture and Public Private Partnerships: Learning from the Cities of Delhi and Hong Kong' *Cities,* 122

Gao Zhe, Qiu Jiayi,Yu Jiayi, and Zhu Yuanyuan (2022)' Influence of School Districts on Housing Prices and the Effect on Socio-Spatial Restructuring: Taking Wuchang District of Wuhan City as a Case' *Progress in Geography*, 41(4),p 609-620.

Huang Cuncun,Wang Xiaowen, and Li Linna (2021)' The Spatio-Temporal Effects of Urban Rail Transit on Housing Price: A Case Study of Fuzhou Metro Line 1' *Geographical Research,* 40(10),p 2808-2822.

Zheng Siqi, Hu Xiaoke, Zhang Bo, and Wang Shouqing (2014)' Urban Rail Transit's Value-Added Capture: From Theory to Reality' *Urban Development Studies*, 21(2),p35-41.

Wang Yue, Zhou Penghui, Pan Haize, and Dai Shige (2022) ' A Study on Multi-Scale Spatial Relationship between Road Network Form and Housing Price Based on sDNA and MGWR' *Geography and Geo-Information Science*, 38(1),p 103-109.

Teng Li, Zhong Chujie, Cai Di(2022)' Study on the spatial type differentiation of Guangzhou metro TOD zones: Based on "Node-Place-Linkage" coupling model' *Economic Geography,* 42(4),p103-111

WANG Y, ZHANG A L.(2021)' Temporal and spatial effects of land value increment of urban rail transit and investment priority: From the perspective of government land value capture' *Journal of Huazhong Agricultural University: Social Sciences Edition*, (2),p165-173, 184

Bao Shanju, Lu Lin(2018)' Impact of planning-guided spatial evolvement on temporal-spatial evolution of land price: Taking Hefei as an example' *Acta Geographica Sinica,* 70(6),p906-918.

WAGNER G A, KOMAREK T, MARTIN J (2017) 'Is the light rail "Tide" lifting property values? Evidence from Hampton Roads' *Regional Science and Urban Economics*, 65,p25-37.

Shen Tiyan,Yu Hanchen, Zhou Lin, Gu Hengyu, and He Honghao (2020)' On Hedonic Price of Second-Hand Houses in Beijing Based on Multi-Scale Geographically Weighted Regression: Scale Law of Spatial Heterogeneity' *Economic Geography,* 40(3),p75-83.

Duncan M.(2011) 'The impact of transit-oriented development on housing prices in San Diego' *Urban Studies*, 48(1),p101-127.

Qu Shijin, Hu Shougen, Li Quanfeng et al(2018)'Quantitative evaluation of the impacts of driving factors on urban residential land price and analysis of their spatio-temporal heterogeneity: A case study of Wuhan City' *Progress in Geography*, 37(10), p1371-1380.

Zhou Xinxin, Li Xin, Xue Xiaotong, et al.(2020) 'Influence of Xuzhou rail transit construction on surrounding housing price: Based on the spatial DID model' *Journal of Jiangsu Normal University: Natural Science Edition*, 38(1), p17-22.

HURST N B, WEST S E. (2014)' Public transit and urban redevelopment: The effect of light rail transit on land use in Minneapolis, Minnesota' *Regional Science and Urban Economics*, 46, p57-72.

Forouhar A.(2016)' Estimating the impact of metro rail stations on residential property values: Evidence from Tehran' *Public Transport*, 8(3), p427-451.

BHATTACHARJEE S, GOETZ A R,' The rail transit system and land use change in the Denver metro region'. *Journal of Transport Geography*, 54, p440-450.

LIANG X J, LIU Y L, QIU T Q, et al(2018)' The effects of locational factors on the housing prices of residential communities: The case of Ningbo, China' *Habitat International*, 81, p1-11.

Cao Zhejing (2019) 'Discussion of the Impact of Public Transport on Equity in Urban Spatial Opportunity' *Urban Planning Forum*, (3), p33-41.

Zheng Yanqiao, Jiao Shitai, Zhang Xiaoqi (2019) 'Impact of urban structure on subway system and real estate price: Evidence from Beijing, Hangzhou, Nanjing and Chengdu' *Economic Geography*, 39(6), p75-85

Research Paper

A Case Study of Singapore HDB Residents on the Formation of Community Attachment in Community Gardens

Kangsheng LIU, School of Architecture and Design, Harbin Institute of Technology, China
Wei DONG, School of Architecture and Design, Harbin Institute of Technology, China
Yu DONG, School of Architecture and Design, Harbin Institute of Technology, China
Tianyi HOU, School of Architecture and Design, Harbin Institute of Technology, China

Abstract

*Rapid urbanization is a global phenomenon that, while driving economic growth and social development, can also pose a number of challenges and problems (Nations, 2017). As a developed country, Singapore, in the course of rapid urbanization, has had to cope with changes in the demand for social services, including health care, housing and community support, brought about by demographic changes. It has also led to a weakening of residents' sense of identity and belonging to their communities (*Building community resilience*, 2022). Against this backdrop, building and maintaining social capital, as well as enhancing the resilience and adaptive capacity of communities, has become particularly important (Benjumea et al., 2022). Singapore has addressed this challenge through multi-stakeholder engagement and a system of indicators to measure community resilience. In particular, National Parks Singapore launched the 'community in bloom' project in 2005, which aims to improve the community environment through the construction of community gardens, while enhancing social welfare and community cohesion (Tan and Neo, 2009). Existing studies have shown that community gardens are effective in improving the overall quality of life and social capital of communities (Lovell et al., 2014). Their specific positive impacts on the community are mainly reflected in the following aspects: Empowering residents to provide opportunities to get close to nature and improve their physical and mental health (Lal, 2020); Supporting local food production and promoting sustainable lifestyles (Opitz et al. 2016); And as well as serving as a platform for education and environmental awareness promotion (Hume et al., 2022). However, the impact of community gardens on community belonging and community attachment has not been adequately studied. Therefore, four community gardens constructed in the last five years in Singapore and the HDB Community in which they are located were selected for this study. First, basic information about the community gardens was obtained from the leaders of the gardens through semi-structured interviews. After that, a questionnaire based on the Community Attachment Scale was used to investigate the gardeners and non-gardeners in the communities where the community gardens were located. Finally, the obtained data were analysed and processed using Structural Equation Modelling (SEM). The results of the study indicate that community gardening positively affects community attachment by increasing residents' community satisfaction, improving neighbourhood relations, and enhancing community perceptions and emotions. A cross-sectional comparison of the relationship between the four gardens and community attachment showed that garden size, organizational structure, and event hosting were positively related to community attachment.*

Keywords

Community Garden, Community Attachment, CIB program, Structural Equation Modelling, HDB Estate, Singapore

1. Introduction

Rapid urbanization is a key feature of global development in the twenty-first century, and it is having a profound impact on the world's cities. According to the Human Development Report of the United Nations Development Programme, by 2050, more than two thirds of the global population is expected to live in urban areas (Nations, 2017). As populations continue to gather and increase, cities are expanding rapidly. This brings not only economic prosperity and increased cultural diversity, but also a series of challenges, such as inadequate infrastructure, environmental pollution, traffic congestion, tight housing and social stratification (Brueckner and Largey, 2008). In the process of urbanization, how to balance development and sustainability and safeguard the quality of life of residents has become an important issue for city managers and planners (Forrest and Kearns, 2001).

Singapore is a tropical island nation in Southeast Asia, known for its highly developed economy and high standard of living. In 2018, Singapore's urbanization rate reached 100%, with all its citizens identified as "urban population" (Nations, 2018). Research in 2019 shows that more than 40% of Singapore's population are immigrants. And increased immigration has been one of the main factors behind Singapore's rapid population growth (Richards et al., 2020). When new residents enter a new living environment, their emotional attachment and community identity are not formed as quickly, leading to isolation from their original productive living environment (Cheong et al., 2007). At the same time, the arrival of foreign immigrants has changed the original living and social environment of the community, and the local sentiments of the original residents have also been affected. This can lead to a decline in the residents' sense of community belonging and identity (Hesari et al., 2020). All these factors will lead to a deterioration in neighborhood relations and are not conducive to the formation of a good social network. In more serious cases, they can even endanger the health and safety of individuals and groups (Berkman, 2000).

In response to the challenges to community resilience posed by a growing population and changing demographics as a result of full urbanisation, Singapore has undertaken a number of efforts (*Building community resilience*, 2022). One of these is the Community in Bloom (CIB) programme, officially launched by the National Parks Board of Singapore in 2005 to encourage residents to establish community gardens (Tan and Neo, 2009)(Figure 1). Community gardens under Singapore's CIB programme are implemented and managed through a government-community partnership model, with residents' committees responsible for the day-to-day management of the gardens, providing a link between higher-level government agencies and residents. The Government encourages more people to visit the gardens as a way to connect with the rest of the community and enjoy the health and well-being benefits of being closer to nature. To date, around 40,000 residents have participated in the programme and more than 1,700 community gardens have been established. The core value of the programme is public participation, bringing together the wisdom and consensus of the community in a collaborative effort to create an inclusive environment (Tan and Neo, 2009).

Figure 1. The Community in Bloom (CIB) program.

Source：National Parks Website. https://gardeningsg.nparks.gov.sg/get-involved/community-gardens/

2. Literature review

2.1. Benefits of community garden

Community gardening began in the 1890s. Early on, academics discovered the benefits of community gardening in terms of beautifying the community environment, increasing the availability of fresh produce in the community, providing opportunities for outdoor physical activity and improving mental health. As a result, community gardens have become an increasingly popular topic of research in recent decades. Community gardens are seen as a 'link' and 'bridge' (Putnam, 2000) to social capital within a community, helping people to become and remain involved in community activities (Sempik et al., 2003). Previous research has identified community gardens as 'social' (Glover et al., 2005), ' socially produced spaces ' (Chitov, 2006), ' spaces of connection ' and 'belonging spaces' (Diamant and Waterhouse, 2010) as they provide opportunities to meet, interact and build relationships with others. Glover states that 'the community garden is not so much about gardening as it is about community' (GLOVER, 2004). This is because it provides a 'third space' away from work and home where people can come together, make connections and develop a sense of community identity.

However, it is only in recent years that attention has been paid to assessing the benefits of community gardens in response to the growing demand for health and well-being among urban residents. (Lovell et al., 2014) summarised the benefits of community gardening in four areas: physical health, mental health, social well-being and quality of life. The researchers found that gardening can address chronic and non-communicable diseases by providing opportunities for physical activity, improved nutrition and stress reduction (Lal, 2020). Community gardening and positive community psychological outcomes were later confirmed (Diamant and Waterhouse, 2010). Participation in gardening can improve well-being through increased community interaction and cultural engagement (Benjumea et al., 2022). Community gardening is also an effective way for residents of high-density cities to interact with nature and build psychological resilience during epidemics. In addition, community gardens provide space for volunteerism and community engagement to enhance residents' personal fulfilment and esteem, and contribute to quality of life (Ohmer et al., 2022). A recent study of community gardens in Japan showed that community gardens play an important role in social networks that contribute to urban resilience (Shimpo, 2024). Overall, the benefits of community gardening are not limited to the individual, but also include improving the environment and sharing the fruits of their labour, helping to create more harmonious and cohesive communities.

2.2. Community attachment

Emotions and feelings shape the world we know and live in, and people form certain emotional relationships with specific spaces. Community attachment theory, based on urban and rural planning, human geography, and environmental psychology, is gaining more and more attention as an effective tool for interpreting and measuring residents' feelings (Anderson and Smith, 2001). Community attachment is a description of the feelings between residents and the community, and it is an important perspective for analyzing the social contents of the community and the living conditions of the residents (Pile, 2010).

Community attachment may be thought of as the extent to which residents of a place possess cognitive or affective ties to each other and to that place (Trentelman, 2009). Social scientists interested in the concept of community attachment have generally defined it as a sense of belonging or rootedness in a community (Cross, 2003). Some researchers explicitly identify dimensions of attachment. Bolan (1997) distinguishes between attitudinal attachment (comprising evaluation and sentiment), and behavioral attachment (comprising informal interaction and formal participation in the community). (Stinner et al., 1990) use three concepts to denote community attachment – amity (local friendships), involvement (participation in the community), and sentiment (degree of satisfaction with the community).

Summarizing previous explanations and definitions of community attachment by many scholars, Cross defined Community Attachment as: A positive effective bond between an individual and the place in which they reside, the main characteristic of which is the desire of the individual to maintain close to that place (Cross 2003). According to this definition, we can see that community attachment has multiple dimensions. Within a community, attachment figures can be the built environment, the natural environment, and the social environment (Figure 2). In addition to attachment objects, attachment itself can also be multi-dimensional, which includes several significant aspects: satisfaction, cognitive preferences (perception of and preference for a place or kind of place), sense of belonging or home, identification with place, and dependence on the place (Cheng et al., 2021) (Figure 3).

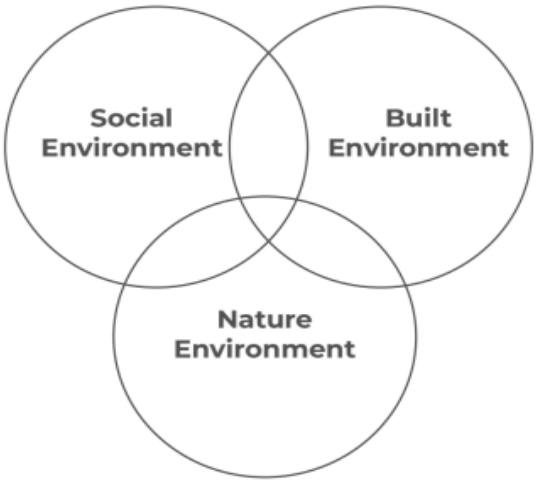


Figure 2. Object of Attachment (Cross 2003)

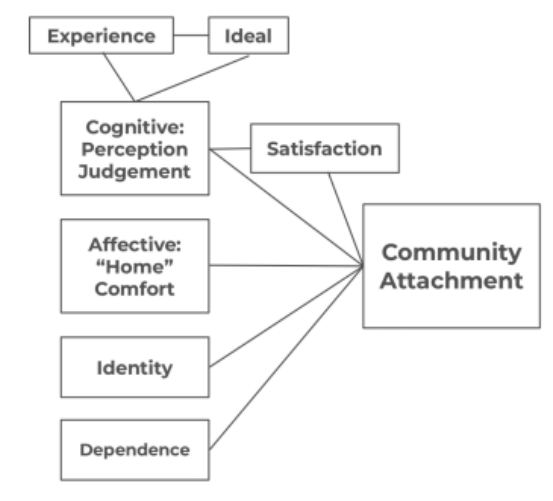


Figure 3. Community Attachment Model (Cross 2003)

2.3. Research Questions and Aims

Based on the above literature review on community gardens and community attachment, two research questions were posed in this study:

1) Do some characteristics of CIB community gardens more strongly facilitate community attachment?

2) How does participation in CIB community gardens facilitate community attachment?

The aim of this research was to demonstrate the positive significance of community gardens to community attachment in order to inform the design principles and construction and operation of community gardens.

3. Methodology

This research employs a mixed-methods analysis including interviews, questionnaire surveys, observations, documents, and photography. Qualitative and quantitative data were collected by distributing closed - ended questionnaires and QR code posters to collect qualitative and quantitative data and to compare data obtained from gardeners and non-gardeners. The questionnaire covered respondents' level of participation in community gardening, the value placed on community gardens, measures of community attachment and personal information (Table 1). In previous research, community attachment has typically been measured to capture residents' emotions and feelings about their local community. The questionnaire survey in this study combined scales summarized by previous researchers to measure community attachment (Jeni Cross, 2003; Theodori, 2004). We also conducted semi-open-ended interviews with key managers of all gardens in order to understand basic information about the gardens, their staffing, operational practices, and social impacts.

Table 1. Questionnaire survey

Factors		Questions
Participate	Q1	Do you currently participate in community garden activities?
	Q2	How often you are active in the community garden?
	Q3	How long have you participated in the community garden?
Importance of Community Gardens	Q5-1	Community gardens are very important to me.
	Q5-2	Community gardens are very important to all community residents.
Cognitive	Q6-1	Your current satisfaction with the community.
	Q6-2	Your initial satisfaction with the community.
Dependence	Q7-1	They are good people.
	Q7-2	I am happy to be their neighbors.
	Q7-3	We greet each other with a friendly hello.
	Q7-4	They try not to make as much noise as possible for us.
	Q7-5	I do not like my neighbors.
	Q7-6	I treat my neighbors as friends.
Identity	Q8-1	This is the ideal community to live in.
	Q8-2	I feel at home in this community.
	Q8-3	I like living in this community.
	Q8-4	This community is part of my identity.
	Q8-5	I feel I belong to this community.
Affective	Q9-1	I would be sorry to move out of my community, without the people who live there.
	Q9-2	I would be sorry if the people who I appreciated in the community moved out.
	Q9-3	I would be sorry if both I and the people who I appreciated in the community moved out.

Personal Information	Q10-1	Your Age
	Q10-2	How long have you lived in this HDB ?
	Q10-3	Which garden do you usually participate in or where do you live nearby? - Selected Choice

3.1. Site selection and sampling

By looking at the registered gardens on the Nparks website and the basic social media profiles of the gardens in question, I finally identified four new community gardens that have been built in the last five years (Figure 4). The selection of new gardens ensures that the residents of the community annexes in the respective neighbourhoods are not disturbed by too many factors other than the gardens, such as the level of improvement of the community infrastructure, the quality of the community council services and the impact of other community engagement activities. This study involved a survey of community residents. The boundaries were determined by the boundaries of the HDB estates served by the specific gardens.

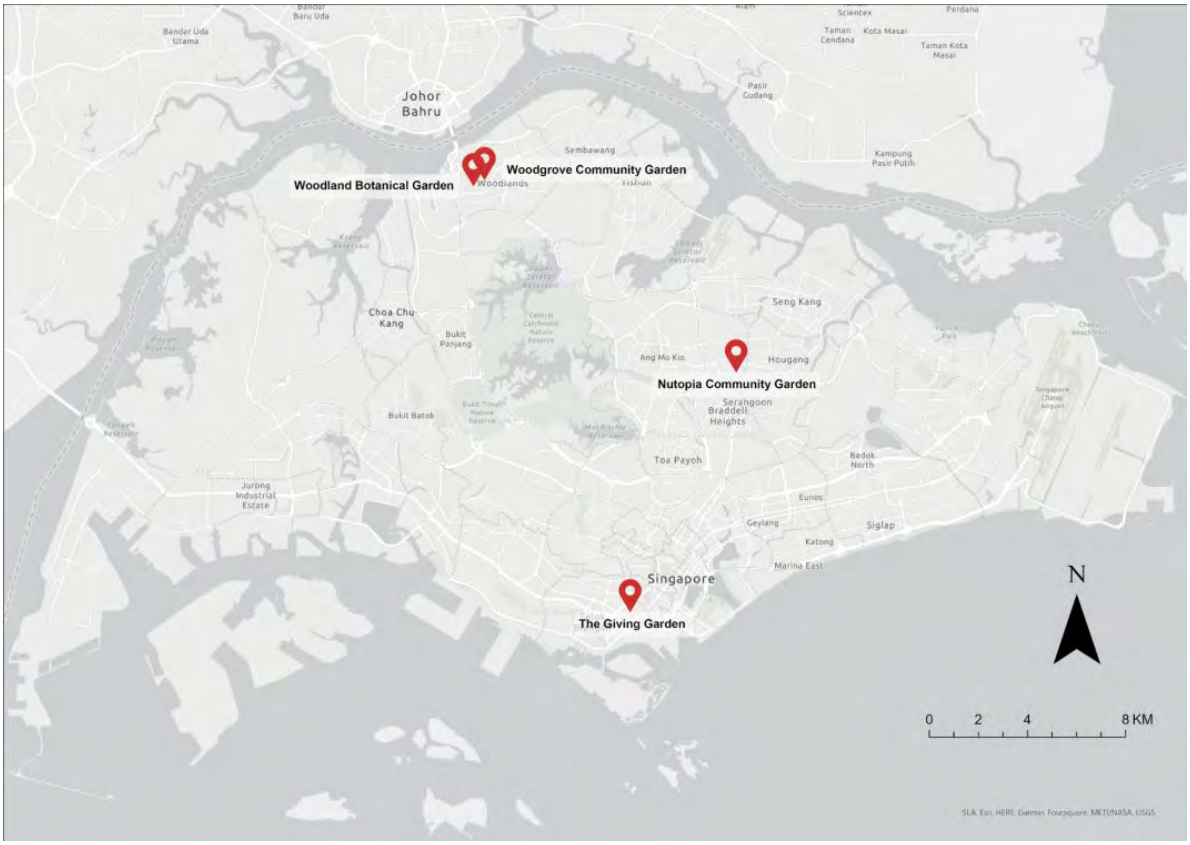


Figure 4. location of four gardens in Singapore. (Edited by author)

We received a total of 162 valid responses from the communities where the four gardens are located. Ten residents were recruited and interviewed prior to conducting the survey to clarify the various meanings their peers may have assigned to the questions and answers in the questionnaire. The information obtained from the interviews helped to improve the questionnaire. The data collected were analyzed by structural equation modeling as well as comparative analysis.

3.2. Structural Equation Modelling (SEM)

Structural Equation Modelling (SEM) is a multivariate statistical technique that can analyze the relationships between multiple dependent and independent variables simultaneously, allowing for measurement error and accurate estimation of complex relationships between variables (Mokhtarian and Bagley, 2002). Because of its flexibility and accuracy, SEM is widely used for theoretical validation and empirical research in fields such as social sciences and psychology (Yang and Cao, 2018).

4. Results

4.1. Configurations of 4 CGs

To achieve the first research goal, I conducted in-depth interviews with four garden leaders and summarized basic information about each of the four gardens in a combination of site research transcripts and photography. Afterwards, the configuration, operation, and activities of the four gardens were entered into the same table for comparative analysis (Figure 5-Figure 12).

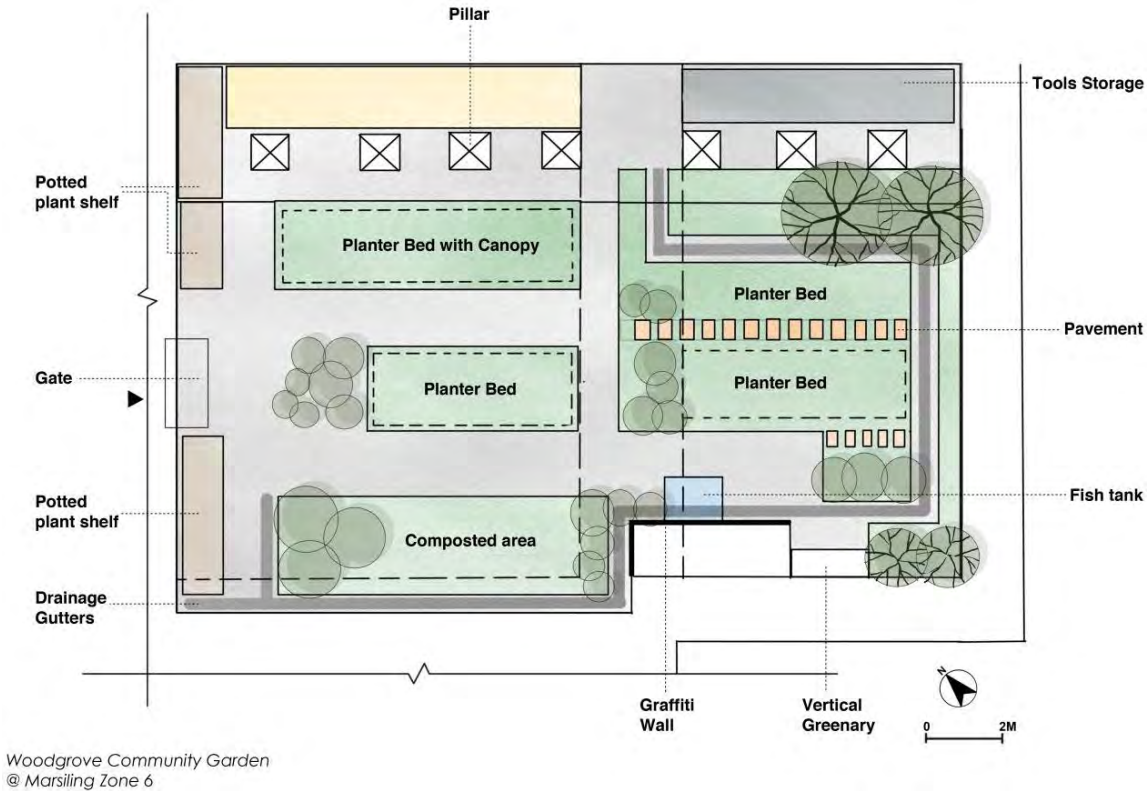


Figure 5. Master plan of WCG (Hand-drawn by author)

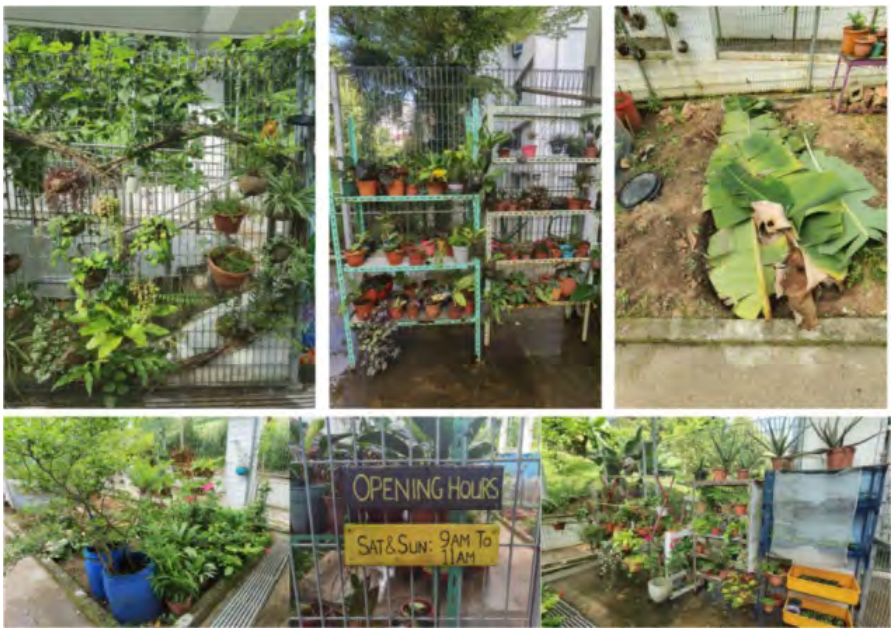


Figure 6. Configuration of WCG (Author's own photograph)

Figure 7. Master plan of WBG (Hand-drawn by author)

Figure 8. Configuration of WBG (Author's own photograph)

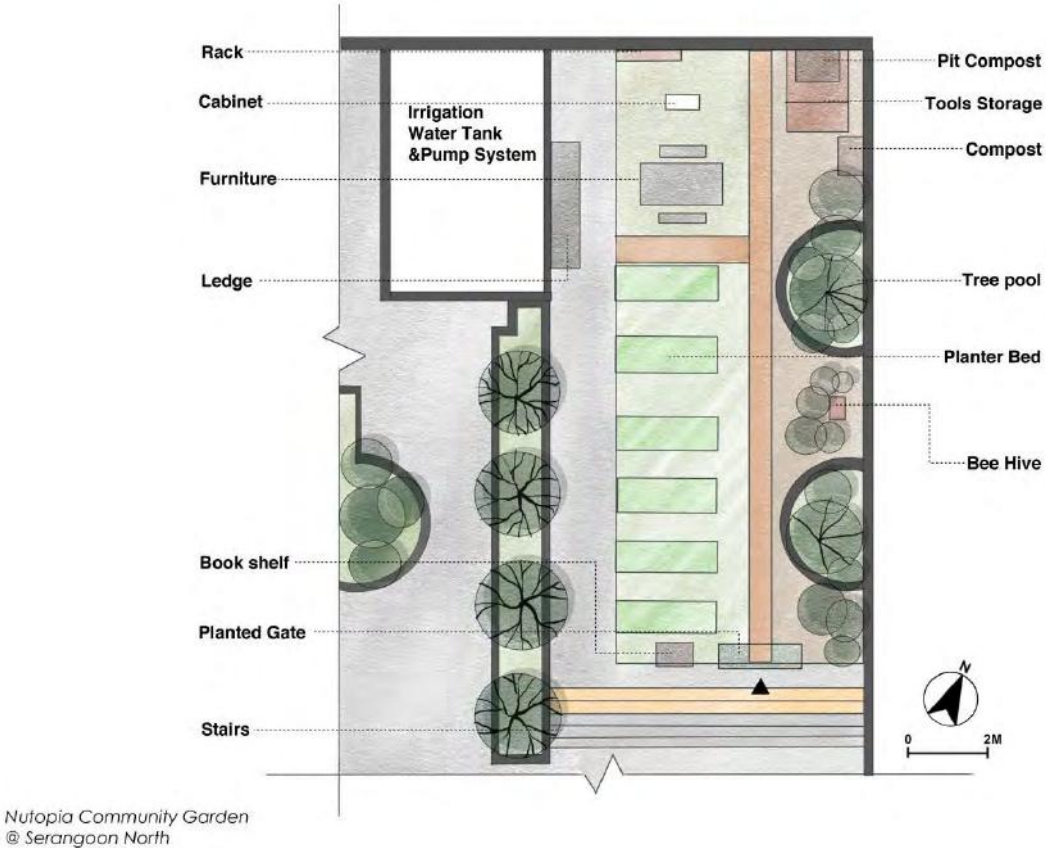


Figure 9. Master plan of NCG (Hand-drawn by author)

Figure 10. Configuration of NCG (Author 's own photograph)

Figure 11. Master plan of TGG (Hand-drawn by author)

Figure 12. Configuration of TGG (Author 's own photograph)

The basic information, configuration, and activities of the four gardens are put into the same table for comparison: WCG was established as early as 2018. NCG and WBG have the longest opening hours and are not gated, while WCG is only open for certain hours on weekends. Of the four gardens, only WBG is themed around healing gardens and ornamental plantings, while the other three are edible gardens. So, in terms of configuration the other three gardens are more or less the same, while WBG is mainly ornamental decoration.

Table 2. General information on 4 CGs

Garden	Woodgrove Community Garden @ Marsiling Zone 6	Woodlands Botanic Garden @ Marsiling Zone 3	Nutopia Community Garden @ Serangoon North	The Giving Garden @ Kim Tian West
Establishment time	2018.11	2020.07	2021.04	2021.11
Area (㎡)	270	3000	60	1100
Stuffing	6 core members up to 30 volunteers	6 core members up to 30 volunteers	4 core members up to 15 volunteers	20 core members up to 60 volunteers
Organization	-	Gardening group; Events holding group; Equipment Maintenance group;	-	Maintenance Team, Store-Room Management Team; Compost Management Team; Leader-In-Charge; Program Organization Team; Education & Learning Team; Garden Landscape Team; Vegetable Section; Herb Section Leader; Ornamental Section Leader;

				Fruit Section Leader; Recycle Theme Section Leader; Therapeutic Garden
Configuration	5 planter beds, 3 potted plant shelves, drainage ditches, 1 fish tank, and 2 plant climbing frames. a sofa, a coffee table, a refrigerator and several chairs，tool storage，Rain harvesting system	wood chip paving paths, bamboo birdhouses, solar panels, fountain ponds, wooden arches, Gazebo	6 planter beds, 2 flower beds, composting a group of furniture, tool storage, a beehive, a bookshelf, an irrigation system	42 planter bed, 1 seeds cultivation, composting, tool storage, meeting area, 2 swings, a handmade beehive, 6 flower beds
Space Type	Between 2 blocks with half shelter.	A corner of town park	Roof top of parking lot	Roof top of parking lot
Opening time	Sat & Sun, 9am - 11am	24 hrs.	24 hrs.	Mon - Sun, 7:30 - 21:00
Theme	Edible Garden Healing Garden (In plan）	Ornamental plants Healing Garden Enriching species diversity	Edible Garden	Edible Garden Healing Garden (In plan）
Activities/ Events	-	Volunteers' sessions Open house	-	Gardeners meeting Harvesting sharing Gardening skills training

4.2. Community attachment and community garden

A structural equation model was developed after the data collected from the questionnaire passed the reliability and validity tests. The model also passed chi-square and degrees of freedom tests. We analyzed the dependence between the four sub-dimensions of community attachment - cognitive, dependency, identity and affective - and residents' valuation of community gardens (CGI) using structural equation modelling (SEM) （Figure 13）. Firstly, engagement was positively correlated with cognitive, dependency, identity and affective were supported by statistically significant positive correlational dependence. Specifically, the path coefficient of involvement on cognitive was 1.296, with a standard error of 0.278, a critical ratio (C.R.) of 4.666, and a significance level (P) of less than 0.001, indicating that increased involvement significantly and positively predicted cognitive. Similarly, the path coefficient of involvement on dependence was 1.104, with a standard error of 0. 292, C.R. of 3.785, $p < 0.001$; for identity, the path coefficient was 1.319, with a standard error of 0.036, C.R. of 3.667, $p < 0.001$; and for identity, the path coefficient was 1.605, with a standard error of 0.506, C.R. of 3.169, $p < 0.001$. These results consistently suggest that as engagement increases, individuals' experiences of cognition, dependence, identity, and affect increase accordingly (Table 3).

The path coefficients of CGI for cognition, dependency and identity were -0.205, -0.241 and -0.289 with standard errors of 0.176, 0.191 and 0.239 and C.R.s of -1.165, -1.261 and -1.21 with p-values of 0.244, 0.207 and 0.226 respectively, none of which reached the level of statistical significance. This suggests that the effect of CGI on cognition, dependency and identity is not significant in the sample of this study. Notably, the path coefficient of CGI on AFFECTIVE was -0.599 with a standard error of 0.346, a C.R. of -1.73, and a p-value of 0.084, which is close to a statistically significant level, suggesting that CGI may have a slightly negative effect on AFFECTIVE (Table 3).

In addition, we found significant positive correlations dependence between a number of sub-dimensions and commitment, cognitive, dependency, and affective. These results further confirm that commitment

plays a central role in shaping an individual's cognitive, dependency, identity, and affective experiences. (Table 3).

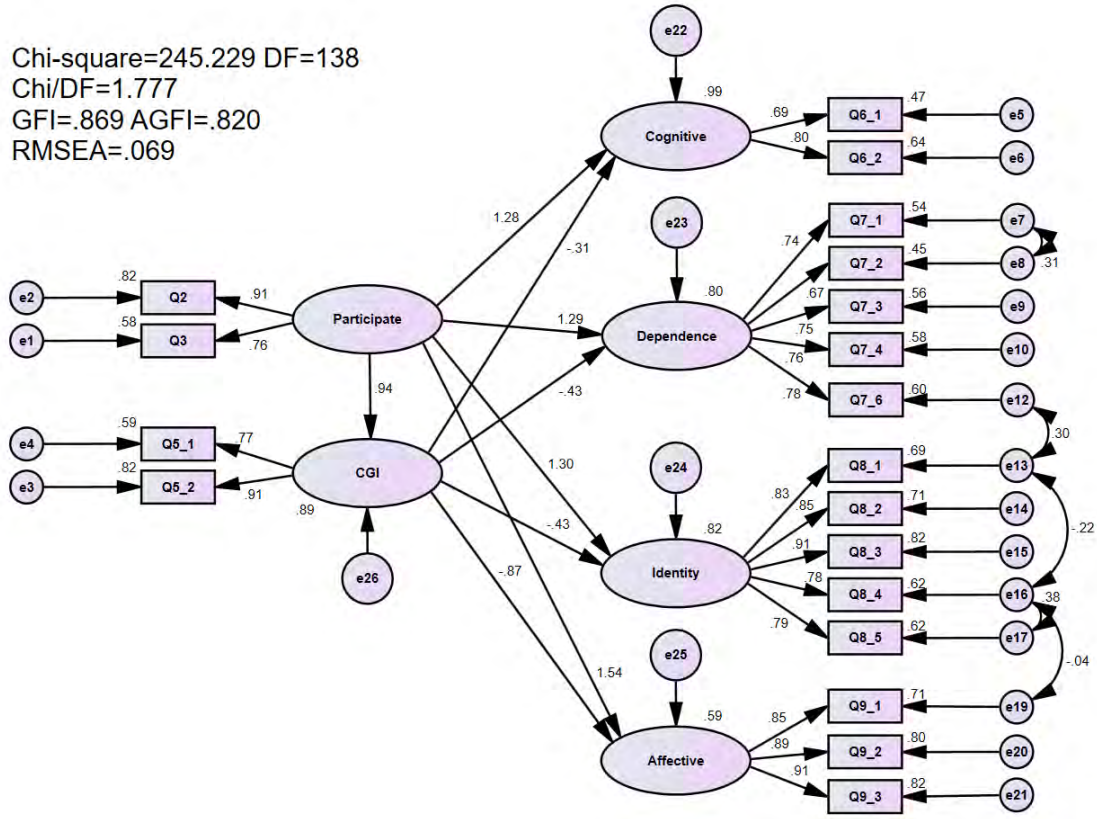


Figure 13. Structural equation model of community gardens and community attachment

Table 3. Parameter estimation results

			Estimate	S.E.	C.R.	P	Label
CGI	<---	Participate	1.437	0.121	11.866	***	par_22
Cognitive	<---	Participate	1.296	0.278	4.666	***	par_14
Dependence	<---	Participate	1.104	0.292	3.785	***	par_15
Identity	<---	Participate	1.319	0.36	3.667	***	par_16
Affective	<---	Participate	1.605	0.506	3.169	***	par_17
Satisfaction	<---	CGI	-0.205	0.176	-1.165	0.244	par_18
Dependence	<---	CGI	-0.241	0.191	-1.261	0.207	par_19
Identity	<---	CGI	-0.289	0.239	-1.21	0.226	par_20
Affective	<---	CGI	-0.599	0.346	-1.73	0.084	par_21
Q3	<---	Participate	1				
Q2	<---	Participate	1.553	0.123	12.583	***	par_1
Q5_2	<---	CGI	1				
Q5_1	<---	CGI	0.787	0.067	11.755	***	par_2
Q6_1	<---	Cognitive	1				
Q6_2	<---	Cognitive	1.159	0.124	9.325	***	par_3
Q7_1	<---	Cognitive	1				
Q7_2	<---	Dependence	0.951	0.096	9.888	***	par_4

Q7_3	<---	Dependence	1.056	0.114	9.258	***	par_5
Q7_4	<---	Dependence	1.009	0.108	9.333	***	par_6
Q7_6	<---	Dependence	1.156	0.123	9.376	***	par_7
Q8_1	<---	Identity	1				
Q8_2	<---	Identity	0.946	0.074	12.836	***	par_8
Q8_3	<---	Identity	1.005	0.068	14.69	***	par_9
Q8_4	<---	Identity	0.833	0.079	10.51	***	par_10
Q8_5	<---	Identity	0.788	0.068	11.657	***	par_11
Q9_1	<---	Affective	1				
Q9_2	<---	Affective	1.08	0.075	14.337	***	par_12
Q9_3	<---	Affective	1.01	0.068	14.82	***	par_13

4.3. Comparison of four gardens

Finally, we compared the level of community attachment across the four sites via cross-sections. Residents of NCG and its communities had the highest mean current community satisfaction score of 4.4 (0.5 std. dev.). Residents of WBG and its communities had the lowest mean score of 3.9 (0.9 std. dev.).WCG and its communities had the highest mean initial community satisfaction score of 2.9 (1.3 std. dev.), while the TGG community had the lowest average initial community satisfaction score of 2.5 (0.9 std. dev.). All four sites showed an upward trend in satisfaction change. NCG had the largest increase in satisfaction, from 2.5 to 4.4, an increase of 1.9, and WBG had the lowest change in satisfaction, from 2.8 to 3.9, an increase of 1.1.In terms of community attachment, WCG and NCG had the highest mean scores of 4.0 (0.7 std. dev.), while WBG had the lowest mean score of 3.8 (0.7 std. dev.) (Annex 1).

5. Conclusion

In conclusion, participation in community gardening can positively influence the formation of community attachment among residents. The size of the garden, the organizational division of labor, and the organization of activities are the key to its influence on community attachment. These factors relate to the influence of the garden on the community and even beyond the community. A community garden with enough space to host daily activities and with a clear staff structure can better engage residents in community gardening and further enhance community attachment. This finding answers the first research question posed previously.

Furthermore, by comparing the different attributes of gardeners and non-gardeners in community attachment one can determine in what ways community gardening affects community attachment. Also, gardeners scored higher on neighborhood relations, community perceptions, and community feelings than non-gardeners. This indirectly indicates that participation in community gardening can help residents improve the way they treat others and strengthen the construction of friendly relationships in their neighborhoods. A garden may become a community signifier and a place of emotional attachment. This is a response to the second research question.

This paper examines the effect of community gardens on the formation of community attachment in HDB neighborhoods in Singapore. This is a direction that has not been adequately studied in the Asian context. These findings can fill some gaps in the research on community garden construction in Asia. They can help subsequent community gardens to consider more influences on community attachment as well as form a better living environment in the process of establishing and developing them.

Although this study still has limitations in terms of pathway establishment and data collection, I think it has broader implications. For instance: the promotion of social inclusion and community integration, the promotion of environmental awareness and sustainability among residents, the positive impact on the urban environment, and the support of local food systems, among others.

6. References

Anderson, K., Smith, S.J., 2001. Editorial: Emotional geographies. Trans Inst Br Geog 26, 7–10. https://doi.org/10.1111/1475-5661.00002

Benjumea, D.M., Kato, Y., Chong, K.H., 2022. Participatory approaches to enact meaningful interconnectedness with the natural environment: a case study in Singapore. Cities & Health 6, 1134–1151. https://doi.org/10.1080/23748834.2022.2124012

Berkman, L.F., 2000. Social Support, Social Networks, Social Cohesion and Health. Social Work in Health Care 31, 3–14. https://doi.org/10.1300/J010v31n02_02

Brueckner, J.K., Largey, A.G., 2008. Social interaction and urban sprawl. J. Urban Econ. 64, 18–34. https://doi.org/10.1016/j.jue.2007.08.002

Building community resilience, 2022. . Centre for Liveable Cities, Singapore.

Cheng, X., Zhong, W., Li, D., 2021. Urban neighborhood self-governance and community attachment: Evidence from southwest China. Cities 112, 103128. https://doi.org/10.1016/j.cities.2021.103128

Chitov, D., 2006. Cultivating social capital on urban plots: Community gardens in new york city. Humanity & Society. https://doi.org/10.1177/016059760603000406

Cross, J., 2003. Conceptualizing community attachment.

Diamant, E., Waterhouse, A., 2010. Gardening and belonging: Reflections on how social and therapeutic horticulture may facilitate health, wellbeing and inclusion. Brit. J. Occup. Ther. https://doi.org/10.4276/030802210X12658062793924

Forrest, R., Kearns, A., 2001. Social Cohesion, Social Capital and the Neighbourhood. Urban Studies 38, 2125–2143. https://doi.org/10.1080/00420980120087081

GLOVER, T.D., 2004. Social capital in the lived experiences of community gardeners. Leis. Sci. https://doi.org/10.1080/01490400490432064

Glover, T.D., Parry, D.C., Shinew, K.J., 2005. Building relationships, accessing resources: Mobilizing social capital in community garden contexts. Journal of Leisure Research.

Hesari, E., Moosavy, S.M., Rohani, A., Besharati Kivi, S., Ghafourian, M., Saleh Sedgh Pour, B., 2020. Investigation the Relationship Between Place Attachment and Community Participation in Residential Areas: A Structural Equation Modelling Approach. Soc Indic Res 151, 921–941. https://doi.org/10.1007/s11205-020-02408-6

Hume, C., Grieger, J.A., Kalamkarian, A., D'Onise, K., Smithers, L.G., 2022. Community gardens and their effects on diet, health, psychosocial and community outcomes: a systematic review. BMC Public Health 22, 1247. https://doi.org/10.1186/s12889-022-13591-1

Lal, R., 2020. Home gardening and urban agriculture for advancing food and nutritional security in response to the COVID-19 pandemic. FOOD SECURITY 12, 871–876. https://doi.org/10.1007/s12571-020-01058-3

Lovell, R., Husk, K., Bethel, A., Garside, R., 2014. What are the health and well-being impacts of community gardening for adults and children: a mixed method systematic review protocol. Environ Evid 3, 20. https://doi.org/10.1186/2047-2382-3-20

Mokhtarian, P., Bagley, M., 2002. The impact of residential neighborhood type on travel behavior: A structural equations modeling approach. Ann. Reg. Sci. 36, 279–297. https://doi.org/10.1007/s001680200083

Nations, U., 2018. 2018 revision of world urbanization prospects [WWW Document]. United Nations. URL https://www.un.org/en/desa/2018-revision-world-urbanization-prospects (accessed 10.29.24).

Nations, U., 2017. Rapid urbanisation: Opportunities and challenges to improve the well-being of societies, Human Development Reports. United Nations.

Ohmer, M.L., Mendenhall, A.N., Mohr Carney, M., Adams, D., 2022. Community engagement: evolution, challenges and opportunities for change. Journal of Community Practice 30, 351–358. https://doi.org/10.1080/10705422.2022.2144061

Pile, S., 2010. Emotions and affect in recent human geography: Emotions and affect in recent human geography. Transactions of the Institute of British Geographers 35, 5–20. https://doi.org/10.1111/j.1475-5661.2009.00368.x

Putnam, R., 2000. Bowling alone: The collapse and revival of American community. https://doi.org/10.1145/358916.361990

Richards, D.R., Law, A., Tan, C.S.Y., Shaikh, S.F.E.A., Carrasco, L.R., Jaung, W., Oh, R.R.Y., 2020. Rapid urbanisation in singapore causes a shift from local provisioning and regulating to cultural ecosystem services use. Iss. Environ. Sci. Tech. 46, 101193. https://doi.org/10.1016/j.ecoser.2020.101193

Sempik, J., Aldridge, J., Becker, S., 2003. Social and therapeutic horticulture: Evidence and messages from research.

Shimpo, N., 2024. Community garden management for resilient cities: A case study in suburban Tokyo during the COVID-19 pandemic. Landscape Urban Plan. 251, 105148. https://doi.org/10.1016/j.landurbplan.2024.105148

Stinner, W.F., Loon, M.V., Chung, S.-W., Byun, Y., 1990. Community size, individual social position, and community Attachment1.

Tan, L.H.H., Neo, H., 2009. “Community in Bloom”: local participation of community gardens in urban Singapore. Local Environment 14, 529–539. https://doi.org/10.1080/13549830902904060

Trentelman, C.K., 2009. Place Attachment and Community Attachment: A Primer Grounded in the Lived Experience of a Community Sociologist. Society & Natural Resources 22, 191–210. https://doi.org/10.1080/08941920802191712

Yang, W., Cao, X., 2018. Examining the effects of the neighborhood built environment on CO2 emissions from different residential trip purposes: A c

Research Paper

Reshaping Citizenship:
A Study on Inclusive Regeneration and Governance in Megacities Based on Beijing's Practices

Zhao ZHAO, Beijing Municipal Institute of City Planning and Design, China

Abstract

This paper discusses the inclusive urban regeneration models in Chinese megacities. Traditional urban regeneration practices often lead to social tensions, a inclusive way to integrate the civic engagement into the urban regeneration process is needed. This study examines the strategies and challenges of inclusive governance in Beijing, and proposes a shared governance among stakeholders approach.
The main findings suggest a comprehensive framework for co-operation that includes constrctuing co-operative relationships, facilitating participation in decision-making, and ensuring benefit for different groups. The study identifies major challenges such as inadequate communication between local governments and the public, the participation of social capital is supposed to be improved. In addition, the article highlights the key role of fostering civic identity and trust as prerequisites for genuine public participation and which could increase public participation in urban regeneration efforts. The study contributes to research on sustainable urban development and provides practical insights for policymakers aiming to create more inclusive urban environments.

Keywords

Urban Renewal; Inclusive Approach; Public Participation; Citizen Empowerment; Planning innovation

1. Introduction

1.1. Study background

Traditional models of urban regeneration tend to exacerbate social tensions such as the over-commercialisation and limited housing support for low-income groups (Mehdipanah *et al.*, 2018). Since economic growth is prioritized over social equity, the unequal distribution of benefits leads to these tensions. Marginalized groups often feel excluded from urban renewal, leading to mistrust and long-term instability. Such outcomes highlight the need for inclusive renewal models that emphasize shared decision-making and equitable resource allocation to reduce conflicts and foster sustainable growth(Xie *et al.*, 2024).

There is a significant shift in urban development regarding to the inclusive governance. The inclusive development is more and more importance around the world. One of the *United Nations' Sustainable Development Goals (SDGs)* is about inclusive cities for sustainable development(*SDG 11-Make cities and human settlements inclusive, safe, resilient, and sustainable).* This goal emphasizes cities should ensure equal opportunities and resources for different groups from diverse social, economic, or cultural backgrounds. China has also paid attention to the necessity of transforming the growth patterns of its

megacities into inclusive development approach. Nationally, China has embraced the principle of cities. *Report to the 20th National Congress of the Communist Party of China addressed that* establishing policies that foster inclusive urban growth. This people-cantered approach guides improvements in urban planning, construction, and governance and accelerates the transformation of super-large and megacity development models.

Beijing provides a context for examining how megacities manage rapid growth through inclusive urban regeneration. On one hand, Beijing has a large population of 21.858 million and a vast area of 16,410 square kilometers create significant spatial and demographic challenges and abundant urban spaces requiring renewal. On the other hand, recent years Beijing have seen substantial progress in urban renewal initiatives which offering valuable insights and models for inclusive urban regeneration.

1.2. Research Objective and Central Questions

This paper reviews the strategies, challenges, and improvement recommendations for inclusive urban regeneration governance in megacities, focusing on the integration of urban renewal and social governance. It employs a structured approach to analyze key strategies for multi-stakeholder co-governance in urban renewal, with a specific application to Beijing's strategies, challenges, and policy responses.

The study addresses three main questions:

1. It examines the background, connotations, and underlying logic of inclusive urban governance in megacities, identifying its key characteristics and challenges.

2. Through a structured analysis, the paper evaluates the main strategies of multi-stakeholder co-governance in urban renewal, proposing an integrative framework and applying it to assess Beijing's strategies, challenges, and policy responses.

3. The paper explores the levels of public participation within the Chinese context, analyzing how inclusive regeneration promotes and strengthens civic identity and public engagement.

2. Literature Review

2.1. Inclusive regeneration

Inclusive regeneration focuses on social equity and community involvement. Seoul's Citizen-led Regeneration Policy is regard as a model for Sustainable Development Goal 11, applying a people-centered approach that revitalizes urban spaces while preserving cultural heritage. Key outcomes include mitigating gentrification, supporting local businesses, and fostering community initiatives, leading to neighborhoods that balance development with social inclusion and cultural preservation(Urban agenda platform, no date).

South Korea strengthens participatory governance for inclusive urban renewal through living labs and intermediary organizations. Living labs empower citizens, fostering community ownership and enhancing collaboration among government, businesses, and citizens (Park and Fujii, 2023). Moreover, intermediary organizations—state or self-funded entities—bridge communication between citizens and the government, highlighting the growth of citizen participation in Korea's "post-developmental urbanization." The Urban Regeneration (UR) Act further institutionalizes this framework by establishing local urban regeneration support centers (local URCs), which actively involve citizens in urban regeneration projects(Kim, Križnik and Kamvasinou, 2021).

Current research focuses on strategies for inclusive urban regeneration within specific projects. For instance, the URBiNAT project explores a consortium that activates Living Labs and establishes a Community of Practice (CoP), wherein municipalities, universities, businesses, and citizens collaborate to share knowledge in co-creating the Healthy Corridor. The CoP is a collaborative framework that empowers participants(Moniz *et al.*, 2022). In Japan, the machizukuri model exemplifies a citizen-centred, self-organising approach that enables communities to lead redevelopment. These practices show a flexible governance approach which promotes local empowerment and leads to an inclusive neighbourhood transformation (Nakajima and Murayama, 2024). In Italy, the ICT-enabled processes (such as real-time data analysis) are used to enhance participatory urban decision-making and which creates an active community engagement (Pontrandolfi and Scorza, 2016). In Liverpool, homebased enterprises utilise technology, new products and skills development to promote community regeneration (Duarte Alonso *et al.*, 2020).

Collaborative frameworks in urban regeneration require interaction between power structures and strategies(Andres, 2013). Some scholars integrate nature-based (NbS) and society-based solutions (SbS) to create a theoretical model combines spatial planning with social strategies(Xiang, Yang and Li, 2020). However, the comprehensive frameworks for inclusive regeneration are still not sufficiently studied(Xiang, Yang and Li, 2020). The structural frameworks for inclusive governance in urban renewal needs to be discuss.

2.2. A Ladder of Citizen Participation

Arnstein's "A Ladder of Citizen Participation" shows different levels in citizen involvement in decision-making. The model outlines eight levels of engagement, divided into three categories: nonparticipation, tokenism, and citizen power(Figure 1). In the nonparticipation category, levels such as "manipulation" and "therapy" show that authorities may seem to include citizens while restricting their real influence. The tokenism stages—informing, consultation, and placation—allow citizens to receive information and provide input, but without genuine decision-making authority. At the top, the citizen power category includes partnership, delegated power, and citizen control, where itizens actively share or take ownership of decision-making(Arnstein, 1969).

Arnstein's model, though influential, has been criticized for oversimplifying complex power relations and failing to account for diverse forms of knowledge and expertise (Tritter and McCallum, 2006a). This critique highlights the need for a multidimensional power assessment that transcends mere authority levels.Purdy (2012)suggest a more nuanced approach to power evaluation, which involves examining authority, resources, and discursive legitimacy as key power sources, as well as analyzing power dynamics across various arenas, including participant roles, process design, and content within collaborative governance. Such an approach allows for a deeper understanding of power interactions in participatory frameworks. Some scholars contend that the concept of "public participation" lacks clarity. Rowe and Frewer (2005) distinguishes public participation from public communication and public consultation and emphasized that these distinctions are shaped by the mechanisms of participation.

Scholars have identified three key variables that influence the effectiveness of civic engagement: environmental factors, such as the attitudes of public officials; organisational arrangements, such as community participate process design; and management models, involving group collaboration quality. They recommended internalising decision-making into organisational processes and promoting continuous interaction between government agencies and stakeholders to enhance participatory governance (Ianniello *et al.*, 2019).

In response to recent socio-political shifts, scholars have refined existing models by expanding actor categorization and interaction levels. This revised model includes disorder, non-participation, symbolism, awakening, civic power, civil disobedience and rebellious action (Kotus and Sowada, 2017).

Many scholars contend that China is currently situated at a lower level of this ladder, where public participation in urban governance tends to be symbolic, with limited real impact(Hu,2013) and public concerns(Liu *et al.*, 2022). Therefore, it's important to study how to increase citizen influence to achieve a more inclusive urban renewal process.

3. Methodology

Data is sourced from practical work and ongoing projects. The collection process includes: (1) Gathering feedback from government bodies, developers, and the public during the local legislation drafting period from August 2021 to November 2022. (2) Collecting details of the "Typical Urban Renewal Projects of Beijing" annually through internal project report, field research, and online resources. Qualitative analysis methods are employed in this study, including case analysis of practical projects, policy analysis of implemented regulations, and content analysis of textual data from various interviews. These methods collectively facilitate a comprehensive understanding of the inclusive regeneration in Beijing.

The article is organized into five main sections(Figure 1) In the findings section, it presents an analytical framework for inclusive regeneration governance while addressing the current challenges faced in this area and offering corresponding recommendations. Finally, it discusses the relationship between inclusive regeneration and public participation from the perspective of civic identity.

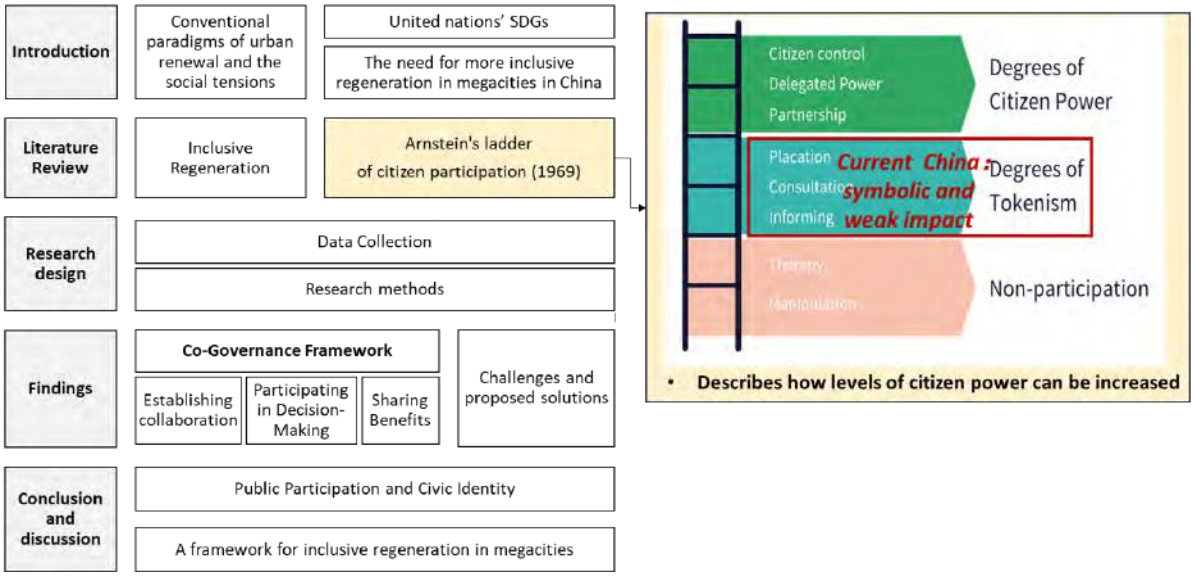


Figure 1. Research framework (Left) and Arnstein's "A Ladder of Citizen Participation" (Right). Source: Illustrated and revised by the author.

4. Findings

4.1. A framework of co-governance in urban regeneration

The paper suggests a co-governance framework involving multiple stakeholders, which includes ***'Establishing Cooperation,' 'Participating in Decision-Making,' and 'Sharing Benefits,'*** to analyze Beijing's approach to inclusive regeneration governance(Figure 2).

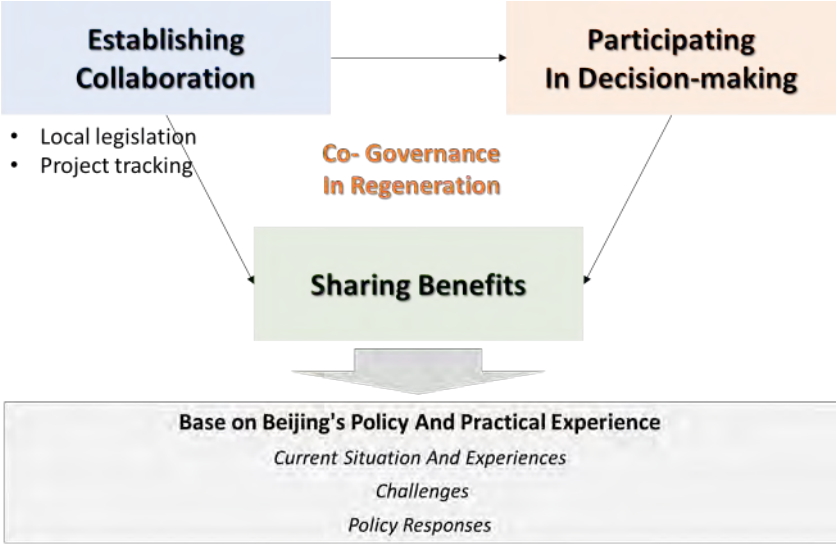


Figure 2. Co-governance framework of inclusive regeneration. Source: Illustrated by the author.

4.1.1 First stage: Establishing Cooperation

The initial step in this framework is to establish collaborative policies, which can be divided into two key components: policy and institutional design, and project implementation guidance.

4.1.1.1 Policy Design for Co-governance

The foundation of collaborative governance is highly relegated with institutional design. In 2023, Beijing announced the local urban renewal regulations ***(Beijing Urban Renewal Regulations).*** This regulation defines the rights and responsibilities of stakeholders and gives guidelines for public participation.With the legal framework, local governments are able to coordinate urban renewal efforts effectively. For example, the regulations specify *Community Hall* as channels for public engagement, where community meetings serve as platforms for public hearings, discussion of project proposals, and post-renewal evaluations(Figure 3). This approach supports the establishment of a democratic deliberation system for urban renewal, creating avenues for diverse stakeholder opinions and suggestions that are responsive to the project's specific needs.

Moreover, the legislative process itself was open to broad participation. During the three rounds of legislative review, over 10,000 public opinions were gathered and incorporated into the final regulations, which reflecting a commitment to transparency and responsiveness in policy-making(Figure 3).

Figure 3. The Coordination Framework from the *Beijing Urban Renewal Regulations*(Left) and word cloud of public opinions in the legislative process(Right). Source: Illustrated by the author.

4.1.1.2 Implanting system for collaboration

The systematic tracking of practical projects exemplifies a collaborative planning model aimed at comprehensively understanding and improving the progress of renewal projects. To facilitate this, a spatial database has been developed for all initiated renewal projects, supporting a more inclusive and holistic planning approach(Figure 4). By 2023, this database has documented information on 150 renewal projects, including data on location, implementation methods, ownership, funding sources, project characteristics, progress, encountered challenges, and overall effectiveness.

The logic underlying the database construction is to integrate top-down master planning with bottom-up project applications. On the one hand, Beijing's master plan provides guidance by conveying the objectives of optimizing urban spaces and enhancing city functions into concrete project implementations. On the other, continuous tracking of urban renewal projects is conducted to ensure effective oversight. Currently, a structured implementation system for urban renewal has been established, comprising the stages of "*expressing renewal intent, selecting an implementation entity, submitting project applications, initiating project development, and conducting scheme reviews*."

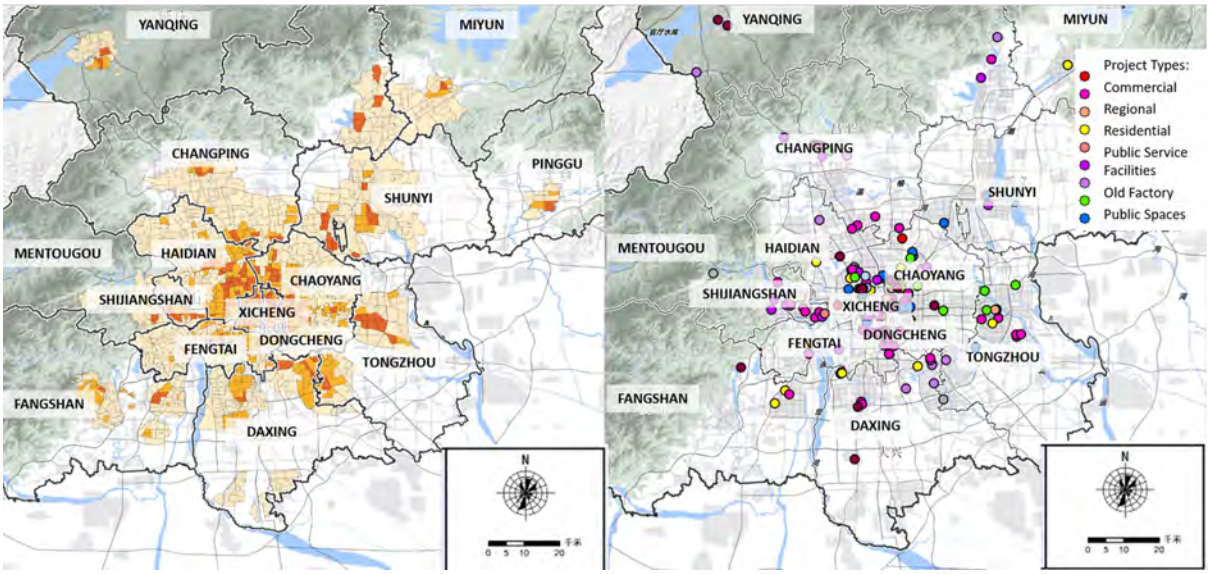


Figure 4. Spatial database for renewal projects(Left) guided by master plan and bottom-up project applications. Source: BMICPD.

4.1.2 Second stage: Participating In Decision-Making

The core objective is to establish a diverse decision-making centre adaptable to various contexts. In different situations, distinct modes of participation should be employed. Table 1 illustrates Beijing's innovative approaches to fostering multi-stakeholder participation in decision-making within urban renewal projects.

A primary approach to enhancing public participation in urban planning is through digital platforms, which streamline and democratize involvement by leveraging technology(Figure 5). In older residential areas with a high percentage of elderly residents, mobility is a significant issue due to the lack of elevators in early-built housing. However, demand for elevators varies by floor level, age, and income, creating challenges in gathering and balancing diverse opinions. To address this, Beijing introduced the "Elevator Installation Map," an online platform where residents can register their interest in elevator installations. If two-thirds of residents in a building unit express support, the building is prioritized for installation, effectively simplifying the decision-making process and enabling more inclusive planning.

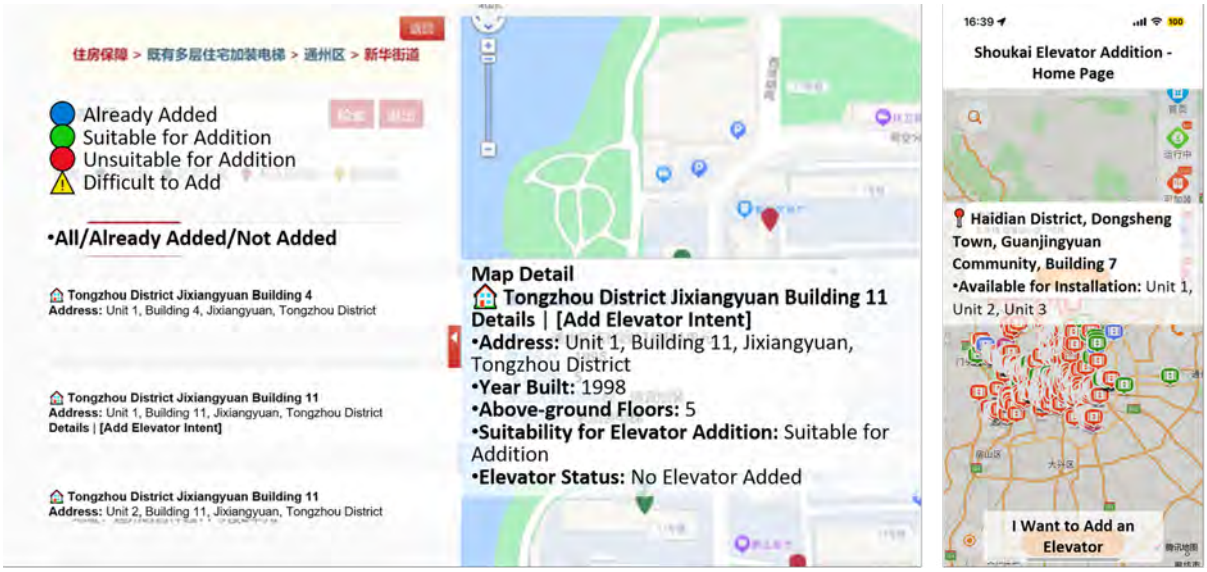


Figure 5. Beijing's "Elevator Installation Map". Source: Internet.

Another effective approach is to engage an influential opinion leader to mediate in complex urban renewal projects. For example, Vanke has served as a key coordinator, collaborating with local governments to design and implement comprehensive neighborhood renewal strategies. This case combines both government funding and private investment and shows the advantages of a multi-party approach. Vanke conducted surveys across different stakeholders, including over 200 questionnaires among 100 households, 87 merchants, and 33 enterprises. This method of multi-party engagement integrates the design and implementation of inclusive urban renewal efforts.

Public engagement across various levels significantly shapes the outcomes of renewal projects. At the neighborhood level, inviting residents to participate in design workshops enables community-scale involvement in spatial planning. Citizen's interest can also guide the preservation and adaptive reuse of historic districts. For example, the Fayuan Temple neighbourhood has hosted Beijing International Design Week for five years, drawing public attention to historic preservation and illustrating the importance of

local memory. This multi-layered public participation enhances the inclusiveness and effectiveness of urban renewal efforts.

In addition, spontaneous public participation is becoming a new way to engage in urban construction. Many people interested in community planning are increasingly involved in these volunteer activities. Their ideas might not always directly influence planning outcomes,while this trend indicates a rising awareness of ublic involvement and the diversification of participation channels. In Beijing, volunteer activities focusing on urban spaces have become increasingly common, which provides a platform for people to share observations, express needs in their daily lives and come up with ideas and suggestions for improving their neighbourhoods. This reflects a growing public enthusiasm to shape the urban development.

Table 1. Diverse Decision-Making Approaches for Different Types of Renewal Projects. Source: Illustrated by the author.

Approach	Features	Project	Target group	Primary project results
Engage online	Collect willingness through online methods	Beijing's "Elevator Installation Map"	residents	Use online approach to collect varying demands across different floors
Engage with an opinion leader	Coordinator Leading Multi-discipline Collaboration	Wangjing Walk & VANKE TIMES	Merchants /Tenants	Multi-party contribution involving government investment and private capital
Engage local users	Community Building of different scales	Jingdian NO.1 Pocket Space	Local community	Invite local users to participate in space design through the workshops
Engage Wider users	Community Building of different scales	Fayuan Temple Neighborhood, Xicheng district	Citizen and tourists	Attract citizens to pay attention to historical protection and local memories
Engage spontaneously and decentralized	More and more people are willing to contribute	Volunteer activities e.g. Jane's Walk	Public who interested in urban planning	Observation, discussion and connection

4.1.3 Third stage: Sharing Benefits

Inclusive urban regeneration is supposed to emphasize enhancing social welfare across diverse demographic groups to ensure equitable distribution of renewal benefits. Beijing's policy framework advances this goal by focusing on the "Seven Accesses" and "Five Expectations," which seek to address the needs of all groups, including workers and residents. The "Seven Accesses" prioritize access to access to childcare, education, employment, medical services, elderly care, housing, and social assistance. Complementing this, the "Five Expectations" focus on convenience, livability, diverse choices, fairness, and

safety in society. Together, these principles aim to create tangible, inclusive benefits, fostering a more balanced and supportive urban environment for all social groups.

Case analyses reveal an increasing attentiveness in urban renewal projects to the interests of diverse social groups (Table 2). A notable example is the transformation of “pocket spaces” into multifunctional public areas. One previously underutilized site was redeveloped into a “Mini-Disneyland,” offering relaxation spaces for workers, rest areas for community security guards, and recreational opportunities for children and young adults. These spaces foster interactions across different social groups, enhancing urban inclusivity. Following renovation, a once-vacant neighborhood area has become accessible to urban workers, exemplifying public recognition and support for improved public spaces.

Moreover, special attention has been directed toward marginalized groups, such as delivery workers, who often experience restricted access to public services and limited social connections. For example, Liu Village is a case that offering these workers a clean and safe living environment through the renewal. The new housing and communal spaces could foster a sense of belonging for them in the city. Prior to the renewal, this outskirts area is recognized as a poor living environment, attracting migrant workers due to low rent. The transformation into a “Delivery workers’ Residence” has added numerous public facilities, including shared spaces for communal laundry, kitchens, reading areas, parenting spaces, and meeting rooms, offering delivery workers high-quality living conditions that support their daily and social needs.

Figure 6. Project *Liu Village Delivery Worker’s Home,* before and after renovation.. Source: Internet.

Additionally, many renewal projects have introduced cultural and recreational spaces for the public. For example, urban space optimization and industrial transformation have left numerous industrial buildings vacant and inaccessible. Following their renovation, these spaces have become open to the public, significantly enhancing the area's vitality. For instance, in Langyuan vintage, residents in the surrounding areas can now enjoy a diverse range of activities, including dining, shared office spaces, social areas, and various cultural and entertainment events.

Table 2. Considerations for Different Social Groups in Renewal Projects Source: Illustrated by the author.

Target group	Features	Project	Primary project results
Multiple groups	"Mini-Disneyland" For All	Jingdian NO.1 Pocket Space, Chaoyang district	Transformed to provide a resting place A place for construction workers and delivery workers to rest Facilities for that both children and young adults like to use.
Elderly Care For Surroundings	Beyond local community's boundary	Fanghuali Community-based Elderly Care	Shared spaces: dining hall, theaters, tea rooms, art exhibitions Provide basic medical services and daily health management for residents
Underrepresents group	Delivery worker, a new working class expanding dramatically	Liu village delivery worker's home	Clean and tidy living spaces
From exclusive to public	Abandoned industrial buildings are prohibited from entering	Langyuan vintage	Open to public and businesses are introduced Offer a wide range of cultural and entertainment activities
From isolated to interactive	Beijing's seine	Liangma river	Activities like picnicking and paddleboarding
	Backyard Garden of CBD	Qingfeng Park	A Wall-less Park Connected to surrounding roads, with greenways for cycling to office buildings

4.2. Key challenges and strategies of Beijing's pluralistic co-governance

4.2.1 Key challenges

While there are many successful cases, challenges still exist. The main issue is a lack of effective communication between local authorities and the public. This challenge manifests in three main areas. First, there is limited involvement of private capital, with privately-led projects accounting for only 10% of urban renewal initiatives, and spontaneous market-driven renewal remains rare. Second, public participation channels are still inadequate, as existing methods for citizen involvement are limited, and proactive engagement remains underdeveloped. Finally, there is an immature mechanism for resolving conflicts of interest among diverse groups, making it difficult to build consensus on differing perspectives and needs.

4.2.2 Strategies and suggestions

Enhancing communication channels between local governments and the public can be achieved by establishing a *participatory planning system* and creating platforms for engagement. First, strengthening top-level design is essential. For instance, Shanghai has established a participatory community planning system, incorporating visits, meetings, resident proposals, and design comparisons into the community planning process. This systemized operational guide serves as a valuable reference for planners and

relevant government departments throughout the design and implementation stages. Second, it is crucial to encourage socialized management and market-oriented operations. Shanghai's Social Organization Service supply-demand platform, for example, publicly lists community renewal needs—such as space management, design proposals, and community governance projects—on an open platform, facilitating information access and enabling social organizations to provide relevant services and products efficiently.

5. Discussion and conclusion

5.1 Public Participation and Civic Identity

The research explores the relationship between public participation and civic identity.The main aim is to identify strategies that enhance citizen engagement and foster identity through regeneration projects. There is a fundamental question to be answered: *What constitutes a sustainable relationship between city and citizen?* Inclusive regeneration is essential for sustainable urban development, which requires a more robust government-society relationship.Given the contexts that the financial pressures are increasing the megacities and the complex public needs, urban governance faces rising challenges. Inclusive governance emphasizes self-organization and collective action,therefore it may offer the most effective and sustainable pathway to achieving long-term urban development goals.

Tritter and McCallum (2006b)argue that Arnstein's model oversimplifies power relations. This article expands the model by incorporating dimensions of trust and empowerment within the participation ladder. The concept of the "Ladder of Citizen Trust"(Figure 7) is introduced and which is expanding on Arnstein's "Ladder of Citizen Participation," to illustrate how a city can genuinely be built by and for its people. True citizen empowerment is rooted in trust: when local authorities trust their citizens, they are more likely to extend meaningful decision-making responsibilities. The stronger the public's perception of government support for collaborative governance, the more likely they are to actively participate in regeneration efforts and accept the corresponding policies(Kim, Kim and Woosnam, 2023). This trust-based approach is vital to fostering a truly inclusive governance model, particularly within the complex environment of a megacity. This also reflects the current lack of communication bridges between the public and the government in Beijing, which makes it difficult to establish trust.

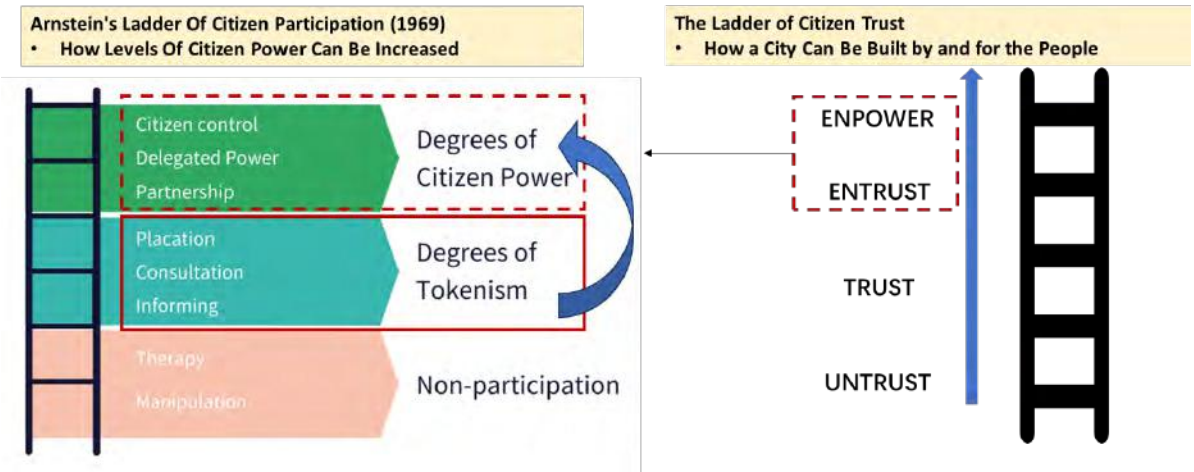


Figure 7. "Ladder of Citizen Trust". Source: Illustrated by the author.

The ultimate question is: *How can city residents feel like true citizens*? Their expectations are straightforward.They wish to feel welcomed, have their voices heard, and be active participants in shaping

the city's future. By achieving these needs, a civic identity could be fosteres and residents could experience a genuine sense of belonging and ownership.

5.2 Support for related work and Suggestion for future

In supporting practical work, this research underscores the role of tracking urban renewal projects to advance digital public participation. A digital approach is explored through two key initiatives. First, broader public involvement is encouraged, as seen in the "Best Practices" award, which combines online public voting with expert evaluation. In 2023, ten "Best Practices" were selected from 151 submitted projects. Second, the launch of a demo WeChat "Comment Map" program allows the public to share their views and suggest renewal needs, highlighting areas for potential updates. Public feedback also offers valuable insights into whether completed projects meet societal expectations.

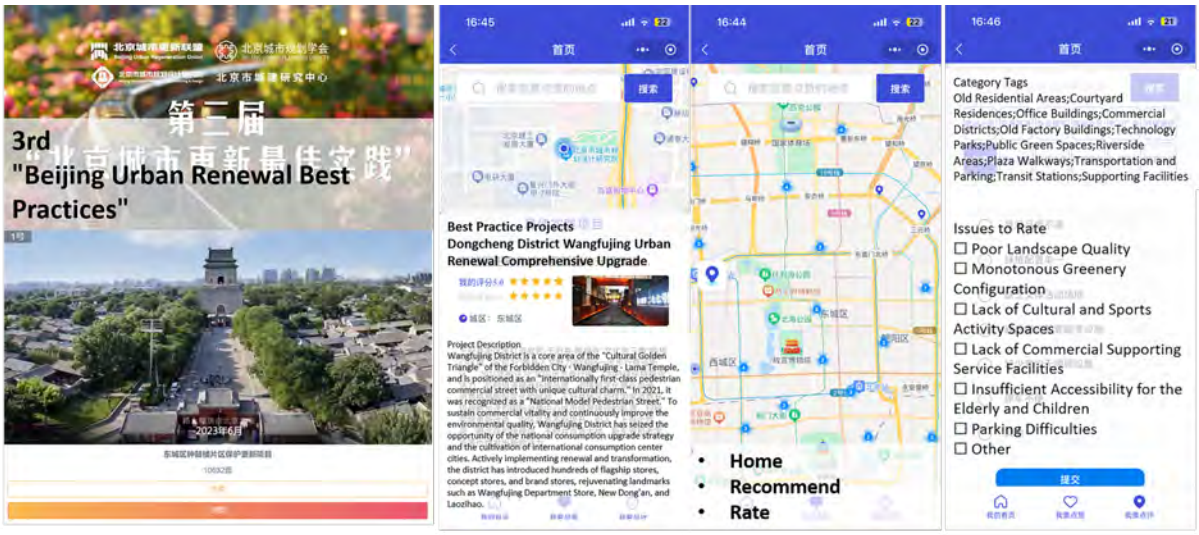


Figure 8. Best Practice Award (Left) and Demo of "Comment Map" (Right). Source: Internet and BMICPD.

In the future, urban planning must integrate the spatial concerns whith multifaceted requirements. Inclusive regeneration should incorporate a wider range of stakeholder interests, including asset valuation, financial feasibility to support sustainable and inclusive urban development. For example, Shanghai has implemented a "Three Experts" collaboration model, where planners coordinate spatial and functional requirements, architects focus on specific renovation designs, and appraisers conduct asset analysis. This interdisciplinary system yields comprehensive renewal plans(Figure 9). Similarly, Beijing is exploring the integration of traditional spatial planning with investment and construction plans to create more operationally effective project strategies(Figure 9).

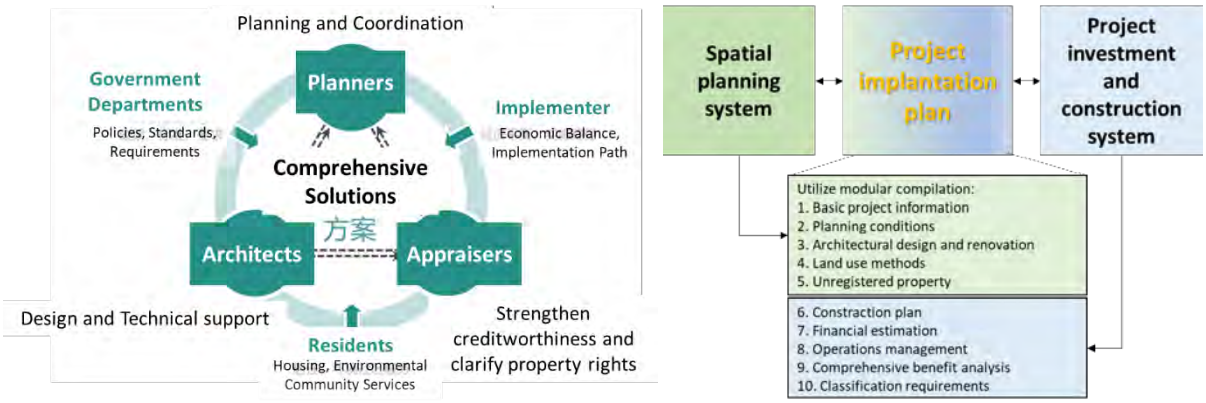


Figure 9. Shanghai explore "Three Experts" collaboration (Left) and Beijing explores the connection of spatial planning with financial and construction planning (Right). Source: Internet and Illustrated by the author.

6. Limitation and future search

This paper primarily investigates the strategies and outcomes of specific case studies in Beijing's inclusive urban regeneration practices. However, it lacks a comparative analysis of approaches in other cities. Future research could prioritize examining policies and practical projects in inclusive urban regeneration across various cities.

7. References

Andres, L. (2013) 'Differential Spaces, Power Hierarchy and Collaborative Planning: A Critique of the Role of Temporary Uses in Shaping and Making Places', *Urban Studies*, 50(4), pp. 759–775. Available at: https://doi.org/10.1177/0042098012455719.

Arnstein, S.R. (1969) 'A Ladder Of Citizen Participation', *Journal of the American Planning Association*, 35(4). Available at: https://doi.org/10.1080/01944366908977225.

Duarte Alonso, A. *et al.* (2020) 'The significance of grassroots and inclusive innovation in harnessing social entrepreneurship and urban regeneration', *European Business Review*, 32(4), pp. 667–686. Available at: https://doi.org/10.1108/EBR-05-2019-0102.

Hu Juan. (2013). Dilemma of Public Participation in Urban Planning Public Decision Making and New Perspectives on Research. Central China Architecture, 000(2),pp 33-35.

Ianniello, M. *et al.* (2019) 'Obstacles and solutions on the ladder of citizen participation: a systematic review', *Public Management Review*, 21(1), pp. 21–46. Available at: https://doi.org/10.1080/14719037.2018.1438499.

Kim, Hyewon, Kim, Hyun and Woosnam, K.M. (2023) 'Considering urban regeneration policy support: Perceived collaborative governance in cultural heritage-led regeneration projects of Korea', *Habitat International*, 140, p. 102921. Available at: https://doi.org/10.1016/j.habitatint.2023.102921.

Kim, K., Križnik, B. and Kamvasinou, K. (2021) 'Between the state and citizens: Changing governance of intermediary organisations for inclusive and sustainable urban regeneration in Seoul', *Land Use Policy*, 105, p. 105433. Available at: https://doi.org/10.1016/j.landusepol.2021.105433.

Kotus, J. and Sowada, T. (2017) 'Behavioural model of collaborative urban management: extending the concept of Arnstein's ladder', *Cities*, 65, pp. 78–86. Available at: https://doi.org/10.1016/J.CITIES.2017.02.009.

Liu, W. *et al.* (2022) 'An Evaluation of Urban Renewal Based on Inclusive Development Theory: The Case of Wuhan, China', *ISPRS International Journal of Geo-Information*, 11(11), p. 563. Available at: https://doi.org/10.3390/ijgi11110563.

Mehdipanah, R. *et al.* (2018) 'Urban renewal, gentrification and health equity: a realist perspective', *European Journal of Public Health*, 28(2), pp. 243–248. Available at: https://doi.org/10.1093/eurpub/ckx202.

Moniz, G.C. *et al.* (2022) 'Inclusive Urban Regeneration with Citizens and Stakeholders: From Living Labs to the URBiNAT CoP', in, pp. 105–146. Available at: https://doi.org/10.1007/978-3-030-89525-9_5.

Nakajima, H. and Murayama, A. (2024) 'Inclusive urban regeneration approaches through small projects: A comparative study of three Japanese machizukuri cases', *Cities*, 152, p. 105241. Available at: https://doi.org/10.1016/J.CITIES.2024.105241.

Park, J. and Fujii, S. (2023) 'Civic Engagement in a Citizen-Led Living Lab for Smart Cities: Evidence From South Korea', *Urban Planning*, 8(2), pp. 93–107. Available at: https://doi.org/10.17645/up.v8i2.6361.

Pontrandolfi, P. and Scorza, F. (2016) 'Sustainable Urban Regeneration Policy Making: Inclusive Participation Practice', in *Computational Science and Its Applications -- ICCSA 2016*, pp. 552–560. Available at: https://doi.org/10.1007/978-3-319-42111-7_44.

Purdy, J.M. (2012) 'A Framework for Assessing Power in Collaborative Governance Processes', *Public Administration Review*, 72(3), pp. 409–417. Available at: https://doi.org/10.1111/J.1540-6210.2011.02525.X.

Rowe, G. and Frewer, L.J. (2005) 'A Typology of Public Engagement Mechanisms', *Science, Technology, & Human Values*, 30(2), pp. 251–290. Available at: https://doi.org/10.1177/0162243904271724.

Tritter, J.Q. and McCallum, A. (2006) 'The snakes and ladders of user involvement: Moving beyond Arnstein', *Health Policy*, 76(2), pp. 156–168. Available at: https://doi.org/10.1016/j.healthpol.2005.05.008.

Urban agenda platform (no date) *Seoul's People-Centric Urban Regeneration Project as a Model of Sustainable Urban Growth*. Available at: https://www.urbanagendaplatform.org/best-practice/seouls-people-centric-urban-regeneration-project-model-sustainable-urban-growth (Accessed: 31 October 2024).

Xiang, P., Yang, Y. and Li, Z. (2020) 'Theoretical Framework of Inclusive Urban Regeneration Combining Nature-Based Solutions with Society-Based Solutions', *Journal of Urban Planning and Development*, 146(2). Available at: https://doi.org/10.1061/(ASCE)UP.1943-5444.0000571.

Xie, H. *et al.* (2024) 'Exploring the Evolution Mechanisms of Social Risks Associated with Urban Renewal from the Perspective of Stakeholders', *Buildings*, 14(5), p. 1470. Available at: https://doi.org/10.3390/buildings14051470.

Research Paper

Research on spatial image and cultural identity between new and old cities：

A case study of Xiamen, China

Whenchen GONG, School of Architecture, Southeast University, China

Han GAO, School of Architecture, Southeast University, China, presenter

Abstract

This study explores the dialectical tension between global spatial flows and local culture in contemporary urban spaces, using Xiamen's Jimei New Town and Zhongshan Street Old District as focal areas. By analyzing perceptions and identity among tourists, local residents, and planners, the research examines how Xiamen's planning and policies guide the reconstruction of local culture. Coding and keyword analysis of interview data reveal that old and new towns serve as opposing spatial cognitive labels, each with distinct imagery and cultural identity associations. Yet an inverse correspondence emerges: the new town is perceived as embodying a sense of traditional place, while the old town represents a forward-looking, modern cultural image. This reflects a reconfiguration of global-local meanings under the different spatial representations of each town. The study further interprets the "space-culture" processes and causal mechanisms shaping these dynamics, considering both macro-level influences, such as capital and policy, and micro-level actions of individual agents.

Keywords

New And Old Cities， *Spatial Image*， *Cultural Identity*；

1. Introduction

1.1. Background

As China's urbanization process enters the second half, that is, the urbanization rate exceeds the target of 65% in advance, the urban spatial planning and land use planning within the scope of the city control and intervention methods are increasingly mature. Specifically, the government-led strategy of combining the new city and the old city is favored by more and more cities, such as Tianjin, Shanghai and Xiamen. In the process of the development of the new city, the relationship with the old city has also undergone subtle changes, both in functional structure and spatial pattern. Especially after the urban structure of dual city is formed, the driving force of industrial development, consumer demand, functional transformation, diversified investment mechanism, as well as the concept of people-oriented and sustainable development continue to emerge, prompting significant new changes in urban space and giving birth to new urban space forms such as urban new district, high-tech district, new central district and new residential district. This has a very significant impact on the original urban spatial structure, and forms an intuitive contrast with the old city, creating a unique Chinese dual city appearance and the potential of cultural integration.

The new city is an incremental space formed through large-scale construction activities and "empowerment" under the institutionalized unit of administrative boundaries, while the old city is formed by the accumulation and precipitation of traditional elements, and plays a key protected and carefully revitalized role in the realistic time series and historical cultural concepts. Although the new and old cities are different in physical space, they are in the same political system framework in development strategy, economic function, spatial strategy and other important aspects, and are closely connected with each other. Because of this, the "dual city" model often naturally organizes a binary space image system. This system subtly implies two distinct but reciprocal cultural landscapes: on the one hand, the old city culture, as a symbol of tradition, carries the historical weight and memory; On the other hand, it is full of hope and future-oriented new city culture, showing the spirit of innovation and pioneering.

1.2. Objective

However, it is worth noting that, as a bottom-up practical force, when people experience the spatial-cultural order constructed by the government in person, the cultural identity generated will be more complex and diverse. This kind of complex cultural identity and the established space image constitute a huge tension, causing a series of problems worthy of in-depth exploration and research.

Therefore, this paper focuses on the neighboring space of the new and old cities and the heterogeneity of local culture, interprets the different forms of cultural identity bearing collective memory in the spatial context of the new and old cities, and further focuses on the measurement and characterization of the local identity of the new and old cities. This study selects Xiamen, China for empirical analysis, and takes the central district in Jimei new city and the tradition districts in Zhongshan Street as typical representatives. In the way of case study, we will deeply explore the reasons and interaction mechanism of the binary formation of cultural and spatial image.

2. Literature review

2.1. Characteristics of the relationship between new and old cities

The relationship between new and old cities is complicated, but they also have common features. For example, in the comparative study of historical urban evolution in Britain and Iran, radical transformation of urban structure in the name of modernization has brought disintegration and alienation to the old core, and there are also cases of re-integration of old cities and harmonious coexistence between new and old cities in the urban center grid. The spatial transformation of the old city not only intensifies the fate turn of the historic core in terms of physical form, but also puts forward more requirements for the aggregation and reorganization of the spatial and cultural elements of the new city in this set of open social systems (Kayvan, 1998). The concept of continuity explains that the spatial structure of the city is a dynamic product of the interaction between the forces that tend to change the physical structure of the city and the forces that tend to retain the urban structure, which fully demonstrates the nature of the unity of conservative and radical dualities in urban disciplines and practices (Kian, 2001). Cities have different growth sites in different periods. While maintaining certain spatial inertia and inertia, government policies and planning can better promote the transfer of development core, whether it is the protection and revitalization of old cities or the expansion and spread of new cities (Bai & Xu, 2023).

2.2 New and old city space and culture

The perception of urban space and cultural image is based on the processes of observation, memory, attitude, and feeling, which are directly created (Cavallo et al.,2014), which means that it is impractical to

analyze urban space and cultural subjects in isolation from the macro picture of individual experience and experience. as a consequence of urban symbolic ecology and hypercity, as a consequence of urban symbolic ecology and hypercity, it should be emphasized that special and renewed attention needs to be paid to these participants and the implicit roles they play in urban Spaces, who are not powerless to the top-down process of meaning giving and communication and the bottom-up production and consumption of symbols (Peter, 2014).

As to whether a single cultural image of the old city or the new city can represent the whole urban space, different scholars have diametrically opposed views. Some scholars take Semarang City in Indonesia as an example. Through a questionnaire survey of tourists and residents, it is confirmed that the old city does not have a decisive influence on the image of the city, but relies on some visually attractive elements, such as landmarks such as churches and cafes (Nugraheni & Hartanti, 2023). In the case of Taipei, the historical context of western development makes certain buildings or places become the label and image of Taipei city. In the different interpretation and presentation of images, there is a tension about the problem of "visibility", which reflects the ideological level of struggle. From the perspective of spatial design of the urban built environment, the public architecture and landscape design proposed in recent years, while pursuing an "international" and "modern" image, also represents a "traditional" image (Yu, 2019).

It should not be ignored that the cultural risks and challenges faced by the old city not only exist in the internal pressure of the new city, but also come from exceeding the geographical space restrictions. At this time, the importance of maintaining the unity of the internal cultural image with the new city is particularly prominent, indirectly creating the possibility of the new city inheriting the urban tradition and context（Zgheib, 2021）. As the compression of time and space deepens, the invasion of new global cultural industries by foreign influences and images disrupts traditional custom orders and ways of life, which traditional communities find too tempting to refuse but too difficult to contain. Global consumerism, though constrained by an uneven "geography of power," propagates the same ideas. A culture and its location, unable to maintain imaginary purity in the face of dramatic change, can only respond by emphasizing cultural openness through cross-regional connections (Crang, 2013).

3.Methodology

The research methods primarily adopted qualitative approaches, including field surveys, questionnaire surveys, and in-depth interviews to gather collective memories and cultural impressions from residents regarding the central district in Jimei New City and the traditional districts in Zhongshan Street. The aim was to assess the extent to which these perceptions deviated from expectations, particularly focusing on the discrepancies among different groups both within and outside the new and old cities. In addition, this study used an AI generative model to increase the readability of the paper.

Structured and semi-structured questionnaires were used to collect samples from selected areas in the new and old cities, resulting in a large volume of textual data and detailed interview transcripts（Bokhove & Downe, 2018）. After collecting these materials, the corpus of interview texts underwent coding analysis and keyword statistics to summarize the relationship between the spatial relationships of the new and old cities and their cultural imagery characteristics（Polkinghorne, 2005）. The number of sources and reference points were tabulated, and axial coding was further employed to analyze the local memories and cultural identities of tourists and residents.

Through interactions with various stakeholders, such as tourists, local residents, and planners, the study explored the individualized experiences of place symbolism and the spatial planning strategies of common cultural symbols of modern civilization. This approach aimed to identify the conceptual errors that arise in the gap between these two perspectives and to compare and contrast the representations of the physical spaces and cultural codes in the new and old cities. A comprehensive analysis was conducted based on the statistical results of the corpus.

4.Imagination and recognition between the old and new city

4.1. Spatial image of Zhongshan District and Xiting District

This research targets two major groups: the external tourists and the local residents. Travelers and residents were interviewed in the central area of Jimei New Town and on Zhongshan Street, along with some urban space planners in charge of management and planning. The interviews took place in April 2024 and included 27 participants: 11 local residents, 10 tourists, and 6 planners. The coding and keyword analysis output is reflected in Table 1 below.

Table 1 Keywords analysis based on interview

Select Encoding	Spindle encoding		Number of sources	Reference points	Keywords	
	Zhongshan District	Xiting District			Zhongshan District	Xiting District
International image	Commercialized historic district	Advanced industry-city integrated new city	20	43	Literature and art, southern Fujian, night scenes, Internet celebrities	International, Bay New Town, hot spot for buying a house
	The function of gentrification	A successful new city model	18	35	Commercialization, cafes, restaurants	Convenient transportation, Jimei old area, university town, subway, education, ecological advantages
Local characteristics	The history of the island area continues	The creation of a bay that alternates between the old and the new	17	32	Nostalgia, ancient houses, nostalgia, old streets, seaside	Jiageng, architectural culture, the combination of old and new, old university
	The value of culture is preserved	The collective perception of citizens is reshaped	8	15	Old customs, own shops, chess and cards, street activities, Hokkien dialect	Modern, white-collar, elite, business

Political conception	A model of urban renewal	The dominant position of the software information industry and business	21	26	Repairs, rectifications, funds, housing, urban living rooms	Urban transformation, economic transformation, software industry, tourism, commerce and trade, manufacturing
	The roots of the core urban area	The central district of the new town	14	19	Pedestrian demonstration area, cultural IP, block culture, consumption	Talents, beautiful environment, cross-island development, Bay Area economy

According to the respondents' views on the new and old city corpus, the classification analysis shows that the new and old city of Xiamen is a binary urban space system, symbolizing a limited set of spatial codes. Zhongshan District became the commercial and cultural center of Xiamen in the early 20th century, showing the architectural features of China's southern Fujian and Western styles. The physical space system of the area includes traditional Nanyang style arcade buildings representing the "old village", ground-level shops for social and small commercial activities, and the pedestrian-friendly historic Zhongshan Road, which serves as the urban backdrop for the daily life of local residents. With initiatives for urban renewal and gentrification, many buildings have been demolished or renovated with a conscious application of modern architectural principles. However, with government efforts to preserve this area and tourism-oriented business strategies, the spatial language of small-scale, body-scale experiences has been further emphasized.In contrast, Xiting Central District in Xiamen’s Jimei New Town is dominated by modernist office buildings, large shopping centers, and high-end residential areas. Xiamen’s developmental aesthetics is inspired by Chan Ka-kee and emphasizes the "fusion of styles" (similar concepts). As a result, the spatial operation of the new town reflects a postmodern approach, with the ground floors of the high-rise buildings decorated with red brick eaves in the southern Fujian style, while the upper floors strictly follow the modernist aesthetic. The new city's spatial functions are closely integrated with financial, trade, and technological exchanges, with ample residential areas, positioning it as the core of the city's modern economy connected to the global production network. Therefore, under the traditional architectural decoration, the spatial code of the new town is still dominated by modernist language.

Figure1 Picture of Zhongshan District

Figure 2 Picture of Xiting

4.2 Spatial identification of residents and tourists

Through a corpus analysis of respondents' responses to new and old towns in Xiamen, this study finds that these areas are a binary system with distinct urban spatial coding. Zhongshan Street, a commercial and

cultural center during the opening of Xiamen's port in the early 20th century, blends southern Fujian and Western architectural styles. Featured elements include Nanyang style arcades symbolizing the "old village," ground-floor shops for social and commercial use, and the pedestrian-friendly Zhongshan Road Historic District that supports the daily lives of local residents. With urban renewal and gentrification, many buildings have been demolished or modernized, and due to government-led conservation and tourism-oriented planning, a smaller scale spatial language has been emphasized to embody experiences. (Figure 1)

In Jimei New Town, Xiamen, the central district of Xiting represents modernist spatial norms with high-rise office buildings, large shopping malls and upscale residential areas. Influenced by the development concept of Chen Jiageng's "integrated style", the new town presents a post-modern collage style. The high-rise building base integrates the red brick eaves of southern Fujian, and the upper floors adhere to modern aesthetics. The main functions of the new city are finance, trade and scientific and technological exchanges, making it the core of Xiamen's integration into the global economic order. Thus, despite the traditional trappings, the language of modernism dominates its spatial code. (Figure 2)

In general, the new and old cities of Xiamen have formed an intuitive binary spatial coding system. The old town is associated with local elements such as streets and historic buildings, while the new town is associated with modern and global themes. However, the boundaries between these codes are blurred, and they permeate each other's spatial structure. Interviews with planners involved in Xiamen's urban master plan and new town planning revealed that this spatial code framework was consciously guided by the planning and design authorities. Unlike other cities where old and new towns are isolated, Xiamen's integrated approach reflects the government and design team's recognition of the city's multiculturalism and spirit, aiming to bridge the cultural segregation between old and new areas.

The study further divides respondents into tourists and local residents, analyzing how each group relates to cultural identity. Both tourists and locals describe Zhongshan Street as "art," "night lights," and "fashion," followed by its association with commerce, cafes, and restaurants linked to the consumer economy. However, visitors tend to interpret the spatial code of the old town as a consumerist spectacle, treating it as a constructed theme park experience that emphasizes the act of observing its cultural context. This commoditized experience is often homogenized for visitors, who may encounter similar historic neighborhoods elsewhere, creating a resistant identity.

Locals have similar descriptions, but have a more positive view of the area, seeing it as a cultural landmark that embodies Xiamen's uniqueness. Instead, visitors are more attuned to the modernist spatial code of the new town because it aligns with their everyday experience of modernity and offers a relevant living environment. For locals, the central district of West Pavilions supports their practical needs - jobs, education and transportation - especially as urban renewal has seen many people move from the old town to the new. Zhongshan Road is a nostalgic place full of imagination, while the new town is the root of their life experience and local identity.

In conclusion, the opposing interpretations of the spatial systems of the old and new towns reflect the conflict between individual experience and the top-down dominance of spatial production. Xiamen's spatial code framework juxtaposes historic local symbols with a globalized cityscape, taking residents and visitors away from their sense of place. The old town reflects a government - and capital-driven consumption space, while the new town is positively welcomed for providing a framework within which individuals can organize their daily lives and connect with a modern Xiamen identity.

5.Dynamics from perspective of political economy

In the subsequent analysis, the focus is on the conflict between political-economic forces and living experience. Through the textual examination of local and migrant populations in Xiamen, as well as field interviews with planning institute personnel, the study further identifies the dynamics underlying the misalignment between the spatial code systems of old and new urban areas and their spatial imagination. Drawing on Henri Lefebvre's theoretical framework of the dialectics of the triad of space (Lefebvre, 1991), the analysis examines the conflict between the perceived space from the perspective of the people and the representative space.

5.1 Cognitive impressions driven by economics

The Xiamen government's approach to controlling cognition is by constructing a top-down spatial representation, shaping an envisioned space. The organization of cultural spaces by the government needs to demonstrate a vision of modernization while also considering the characteristics of space protection, which is selectively accepted. Traditional historical spaces require a balance with cultural promotion, while modern commercial spaces need to consider the selective use of historical elements.

The Xiamen municipal government is at the forefront of implementing a unified planning policy. In this process, strategic control has replaced the drawbacks of a fragmented planning system, where spatial policies and authorities overlap. Consequently, top-down spatial organization activities and large-scale urban growth actions have shaped the local cultural landscape (Wei, 2012). The dual coding system of Xiamen's old and new cities actually reflects the government's pursuit of spatial imagery, demonstrating its preference for modernization and the isolated protection of cultural spaces, two distinctly different demands within isolated spatial structures.

From the perspective of planners and decision-makers, the government's drive to shape new urban spaces is rooted in local political interests (Barthel et al., 2005). Beneath the appearance of globalization is the intervention of political power in shaping planning objectives and carriers of identity imagery, shifting from a global image to planning judgments that align with the local political situation(Figure 3).

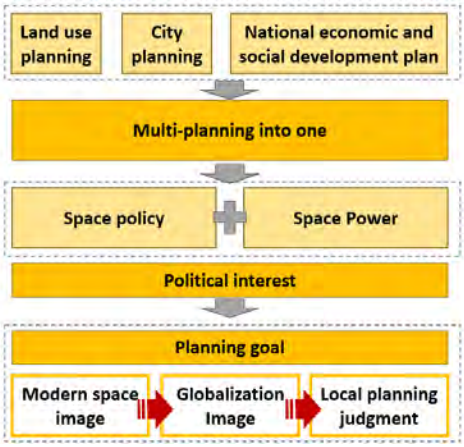


Figure 3 The process of shaping the new and old city image space under the government

5.2 Cognitive solidification of political subjects

For the economy, it is the market that dictates spatial preferences based on economic profitability demands and the functional characteristics it bestows upon spaces. In Xiamen, the integration of localized spatial elements in new town construction and old city renewal practices is a crucial strategy. This aims to

protect and promote local culture while enhancing the city's living quality and attractiveness. The planning and construction of new towns are not only about the expansion of physical space but also the continuation of culture and history (Stenseke, 2009). In this process(Figure 4), architectural design becomes key to showcasing local characteristics. Designers employ Southern Fujian architectural styles, skillfully integrating traditional elements such as red bricks and swallow-tailed ridges into modern architecture, creating a cityscape that is both contemporary and imbued with local identity (Della & Trunfio, 2018). These buildings not only provide residents with a living environment that offers a sense of cultural identity but also serve as symbols and landmarks of the city's culture.

The placement of public art is also an indispensable part of new town construction. In parks, squares, and other public spaces, sculptures and murals are used to tell Xiamen's stories, reflecting its rich history and culture. These artworks not only beautify the urban environment but also become focal points for residents' daily leisure and socialization, strengthening the community's cultural cohesion (Borrup, 2006). Additionally, the planning and construction of green spaces are an important aspect of new town development. By preserving and increasing green areas, such as building parks featuring local plants from Xiamen, the ecological value of the city is enhanced, and residents are provided with more spaces for leisure and entertainment, improving the quality of life.

Old city renewal focuses more on cultural protection and revitalization. In this process, the preservation and restoration of historical buildings are central tasks. Through meticulous restoration efforts, historical buildings in old urban areas retain their original appearance while being given new functional uses, such as being transformed into cultural exhibition halls, cafes, or art studios. These renovations not only protect the city's historical heritage but also inject new vitality into old urban areas. Community revitalization is another important aspect of old city renewal. By encouraging community residents to participate in renewal projects, such as through community activities and workshops, not only is community cohesion strengthened, but community culture is also protected and passed down. Moreover, the improvement of transportation facilities is key to enhancing the living quality of old urban areas. By adding bicycle lanes and pedestrian zones, the accessibility and comfort of old urban areas are increased, and more environmentally friendly modes of transportation are encouraged.

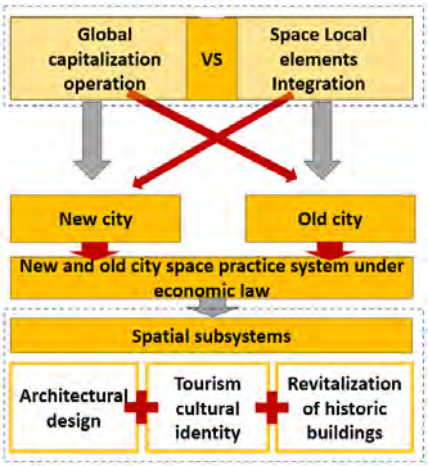


Figure 4 The formation process of cultural identity driven by economy

5.3 The generation of perversion structure of human spatial experience and spatial cognition

With the support of political and economic spaces, planning policies have become more entrenched in their consistent connection to spatial image and cultural identity within a highly integrated dual-city region, inevitably leading to conflicts with everyday lived experiences. The delineation of roles among external tourists, locals, and planners facilitates our exploration of the interactions and relationships between subjective perceptions and rational policies, yet it also hinders attention to the integrated existence of individuals as a whole (Braun, 2008). People serve as carriers of complex networks of nodes influenced by market, social, and governmental actions, thus bearing intricate multi-path dependencies and resource occupation mechanisms, which similarly affect cultural identity in both old and new cities. Furthermore, individuals occupy intermediary points in planning practices and spatial imaginations, simultaneously acting as points of inversion that alter the seemingly natural and inherent shaping order of spatial creators (Figure 5). It is precisely the existence of these points of inversion that explains the reasons for the multiple opposing reversals, where a singular logic emerges from the spatial derivations of old and new cities that are vertical to the inherent institutional framework. The parallel inherent paths of the old and new cities intersect in three overlapping dimensions, generating a social-local network identity system within the inverted concepts of multiple participants. This not only reveals a complex leap in scale from micro to macro but also deeply embeds itself into the inverted rather than opposing local identity structure of Xiamen, attempting to smooth the ripples created by the fluctuating local planning practice models shaped by the market, society, and government, alongside the contemporary mainstream theoretical discourse.

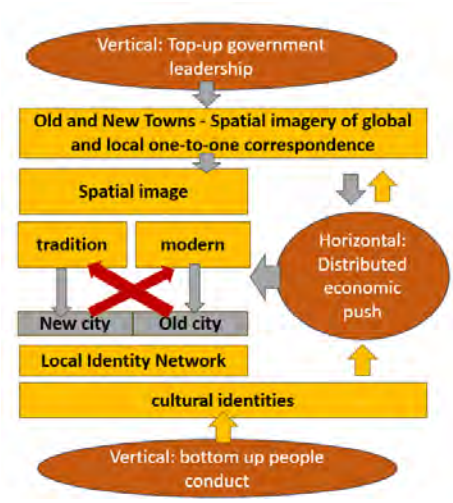


Figure 5 The inherent and inverted paths of spatial imagery and cultural identity in the old and new cities of Xiamen

Declaration of generative AI in the writing process

During the preparation of this work Gao Han used ChatGPT 4o Model in order to Improving readability and eliminate grammar mistakes. After using this tool/service, Gao Han reviewed and edited the content as needed and takes full responsibility for the content of the publication.

6. References

Bai, X. and Xu, H. (2023) 'Understanding spatial growth of the old city of Nanjing during 1850–2020 based on historical maps and Landsat data'. The Egyptian Journal of Remote Sensing and Space Science, 26(1), pp.25–41.

Barthel, S., Colding, J., Elmqvist, T., and Folke, C. (2005) 'History and local management of a biodiversity-rich, urban cultural landscape'. *Ecology and Society*, 10(2).

Cavallo, R., Komossa, S., Marzot, N., Meta Berghauser Pont, Joran Kuijper and Technische Universiteit Delft. Faculteit Bouwkunde. (2014) *New urban configurations. Amsterdam: Ios Press*, Under the Imprint Delft University Press.

Crang, M. (2013) *Cultural Geography*. Routledge.

Braun, E. (2008) *City Marketing: Towards an integrated approach*. Erasmus University Rotterdam.

Bokhove, C. and Downey, C. (2018) 'Flexible Coding of In-depth Interviews', *Sociological Methods & Research*, 50(2), pp. 708–739.

Della Lucia, M. and Trunfio, M. (2018) 'The role of the private actor in cultural regeneration: Hybridizing cultural heritage with creativity in the city', *Cities*, 82, pp. 35–44.

Kayvan, K. (1998) *Continuity and change in old cities: An analytical investigation of the spatial structure in Iranian and English historic cities before and after modernisation*. Dissertations & Theses.

Kian, T. (2001) *The promise of the city: space, identity, and politics in contemporary social thought*. Ca, Usa: University of California Press.

Lefebvre, H. (1991) *The Production of Space*. Oxford: Blackwell.

Liu, Y. (2019) 'City Image Analysis of Western Taipei'. *International Review for Spatial Planning and Sustainable Development*, 7(4), pp.18–36.

Nas, Peter J.M. (2011) *Cities full of symbols: a theory of urban space and culture*. Leiden, Netherlands: Leiden University Press.

Nugraheni, C. and Hartanti, N.B. (2023) 'Attractiveness of the old town to strengthen the image of the city of Semarang'. *International Journal on Livable Space*, 8(1), pp.21–28.

Polkinghorne, D. E. (2005) 'Language and meaning: Data collection in qualitative research'. *Journal of counseling psychology*, 52(2), 137.

Stenseke, M. (2009) 'Local participation in cultural landscape maintenance: Lessons from Sweden', *Land Use Policy*, 26(2), pp. 214–223.

Wei, Y.H.D. (2012) 'Restructuring for growth in urban China: Transitional institutions, urban development, and spatial transformation', *Habitat International*, 36(3), pp. 396–405.

Zgheib, H. (2021) 'Rebranding City Image: Keeping its Old'. *The International Journal of Architectonic, Spatial, and Environmental Design*, 16(2), pp.95–103.

Research Paper

Spatial Contraction Characteristics and Regeneration Pathways in Industrial Areas:

A Comparative Study of Venice and Nanjing

Kailun LI, Southeast University, China

Abstract

The rapid industrialization of metropolises has facilitated the formation of industrial areas, but urban transformation has challenged these industrial areas, leaving behind brownfield sites that affect urban density, environment and memory. The path of shrinkage and regeneration of these brownfield sites varies from region to region, reflecting the city's response to the transformation. Although there have been studies on brownfield identification and restoration, there is a lack of comparative studies on industrial shrinkage and regeneration paths in different areas. Taking Venice and Nanjing as examples, this study compares and analyzes the shrinkage characteristics and regeneration mechanism of brownfield in their industrial zones. The results show that there are both commonalities and differences in the contraction of industrial land in the two cities, which are closely related to the life cycle and development strategy of enterprises. While the industrial regeneration of Nanjing is government-led, the industrial regeneration of Venice is market-driven, and although it has some flexibility, it needs a stronger voice in the implementation of major projects and the coordination of heritage protection. Although the industrial areas of the two places face different development environments and land system backgrounds, their paths and experiences in spatial shrinkage and regeneration have certain mutual learning value, which can provide a reference for industrial and spatial regeneration in other cities around the world.

Keywords

Spatial Contraction, Industrial Areas, Regeneration Pathways

1. Introduction

After the industrial Revolution, along with the rapid industrialization and urbanization process, a number of industrial clusters have appeared in cities, which have made great contributions to the development of urban industries. However, with the continuous transformation of urban industrial structure, the number of idle land and abandoned brownfields in these industrial areas is rising day by day, and the proportion of brownfields in some industrial areas has reached a certain extent, and the regions have contracted and declined. These brownfield sites have a profound impact on urban density, urban environment, and urban memory, and pose challenges for urban planners. Therefore, the restoration of brownfield is not only to promote the sustainable development of industry, but also to preserve the memory of urban production and lifestyle.

Brownfield is an important issue in every country, which has been paid attention to by scholars from all over the world, and a wealth of research has been conducted(Newman,2016). The concept of brownfield is broad, and the emphasis is different. The U.S. brownfield concept emphasizes contaminated industrial and commercial abandoned land, Japan expands the concept to include "potential brownfield sites" that

may be abandoned in the future, and Canada's brownfield concept focuses more on market redevelopment value.

The identification, assessment, and remediation of vacant land have also been key areas of focus for scholars. In terms of identification, the formulation of identification standards primarily involves establishing a multi-indicator identification evaluation system or model (Wang,2022; Ahmad,2018), yet significant discrepancies exist in indicator selection and weight determination due to different value orientations and research perspectives among scholars, leading to varied identification and evaluation results. In terms of assessment, existing research primarily revolves around the land use characteristics, spatial distribution features, and spatial morphological characteristics of vacant land (Coffin,2003). Relevant assessments mainly involve evaluations of vacant land types, spatial compactness, hollowing-out, and fragmentation, with evaluation methods evolving from single-indicator measurements to systematic index system evaluations (Sun et al,2023). As measurement indicators gradually expand, measurement domains deepen, and evaluation methods become increasingly quantitative, traditional spatial analysis methods have gradually become inadequate for studying land use patch morphologies (Bacon,2007; Hayek et al,2010). Therefore, in addition to spatial analysis methods, interdisciplinary techniques such as landscape pattern analysis are often employed for auxiliary analysis (Zhong et al,2020).

In terms of vacant land redevelopment, many scholars have proposed a series of development concepts in response to urban shrinkage, including smart growth, compact development, and infill development, all embodying the idea of urban morphological adjustment (Dixon et al,2006; Klusáček et al,2018). These concepts emphasize achieving "dynamic transformation and smooth transition" in urban morphology through planning intervention and landscape management (Gao,2017). Howland (2003) argues that the key to redevelopment lies in addressing financial issues and decentralized ownership; Pagano (2000) believes that land banks have played a crucial role in addressing land vacancy and abandonment issues in the United States, and insurance products such as pollution liability insurance and cost coverage insurance can also help developers reduce pollution cleanup cost; Dewar (2006) and Hackworth (2014) suggest that compared to purely market-driven models, government-intervened redevelopment approaches yield better results. In terms of spatial remediation, substantial practical experience has been accumulated in brownfield pollution treatment and landscape reconstruction (Song et al,2019). However, existing research primarily focuses on large-scale projects, with limited attention given to regional vacant land distribution and holistic renewal.

The characteristics of industrial area contraction and their regeneration pathways vary across regions, reflecting both commonalities and profound differences in urban responses to industrial transitions(Rall et al,2011; Dixon,2007). Jigoria (2017) conducted a comparative analysis of the brownfield regeneration pathways in two single-industry cities in neighboring former socialist countries (Romania and Serbia) but did not delve deeper into their commonalities and characteristics. Therefore, existing research on vacant land is limited to the identification of phenomena or detailed analysis of single cases(Smoḷakova,2017; Osman et al,2015), lacking comparative studies to examine the different pathways of industrial area contraction and regeneration across different regions.

This study aims to address this gap by exploring the spatial characteristics of industrial area contraction and the mechanisms underpinning their regeneration in two globally renowned tourist destinations with rich historical and cultural heritages: Venice and Nanjing. Venice, known for its canals and rich historical architecture, has a profound industrial legacy exemplified by Porto Marghera, which once housed a vibrant shipbuilding and chemical industry. Nanjing, on the other hand, is famous for its ancient history and culture, and is also an important industrial development center in the middle and lower reaches of the Yangtze River, with 15 provincial-level and national-level development zones. Both cities now grapple with the

proliferation of vacant land and the challenge of transformation. By comparing these two cities, this study aims to provide valuable insights into the shared and distinct paths of industrial district contraction and regeneration. Utilizing Google Earth satellite imagery and diverse open-source data, this study adopts a hybrid approach combining visual interpretation of satellite imagery with multi-source data calibration to identify brownfields. A comprehensive methodology for vacant land recognition and assessment is established, validated, and refined through localized empirical tests. Based on that, This study delved into the spatial characteristics of industrial area shrinkage, analyzed the formation and evolutionary texture of vacant land clusters, and explored and compared the redevelopment paths of different industrial areas.

2. Data and Methods

2.1. Research Objects

This study selects two cities, Nanjing in China and Venice in Italy, as the research subjects, with a comparative analysis focusing on the *Porto Marghera* Industrial area in Italy and the *Nanjing Economic and Technological Development Zone (NETDZ)* in China as specific case studies. Both industrial areas are representative within their respective cities, forming industrial agglomerations of significant economic and land-use scale. They have made substantial contributions to the economic development of their cities during specific historical periods and currently face renewal challenges characterized by business closures and land-use contraction.

Figure 1 Real scene inside Porto Marghera. Source: Author.

Located in the Veneto in northeastern Italy, Porto Marghera is a representative area of Italy's traditional industries and one of Europe's largest coastal industrial zones, with chemicals, steel, shipbuilding, and petroleum processing as its leading industries. Centered around the core Porto Marghera, several major industrial clusters have formed within the current industrial zone, including shipbuilding, oil refining, old petrochemicals, new petrochemicals, and biotechnology, which contribute significantly to the industrial zone's output and employment. In terms of overall production scale and employment, it serves as a crucial economic hub for Venice and the entire northeastern region of Italy. As of 2020, the Porto Marghera and Industrial Zone occupy an area of 2,200 hectares, with 884 enterprises, 11,060 employees, and an annual

turnover of €27 billion. However, due to its proximity to the historic center of Venice and its orientation towards the vast lagoon area, Porto Marghera is bordered by the culturally rich World Heritage Site on one side and the thriving production scene of a giant tanker manufacturing base on the other. Consequently, the industrial zone faces immense pressure in terms of ecological and environmental protection. Over the past few decades, many factories and companies within the industrial zone have temporarily or permanently closed. For instance, the EVC Compounds company ceased operations in 2006 and relocated to the Emilia-Romagna region, where factories offered more advanced technology. Under the influence of EVC, five other factories that used dichloroethane as a raw material also closed, highlighting the low resilience of the company's supply chain.

The Nanjing Economic and Technological Development Zone, situated in Qixia District of Nanjing, is one of the earliest national economic and technological development zones in Nanjing. It ranks among the top ten national development zones in China, is a national eco-industrial demonstration park, a world-class photoelectric display industry base, and a national Yangtze River shipping and logistics hub. In 2020, the Nanjing Economic and Technological Development Zone had a regional GDP of €15.5 billion, a total industrial output value of € 40 billion for above-scale industries, and an area of 200 square kilometers. It focuses on the development of three leading industries: photoelectric display, new materials, and high-end equipment.

2.2. Data Source and Technical Methodology

Based on the review of identification standards for vacant land in Italy and China, this study initially proposes criteria for vacant land identification. Considering the accuracy of vacant land identification in existing research and the average scale of industrial enterprises, and to fully leverage the advantages of visual interpretation of satellite imagery, this study determines an identification accuracy threshold of industrial land areas greater than or equal to 1 hectare and a time criterion of being vacant for at least six months. The key criterion for identifying vacant land lies in whether the land is in a state of disuse, regardless of the presence of buildings or the level of building density.

To minimize errors and biases introduced by satellite imagery identification, the identification should be subjected to multi-source data calibration based on visual interpretation of satellite imagery, with the aim of supplementing and correcting the identification results. The correction process consists of two rounds. The first round involves confirming the property rights and operational status of enterprises using open-source online data to supplement a batch of abandoned land that cannot be identified through visual interpretation of satellite imagery. The second round involves field corrections and multi-party verifications, with specific methods including field inspections and enterprise interviews, aimed at reconfirming the land use status of enterprises and making final judgments on cases that are difficult to assess through satellite imagery. These two rounds of corrections not only correct and supplement the results of manual identification but also allow for in-depth engagement with enterprises through visits to uncover their actual needs and typical experiences, discover new issues, and summarize new characteristics. Specific methods include supplementary online data, field inspections, enterprise interviews, and so forth.

Figure 2 Abandoned buildings in Nanjing Economic and Technological Development Zone. Source: Author.

Following identification, an evaluation of vacant land is conducted to comprehensively assess the level of vacancy and contraction in the industrial areas. Based on existing research methods and considering the actual industrial development situations in Nanjing and Venice, evaluation indicators are selected from three dimensions: quantity, morphology, and distribution, to professionally evaluate the distribution status of vacant brownfields within the study area. Ultimately, the framework for brownfield identification and evaluation is established as illustrated in the figure.

3. Results

3.1. Spatial Characteristics of Industrial District Contraction

Firstly, the contraction of industrial spaces in Nanjing and Venice exhibits both common and unique features. The spatial distribution of vacant land in both cities demonstrates a degree of dispersion and randomness. From the perspective of land use morphology, compared to general construction land, vacant land typically exhibits smaller areas, irregular shapes, and fragmented boundaries. At the micro-level, the

vacant land within industrial areas tends to be located in less accessible areas, often developing away from major roads, resulting in hollowed-out and porous internal plots. Different industrial parks exhibit distinct patterns of localized aggregation of vacant land, primarily categorized as "center-periphery" and "clustered development," which are closely related to the timing of park development.

Secondly, from a temporal perspective, the evolution of vacant land is dynamic, with each plot potentially becoming vacant land at some point, influenced by policy factors, corporate lifecycles, and regional development strategies. The transformation of these lands reflects the interplay between economic, social, and environmental dynamics.

In terms of specific differences, the types, causes, and mechanisms leading to the emergence of vacant land during industrial contraction differ between the two cities. In Venice, the appearance of vacant land in Porto Marghera is predominantly market-driven. The decline of the shipbuilding and chemical industries in the area has led to the abandonment of numerous industrial facilities, with some enterprises closing down due to poor performance or mismanagement, resulting in a proliferation of vacant land. Market forces have played a significant role in shaping the spatial distribution of these vacant land, as areas closer to the city center, with higher land values, are more prone to redevelopment. The vacant land in Porto Marghera is mostly brownfield, already developed but abandoned and contaminated to some extent.

Conversely, the vacant land in Nanjing Economic and Technological Development Zone is predominantly underutilized. The government has preemptively supplied a portion of the land, some of which has been leased to enterprises, while others remain in a state of preparation and are largely undeveloped. Given that China does not impose fees for land idleness, some of these lands have been left idle for extended periods. The government manages these lands by covering them with green membranes to maintain the city's overall appearance. This situation is related to the different land development systems between the two cities.

3.2. Different regeneration paths in industrial zones

The regeneration pathways of these industrial areas differ significantly between Nanjing Economic and Technological Development Zone and the Porto Marghera in Venice. The regeneration of industrial land in Nanjing is led by the government, showing a stronger ability of land consolidation and overall planning. The government has played a key role in promoting brownfield regeneration, implementing many policies and initiatives to promote economic growth, environmental improvement and social cohesion. The renewal process often involves converting brownfield sites to new urban uses, such as residential, commercial and recreational areas. This is thanks to the government's ability to consolidate land and implement comprehensive planning strategies, ensuring that the regeneration process is coherent and sustainable. Another type of renewal includes the redevelopment of underutilized land, realizing the development concept of phased development by filling in undeveloped vacant land within the development zone.

Conversely, Venice's regeneration process is primarily market-oriented, offering greater flexibility but requiring stronger authority in executing significant projects. Market forces play a significant role in brownfield regeneration, with private investors and developers often driving the process. For instance, under the supervision of the Venice Development Agency, the Industrial Transformation and Redevelopment Initiative (PRRI) serves as a focal point, and the specific brownfield redevelopment process is mainly divided into three stages.

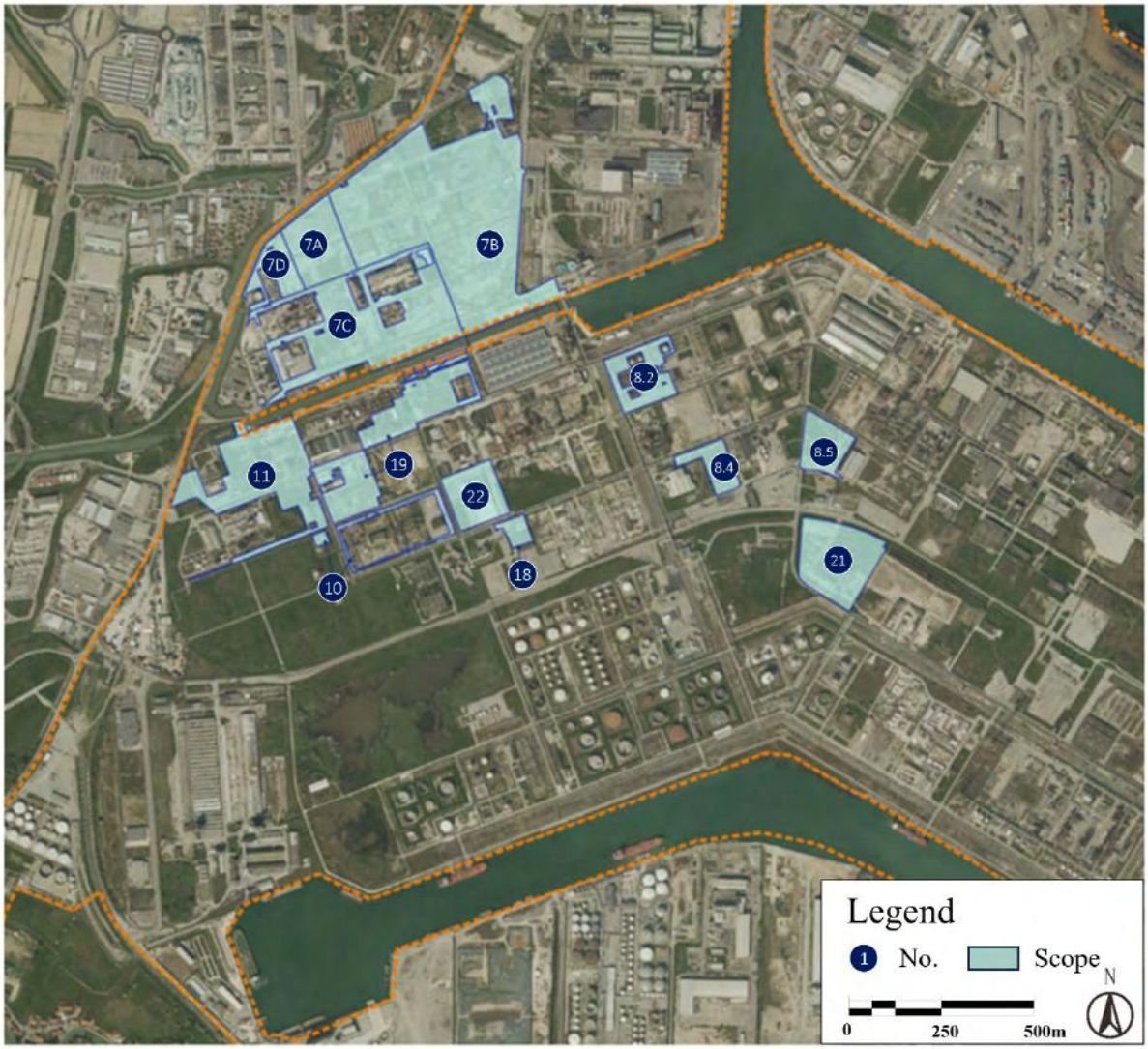


Figure 3 The information of the land parcels to be updated on the website of Venice Development Agency. Source: https://www.venicedevelopmentagency.org/it/home-asv.

In the early stages of corporate decline, abandoned spaces are assigned temporary functions such as warehousing and logistics, providing partial logistics and service functions for the port to safeguard its core competitiveness in transportation; in the medium-term land idleness, professional third-party companies are introduced to coordinate and acquire abandoned and brownfield sites, handle property rights withdrawal, conduct environmental remediation and restoration, and build necessary infrastructure to meet the needs for reuse, determining the priority of development based on factors such as market value, environmental contamination, renovation costs, and planning restrictions; in the later stages of transformation, the Venice Development Agency introduces investment promotion and tax incentive policies to reintroduce brownfields into the market, with third-party companies providing cooperation and receiving dividends. The coordination among these three stages allows the renewal of vacant land in industrial zones to proceed in an orderly manner.

Despite these differences, both cities have formed relatively complete renewal processes and mechanisms in updating industrial areas, leveraging their respective institutional advantages to promote the

regeneration and transformation of urban industrial areas. At the same time, they face common challenges in the transformation and revitalization of industrial landscapes. These challenges include balancing economic growth with environmental sustainability, preserving urban memory and cultural heritage, and ensuring social cohesion and equity in the regeneration process.

4. Discussion

The contraction of industrial areas represents a transitional phenomenon arising from the mismatch between supply and demand during the shift from an extensive to an intensive development model. It is also a consequence of local governments guiding the optimization of spatial structures and industrial structures. On the one hand, the decline of enterprises and structural adjustments are outcomes of market selection. The continually released idle land resources provide new space for the future development of parks. The renewal and replacement of brownfields drive industrial upgrading within the parks, and the land within parks continuously undergoes replacement to realize the continuation of market value. On the other hand, appropriate government intervention and proactive adjustments have, to a certain extent, mitigated risks and promoted the healthy development of industrial areas.

The government-led renewal in Nanjing and the market-led renewal in Venice exemplify two of the most typical industrial area renewal pathways. However, in practice, neither government-led nor market-led approaches are absolute and often function synergistically. In 2017, the Marghera Industrial Area was recognized by the government as a region with complex industrial crises and benefited from specific national industrial policies, including financial support, infrastructure interventions, optimization of lending networks, worker reemployment, administrative procedure simplification, and environmental governance policies. Among these, over €26 million was allocated as investment incentives for certain heavy industries. These policy incentives also played a significant role in the market-led industrial area renewal of Porto Marghera.

Similarly, in Nanjing, policies guided the key transformation directions of different industrial areas, provided that policymakers conducted thorough market research and made decisions that maximized the benefits for all stakeholders in line with public interests. At the specific site level, the utilization of new industrial sites still followed a commercial bidding process, with the market determining specific actions. Therefore, both market regulation and government intervention are indispensable in the process of comprehensive industrial area renewal. Industrial areas are constantly evolving under the dual influence of market regulation and government intervention, achieving continuous renewal and development of urban industrial space.

These research results have some implications for urban planning under the background of urban industrial zone shrinkage. First, there is a need to develop more inclusive and adaptive planning to deal with the shrinkage of industrial space, in particular to balance multi-stakeholder relationships and maintain the sustainability of renewal projects. Second, government intervention is necessary to provide a coherent and sustainable framework for regeneration, but market forces should also be allowed to play their part in driving innovation and economic growth. Third, the preservation of cultural heritage and urban memory should be a key consideration in the regeneration process of industrial space. It is premised on recognising the historical and social value of brownfield sites and being able to contribute to the overall richness and diversity of the urban landscape.

Finally, although the industrial areas of the two places face different development environments and land system backgrounds, the paths and experiences in spatial shrinkage and regeneration have certain mutual

learning value. In particular, in dealing with industrial spatial contraction and urban memory inheritance, more universal and inclusive strategies and paths can be explored to provide references for industrial and spatial regeneration in other cities around the world.

5. References

Ahmad, N., Zhu, Y., Ibrahim, M., Waqas, M., and Waheed, A. (2018). 'Development of a standard brownfield definition, guidelines, and evaluation index system for brownfield redevelopment in developing countries: The case of Pakistan', *Sustainability,* 10(12), 4347.

Area Sviluppo del Territorio e Città Sostenibile.(2023) 'Area di crisi industriale complessa', *Città di Venezia*. [online]. Available at: https://www.comune.venezia.it/it/content/area-crisi-complessa(Accessed: 08 October 2024).

Bacon, G. M. (2007). *Application of object-oriented image classification to identify potential brownfield sites in Syracuse, New York.* MSc thesis. State University of New York College of Environmental Science and Forestry. Available at: https://www.proquest.com/openview/8157cfd978dd3216ca30256603fe81bf/1?cbl=18750&pq-origsite=gscholar(Accessed: 18 March 2025).

Clegg, E., and Vogt, K. (2010). *Quality Infill Recommendations and Tools*. Idaho District Council: Urban Land Institute.

Coffin, S. L. (2003). 'Closing the brownfield information gap: Some practical methods for identifying brownfields', *Environmental Practice*, 5(1), 34-39.

Dewar, M. (2006). 'Selling tax-reverted land: Lessons from Cleveland and Detroit: New this spring Westchester', *Journal of the American Planning Association*, 72(2), 167-180.

Dixon, T. (2007). 'The property development industry and sustainable urban brownfield regeneration in England: An analysis of case studies in Thames Gateway and Greater Manchester', *Urban studies*, 44(12), 2379-2400.

Dixon, T., Pocock, Y., and Waters, M. (2006). 'An analysis of the UK development industry's role in brownfield regeneration', *Journal of Property Investment & Finance*, 24(6), 521-541.

Gao S.Q.(2017). 'Tracing the Phenomenon, Concept and Research of Shrinking Cities', *Urban Planning International*, 32(03): 50-58.

Hackworth, J. (2014). 'The limits to market-based strategies for addressing land abandonment in shrinking American cities', *Progress in Planning*, 90, 1-37.

Hayek, M., Novak, M., Arku, G., and Gilliland, J. (2010). 'Mapping industrial legacies: Building a comprehensive brownfield database in geographic information systems', *Planning Practice & Research*, 25(4), 461-475.

Howland, M. (2003). 'Private initiative and public responsibility for the redevelopment of industrial brownfields: Three Baltimore case studies', *Economic Development Quarterly*, 17(4), 367-381.

Jigoria-Oprea, L., and Popa, N. (2017). 'Industrial brownfields: An unsolved problem in post-socialist cities. A comparison between two mono industrial cities: Reşiţa (Romania) and Pančevo (Serbia)', *Urban Studies*, *54*(12), 2719-2738.

Klusáček, P., Alexandrescu, F., Osman, R., Malý, J., Kunc, J., Dvořák, P., ... and Trojan, J. (2018). 'Good governance as a strategic choice in brownfield regeneration: Regional dynamics from the Czech Republic. *Land use policy*', 73, 29-39.

Nanjing Municipal People's Government.(2022) 'The comprehensive level of Nanjing Economic and Technological Development Zone once again ranks ninth in the country', *Nanjing Municipal People's Government*. [online]. Available at: https://www.nanjing.gov.cn/zgnjsjb/jrtt/202101/t20210129_2808895.html(Accessed: 29 January 2021).

Newman, G. D., Bowman, A. O. M., Jung Lee, R., and Kim, B. (2016). 'A current inventory of vacant urban land in America', *Journal of urban Design*, 21(3), 302-319.

Osman, R., Frantál, B., Klusáček, P., Kunc, J., and Martinát, S. (2015). 'Factors affecting brownfield regeneration in post-socialist space: The case of the Czech Republic', *Land Use Policy,* 48, 309-316.

Pagano, M. A., and Bowman, A. O. M. (2000). *Vacant land in cities: An urban resource*. Washington, DC, USA: Brookings Institution, Center on Urban and Metropolitan Policy, pp. 1-9.

Rall, E. L., and Haase, D. (2011). 'Creative intervention in a dynamic city: A sustainability assessment of an interim use strategy for brownfields in Leipzig, Germany', *Landscape and Urban Planning,* 100(3), 189-201.

Smoļakova, A. (2017). 'Exploring spatial patterns of urban brownfields: The case of Daugavpils city', *In ENVIRONMENT. TECHNOLOGIES. RESOURCES. Proceedings of the International Scientific and Practical Conference*, Vol. 1, pp. 265-270.

Song, Y., Kirkwood, N., Maksimović, Č., Zheng, X., O'Connor, D., Jin, Y., and Hou, D. (2019). 'Nature based solutions for contaminated land remediation and brownfield redevelopment in cities: A review', *Science of the Total Environment*, 663, 568-579.

Sun, Y., Hu, H., Han, Y., Wang, Z., and Zheng, X. (2023). '*Large-Scale Automatic Identification of Industrial Vacant Land*', *ISPRS International Journal of Geo-Information*, 12(10), 409.

Venice Development Agency.(2022) 'Notice Areas in Porto Marghera', *Venice Development Agency*. [online]. Available at: https://www.venicedevelopmentagency.org/it/portfolio(Accessed: 06 April 2023).

Wang, Y., Liu, Y., Zhou, G., Ma, Z., Sun, H., & Fu, H. (2022). 'Coordinated relationship between compactness and land-use efficiency in shrinking cities: A case study of Northeast China', *Land*,11(3): 366.

Zhong, Q., Zhang, L., Zhu, Y., Konijnendijk van den Bosch, C., Han, J., Zhang, G., and Li, Y. (2020). 'A conceptual framework for ex ante valuation of ecosystem services of brownfield greening from a systematic perspective', *Ecosystem Health and Sustainability*, 6(1), 1743206.

Research Paper

Socio-Economic spatial framework for Assessing the Character of Urban liminal Spaces in Regulating Ecosystem Services

Case of Chennai City, India

Yaazhini P.R., Research Scholar, Anna University, India

Dr. Kiranmayi Raparthi, Assistant Professor, Anna University, India

Dr. K. Pratheep Moses, Professor, Anna University, India

Abstract

Generally, urban landscapes, and urban spaces are delineated with clear specific boundaries. However due to rapid urbanization, certain areas within these spaces are characterized by co-presence and intermediateness such as the banks of water bodies, coastlines, and peri-urban spaces,referred to as liminal spaces. These spaces are in a state of constant transformation,and transition historically and functionally, due to various socio-economic and cultural factors. This dynamic heterogenous nature of liminal spaces have been regarded as key providers for many ecological services by urban experts. Apparently, it is noticed that the character and usage of the liminal urban spaces is often affected by the built and land use dynamics and socio-economic conditions of the liminal space and its surrounding area. Moreover, due to the absence of proper ownership, these spaces tend to lack territoriality. As such, they are often overlooked by urban policy makers rendering them more vulnerable to environmental hazards.

Most urban planners consent to the spatiotemporal character of liminal spaces and advocate that there is a significant link between urban liminal spaces and climate resilience, thereby, agree that by integrating urban liminal space policies in urban planning there is an ability to adapt to climate change. However, lack of convincing studies with respect to the ecosystem services offered by the liminal spaces and the effect of these ecosystem services provided by the liminal spaces that support this ability might have halted the process of mainstreaming to some extent.
In this context, this research paper aims to understand the changing dynamics of liminal spaces. Specifically, this research investigates 1) how the land use dynamics affect the ecosystem services offered by the liminal spaces; and 2) Do these liminal spaces affect the psychosocial, socioeconomic and cultural ability of people in withstanding climate change.
This research undertakes a mixed method approach wherein by combining an array of methods, the ecosystem services provided by various liminal spaces are evaluated by both stated preference methods and market based methods assigning value value to the indicators. As such the research will aid in establishing a relationship between socioeconomic conditions and environmental degradation as well socioeconomic conditions and consumption of land.
Accordingly, this research paves the way for a deeper understanding of ecosystem services offered by liminal spaces. Thereby has an implication for effective decision making related to urban liminal spaces.

Also, this research significantly contributes to the field of urban planning and public policy by developing empirical evidence that analyzes the relationship between urban liminal spaces and

climate change resilience. This research supports the use of urban liminal spaces as an effective tool in adapting to climate change thereby promoting climate resilience through urban planning. This research has an implication for mainstreaming climate change resilience in urban planning

Keywords

Liminal spaces, ecosystem services, socio-economic conditions, environmental degradation

1. Introduction

As urban areas expand to meet the demands of their growing populations, they create not only functional spaces for living and commerce but also "liminal spaces"—zones that exist in transitional states. The word liminal has its root in Latin, it was derived from the Latin word “Limen” which means boundary or limit. Urban liminal spaces are in between / transition spaces; spatially they represent any piece of land marking a transition, edges, borders, peripheries, terraqueous zones, or any wasteland which are at transition – spatially, temporally, and socially (Fourny, M.C., 2013). These liminal spaces are neither fully integrated into urban functionality nor entirely abandoned, making them unique intersections between the built environment and natural processes (Jorgensen & Tylecote, 2007). Often overlooked in urban planning, these spaces can contribute unexpectedly to biodiversity and environmental resilience, providing habitats for flora and fauna and supporting ecological functions like flood mitigation and air purification. As urbanization intensifies, understanding and reimagining the role of liminal spaces becomes increasingly relevant in promoting sustainable and resilient cities (Krasny & Tidball, 2012).

In the Global South, the character and usage of liminal spaces are often affected by built and land use dynamics and socio-economic conditions of the liminal space and its surrounding area. (Franck, K.A., & Stevens,Q. ,2007) (Lehtovuori, P.,2010). Moreover, due to a lack of proper ownership, these spaces tend to lack territoriality (Thompson, C.W.,2002).

Also, liminal spaces have a symbiotic relationship with the environment, the way a liminal space is utilized has a direct impact on the ecosystem. Since urban liminal spaces are products of urbanization and development, these spaces and their connotations should be evaluated quantitatively to shed light on their importance. In this context, this research has utilized ecosystem services as a means to measure the impact of ecosystem services. Ecosystem services is an emerging concept in the field of environmental economics, that aids in the valuation of different services provided by the ecosystem and integrates various management strategies to address the challenges related to water security, climate change, human well-being along with quality of life. According to the Millennium Ecosystem Assessment Report 2005, there are four types of ecosystem, namely, provisioning, regulating, cultural, and supporting. While the concept of liminality is often overlooked due to its qualitative nature, the concept of ecosystem services which provides valuable insights about the ecosystems' worth is rarely studied spatially.

In this setting, the research puts forth to analyse the effects of land use dynamics on the ecosystem services offered by the liminal spaces(L.S.), the role of psychosocial, socioeconomic, and cultural factors, in understanding ULS and the Willingness of people To Pay (WTP) for protecting/preserving the ecosystem services offered by the L.S. The Adyar River flowing in Chennai, Tamil Nadu, India is an urban liminal space satisfying both spatial and temporal liminality and is chosen as the case study area. The river’s fabric has a

diverse fabric of socio-economic conditions, land use patterns, and ownership; a result of rapid urbanization, pollution, and encroachment.

Much of the river and its surrounding floodplains have become liminal spaces—underutilized, degraded, and subject to fluctuating, often informal land use. These areas, which are neither fully integrated into the urban fabric nor entirely preserved as natural ecosystems, highlight the complex interaction between urban development, environmental sustainability, and socio-economic factors. This research will offer insights into how urban planning can address the challenges faced by liminal spaces in rapidly urbanizing cities like Chennai.

2. Site and Methodology

2.1. Site

Adyar river is one of the three rivers which flows across Chennai. Originating from Chembarambakkam lake, the river runs a total distance of 42.5 Km from the west to east of Chennai, draining into the Bay of Bengal at Adyar Estuary. The Adyar river has a catchment area of 530 Sq. Km and has depth varying from 0.75 m and 0.5 Km in its upper and lower reaches respectively. The river and its banks have undergone and is undergoing many changes due to various factors like abutting land use, urbanisation, industrialization. The River, which was once a major transportation mode during the British and post-independence times, started facing its downfall upon the advent of industries along the banks, this was further aggravated by the rapid urbanisation – leading to an increase in the number of slums along the banks. This rapid industrialization and contamination led to severe contamination of Adyar, rendering it a dead river. There have been/ are several initiatives to clean up the river, some of which are under process.

The River has been in a state of liminality in both spatial and temporal dimensions. It is also evident and widely accepted by environmental economists that rivers and its banks are major providers of ecosystem services. Based on this, the sizable part of Adyar, 9.68 Km from the mouth of the river till Jafferkhanpet has been chosen as a case study. This part of the river has been a part of Chennai from the times of British rule, making it a major component of temporal liminality of Chennai City.

2.2. Methodology

A mixed-method methodology has been employed in the study. The spatial aspects have been studied with relation to land use, a detailed Survey number based on existing land use (observations through primary survey) for a 200 m buffer of the identified 9.68 Km stretch of the Adyar River. The various ecosystem services available in this stretch are mapped through primary surveys, photo documentation and secondary data from government websites. This has been compared with the existing land use and the Government Land Value of the abutting residential land. With this, the relationship between the land use and land value and the ability of the adjoining stretch of Adyar river bank to provide ecosystem services is analyzed.

For the evaluation of Willingness to pay the people- Contingent valuation, a mixed method survey (online and in-person surveys) has been utilized. By using Tableau and Microsoft Excel, quantitative analysis of the interview transcripts - Descriptive statistics and Correlation analysis - have been carried out. Average WTP was carried for the data collected during the primary survey. ChatGPT was utilized to generate an APA-style reference list.

3. Analysis and Findings

3.1. Ecosystem Services

Ecosystem Services are the direct and indirect benefits a person obtains from the ecosystem. According to Costanza, R., d'Arge, R., de Groot, R. et al (1997), ecosystem services could be referred to as ecosystem goods (such as food) and services (such as carbon cycle, waste assimilation) put together. While Costanza, R., d'Arge, R., de Groot, R. et al (1997) had identified 17 ecosystem services: Gas Regulation, Climate Regulation, Disturbance Regulation, Water Regulation, Water Supply, Erosion control and sediment retention, Soil Formation, Nutrient Cycling, Waste treatment, Pollination, Biological Control , Refugia, Food production, Raw materials, Genetic resources, Recreation and Cultural based on different biomes available on Earth. Further, in 2005, the Millennium Ecosystem Assessment framework identified 4 broad categories for identifying and analyzing ecosystem services available, they are:

Provisioning services - These are the products and goods which are taken from the ecosystem to fulfill our needs,, i.e., provisioned by the ecosystem. Some examples of provisional services are food, wood, water, fuel.

Regulating services - These are the benefits obtained from the moderation or regulation of ecosystems. Some examples of regulating services are carbon sequestration, pollination, climate regulation, flood prevention

Supporting Services - These are services which are essential for the functioning of all other services. These services support the functioning of other ecosystem services. Some examples of soil formation, nutrient cycling, habitat provision

Cultural Services - These are the non material services and benefits that are meant for satisfying cultural, aesthetic, educational, spiritual and psychological needs. Examples of cultural services include tourism, audio visual tours, bird watching.

3.1.2. Ecosystem Services offered by the banks of Adyar River

As per the literature reviewed, the banks of the river provide the following ecosystem services:

Provisioning services: Food, fresh water, fibre & fuel, genetic material, biodiversity, etc.

Regulating services: Climate Regulation, Hydrological flows, pollution control & detoxification, habitat, natural hazards, etc.

Cultural: Spiritual & inspirational, Recreational, aesthetic, educational, etc.

Supporting: Carbon sequestration, nutrient cycling, etc.

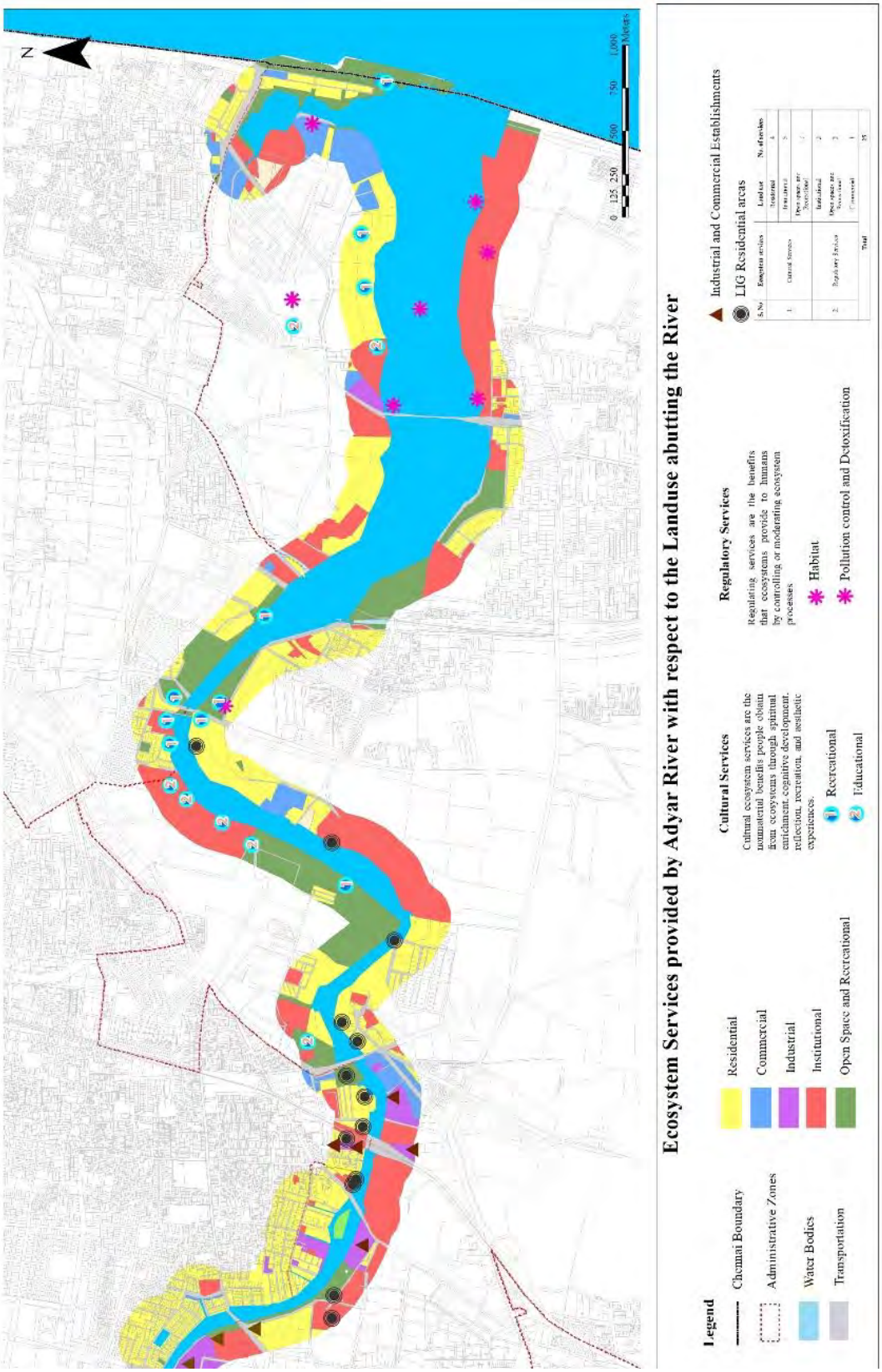


Figure 1 Ecosystem Services provided by the banks of Adyar River (Source: Author)

The availability of Ecosystem services has been surveyed in the case study area. The primary survey observed that the case study area provided Cultural services (17 Nos.) and Regulating services (8 Nos). The cultural services identified fall under recreational and educational categories, while the Regulatory services fall under habitat and Pollution control & Detoxification categories.

To further understand these services and their availability, the location of these services was mapped with the corresponding land use of the Adyar river bank. Based on this mapping it was observed that 41% of the cultural services was found in the open spaces and recreation land use, 29.5 % of the cultural services was found in the institutional land use and the remaining 29.5 % of the cultural services was found in residential land use. From the primary survey, it was evident that the parts of the river bank falling under industrial and commercial land use did not provide for any cultural ecosystem services.

The regulatory ecosystem services were majorly found in institutional land use (50%), followed by open spaces and recreational land use (33%) and the rest (17%) are available in commercial land use. Cumulatively, 36% of the ecosystem services are located in open spaces and recreational land use, 32% of the ecosystem services are located in Institutional land use, 16% of the services are available in residential land use and 4% of the ecosystem services are available in commercial land use. It is observed that industrial land use areas do not contribute to any of the ecosystem services in the study area.

3.1.3. Socio-Economic Conditions – Ecosystem Services

Government land value (GLV) has been taken as an indicator for socioeconomic conditions. It is widely accepted by economists that higher land values correlate to wealthier neighbourhoods (Harvey,D., 1973), which implies, the higher the GLV, the better the socio economic conditions. The location of ecosystem services were correlated to the land value of adjacent residential areas. It was observed that predominant of the Ecosystem services were located in the high value neighbourhoods - 12 numbers in INR 25k to 36k per Sq. Ft and (48% of the services), followed by 10 numbers in INR 10k to 15k per Sq.Ft neighbourhoods (40 %). The detailed split up is given in the following table.

Table 1 Location of E.S. and abutting Land Value (Compiled by Author)

Land Value in abutting Residential areas	No. of services
Less than 5000	1
5001 - 10000	2
10001- 15000	10
15001- 20000	0
20001- 25000	0
25001- 36000	12
Total	**25**

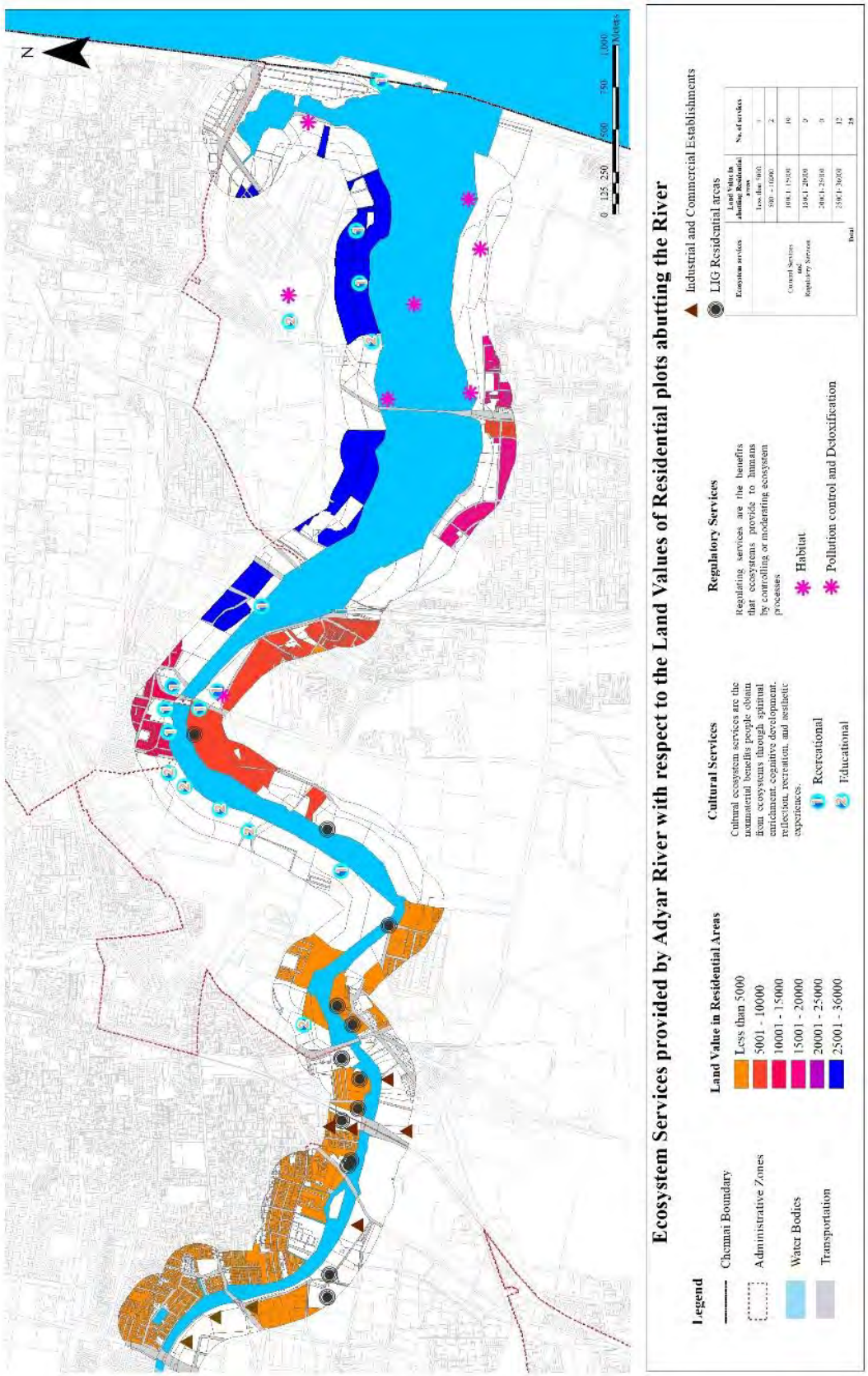


Figure 2 Location of E.S. with respect to Land Value (Source: Author)

To further support the role of socio-economic conditions on the location of ecosystem services, a people perception survey was carried out. The results of which are summarised in the section below.

3.2. Ecosystem Services and income level

In the people perception survey, various domains like the importance of ecosystem services, the importance of Adyar River in maintaining religious and cultural identity, cultural impact of Ecosystem services on liminal spaces and annual willingness to pay for ecosystem services among different income groups were analysed.

3.2.1. Importance of ecosystem services

Based on literatures and government plans, 6 types of ecosystem services were shortlisted to study their importance among the general public. The chosen services were Water Quality Improvement, Biodiversity Conservation, Recreational Services, Cultural and religious services, aesthetic value and flood resilience.

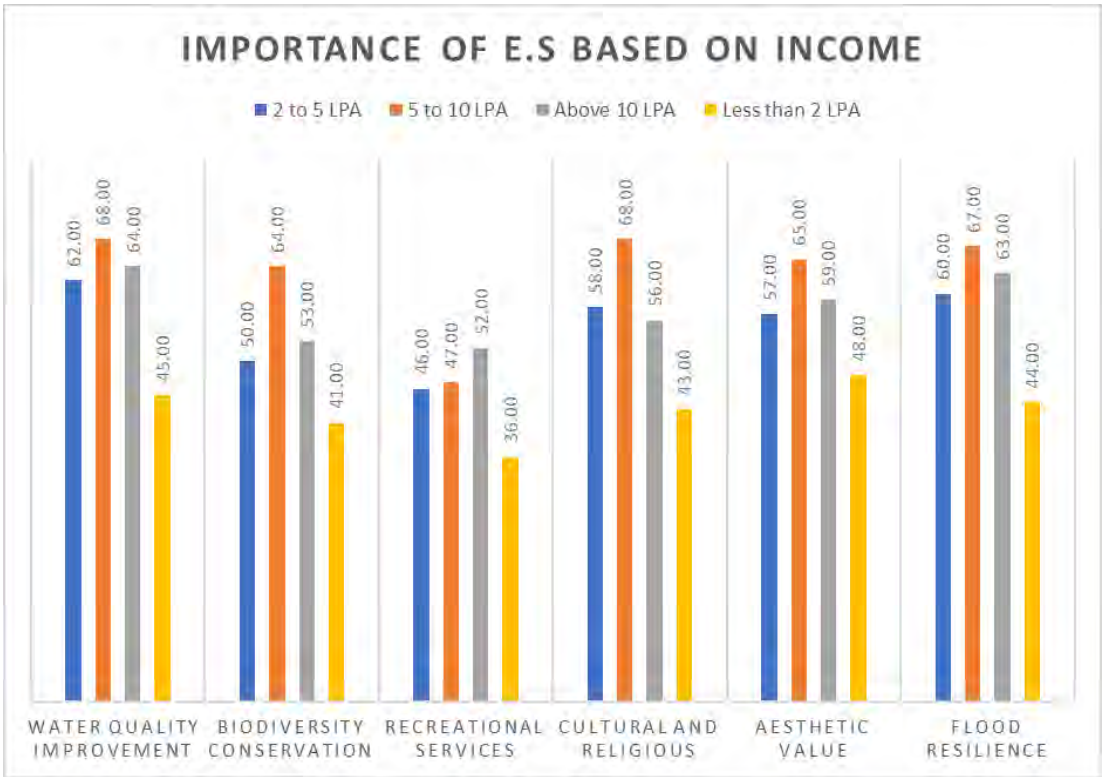


Figure 3 Importance of E.S. Based on income (Source: Author)

Water Quality Improvement: Individuals with higher incomes (5 to 10 LPA and above 10 LPA) rate this service the highest, with scores of 68 and 64, respectively. The 2 to 5 LPA group gives a moderately high importance (62), while the less than 2 LPA group assigns the lowest importance (45).

Biodiversity Conservation: Individuals with an income of 5 to 10 LPA (64) and above 10 LPA (59) groups give more importance to biodiversity conservation while people earning 2 to 5 LPA (50) rate it relatively important, and individuals earning less than 2 LPA group (41) give it least prefernce.

Recreational Services: Similar to other services, higher-income groups (above 10 LPA and 5 to 10 LPA) assign higher importance values (52 and 47, respectively). The 2 to 5 LPA group rates it moderately (46), whereas the less than 2 LPA group assigns the lowest score (36).

Cultural and Religious Services: This service is most valued by the above 10 LPA (68) and 5 to 10 LPA (58) groups. The 2 to 5 LPA and less than 2 LPA groups rate it lower at 56 and 43, respectively.

Aesthetic Value: High importance is noted across all income groups, with the 5 to 10 LPA group assigning the highest importance (65), followed closely by the 2 to 5 LPA group (57), above 10 LPA (59), and a lower score from the less than 2 LPA group (48).

Flood Resilience: The highest importance is seen in the 5 to 10 LPA group (67), with above 10 LPA and 2 to 5 LPA groups rating it slightly lower (63 and 60, respectively). The less than 2 LPA group assigns the lowest importance (44).

To summarize, the survey suggests that ecosystem services are valued more by individuals falling under the higher income bracket, while the lower income bracket gives less importance to ecosystem services in general, water quality improvement, and flood resilience in particular. This shows the varying levels of dependence and associateship with ecosystem services across various income levels.

3.2.2. Importance of Adyar river in maintaining religious and cultural identity

The data showcases a non-linear trend in perceived importance, with the importance showing an ascending trend from ascending trend from the lowest- and middle-income groups to the highest-income group (more than 10 LPA) rates the importance significantly higher. This suggests that higher-income individuals may have a greater attachment to the Adyar River.

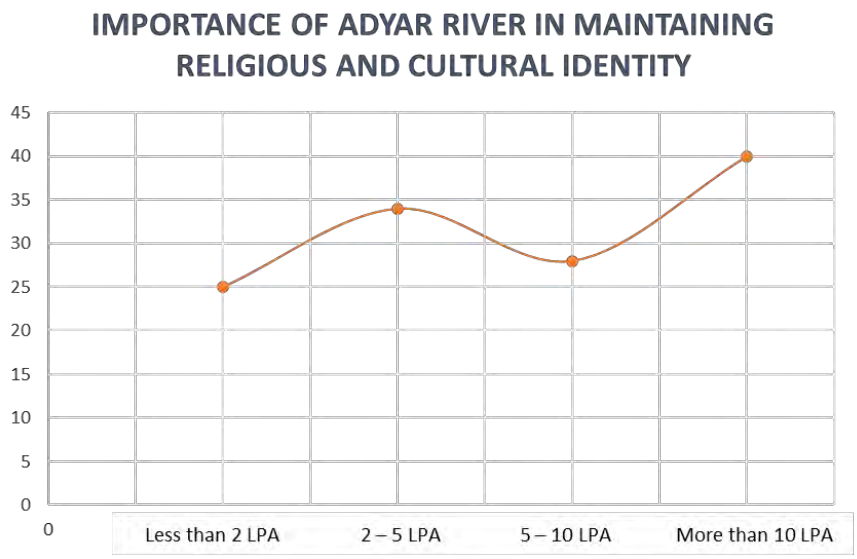


Figure 4 Importance of Adyar River in maintaining religious and cultural identity (Source: Author)

3.2.3. Cultural impact of ecosystem system services provided by liminal spaces

Community bonding is the most important factor associated with ecosystem services for individuals with 5 to 10 LPA and less than 2 LPA income groups. On the contrary, for individuals in the 2 to 5 LPA and above 10 LPA income brackets, environmental stewardship is the most important factor. This difference in preferences among various income groups is influenced by the emotional connections that liminal spaces foster, attributing to the respondents' different socioeconomic backgrounds and environmental perspectives.

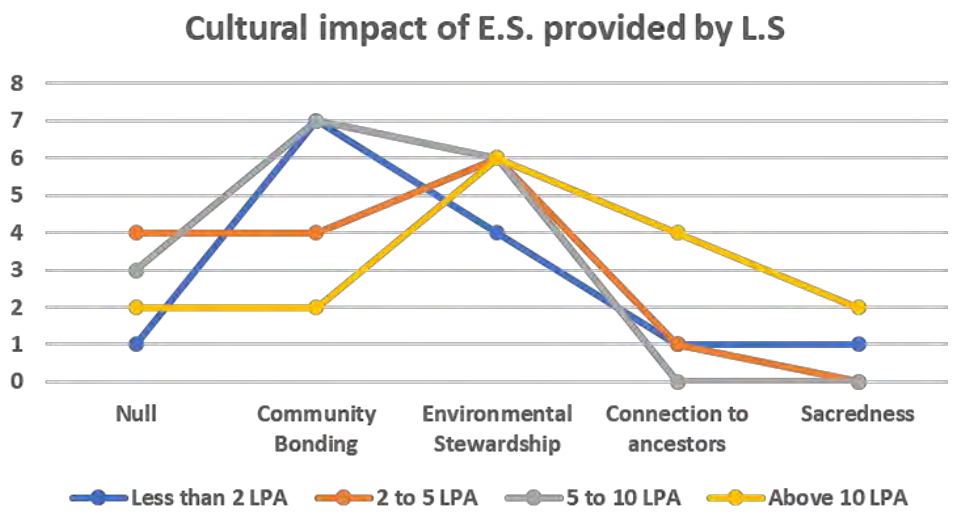


Figure 5 Cultural Impact of E.S. provided by L.S.

3.2.4. Annual Willingness to pay for ecosystem services

Concerning willingness to pay (WTP) for the improvement of ecosystem services provided by liminal spaces, individuals in the higher income bracket, i.e., above 10 LPA, exhibited a higher WTP compared to other income groups, which could be attributed to their favorable economic conditions.

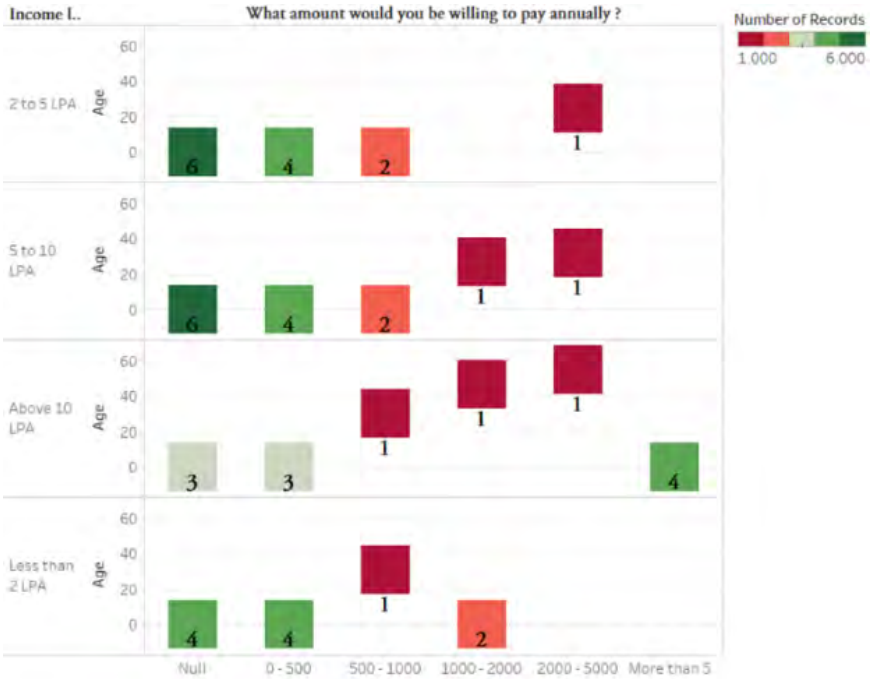


Figure 6 Annual W.T.P.

In particular, the survey results show that 72% of the total sample population has shown a willingness to contribute financially to the betterment of ecosystem services. This finding shows a growing acceptance of the importance of ecosystem services across income groups, though with variations in the WTP based on their economic capacity.

3.2.5. Willingness to pay - Choice experiment

A sample size of 51 was chosen for the choice experiment. The people were presented with 3 scenarios and their positive responses were noted down. The three scenarios provided were:

Improved water quality and biodiversity at INR 1000 per household

Enhanced Recreational and cultural facilities at INR 500 per household

Riverfront Development with Cultural Preservation at INR 2000 per household

The responses obtained are given in the table below:

Table 2 Results of Choice Experiment (Compiled by Author)

S. No	Scenario	Number of Positive Responses	Total Amount
1.	Improved water quality and biodiversity – INR 1000 Per household	37	37,000
2.	Enhanced Recreational and Cultural Facilities – INR 500 per household	38	19,000
3.	Riverfront Development with Cultural Preservation – INR 2000 per household	31	62,000
Total			INR 1,18,000 (or) $ 1413

From the choice experiment conducted with a sample size of 51 participants, it was found that 72% of the survey respondents were willing to pay for the ecosystem services offered by the liminal spaces. A cumulative amount of $1413 was found as the WTP from the willing respondents. This reflects a sizeable amount of support for investing in the improvement of ecosystem services in the liminal spaces, showcasing the importance and acceptance of these ecosystem services among the sampled population.

4. Findings and Recommendations

The mapping of the location of Ecosystem system services with its land use reveals that the cultural ecosystem services are available in open spaces and recreational areas land use, institutional land use, and residential land use; while regulatory ecosystem services are present in the open spaces and recreational areas land use, institutional land use and commercial land use. Statistically speaking, 36% of the ecosystem services are found in open spaces and recreational land use, 32% in institutional areas, 16% in residential zones, and 4% in commercial land use areas. Individuals in the higher income bracket not only perceive the river with increased cultural and religious importance due to their close ties to heritage and natural resources but also demonstrate a strong emphasis on ecosystem services. The socioeconomic conditions of the respondents shaped the differing environmental perspectives, with environmental stewardship given priority among the individuals in the INR 2 to 5 LPA category and above INR 10 LPA category; while community bonding was prioritized by the individuals in the INR 5 to 10 LPA and less than INR 2 LPA brackets. From the choice experiment, it was observed that from a sample size of 51, 72% of the people are willing to pay a total of 1413 USD for the ecosystem services offered by the liminal space, i.e., Adyar River in our scenario. If this experiment is done covering a larger population, we could calculate the willingness to pay (WTP) for the Adyar River Bank which is directly proportional to the importance of the liminal space.

5. Conclusion

Liminal spaces are usually studied based on their qualitative nature, but in this research by considering Ecosystem Services as a means of Quantifying liminal spaces, a value could be assigned to them to prove their importance. Though much research has been done based on Ecosystem services, the spatial and social characteristics of places providing ES have not been explored. This paper addresses this issue, a paradigm shift in how ecosystem services are studied. This method could be replicated for other spatial liminal spaces (e.g., peri-urban spaces, edges of urban forests, historical monuments/spots) and determine their economic value, aiding in their protection and conservation.

6. References

Costanza, R., d'Arge, R., de Groot, R. et al. (1997) 'The value of the world's ecosystem services and natural capital', *Nature*, 387, pp. 253–260. doi:10.1038/387253a0.

Fourny, M.C. (2013) 'The border as liminal space', *Journal of Alpine Research | Revue de géographie alpine*, 101(2). doi:10.4000/rga.2120.

Franck, K.A. and Stevens, Q. (2007) *Loose Space: Possibility and Diversity in Urban Life*. Routledge.

Frolking, S., Mahtta, R., Milliman, T. et al. (2024) 'Global urban structural growth shows a profound shift from spreading out to building up', *Nature Cities*, 1, pp. 555–566. doi:10.1038/s44284-024-00100-1.

Harvey, D. (1973) *Social Justice and the City*. Johns Hopkins University Press.

Jorgensen, A. and Tylecote, M. (2007) 'Ambivalent landscapes—wilderness in the urban interstices', *Landscape Research*, 32(4), pp. 443-462.

Krasny, M.E. and Tidball, K.G. (2012) 'Civic ecology: A pathway for Earth Stewardship in cities', *Frontiers in Ecology and the Environment*, 10(5), pp. 267-273.

Lehtovuori, P. (2010) *Experience and Conflict: The Production of Urban Space*. Routledge.

Millennium Ecosystem Assessment (2005) *Ecosystems and human well-being: Synthesis*. Island Press.

OpenAI (2023) *ChatGPT (v2.0) [Large language model]*. Retrieved 31 September 2024, from https://www.openai.com/.

Qi, Z., Mao, G.L. and Wu, J. (2015) 'Urban ecosystem services: A review', *Journal of Applied Ecology*, 26(4), pp. 1023-1033.

Thompson, C.W. (2002) 'Urban open space in the 21st century', *Landscape and Urban Planning*, 60(2), pp. 59-72.

Turner, V. (1969) *The Ritual Process: Structure and Anti-Structure*. Aldine Publishing.

United Nations, Department of Economic and Social Affairs, Population Division (2019) *World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420)*. New York: United Nations.

Research Paper

Transforming Urban Landscapes: The Role of Commercial Centres in Shaping Collective Memory in Tier-II Cities

A Case Study from the Developing Country Context

Archiman BISWAS, Indian Institute of Technology Kharagpur, India
Subrata CHATTOPADHYAY, Indian Institute of Technology Kharagpur, India
Purbita SAMANTA, Indian Institute of Technology Kharagpur, India

Abstract

Commercial centres play a significant role in shaping the identity and image of cities. These centres enhance the visual appeal of urban environments and often become iconic landmarks through their architectural design and physical presence. They evoke specific emotions and leave lasting impressions on the minds of residents of a city. This experience contributes significantly to the collective memory of these residents. The studies from developed countries report a decline in small to medium-sized commercial centres. This has an impact on the urban landscapes and alter the street-level dynamics. However, negligible research has explored how traditional commercial hubs in Indian cities are evolving or how these shifts affect urban memories. The study investigates the transformation of commercial centres in Tier-II Indian cities and their implications for collective memory. The paper analyses the spatial data from 2014 to 2024 with Kernel Density Estimation in ArcGIS, alongside in-depth interviews with residents to analyse the changing dynamic of commercial centres. The results show that traditional retail clusters, like fashion stores, are declining while construction-related stores are increasing. The redesign of activities improves the sensory experiences of the people who live in these areas. These changes show the necessity of urban renewal plans that uphold cultural vitality of a city.

Keywords

Urban memories, Commercial centre, Sentiment analysis, Kernel density estimation, Developing country, Retail

1. Introduction

Urban areas are complex systems with interconnected activities that shape cities both functionally and aesthetically (Araldi, 2019). Commerce, especially retail, is a vital activity that defines the economic and social fabric of cities (Öner, 2017). Retail drives the local economy as well as influences how people perceive and interact with urban environments (Biswas *et al.*, 2024). The location, design, and development of retail spaces significantly contribute to the city's image (Araldi, 2019). Urban research has focused on the growth of retail centers, with numerous studies examining the effects of retail expansion on social interactions and the urban economy (UN, 1992; Choguill, 2008). Through their physical presence and architectural style, commercial centers significantly contribute to the formation of cities' identities (Narayanan, 2015). A well-

designed commercial center can change a neighborhood into a lively place. It can bring out certain feelings, create unique atmospheres, and encourage social interactions (Dhingra and Chattopadhyay, 2016; Lara *et al.*, 2016; Dhingra, Singh and Chattopadhyay, 2017; Sen *et al.*, 2017; Axelsson and Granath, 2018; Balducci and Ferrara, 2018). The city as a whole is greatly impacted by the way retail spaces are evolving. Busy shopping streets, filled with sights, sounds, and smells, create shared memories for the people who live there. Over time, these experiences help shape the city's culture and way of life (Qureshi *et al.*, no date; Perry, 1929; UN, 1992; Choguill, 2008; Larsen, 2008; Rohe, 2009; Johnson, 2010; Aulia, Marpaung and Zahrah, 2017). Therefore, the evolution, adaptation, or decline of retail spaces directly impacts how the city is perceived by both residents and outsiders (Larsen, 2008).

While many studies have tried to understand how retail commercial centers are changing as a result of the rise of e-commerce, relatively few have tried to understand how the transformation of retail spaces affects urban image and collective memory (Biswas *et al.*, 2024). Collective memory is heavily influenced by urban spaces (Lakhani, 2021). Commercial centres have a major influence on collective memory because of their importance in day-to-day life (Dillard, Dujon and King, 2008; Rydin, 2013; Vaughan, 2018). The architecture, layout, and sensory experiences associated with these centres leave lasting impressions on the individuals and communities (Johnson, 2010; Roger Tym & Partners, 2010; AlWaer, Sibley and Lewis, 2011; Rydin, 2019). With the growth of organized retail and e-commerce, it is significant to comprehend how these changes impact urban memories (Wells and Watson, 2006). **T**he Indian context presents a special case study. The shop density in India is about 11 stores per 1,000 people. It is significantly higher than in many developed countries like the United States, which has around 4 shops per 1,000 people (Sridhar and Monkkonen, 2024). Street vendors and independent small businesses make up the majority of the high retail outlet density of Indian cities (Biswas and Chattopadhyay, 2024). However, traditional retailers are facing constant challenges after the rise of large shopping malls and retail chains (Biswas *et al.*, 2024).

In India, organized retail and e-commerce are expanding quickly. India's online retail channel is projected to grow at a compound annual growth rate (CAGR) of 26 percent between FY 2020 and FY 2025, compared to a 20 percent CAGR for the organized brick-and-mortar retail channel (IBEF, 2021; Deloitte, 2023). Furthermore, India's e-commerce sector is anticipated to reach USD 53.08 billion in 2024, with an annual growth rate of 11.45 percent, and is projected to reach USD 91.24 billion by 2029 (Deloitte, 2023). The increase in digital payment platforms, such as the Unified Payments Interface (UPI), has facilitated this growth, with UPI transactions amounting to USD 1.51 trillion in 2022, supported by a user base exceeding 800 million. The spatial arrangement of retail outlets is changing drastically due to the changing retail landscape in Indian cities. Modern shopping malls, hypermarkets, and online retail platforms are replacing traditional marketplaces and shopping streets. This change is altering not just how people shop but also how cities are physically laid out.

Several reports have indicated in recent years, that organized retail and e-commerce are experiencing significant growth. This expansion is modifying urban dwellers' interaction with their cities and their memories of these spaces. It is important to investigate how these changes have affected India's urban populations' collective memory considering the magnitude of changes. Communal experiences in public places create collective memories. The physical landscape is inextricably linked to it. With the transformation of retail spaces transforms, the sensory experiences and social dynamics that individuals associate with these locales also changes. The busy visuals of marketplaces, presence of street vendors, and the smells of street foods are progressively being replaced by the clean, structured modern malls and the impersonal convenience of internet shopping. These changes may impact the memories and ties of the locals to their cities. The change may cause residents to feel nostalgic or a sense of loss for the traditional areas. Hence, this research aims to:

i. Explore the evolving nature of retail in the Indian context.

ii. Examine how changes in the spatial distribution of retail spaces are influencing the collective memories of customers.

2. Materials and Method

2.1 Study area

Several reports highlighted that the tier II Indian cities are acting as the major driver of the next wave of the retail growth in the Indian context. As negligible studies attempted to understand the change in the spatial distribution of retail and its impact on the collective urban memories in tier II Indian cities, in this study Benachity Market, Durgapur is selected as the study area. Durgapur is a planned, tier II Industrial city in India. Benachity Market, Durgapur, West Bengal, India, is a traditional retail street stretching approximately 2.5 kilometres along Ananda Gopal Mukherjee Sarani Road. This commercial centre spans from the Bhiringi More Bus Stand in the south to the Prantika Bus Stand in the north. NH19 is located at the south of this commercial centre. Figure 1 shows the location of the study area.

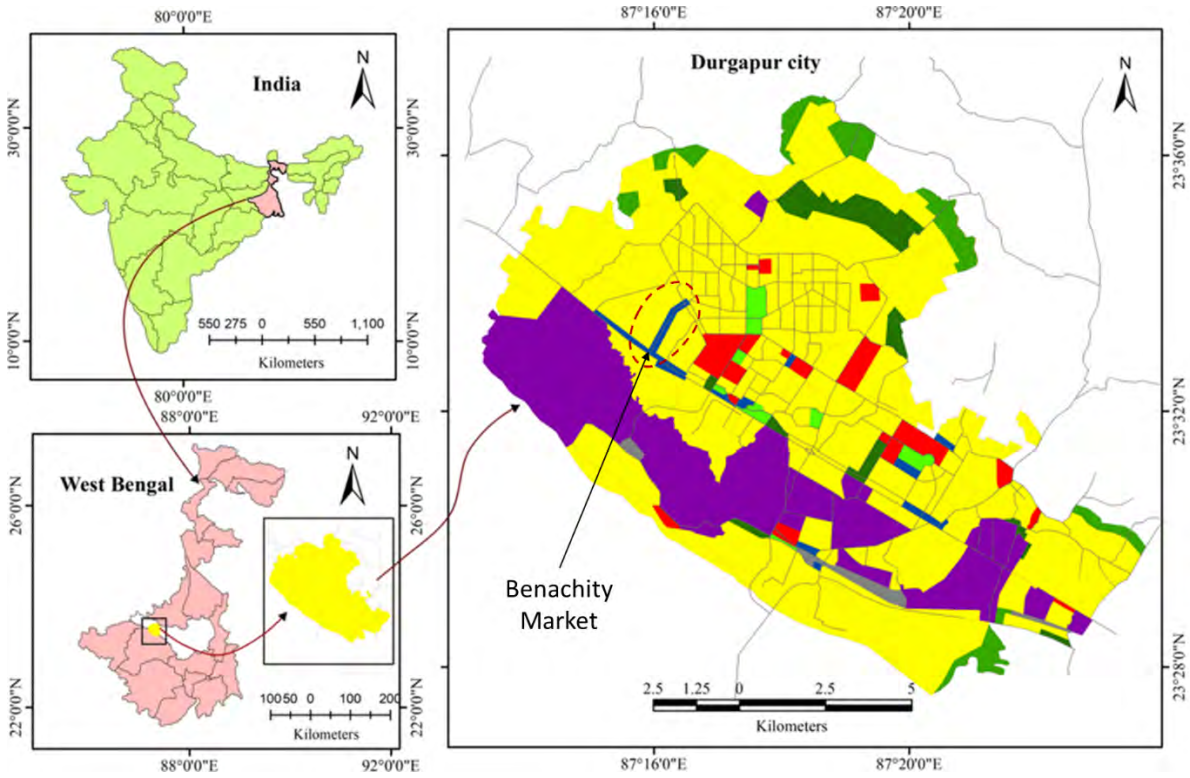


Figure 1 Location of the study area: Benachity Market, Durgapur. Source: Authors

2.2 Data Collection

The data was collected at two stages. First, a primary survey was conducted with the shopkeepers to document the spatial distribution of retail outlets within the Benachity market. This involved documentation of the approximate area of each shop, its year of establishment, any changes in business type over the past ten years, and previous uses (if applicable). This data was essential for understanding

the spatial evolution of the market. This survey of the shopkeepers provided insights into the challenges and opportunities faced by the retail sector in the study area. In the next stage, in-depth interviews were conducted with frequent customers of the Benachity market to explore the subjective dimension of urban memory. These interviews aimed to understand how the market has shaped their memories and perceptions of the city. This interview helped us to understand the emotional and cultural factors associated with the market. The data collection and data analysis methodology are summarised in Figure 2.

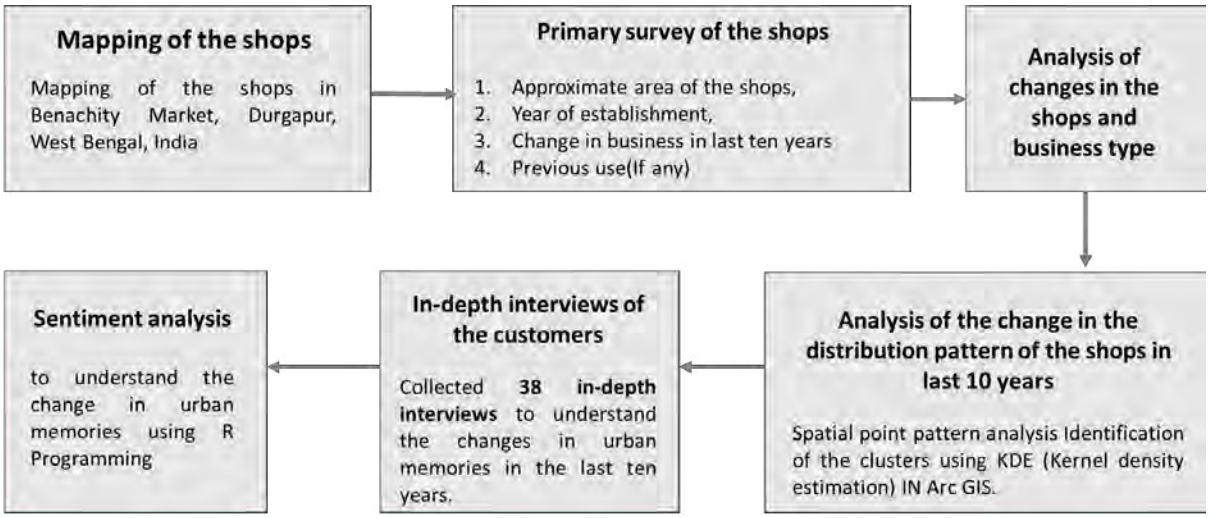


Figure 2 Data collection and data analysis methodology

For mapping the shops, they were classified into four major categories based on the classification provided by a previous study in the Indian context (Biswas and Chattopadhyay, 2024) and the classification given by the National Sample Survey Office (NSSO). The shop classifications are explained in the table below.

Table 1 Classification of shops based on the chassification given by National Sample Survey Office (NSSO)

Classification for this study	Commodity type
Group 1	Cereals, pulses, milk, sugar and salt
	Edible oil, egg, fish, meat, vegetables, fruits, spices, beverages, processed food, pan, tobacco and intoxicants
	Fuel, light and household appliances
Group 2	Clothing and bedding
	Footwear
Group 3	Education and medical (institutional) goods and services
	Miscellaneous goods (toiletries, flowers, mosquito repellent, electrical, sanitary napkin)
Group 4	Services and construction (including repair and maintenance of durable goods for domestic use)

3. Data Analysis

This study employs a mixed-method approach, integrating both quantitative and qualitative methods to explore the evolving role of retail centers in shaping urban landscapes and collective memory. The study combines sentiment analysis and Kernel Density Estimation (KDE) to capture the spatial and emotional changes in the urban retail landscape over the past decade. KDE quantitatively assesses changes in the spatial distribution of retail outlets to give a clear picture of clustering patterns and density shifts. Complementing this, sentiment analysis delves into the qualitative aspect, examining how these spatial transformations affect residents' collective memory and emotional connections to urban spaces. Together, these methods provide a comprehensive understanding of the impact of retail evolution on social dynamics and urban identity.

3.1 Kernel density estimation: to understand the change in the spatial distribution of the retail outlets

Kernel Density Estimation (KDE) is used to analyse changes in the spatial distribution of retail establishments over the past decade that focused on four specific types of retail shops. Shop owners were surveyed as part of the methodology. The spatial distribution of shops was extracted using GIS-based spatial analysis. This approach allowed us to study the distribution and clustering of retail shops over time. We geocoded each shop location in GIS to create a spatial dataset. This dataset included four types of shops that we examined. We used Kernel Density Estimation (KDE) to determine the density of retail locations. KDE helped us visualize the clustering patterns in the study area. To use KDE, we adjusted the bandwidth parameter. This adjustment set the spatial window for density calculations. We used a Gaussian kernel function, which offered a smooth, symmetric distribution around each data point. The density values were estimated as an average within the selected bandwidth. We extended traditional two-dimensional KDE to Network-based Kernel Density Estimation (NKDE). This method looks at the layout of streets and pathways instead of just measuring simple distances. It works well in urban retail areas. The NKDE method uses the shortest path distance to show how close things are within the network. We carried out KDE analysis in 2014 and 2024. This approach helped us compare the temporal changes in clustering patterns. We observed the density changes by layering the KDE results of two decades. We found that existing clusters were either declining or intensifying, while new clusters were emerging. This process highlighted shifts in how retail activities are distributed in the area.

3.2 Sentiment Analysis to understand the change in collective memories of the individuals

After performing KDE, sentiment analysis was conducted to explore how the changing spatial distribution of retail influences collective urban memories. Sentiment is a persistent emotional response that shapes how individuals perceive and interact with particular subjects or environments (Samanta and Chattopadhyay, 2024). Sentiment analysis offers a window into understanding social, emotional, and linguistic indicators, providing insight into individuals' or groups' perceptions of evolving urban landscapes. Sentiment analysis is frequently employed by consumer product companies to gain insights into how consumers perceive their products. In this case, it also reveals how people's relationships with these spaces are changing and how spatial changes in retail clusters may affect urban collective memories. With transformations in urban retail spaces, collective memories—such as a sense of belonging, attachment to cultural landmarks, and urban identity—shift accordingly. Sentiment analysis captures these emotional responses, and sheds light on participants' experiences and attitudes toward spatial changes in retail distribution. In this study, 38 customers were interviewed to gauge these sentiments, to capture their

perceptions and feelings associated with urban space transformation. Interviews were transcribed, organized into a text corpus, and analysed using thematic content analysis. Through the R-studio software, we identified significant keywords via Term Frequency (TF), highlighting terms frequently used by participants. These keywords, once examined for contextual relevance, helped build a semantic network that illustrated participants' collective sentiments.

This analysis found significant differences in sentiment. It revealed layers of attachment and cultural continuity within ethnic communities. As retail patterns change, perceptions shift as well. Every latent sentiment represented a range of feelings, including resistance, grief, nostalgia, and happiness. This highlights how these changes resonate differently within the community. Sentiment analysis offered a detailed view of the emotional landscape linked to urban retail transformations. Figure 3 summarizes the data analysis methodology using sentiment analysis.

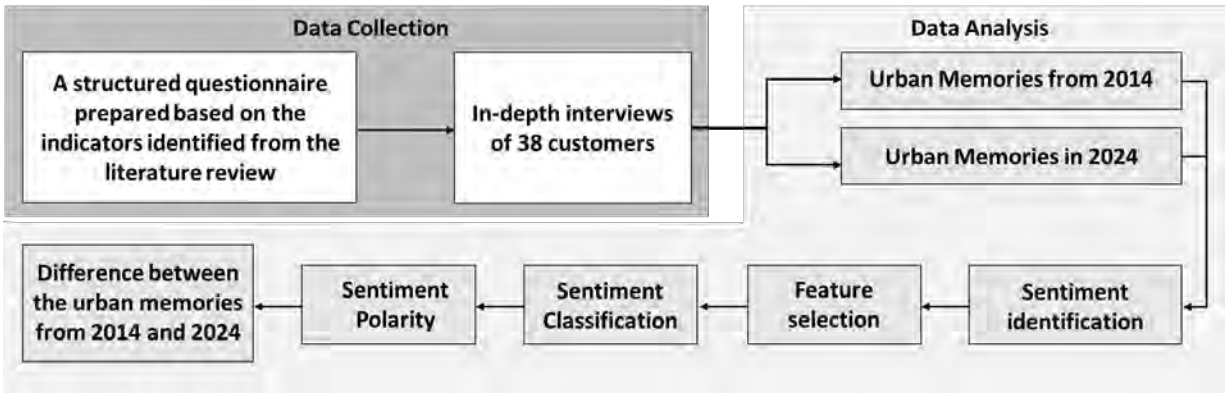


Figure 3 Data analysis methodology: Sentiment analysis

4. Results and discussion

The Kernel Density Estimation (KDE) results show a shift in retail shop locations over the past decade (Figure 4 and 5). This shift indicates changes in how different types of stores are distributed. The KDE maps reveal an overall increase in shops. This suggests significant growth in retail activity. However, clustering trends differ by shop type. Shops in Group 2, such as apparel and shoe stores, exhibit a significant decrease in clustering. This suggests that traditional retailers encounter difficulties in these categories. These changes are probably influenced by the growth of e-commerce. Due to this change, some entrepreneurs have shifted their focus to Group 4 businesses (e.g., service shops like salons, eateries, beauty parlors, and construction materials shops). In these businesses, a noticeable rise in clustering has been noted. Unlike Group 2, which has seen a decline in clustering, the expansion of Group 4 may reflect a broader trend toward service-oriented businesses that offer in-person experiences and are less affected by online competition. In contrast, the number and distribution of Group 1 shops (convenience stores) and Group 3 shops (bookstores, stationery, and medicine shops) have remained relatively stable over the decade. These retail types appear to face less competition from e-commerce, maintaining steady clustering patterns as they continue to serve essential and frequently needed goods.

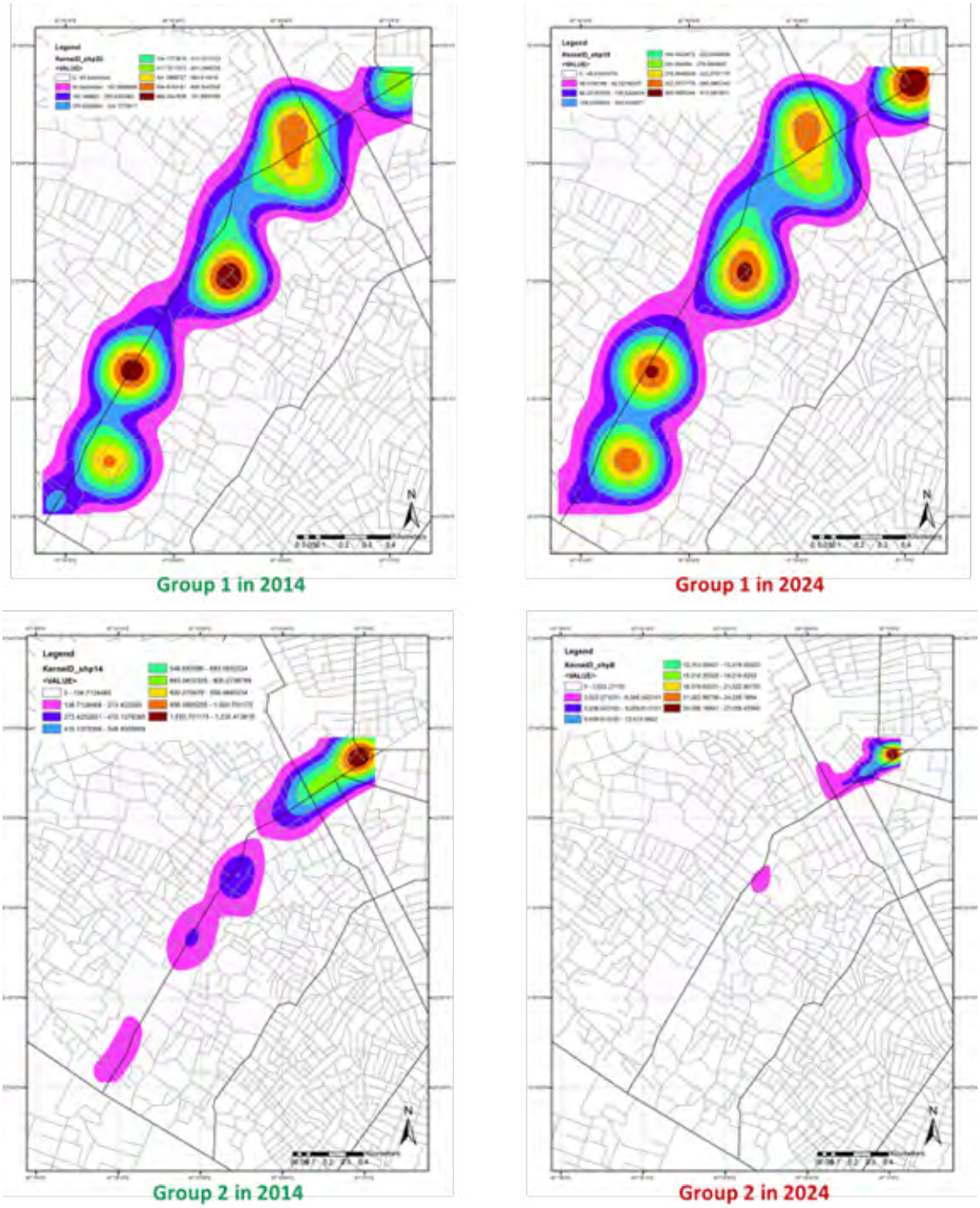


Figure 4 Result of KDE: Change in cluster pattern of the shops from 2014 to 2024 for Group 1 and 2. Source: Authors

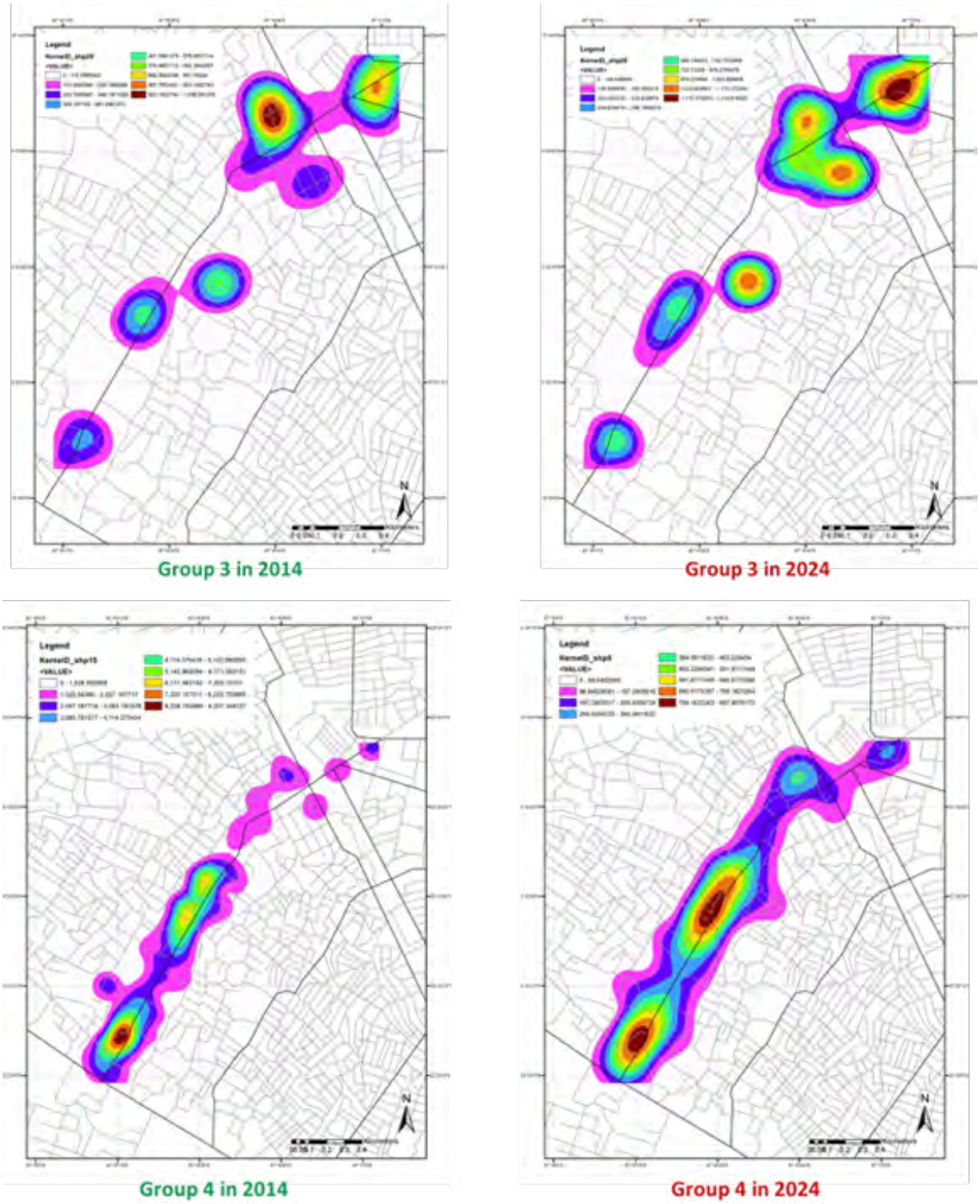


Figure 5 Result of KDE: Change in cluster pattern of the shops from 2014 to 2024 for Group 3 and 4. Source: Authors

4.1 Narratives of the customers

The analysis of Benachiti Market's spatial and sentimental transformations from 2014 to 2024 reveals a significant shift not only in retail distribution but also in the collective urban memory associated with this market. The sentiment analysis divided the interview statements into two main categories: urban memories from 2014 and urban memories from 2024 (Figure 7). KDE maps show noticeable changes in clustering patterns. Traditional retail stores like clothing shops, jewelry stores, and electronics shops have changed. They are moving away from the center of the market. Rather, the central area is now a concentration of service-oriented businesses like restaurants, repair shops, and suppliers of building materials. Interviews with 38 people show how these changes have impacted how individuals view the market's role, its atmosphere, and its cultural importance over the last ten years. Many long-time residents and regular visitors remember the market's unique vibe in 2014. They describe it as lively and friendly. It was an important part of their daily lives.

A 42-year-old man who participated in the survey shared his thoughts. He said, *"I've seen Benachiti Market evolve quite a bit over the years. The changes in the last decade have been particularly striking. There used to be many shops that sold clothes, jewelry, footwear, and electronics. There was a cobbler who sat at one of the corners. He repaired our shoes and chappals when we were young., now I do not see that old man sitting there."* A 52-year-old female customer expressed a similar view. She noted that the market was a *"lifeline."* She also added that *"we had a family tailor. He used to make all our shirts, frocks and blouses. But he has long gone. He always gave us candies whenever we visited him."* The familiarity and trust with the vendors made shopping a cherished experience. Many participants spoke of the lively bargaining, social interactions, and strong sense of community. A 63 year old resident said, *"I used to look forward to the evenings after coming home from my office. We had a big group. All of us used to meet at a tea-shop in the market. We would talk about politics, cinemas, share markets and what not. Then while returning, I would buy some groceries for my home. Now-a-days we do not meet each other anymore. The connections are also losing…"* Because of this setting, the market became more than just a place for commerce.

However, the sentiment analysis revealed a nostalgia for these earlier experiences, particularly among older customers who felt that the essence of Benachiti Market had shifted. A 78-year-old mentioned that there used to be a lot of stores in the central portion of the market. These stores sold jewelry, electronics, and clothing. Now, this area has started to change. It is being replaced by service shops. A 45-year-old woman who was a customer also expressed her opinions about this change. She thinks it's a response to the economy's shifts. She said, *"Over the last few years, my shopping habits have changed a lot. I am using online shopping platforms a lot. I buy several things online. These changes are obviously due to the rise of online shopping. Why would someone visit a shop if you can get it at your door-step by ordering it on your phone?"*

This change demonstrates how the retail industry is being impacted by e-commerce. Conventional retail establishments are shifting to the periphery of the market. They are being replaced by service-oriented shops that provide in-person experiences, which online platforms cannot replicate.

The clustering of service shops at the center has also altered the physical and sensory attributes of Benachiti Market. Changes in non-stationary elements, like ambient sounds and smells, as well as stationary elements, like signage and store layouts, were reported by the respondents. For example, an older customer (male, 63) commented on how *"the market's signage had evolved... There used to be handwritten and painted signs... All have been replaced by digitally-led panel-based signages."* The modernized signages give the market a more standardized and commercial feel. Additionally, the once-diverse smells of incense, fresh produce, and street food have evolved with the arrival of new eateries, cafeterias and services that creates a less varied but more food-focused sensory experience.

Changes in transportation patterns add to this sense of disconnection. Where once the market's paths were filled with people walking, cycling, or using cycle rickshaws, today's Benachiti is dominated by e-rickshaws, motorbikes, and cars, creating a more congested and less pedestrian-friendly environment. This shift in transportation not only affects accessibility but also impacts the pace and experience of moving through the market.

The erosion of social interactions and community gatherings, once central to Benachiti's atmosphere, marks another significant transformation. Many respondents remembered that multigenerational interactions thrived in informal settings like tea stalls and shady places to sit and chat. With the advent of modern complexes, these informal hubs have largely disappeared, leaving younger patrons to occupy spaces designed for convenience rather than community. Ultimately, Benachiti Market remains significant in Durgapur's urban landscape but has lost much of its original soul. Interviewees expressed concern that while modernization and service-oriented businesses have ensured Benachiti's economic continuity, the market's cultural and communal value has diminished.

This analysis also captured the emotional tone behind each set of memories and identify clusters of positive and negative keywords within the text. The findings revealed a notable shift in sentiment over the decade. In the memories from 2014, 80% of the keywords in the 2014 memories were positive that indicated a generally positive and sentimental view of the market at the time. However, the percentage of positive keywords dropped to 56.9% in the 2024 memories. This suggests that sentiments have shifted toward being more neutral or negative. In accordance to the responses by the interviewees, these findings highlight a gradual deterioration in the market's positive emotional connection and sense of community (Figure 6).

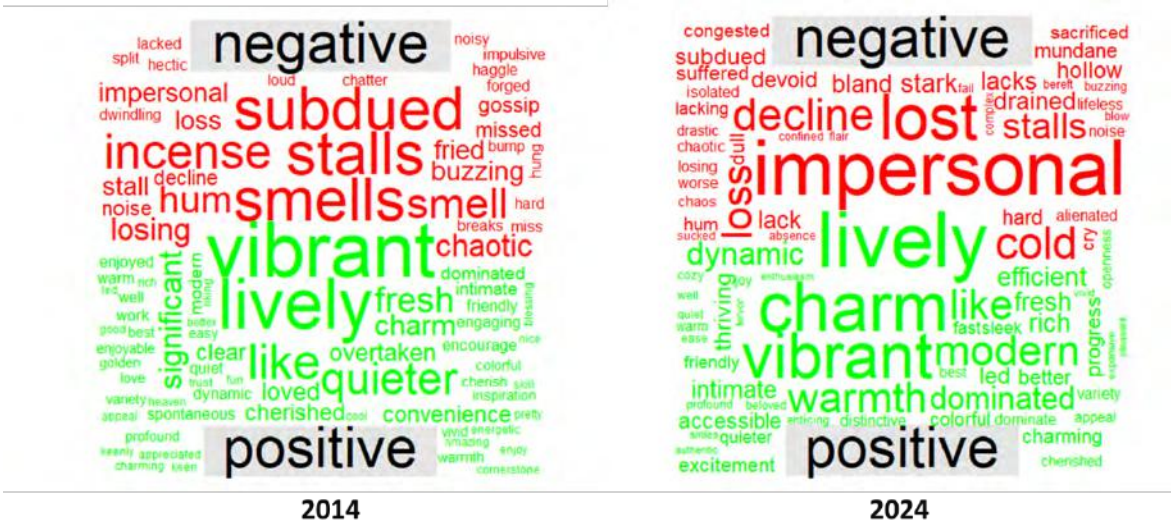
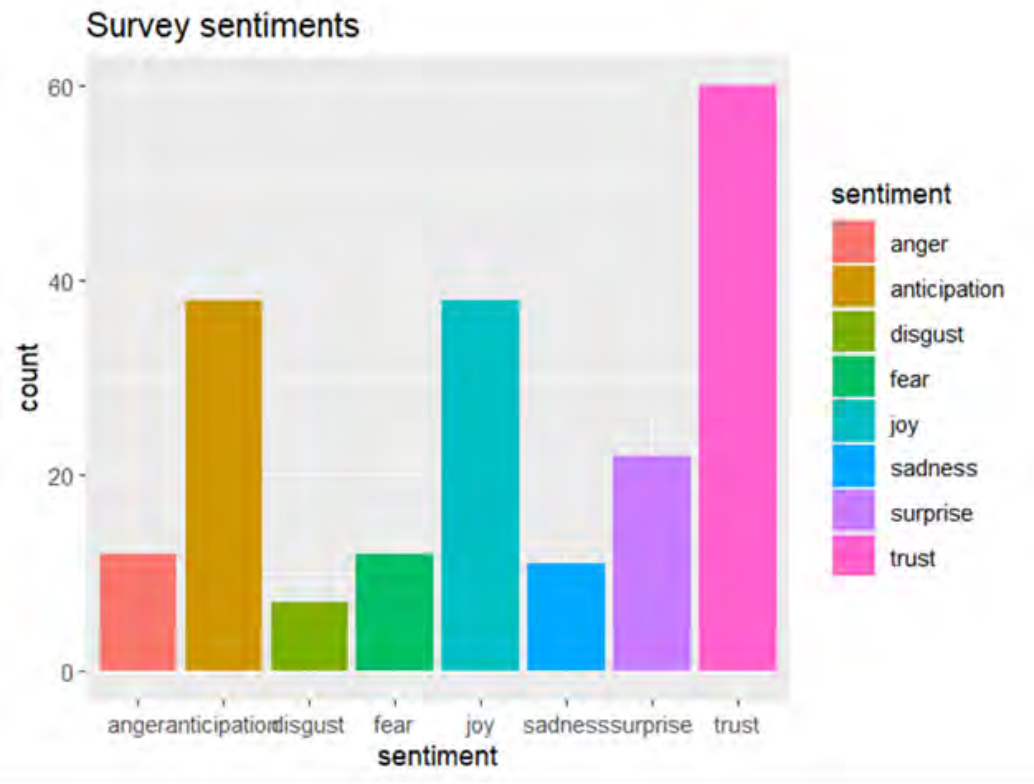
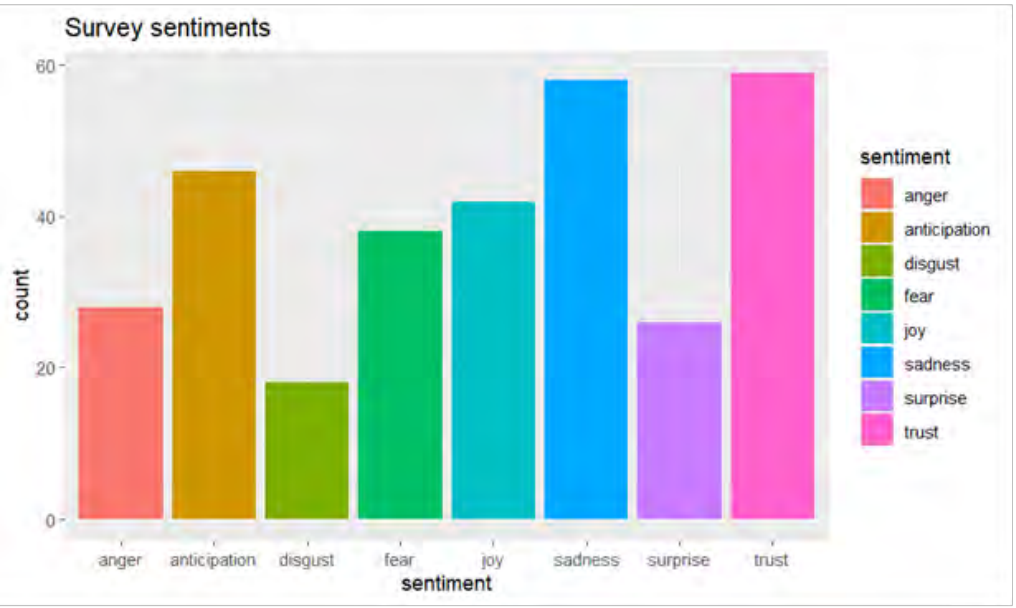


Figure 6 Term frequency to understand the temporal change of sentiments



2014



2024

Figure 7 Change in sentiment frequency from 2014 to 2024

Over the past ten years, Benachiti Market has changed a lot (Figure 9). This market used to be a lively place where the community came together. Now, it has become more commercialized and focused on services.

The changes in the market show a larger trend happening in cities around the world. As the market's character shifts, it affects how people experience, remember, and understand urban spaces. This reflects important changes in social interactions and the way cities are designed.

Figure 8 Shift in Urban Symbols transformation of the sign boards (top: 2014, bottom: 2024) Source: Authors

Figure 9 Benachity Market, 2024: showcasing its evolving mix of traditional shops alongside new commercial establishments. Source: Authors

To summarise, Benachiti Market has changed a lot over time. It used to be a lively place where the community came together. People interacted across generations, engaged in cultural activities, and gathered in commonplace locations. It now seems more like a place for transactions. Many of the recognizable interactions and symbols have vanished (Figure 8). Corporate enterprises and service-oriented stores have replaced them. This change disrupts communal bonds, urban memories, and local identity, although it aligns with globalized, commercial trends.

5. Conclusion

This study concludes by examining the effects of shifting retail landscapes on urban memories. The reduction of traditional retail (like clothing and electronics) and rise in service-based shops alter the social fabric that weakens residents' emotional connections to these areas. Indian urban markets exemplify how commercial shifts erode communal identity that disrupts the symbols which define market heritage, such as local branding and hand-painted murals. The loss of informal gathering spaces also diminishes community engagement and leaves a homogenized urban landscape. Ultimately, these changes in urban commerce dilute cultural identity and affects both social cohesion and collective memory.

To address these issues, it is essential to preserve the stationary elements that shape urban memories, such as traditional shops, historical signboards, and culturally unique design elements, which contribute to the market's distinctive character. Cultural homogenization can be greatly reduced by government regulations that assist small businesses and that maintain traditional branding and signage. Community pride in local culture is also essential for preserving non-stationary elements like ambient sounds, social interactions, and intergenerational interactions. Public awareness initiatives can encourage residents to value and uphold their shared heritage, thereby strengthening the community's bond with its urban environment. This dual approach of preserving both the physical and social aspects of urban spaces can help retain the identity of traditional markets and sustain the rich urban memories associated with them.

It is important to acknowledge the limitations of this study. This ensures a balanced interpretation of the findings and highlights areas for future research. The research took place in a specific market context within a tier-II planned industrial city in India. This context may limit the generalizability of the findings to other urban environments. To apply these insights to a wider range of Indian cities, future studies should reproduce similar research in different urban contexts. This includes historical cities, where market transformations might affect heritage and cultural identity in unique ways. Although sentiment analysis offers insights into community emotions, it may not capture the full range and depth of individual experiences. It struggles to convey detailed emotions and complex perceptions. Sentiment analysis can identify significant trends in both positive and negative expressions, but it is important to exercise caution when interpreting these results. It is important to recognize that layers of human emotions may not be fully expressed through text alone. Qualitative approaches should be used in addition to obtain a deeper comprehension of community experience. Sentiment analysis may overlook fine points that can be captured by methods like observations, interviews, and ethnographic research. This approach can deepen our understanding of urban memory and the social impacts of market transformations.

6. Acknowledgement

This research is supported by the Indian Institute of Technology Kharagpur, India.

7. References

AlWaer, H., Sibley, M. and Lewis, J. (2011) 'Factors and Priorities for Assessing Sustainability of Regional Shopping Centres in the UK', *http://dx.doi.org/10.3763/asre.2008.5143*, 51(4), pp. 391–402. doi: 10.3763/ASRE.2008.5143.

Araldi, A. (2019) *Distribution Des Commerces Et Forme Urbaine*.

Aulia, D. N., Marpaung, B. O. and Zahrah, W. (2017) 'Place Shaping in Residential Area as a Process of Increasing

Livable Neighbourhood'.

Axelsson, K. and Granath, M. (2018) 'Stakeholders' stake and relation to smartness in smart city development: Insights from a Swedish city planning project', *Government Information Quarterly*, 35(4), pp. 693–702. doi: 10.1016/J.GIQ.2018.09.001.

Balducci, F. and Ferrara, A. (2018) 'Using urban environmental policy data to understand the domains of smartness: An analysis of spatial autocorrelation for all the Italian chief towns', *Ecological Indicators*, 89, pp. 386–396. doi: 10.1016/J.ECOLIND.2017.12.064.

Biswas, A. *et al.* (2024) 'Understanding the relationship between in-store and online shopping channel choice behaviour of customers: a systematic literature review', *Cogent Business and Management*, 11(1), p. 2402510. doi: 10.1080/23311975.2024.2402510.

Biswas, A. and Chattopadhyay, S. (2024) 'What makes neighbourhood-level commercial centres attractive for neighbourhood residents ?', *Regional Studies, Regional Science ISSN:*, 11(1), pp. 291–310. doi: 10.1080/21681376.2024.2334057.

Choguill, C. L. (2008) 'Developing sustainable neighbourhoods', *Habitat International*, 32(1), pp. 41–48. doi: 10.1016/J.HABITATINT.2007.06.007.

Deloitte (2023) *Future of Retail Emerging Landscape of Omni-Channel Commerce in India*.

Dhingra, M. and Chattopadhyay, S. (2016) 'Advancing smartness of traditional settlements-case analysis of Indian and Arab old cities', *International Journal of Sustainable Built Environment*, 5(2), pp. 549–563. doi: 10.1016/J.IJSBE.2016.08.004.

Dhingra, M., Singh, M. K. and Chattopadhyay, S. (2017) 'Macro level characterization of Historic Urban Landscape: Case study of Alwar walled city', *City, Culture and Society*, 9, pp. 39–53. doi: 10.1016/j.ccs.2016.10.001.

Dillard, J., Dujon, V. and King, M. C. (2008) 'Understanding the social dimension of sustainability', *Understanding the Social Dimension of Sustainability*, pp. 1–300. doi: 10.4324/9780203892978/UNDERSTANDING-SOCIAL-DIMENSION-SUSTAINABILITY-MARY-KING-VERONICA-DUJON-JESSE-DILLARD.

IBEF (2021) *Indian Retail Industry Analysis Presentation*. doi: 10.36076/ppj.2021.24.1.

Johnson, D. L. (2010) 'Origin of the Neighbourhood Unit', *http://dx.doi.org/10.1080/02665430210129306*, 17(3), pp. 227–245. doi: 10.1080/02665430210129306.

Lakhani, A. R. (2021) 'Informal in Formal - Street Vending in Neighbourhood Markets of Chandigarh', *Descriptio*, 3(1).

Lara, A. P. *et al.* (2016) 'Smartness that matters: towards a comprehensive and human-centred characterisation of smart cities', *Journal of Open Innovation: Technology, Market, and Complexity*, 2(2), pp. 1–13. doi: 10.1186/S40852-016-0034-Z.

Larsen, K. (2008) 'Research in progress: the Radburn idea as an emergent concept: Henry Wright's regional city', *http://dx.doi.org/10.1080/02665430802102849*, 23(3), pp. 381–395. doi: 10.1080/02665430802102849.

Narayanan, Y. (2015) *Religion, heritage and the sustainable city : Hinduism and urbanisation in Jaipur*. Abingdon, Oxon ; New York, NY: Routledge (Routledge research in religion and development.).

Nathan, A. *et al.* (2012) 'Access to neighbourhood commercial destinations and associations with walking in older Australians', *Journal of Science and Medicine in Sport*, 15, p. S46. doi: 10.1016/j.jsams.2012.11.111.

Öner, Ö. (2017) 'Retail city: the relationship between place attractiveness and accessibility to shops', *Spatial Economic Analysis*, 12(1), pp. 72–91. doi: 10.1080/17421772.2017.1265663.

Perry, C. (1929) 'The Neighborhood Unit: A Scheme of Arrangement for the Family-Life Community', *Regional Plan of New York and Its Environs New York*, VII, pp. 636–637.

Qureshi, S. *et al.* (no date) 'Association between Objectively Measured Neighbourhood Built Environment and Walkability', *Mehran University Research Journal of Engineering and Technology*, 41(1), pp. 157–168. doi:

10.3316/INFORMIT.263594976826073.

Roger Tym & Partners (2010) *Greater London Authority LONDON SMALL SHOPS STUDY 2010*.

Rohe, W. M. (2009) 'From local to global: One hundred years of neighborhood planning', *Journal of the American Planning Association*, 75(2), pp. 209–230. doi: 10.1080/01944360902751077.

Rydin, Y. (2013) 'The future of planning'. doi: 10.2307/J.CTT9QGWG6.

Rydin, Y. (2019) 'Planning for Sustainability: Lessons from Studying Neighbourhood Shopping Areas', *https://doi.org/10.1080/02697459.2019.1679428*, 34(5), pp. 522–536. doi: 10.1080/02697459.2019.1679428.

Samanta, P. and Chattopadhyay, S. (2024) 'Exploring the perception of ethnic migrants in Kolkata, India: A comparative study using sentiment analysis', *Journal of Urban Affairs*, 00(00), pp. 1–20. doi: 10.1080/07352166.2024.2345649.

Sen, J. *et al.* (2017) 'Smart Economy in Smart Cities Varanasi India: Case of a Smart Traditional Economy of Knowledge-Based Institutional Services and Creative-Cultural Products', *Advances in 21st Century Human Settlements*, pp. 553–576. doi: 10.1007/978-981-10-1610-3_21/FIGURES/12.

Sridhar, K. S. and Monkkonen, P. (2024) 'Urban form in India 1975–2015: Have India's cities become flat?', *Cities*, 145, p. 104705. doi: 10.1016/J.CITIES.2023.104705.

UN (1992) 'Global Strategy for Shelter to the Year 2000', p. 3 p.

Vaughan, L. (2018) 'High Street Diversity', *Suburban Urbanities*, pp. 153–174. doi: 10.2307/J.CTT1G69Z0M.15.

Wells, K. and Watson, S. (2006) 'A politics of resentment: Shopkeepers in a London neighbourhood', *https://doi.org/10.1080/01419870420000315843*, 28(2), pp. 261–277. doi: 10.1080/01419870420000315843.

Research Paper

Evaluation and Planning Strategies for Ice-Snow Cultural Tourism Destinations Based on Public Perception: A Case Study of Heilongjiang Province, China

Shuai Yu, School of Architecture and Design, Harbin Institute of Technology;Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and TechnologyMinistry of Industry and Information Technology, China

Xiaoxiang Yi(Corresponding author) , School of Architecture and Design, Harbin Institute of Technology;Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and TechnologyMinistry of Industry and Information Technology, China

Lei Xia, School of Architecture and Design, Harbin Institute of Technology;Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and TechnologyMinistry of Industry and Information Technology, China

Cheng Shi, School of Architecture and Design, Harbin Institute of Technology;Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and TechnologyMinistry of Industry and Information Technology, China

Abstract

This study utilizes online data from Dazhong Dianping to examine eight ice and snow cultural tourism destinations within Heilongjiang Province, compared against a control group of twenty popular ice and snow cultural tourism destinations from other regions of China. Firstly, sentiment analysis and semantic analysis are employed to dissect the image perception and visitor satisfaction associated with both domestic and external ice and snow tourism destinations. Secondly, Importance-Performance Analysis (IPA) is applied to categorize the tourism destinations into four quadrants based on the dimensions of importance and satisfaction. This analysis allows for an evaluation of the development patterns of ice and snow cultural tourism destinations in Heilongjiang and the formulation of targeted optimization strategies. The objective of this study is to enhance inclusivity and recognition of cities in cold regions, improve the image of ice and snow cultural tourism destinations, and provide references for revitalizing urban landscapes and constructing urban memory sites.

Keywords

Tourism Destinations, Public Perception, Ice-Snow Cultural, Heilongjiang Province

1. Introduction

Ice and snow cultural tourism resources are the distinctive features and unique memories of cities in cold regions. In recent years, the image of tourist destinations has not only attracted tourists, but also been a key factor in increasing local identity. Exploring the public perception of tourists can provide theoretical basis for decision-makers to formulate management measures such as tourism industry development and tourism destination planning.

With the rapid development of informatization and networking, people tend to post travelogues and comments on social media to express their travel experiences. This allows researchers to transform intangible perceptual experiences into tangible text and data through methods such as big data (Sun et al., 2024; Xi et al., 2022). Many scholars have used structural equation modeling (Rasoolimanesh et al., 2023; Li et al., 2017) and questionnaire survey methods (Herman et al., 2021; Lenis Escobar et al., 2020) based on website travel notes and comment text data Image analysis (Marine-Roig and Ferrer-Rosell, 2018; Chen et al., 2021) and other methods are used to evaluate the perception of tourist destinations in different countries. Like Teles (Teles et al., 2024), Based on online reviews, analyze tourists' opinions on Nazaire, Portugal; Kovacic, S. (Kovacic and Sagovnovic, 2023) explored the relationship between destination image and tourists' emotional perception; Xu, J. (Xu et al., 2024) analyzed tourists' views on the competitiveness of tourist destinations. These studies understand how tourists perceive the development of tourist destinations (Harrill, 2004; Ren and Hong, 2017) and explore which factors are more attractive (Rodriguez-Diaz and Espino-Rodriguez, 2018; Baka, 2016; Wong and Qi, 2017), In order to better promote the development of the tourism industry and achieve a win-win situation for all parties involved(Del Mar Galvez-Rodriguez et al., 2020; Lee and Xue, 2020).

However, overall, existing research has paid less attention to ice and snow cultural tourism destinations. This article is based on online data from Dianping, selecting 8 ice and snow cultural tourism destinations in Heilongjiang Province as the research object, and 20 popular ice and snow cultural tourism destinations in other regions of China as the control group. Firstly, using sentiment analysis and semantic analysis methods, analyze the image perception and resident satisfaction of ice and snow tourism destinations both inside and outside the province; Secondly, based on existing research on Pan, S (Pan, Steve)、, Using the Importance Performance Analysis method, tourist destinations are divided into four quadrants based on the dimensions of importance and satisfaction. Analyze the development form of ice and snow cultural tourism destinations in Heilongjiang Province and propose targeted optimization strategies. This article aims to enhance people's tolerance and sense of identity towards cities in cold regions, improve the image of ice and snow cultural tourism destinations, and provide reference for revitalizing and utilizing urban landscapes and building urban memory sites.

2. Research Data and Methods

2.1. Research Subjects

This study selects research subjects from both within and outside Heilongjiang Province. The destinations within the province were selected according to the "Heilongjiang Province Tourism Development Master Plan (2020–2030)," the "Heilongjiang Province Ice and Snow Economy Development Plan (2022–2030)," and the "14th Five-Year Plan and 2035 Long-Range Goals for National Economic and Social Development of Heilongjiang Province." These include eight core ice and snow tourism destinations: Harbin Hot Snow Miracle (Sunac Snow World), Yabuli Ski Resort, Harbin Songhua River Ice and Snow Carnival, Harbin Ice and Snow World, Daqing Lianhuan Lake Hot Spring Scenic Area, Beiji Village, Beihong Village, and China Snow Town. For destinations outside Heilongjiang, the study referred to the "China Ice and Snow Tourism Consumption Big Data Report (2023)" and the "China Ice and Snow Tourism Development Report (2022)." The selected popular destinations across China include cities and areas such as Changchun, Shenyang, Urumqi, Hohhot, Mudanjiang, Zhangjiakou, and Altay. Specifically, the 20 selected destinations are Tianshan Ski Resort, Lotus Mountain Ski Resort, Changbai Mountain Wanda International Ski Resort, Beidahu Ski Resort, Guai Po International Ski Resort, Baiyun International Ski Resort, Taiwei Ski Resort, Taiwu Ski Town, Taizi Ridge Ski Resort, Window of the World Alps Snow World, Damingshan Ski Resort,

Changchun Ice and Snow Wonderland, Shenyang Olympic Sports Ice and Snow Carnival, Guoxin Nanshan Hot Spring, Changbai Mountain Julong Volcano Hot Spring, Changbai Mountain Tianmu Daisi Hot Spring, China Korean Folk Village, Hemu Scenic Area, Dagu Glacier Scenic Area, and Bipeng Valley Scenic Area. Both the destinations inside and outside Heilongjiang were selected due to their significant numbers of local and non-local visitors, ensuring data validity and analyzability.

2.2. Data Sources and Processing

Data for this study were collected from Dazhong Dianping (Public Reviews), using web scraping tools to extract review information from 27 tourism destinations. The data collection periods were from December 1, 2021, to February 28, 2022, and from December 1, 2022, to February 28, 2023. Data fields include destination name, destination address, reviewer's nickname, rating, review text, review time, and more. After excluding reviews with missing information and invalid reviews, a total of 2,457 valid reviews were retained, amounting to approximately 308,300 words.

2.3 Analysis Methods

This study employs sentiment analysis, content analysis, and Importance-Performance Analysis (IPA) methods on online texts. Using the text frequency statistics of the WeiciYun (MicroWordCloud) software, online texts were quantitatively processed and analyzed. Common issues mentioned in tourist reviews were extracted through keywords and high-frequency words for further research. Sentiment analysis through the MicroWordCloud software provided insights into the positive and negative information in the online text, along with tourist sentiment values, to analyze tourists' experiences and preferences regarding the spatial elements of tourism destinations. Using IPA analysis, tourists' satisfaction with tourism destinations was explored, categorizing destinations into four quadrants to propose targeted planning strategies (Feng et al., 2014).

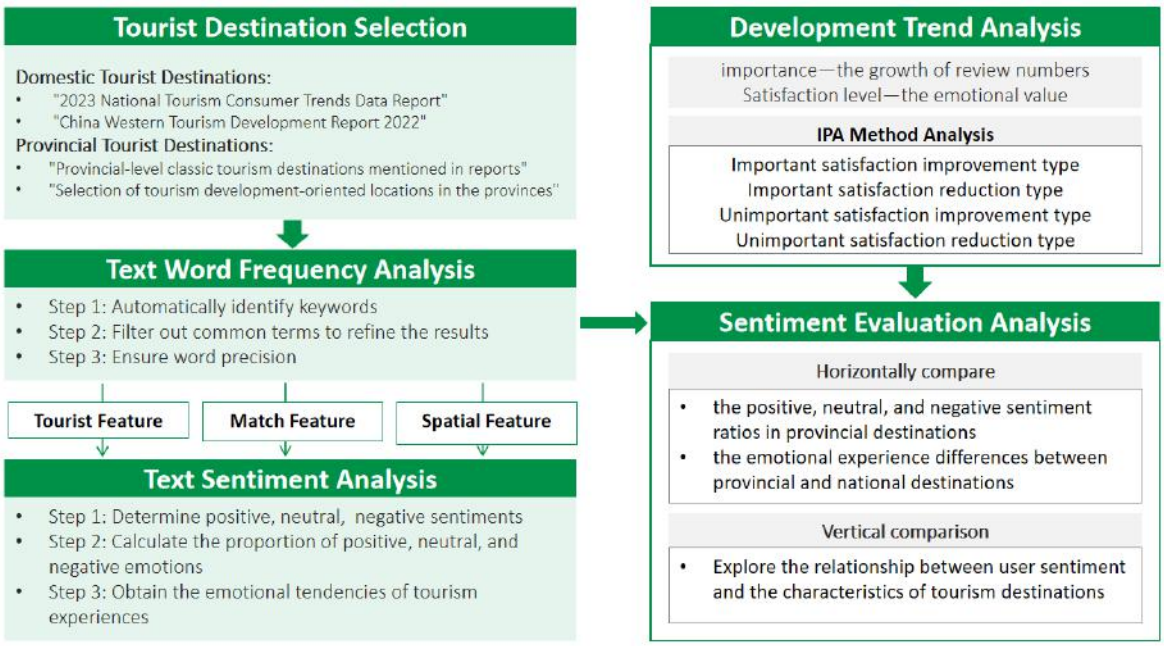


Figure 1. Research Technology Roadmap. Source: Self Drawing

3. Evaluation Analysis of Ice and Snow Tourism Destinations in Heilongjiang

3.1 Changes in the Popularity of Tourism Destinations

The development status of tourism destinations was analyzed based on two indicators. The first is the number of tourist reviews on Dazhong Dianping, analyzing the change in the growth rate of reviews for Heilongjiang's core ice and snow tourism destinations. This indicator reflects the popularity of tourism destinations and their significance to tourists. The second is sentiment analysis of tourists' review texts to determine the proportions of positive, negative, and neutral comments for each destination, thereby calculating a sentiment score that represents tourist satisfaction with the destination.

Statistics on the number of evaluations for each tourism destination reveal a general increase in the popularity of the seven core destinations within Heilongjiang Province between 2022 and 2023, excluding Harbin Hot Snow Miracle. The Yabuli Ski Resort showed the highest increase, at 519.5%, followed by Harbin Ice and Snow World at 415.6%, and China Snow Town at 304.9%. Notably, five destinations within Jilin Province showed growth, with Changbai Mountain Tianmu Daisi Hot Spring and Changbai Mountain Julong Volcano Hot Spring taking the top two positions with growth rates of 478.57% and 176.92%, respectively. In addition, Taiwu Ski Town in Zhangjiakou, Hebei Province, experienced growth of over 100%. Overall, the popularity of tourism destinations within Heilongjiang Province is markedly higher than that of destinations outside the province. The Heilongjiang ice and snow tourism brand, supported by its rich resources and long-standing influence, has a high level of recognition and appeal among tourists.

Table 1. The popularity of tourist destination reviews. Source: Self Drawing

Tourism Destination	Comment Growth Rate (2022-2023)	Sentiment Value
Harbin Hot Snow Miracle	-13.8%	1.08
Yabuli Ski Resort	519.5%	0.00
Harbin Ice and Snow World	415.6%	0.04
Harbin Songhua River Ice and Snow Carnival	83.3%	5.62
Daqing Lianhuanhu Hot Spring Scenic Area	150.0%	3.00
China Snow Tow	304.9%	3.50
Arctic Village	75.0%	0.92
Beihong Village	100.0%	1.20
Tianding Mountain Ski Resort	-63.33%	5.17
Baiyun International Ski Resort	-45.00%	4.33
Dagu Glacier Scenic Area	-56.92%	2.75
Daming Mountain Ski Resort	11.49%	3.3
Guai Po International Ski Resort	-61.92%	7.23
Beidahu Ski Resort	39%	5.11
Guoxin Nanshan Hot Spring	-38.30%	4.5
Hemudu Scenic Area	-26.67%	4.16
Shenyang Olympic Ice and Snow Carnival	-34.12%	5.22
Window of the World Alps Ice and Snow World	-29.11%	3.62

Taiwei Ski Resort	9.09%	3.67
Taiwu Ski Town	132.26%	6.05
Taiziling Ski Resort	-57.75%	-2.08
Changbai Mountain Julong Volcano Hot Spring	176.92%	1.79
Changbai Mountain Taimu Dayspring Hot Spring	478.57%	7.05
Changbai Mountain Wanda International Ski Resort	8.25%	4.76
Changchun Lotus Mountain Ski Resort	29.03%	1.05
Bipenggou Scenic Area	-51.02%	2.19
Chinese Korean Ethnic Culture Park	88%	5.32
Changchun Ice and Snow New World	-42%	8.41

3.2 Emotional Evaluation of Tourism Destinations

An analysis of tourist satisfaction with each destination shows that all eight destinations within the province have a higher proportion of positive than negative reviews. However, negative reviews exceed 20% and neutral reviews exceed 25%, indicating that while tourists are generally satisfied with their experiences, there remains significant room for improvement. The top three destinations in terms of satisfaction are Harbin Songhua River Ice and Snow Carnival, China Snow Town, and Daqing Lianhuan Lake Hot Spring Scenic Area. Despite their popularity, Yabuli Ski Resort and Harbin Ice and Snow World have lower levels of satisfaction.

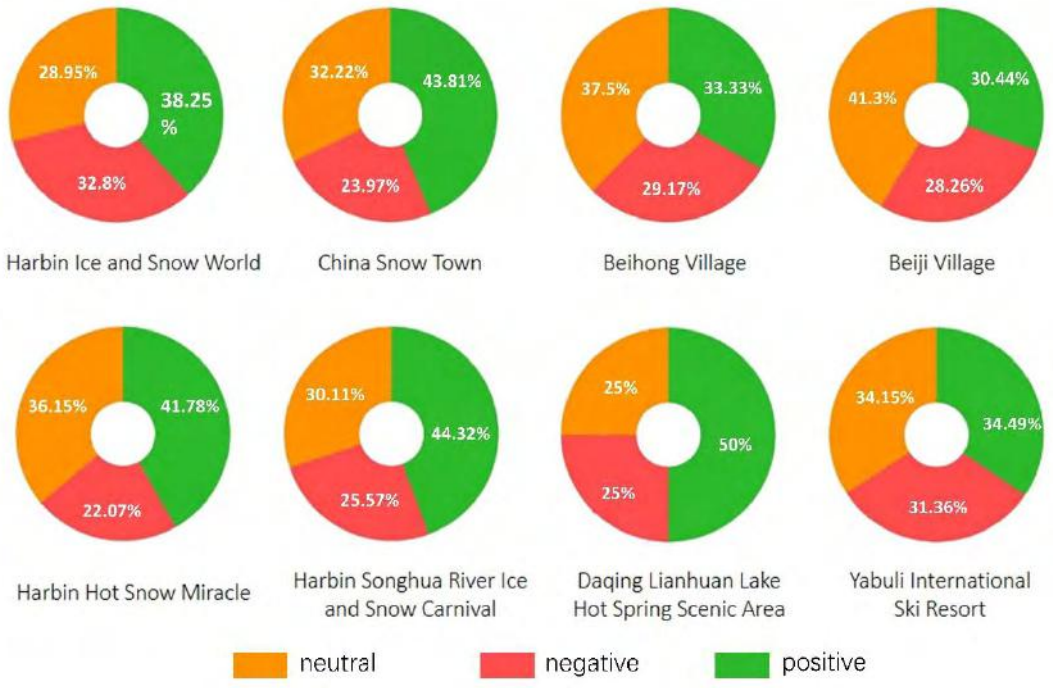


Figure 2. Emotional value of tourist destinations. Source: Self Drawing

3.3 Analysis of Tourism Destination Image Perception — Word Frequency Analysis

High-frequency word analysis begins with extracting and interpreting keywords from all review texts, with meaningless words uniformly removed. The top 100 keywords are then extracted and categorized, and similar words with close meanings are merged to obtain the high-frequency keywords for each tourism destination. The review keywords for the 27 tourism destinations are then classified and analyzed in three aspects: tourist experiences, supporting services, and spatial elements.

(1) Analysis of high-frequency words in natural environment

According to the high-frequency words related to tourist experiences, visitors to China Snow Town, located in Quadrant I, mainly focus on the natural environment, with comments such as "dreamlike paradise" and "so beautiful." Many reviews also highlight recreational activities like "snowmobile," "water splash freezing," and "dog sledding," though a few comments indicate that China Snow Town is not considered cost-effective, noting it as "quite expensive" and "commercialized." Overall, positive comments far outweigh negative ones.

In Quadrant II, reviews for Harbin Songhua River Ice and Snow Carnival and Daqing Lianhuan Lake Hot Spring Scenic Area primarily focus on activity experiences and general impressions. Comments on Harbin Songhua River Ice and Snow Carnival frequently mention ice and snow activities, including "snow projects," "sledding," and "snowmobile." Some reviews also reflect tourists' perceptions of the climate and play experiences, using terms like "very cold," "fun," and "enjoyable."

In Quadrant III, reviews for Harbin Hot Snow Miracle primarily highlight skiing experiences, with keywords such as "professional" and "suitable for beginners." Tourists' experiences in Beihong Village and Beiji Village focus on the village setting and natural environment, with Beihong Village often described as "authentic" and "pristine." Some reviews mention it as "indescribable" or "relatively underdeveloped." In contrast, Beiji Village is frequently described with terms like "vast," "nature," "joyful," "relaxing," and "commercialized."

In Quadrant IV, keywords for Harbin Ice and Snow World and Yabuli Ski Resort focus on ice and snow activities and service management. For Yabuli Ski Resort, terms like "tipping" and "coach fees" appear frequently. Meanwhile, Harbin Ice and Snow World is associated with terms like "unable to book," "15-minute advance reservation," and "need to queue."

(2) Analysis of high-frequency words in tourism service

According to the high-frequency words related to tourism services, tourists generally pay attention to the quality and convenience of supporting facilities such as food, accommodation, and transportation. For example, reviews of Harbin Ice and Snow World mention "direct metro access" and "Metro Line 2," while reviews of Harbin Hot Snow Miracle highlight "convenient transportation." For Harbin Songhua River Ice and Snow Carnival, terms like "walking" and "bicycles" are common, and for China Snow Town, "taking the bus" and "taking the train" are frequently mentioned. In terms of accommodation and dining, tourists focus on the quality and service level of nearby inns and hotels, as well as local specialty foods. For instance, reviews of China Snow Town mention "frozen pear" and "accommodation conditions," while Beihong Village is often associated with terms like "farmhouse accommodation" and "lodging." Yabuli Ski Resort has high-frequency words such as "inns" and "restaurants." For skiing facilities, Yabuli Ski Resort and Harbin Hot Snow Miracle have similar high-frequency keywords, with tourists frequently mentioning "coaches," "ski equipment," and "cable cars."

(3) Analysis of high-frequency words in spatial elements

According to the high-frequency words related to spatial elements, ice and snow structures, natural landscapes, and indoor and outdoor environments attract the most attention from tourists. For Harbin Ice and Snow World, keywords like “ice sculptures,” “snow sculptures,” “Ferris wheel,” and “giant slide” give visitors a direct impression of entering an “ice and snow world.” In Harbin Songhua River Ice and Snow Carnival, terms like “snow slide,” “ice slide,” and “Bund snowman” are commonly mentioned. Analyzing the reasons, it may be due to the location advantages of these destinations, which are close to landmark buildings in the city, resulting in a corresponding increase in passenger flow.

According to the high-frequency word statistics of tourism services, tourists generally pay attention to the quality and convenience of supporting facilities such as food, accommodation, and transportation. Comments on Harbin Ice and Snow World include "direct subway" and "Metro Line 2"; In terms of accommodation and catering, tourists focus on the hardware quality and service level of homestays and hotels near the tourist destination, as well as the unique cuisine. Comments on "frozen pears", "accommodation conditions", etc. in China's Snow Village; The comments from Beihong Village mention "rural tourism", "accommodation", and so on. In terms of skiing supporting services, there is a certain similarity between the high-frequency words of Yabuli Ski Resort and Harbin Hot Snow Miracle, with "coach", "skiing equipment", "cable car" and other key focuses.

According to the high-frequency word statistics of spatial elements, ice and snow structures, natural landscapes, indoor and outdoor environments, and other aspects have attracted the attention of most tourists. The ice sculptures, snow sculptures, Ferris wheels, and large slides in Harbin Ice and Snow World provide visitors with a visual experience of being in the "Ice and Snow World"; The "Snow Slide," "Ice Slide," and "Bund Snowman" of the Harbin Songhua River Ice and Snow Carnival were all mentioned.

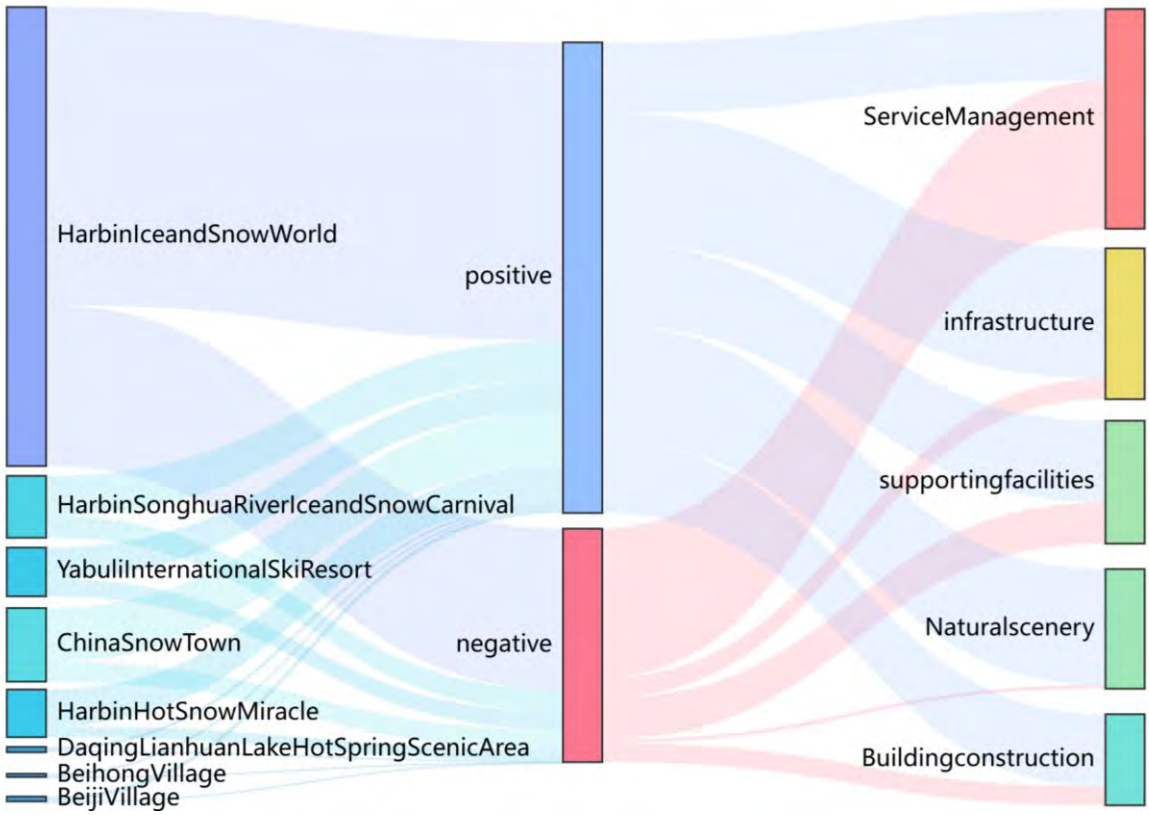


Figure 3. High frequency words for tourist destinations, such as Sangjitu. Source: Self Drawing

3.4 Analysis of Tourism Destination Development Trends

After calculating the popularity (importance) and satisfaction of tourist destinations, this article divides the development trend of tourist destinations through IPA analysis method. The chief determines the importance and satisfaction score range of the destination, then calculates the average importance and satisfaction of each destination, and finds the intersection of the two average values on the IPA chart.The third step draws horizontal and vertical lines through this intersection to establish four quadrants, positioning each destination in its respective quadrant. Based on Lai, IKW perspectives, the first quadrant represents high importance and high satisfaction, indicating high tourist attention and experience quality, suggesting continued focus and effort (Lai and Hitchcock, 2015). The second quadrant signifies high satisfaction but low importance, suggesting good tourist experiences with lower attention, where natural development is advisable. The third quadrant represents low importance and low satisfaction, indicating overall poor development potential and a "low-priority" status. Finally, the fourth quadrant indicates high importance and low satisfaction, showing that tourists place a high value on these destinations but are unsatisfied with their services and experiences, necessitating immediate improvement efforts.

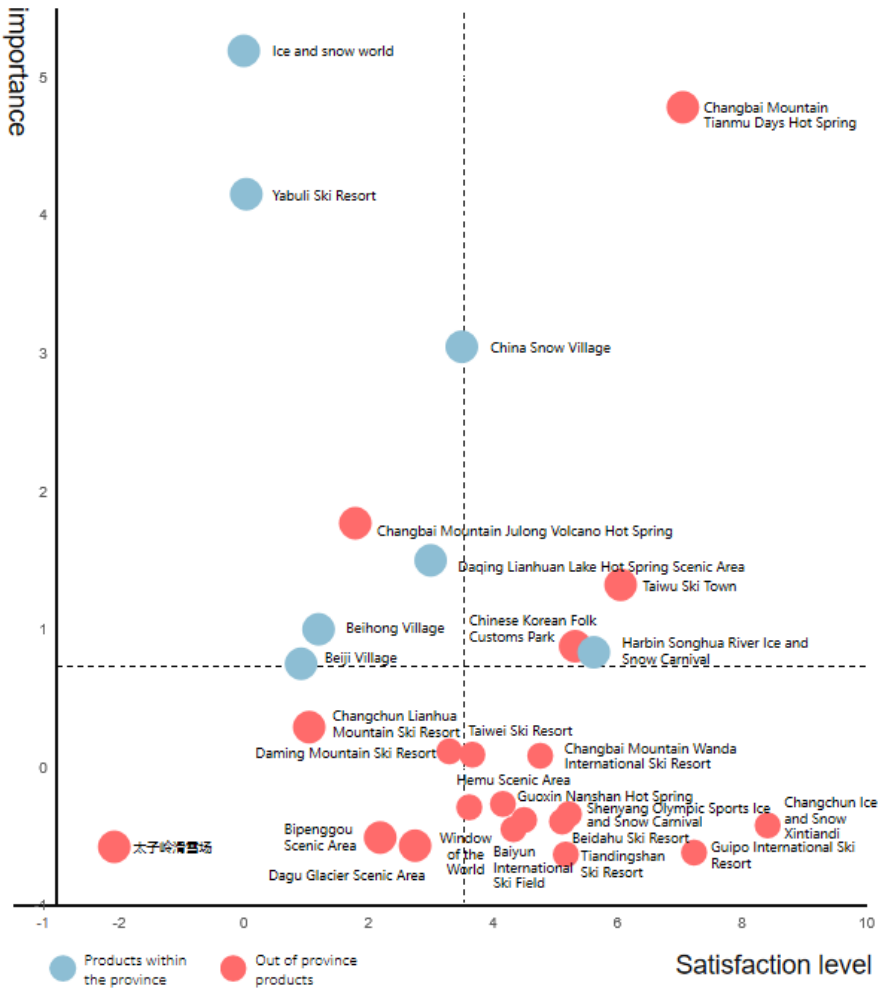


Figure 4. Quadrant Map of Tourist Destination Distribution. Source: Self Drawing

The analysis reveals that all destinations within Heilongjiang Province fall into the quadrant of high importance. The "Harbin Songhua River Ice and Snow Carnival" is the only product positioned in the dual

high quadrant; however, its popularity is close to the average value. Although it receives a relatively high rating, several factors warrant consideration: the product has not been operational for a long period, the number of reviews is limited, and visitors experience a high level of novelty, which contributes to its favorable evaluations. Therefore, there is a need to further explore its advantages and enhance its competitiveness. Conversely, the "Harbin Hot Snow Miracle" is categorized as a dual low product, while the remaining destinations predominantly exhibit high popularity but low ratings. The most extreme case is the Ice and Snow World, which ranks the highest in terms of popularity but the lowest in quality.

Most external tourism destinations are situated in the quadrant of lower importance, with over half of these destinations falling into the fourth quadrant characterized by low importance and high satisfaction. In contrast, the characteristics of Heilongjiang's ice and snow tourism destinations are distinctly marked by a profile of high importance but low satisfaction. This stands in stark contrast to the core products of external ice and snow tourism destinations, which predominantly feature low importance but high satisfaction. It is evident that the advantages of Heilongjiang's products lie in their resource endowments and the long-term influence they have accrued. However, their disadvantages are rooted in product quality, indicating that the potential for sustainable development is inferior to that of competing products.

Through the above analysis, it is found that tourist destinations within the province exhibit similar development characteristics, receiving widespread praise from tourists in terms of spatial environment, ice and snow scenery, etc. However, there are many problems in service and management, such as "poor service attitude", "lack of management", "long waiting time", etc. Therefore, in the future, it is necessary to further improve the management level and service quality, so that the soft power of tourism destinations within the province can keep up with their hard advantages.

4. Conclusion and Recommendations

4.1 Conclusion

(1) Tourists generally perceive their experiences at the eight tourism destinations as satisfactory, with a predominance of positive comments; however, there are also a significant number of negative reviews. Regarding the importance ratings of the eight tourism destinations, all except Harbin Hot Snow Miracle (Sunac Snow World) have shown an increase in their perceived significance.

(2) The development trends of the tourism destinations, analyzed through the Importance-Performance Analysis (IPA) method, reveal that China Snow Town is positioned in Quadrant I, indicating it is characterized by both high importance and high satisfaction, reflecting a positive development trend. In contrast, the Harbin Songhua River Ice and Snow Carnival and Daqing Lianhuanhu Hot Spring Scenic Area are situated in Quadrant II, categorized as having high satisfaction but low importance. Harbin Hot Snow Miracle, Arctic Village, and Beihong Village fall into Quadrant III, which is marked by low importance and low satisfaction. Finally, Yabuli Ski Resort and Harbin Ice and Snow World are located in Quadrant IV, indicating low satisfaction but high importance.

(3) An analysis of frequently used terms in tourist reviews, categorized by visitor experiences, tourism services, and spatial elements, reveals the following insights. In terms of visitor experiences, high-frequency terms predominantly focus on activity experiences, management mechanisms, and the natural environment. Regarding tourism services, visitors generally emphasize the quality and convenience of supporting facilities such as dining, accommodation, and transportation. Finally, in relation to spatial elements, significant attention is given to the ice and snow environment as well as ice and snow structures.

(4) A further analysis of tourists' positive and negative reviews reveals that the eight tourism destinations commonly face issues such as chaotic management, subpar quality of supporting facilities, and inadequate tourism environments.

4.2 Recommendations

(1) Quadrant I: Maintain Advantages and Develop Distinctiveness

For Chinese snow towns, their natural environment and cultural landscapes are unique and highly attractive to tourists. In the future, it is necessary to further improve the level of facility construction and service quality, and continuously optimize the tourism market environment. While attracting tourists, pay attention to reputation building and further enhance brand image.

(2) Quadrant IV: Place High Importance and Gradually Enhance

For the Harbin Ice and Snow World and Yabuli Ski Resort in the fourth quadrant, both show a trend of high importance but low satisfaction, so improving tourist satisfaction is the focus of future construction. In response to the problems of chaotic management and low cost-effectiveness discovered, there is an urgent need to improve service attitude, skills, and awareness in the future, create an intelligent service network, and provide clear travel guidance for tourists. At the same time, it is necessary to enrich the types of catering, cultural and creative products, interactive activities, increase the number of public rest areas and heated cabins, and enhance the amusement environment.

(4) Quadrant III: Confront Problems and Actively Expand

Harbin Hot Snow Miracle, Beiji Village, and Beihong Village, located in the third quadrant, have issues of low importance and satisfaction. These tourist destinations have poor performance in terms of built environment, supporting facilities, and service levels, and require comprehensive overall improvement in the future. For Arctic Village and Beihong Village, they can rely on their unique natural resources and folk culture to market and promote the brand image of the "northernmost village" and enhance the attractiveness of the destination. On this basis, enhance the convenience and accessibility of transportation and other infrastructure, and improve supporting services. For the Harbin Hot Snow Miracle, the focus should be on improving the level of management and service, regulating the behavior of coaches and skiing equipment consumption, and creating a good experiential environment for tourists.

(4) Quadrant II: Moderate Regulation and Sustainable Development

The satisfaction level of Harbin Songhua River Ice and Snow Carnival and Daqing Lianhuan Lake Hot Spring Scenic Area is relatively high, but their importance is relatively low. In the future, it is necessary to strengthen marketing and publicity by organizing special events such as sports events, festival celebrations, concerts, and expos; Enhance visibility and influence through online marketing, film and television marketing, television and print media marketing, and other methods.

5. References

Baka, V. (2016) 'The becoming of user-generated reviews: Looking at the past to understand the future of managing reputation in the travel sector', Tourism Management, 53, pp. 148–162. DOI: 10.1016/j.tourman.2015.09.004.

Chen, H., et al. (2021) 'Improving the tourist's perception of the tourist destinations image: An analysis of Chinese Kung Fu film and television', Sustainability, 13(7), p. 3875. DOI: 10.3390/su13073875

Del Mar Galvez-Rodriguez, M., et al. (2020) 'Exploring best practices for online engagement via Facebook with local destination management organisations (DMOs) in Europe: A longitudinal analysis', Tourism Management Perspectives, 34, p. 100636. DOI: 10.1016/j.tmp.2020.100636.

Enright, M.J. & Newton, J. (2004) 'Tourism destination competitiveness: A quantitative approach', Tourism Management, 25(6), pp. 777–788. DOI: 10.1016/j.tourman.2004.06.008.

Feng, M., et al. (2014) 'Investigating the different approaches to importance-performance analysis', Service Industries Journal, 34(12), pp. 1021–1041. DOI: 10.1080/02642069.2014.915949.

Harrill, R. (2004) 'Residents' attitudes toward tourism development: A literature review with implications for tourism planning', Journal of Planning Literature, 18(3), pp. 251–266. DOI: 10.1177/0885412203260306.

Herman, G.V., et al. (2021) 'The perception of Bihor Mountain tourist destination, Romania', Geographia Polonica, 94(4), pp. 573–587. DOI: 10.7163/GPol.0221.

Joo, D., Cho, H. & Woosnam, K.M. (2019) 'Exploring tourists' perceptions of tourism impacts', Tourism Management Perspectives, 31, pp. 231–235. DOI: 10.1016/j.tmp.2019.05.008.

Kovacic, S. & Sagovnovic, I. (2023) 'Exploring the relationship between tourists' emotional experience, destination personality perception, satisfaction and behavioral intentions', Psihologija, 56(3), pp. 371–398. DOI: 10.2298/PSI210626025K.

Lai, I.K.W. & Hitchcock, M. (2015) 'Importance–performance analysis in tourism: A framework for researchers', Tourism Management, 48, pp. 242–267. DOI: 10.1016/j.tourman.2014.11.008.

Lee, S.W. & Xue, K. (2020) 'A model of destination loyalty: Integrating destination image and sustainable tourism', Asia Pacific Journal of Tourism Research, 25(4), pp. 393–408. DOI: 10.1080/10941665.2020.1713185.

Lenis Escobar, A., et al. (2020a) 'Perception, motivation, and satisfaction of female tourists with their visit to the city of Cordoba (Spain)', Sustainability, 12(18), p. 7595. DOI: 10.3390/su12187595.

Lenis Escobar, A., et al. (2020b) 'Perception, motivation, and satisfaction of female tourists with their visit to the city of Cordoba (Spain)', Sustainability, 12(18), p. 7595. DOI: 10.3390/su12187595.

Li, L., et al. (2017) 'Tourists' perceptions of crowding, attractiveness, and satisfaction: A second-order structural model', Asia Pacific Journal of Tourism Research, 22(12), pp. 1250–1260. DOI: 10.1080/10941665.2017.1391305.

Marine-Roig, E. & Ferrer-Rosell, B. (2018) 'Measuring the gap between projected and perceived destination images of Catalonia using compositional analysis', Tourism Management, 68, pp. 236–249. DOI: 10.1016/j.tourman.2018.03.020.

Pan, S., Lee, J. & Tsai, H. (2014) 'Travel photos: Motivations, image dimensions, and affective qualities of places', Tourism Management, 40, pp. 59–69. DOI: 10.1016/j.tourman.2013.05.007.

Rasoolimanesh, S.M., Chee, S.Y. & Ragavan, N.A. (2023) 'Tourists' perceptions of the sustainability of destination, satisfaction, and revisit intention', Tourism Recreation Research. DOI: 10.1080/02508281.2023.2230762.

Ren, G. & Hong, T. (2017) 'Investigating online destination images using a topic-based sentiment analysis approach', Sustainability, 9(10), p. 1765. DOI: 10.3390/su9101765.

Rodriguez-Diaz, M. & Espino-Rodriguez, T.F. (2018) 'A methodology for a comparative analysis of the lodging offer of tourism destinations based on online customer reviews', Journal of Destination Marketing & Management, 8, pp. 147–160. DOI: 10.1016/j.jdmm.2017.02.006.

Sun, S., et al. (2024) 'How do tourists perceive churches as tourism destinations? A text mining approach through online reviews', International Journal of Tourism Research, 26(4), p. e2711. DOI: 10.1002/jtr.2711.

Teles, R., et al. (2024) 'Tourists' perception of tourist destinations: The case study of Nazaré (Portugal)', Sustainability, 16(4), p. 1387. DOI: 10.3390/su16041387.

Wong, C.U.I. & Qi, S. (2017) 'Tracking the evolution of a destination's image by text-mining online reviews - the case of Macau', Tourism Management Perspectives, 23, pp. 19–29. DOI: 10.1016/j.tmp.2017.03.009.

Xi, Y., et al. (2022) 'A cross-cultural analysis of tourists' perceptions of Airbnb attributes', International Journal of Hospitality & Tourism Administration, 23(4), pp. 754–787. DOI: 10.1080/15256480.2020.1862014.

Xu, J.B., McKercher, B. & Ho, P.S. (2024) 'Tourists' perceptions of the competitive destination', Journal of Vacation Marketing. DOI: 10.1177/13567667241236490.

Research Paper

Existing in Kinship to Everything

Fourth Nature: Patterns and Paths to Regeneration

Simone Back Prochnow, Fourth Nature, Brazil

Abstract

Existing means more than only surviving. Means experiencing. Fourth Nature concept brings a new level of experiences for mankind through the consciousness of a new level of interconnectedness between us and the environment. Knowledge that goes through experience turns into wisdom. And wisdom allows us to access cosmic consciousness, where all that existed and all that will one day exist gather. Our daily lives are composed of innumerous experiences, some trivial, some exceptional, but always, the world that surrounds us plays a critical role in it, because we are one. In order to access this wisdom it is necessary to be aware not only of our position in relation to Nature itself, but also in relation to past and future. We do only exist because the planet's evolution through the millions of years allows us to - our existence is worth it in kinship to everything. There is no chance for this civilization to grant its participation in the evolutionary process when we consider ourselves separated or even worse, superior to the essence of Nature. Attending Isocarp 2024 demands, some unseen perspectives are brought as result of the research in which this paper is based - arguing that urban regeneration will properly occur when allied to human evolution. Our actions interfere in the flow, while conscious beings that can select and focus on positive perspectives among the infinite possibilities available for the story to be told. If we do not have positive perspectives, we have no life. At the critical moment we find ourselves in, it is pivotal to recover our capacity of co-creating the exceptional world we live in. But how? Researching manuscripts and old books in different libraries around the world, as well as visiting historical sites, it became clear that our ancestors had this capacity of accessing cosmic consciousness. It is shown in various manifestations in the different areas (and eras) - such as architecture, literature, art and science, but above all, it becomes obvious when we understand how they considered Nature a profound source of well being, healing and inspiration. How they respected Nature as a true partner in what they were creating. What kind of incredible knowledge is written, what kind of amazing energy is hidden, what kind of gorgeous results are forgotten, in all that what was once experienced by them? It is time to gain courage to admit we have been dismissing all this and recover the power we have inside us to co-create the world we know we want to live in. This paper relates some important findings of the Fourth Nature Concept research, that bring us once more the chance to see the invisible and therefore comprehend how to reinvent a coherent life to our role as mediators between tradition and progress.

Keywords

Fourth Nature; Urban Regeneration; Human Evolution; Ancestral Knowledge

1. Existing means more than only surviving

Fear and hope are rife. We are living in unprecedented moments and situations, to which unprecedented thoughts and movements must take place. We are seeing the planet urging for actions from our side, that were until now not common. It is necessary to review our way of inhabiting and coexisting with the planet as a whole. We are one. This is the forgotten truth.

We have been constructing and modifying Nature in our favour since a long time ago. As described in my research, Cicero has written, b.C., about a nature modified by man to fulfil its basic needs - food and transport - so plantations and roads were made and this he described as Second Nature. He does not speak about a First nature, but it is implicit that it is the pristine, the untouched, the realm of Gods. Researchers believe that the Italians in the Renaissance knew about Cicero's concept, because they wrote then about *una Terza Natura*, a Third Nature, as the one being modified by man, added with all technological performances available as well as with art, to bring humanity the pleasure of contemplating (Hunt, 1992). Nowadays, after the unimaginable moment of pandemics and experiencing this huge climate crisis, the Fourth Nature Concept emerges and can be seen as a breath of hope amongst so much fear - due to our capacity for self destruction and disconnectedness.

The Fourth Nature concept is the next step, which is about a shift in our consciousness. It is about us as humanity waking up and getting again connected to what really matters - the flow of life - the way of thinking and acting that will allow us to continue existing and telling the history we want to tell - as Marcelo Gleiser says in The Dawn of a Mindful Universe (2023). When we realise the miracles that happen in our everyday life, the way the cosmos is self organised and perfect, maybe we can understand our role in the expansion and in the evolution. Our own evolution as well as the planet's evolution.

It is about seeing ourselves as Nature again - as living beings that are connected to the whole and subject to the same laws of Nature as any other animal or plant. Because we are supposed to be here, and comprehending that our existence is possible only in kinship to everything else that shares with us the here and now is the turning point.

2. Our role

Fourth Nature is the evolution in the humankind relationship to the planet- the needed evolutionary moment we are about to experience as conscious human beings. This is why urban regeneration will only take place if it happens together with human evolution. We are already seeing different sectors working in the circular economy, upcycling, as very significant movements - but they all will succeed when our consumer mentality changes.

Where was the point when we lost track of being truly connected to everything else? Our great grandparents had so much knowledge coming from their daily experiences, which we have totally forgotten. And that was not so long ago. They knew about Nature's cycles and rhythms, and that our lives are totally influenced by these same forces. When to plant, when to harvest, what to plant in each season, how to keep the seeds for the next season. Feeling what our bodies demands are, and finding the support for its well being in Nature that surrounds us.

Because, after all technological development, we are still human beings. We need sunlight, fresh air, we need clean water, we need to walk barefoot on grass to get energy for our bodies to keep their functions and metabolism going on perfectly. This is what we really need. Do our cities provide us nowadays with

it? It does not seem so. We now are totally separated from Nature. Architecture and urban planning are the layers that permeate our relation to the natural world. What an important issue that has not been taken into account lately (Prochnow, 2024).

Specifically in architecture, there is knowledge showing that our houses and cities are not only the walls and floors we see. Its design does really influence our perception and our way of responding to the situations, because it influences our feelings and mood - because there is a connection to other dimensions that is affected by the "envelopes" we put ourselves in (Von Bingen, 1151 - a true inspiration from the XII century).

> *We do not benefit from the seven or seventy-seven wonders of a city, but from the answer it gives to our questions.* Says Italo Calvino.

The main question is towards which objectives are we going to regenerate our cities? We shall aim for cities that do offer conditions for us to practise and feel the connection we are missing. Urban design has this power of enhancing or dismissing this desired and fundamental connectedness. First item on a planning demand shall again be how is Nature in this place where we intend to build? It seems really obvious, but it is something that has become extraordinary. Solar orientation, water management, plants of any size that are native to that specific location, just to mention some basic items. If there is something already built, how can we restore Nature in that place?

It is about creating and designing together with Nature, not against it.

All disasters we see happening are consequences of actions that happened somewhere, anytime ago. Humboldt already said in the 19th Century, that all human actions have consequences in the balance of Nature, but we do not know how, when or where it will take place (Wulf,2016). So first of all, let's stop interfering in Nature's balance - let's give it the chance to start regeneration by itself.

Fourth Nature is about mutual healing - we let the presence of Nature heal us, while we again "see" it in our cities, when we again want it in our cities. When we value its miraculous processes happening right in front of our hypnotised eyes. This will be possible if we get to know our powerful intrinsic characteristics. Searching for ancestral knowledge, we may find our path back.

One of the recent important findings of the research developing the Fourth Nature Concept is the work of Robert Fludd (1617)- his captivating imagery can inspire an awareness of much that has been lost in modernity.

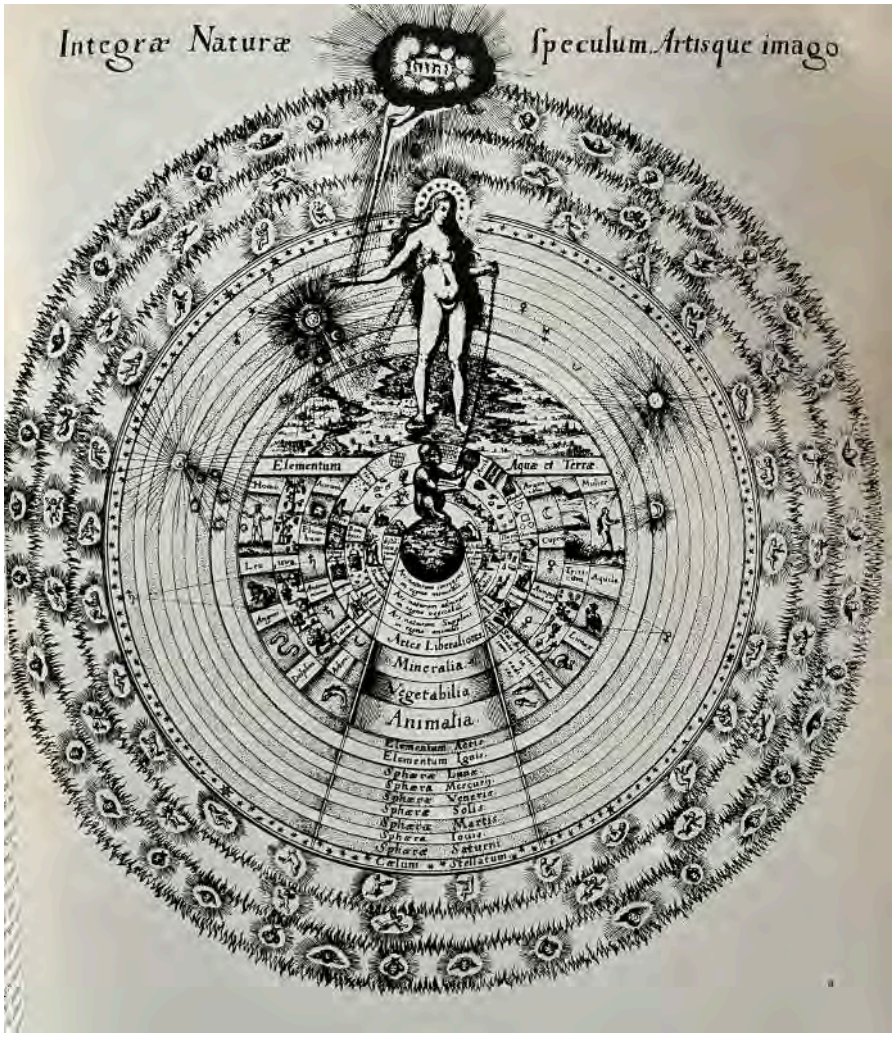


Figure 1. Integrae Naturae. Source: Fludd, Robert - Utriusque Cosmi Historia, 1617.

Integrae Naturae (fig.1) is one of his most impressive works showing how the cosmos can be understood. It shows Nature as the divine mediator between humanity and the creative power of the universe. It has its left hand attached to the divine and the right hand holding a chain attached to humanity - here symbolised by a monkey - or the lowest level of human consciousness as a rational creature. Our position on the planet, in turn, is as mediators between the unmanifested world and the manifested one.

When we think that everything we see manifested or created was before in someone's mind - we get to understand our responsibility, and once again, why regeneration must occur together with human consciousness evolution. And it becomes even clearer seeing that our minds are much more malleable than what is already materialised - it is possible to achieve huge changes, when we change our thoughts.

3. Reinventing the (in)visible - is searching for harmony between microcosm and macrocosm

One of the essential problems we are facing today not only as city dwellers but also as planners, is that we do not see ourselves as Nature. In this sense, we do not see or imagine the city as one form of Nature, as it should be. This is also why regeneration depends on human evolution: it is an inside out movement. Everything is connected, as has been said, from Hildegard von Bingen, in 1151 (fig.2) as well as by Fritjof Capra in 1980.

And why is seeing the city as one form of Nature so important? Because there is an intrinsic flow in Nature, because nothing is missing and nothing is wasted in Nature. This is totally the opposite of what we see in our urban settlements. They are unsustainable. Almost everything must come from somewhere else - for instance: food, energy, water - and an unimaginable amount of waste is produced and must go out of the city's limits. Is this not sick? We are living sick in sick cities.

Figure 2: Connection between the heavens and the earth. Source: Ellcock, 2022.

> *Everything in the heavens, on the earth and under the earth, is impregnated with connection, impregnated with relationship.*
> Hildegard von Bingen, (1151).

The natural flow of life follows some basic rules of Nature - since, as seen in Fludd's image previously, Nature is the mediator between us humanity and the creative powers. When these rules are broken or disconsidered, there are disruptions and consequently unbalance. Being aware of the main rules, we can again have life proper flows and paths.

As above, so below.

We are living a moment where all that happens in our lives needs something external from us. In every scale. We do not produce our food, we do not cook at home, we do not recycle our waste, on a domestic scale. In the same way, we have invented equipment for almost everything - we do not walk, we do not talk, we do not communicate face to face with our neighbours. We do not find happiness within ourselves - we need to consume to have satisfaction - ephemeral satisfaction. This is the (in)visible that we have to reinvent. The joy, the happiness, the wonder at life. As Calvino says, it is the mood of those who look that give shape to the city.

Nature based solutions are a very important path to regeneration, mainly because they give power back to Nature to regenerate itself in the cities, and consequently be close to our daily lives again - making us perceive it and profit from it as a true realer. But they are just a beginning. Each minimal action in our routine ends up creating our reality - when we are able to perceive Nature's presence and cycles, it has direct answers from our body and for our living energy. Factors like our circadian cycle, for example, influenced directly by the places we live in (with natural light presence or not) is responsible for all our hormone system balance. This shows how the microcosm shall pulse and organise itself following the macrocosm rhythms.

Aiming this connection should be the focal point for every project that is designed - the so-called invisible. Being aware of how our cities are built now and how our lives are structured , we understand how we are giving the power over our individual journey to a broken system.

4. Fourth Nature: Patterns and Paths to Regeneration

Our senses absorb and process the world surrounding us. We see, we hear, we smell, we touch, we taste - these information are directly connected to our main processing system. After that, we draw conclusions, we have ideas. Through our ideas we can accept or change what is around us. Nature's presence can modify our perception of the world and consequently the way we interfere with it (fig. 3).

A new reality may not be a new place, it may be a new mindset.

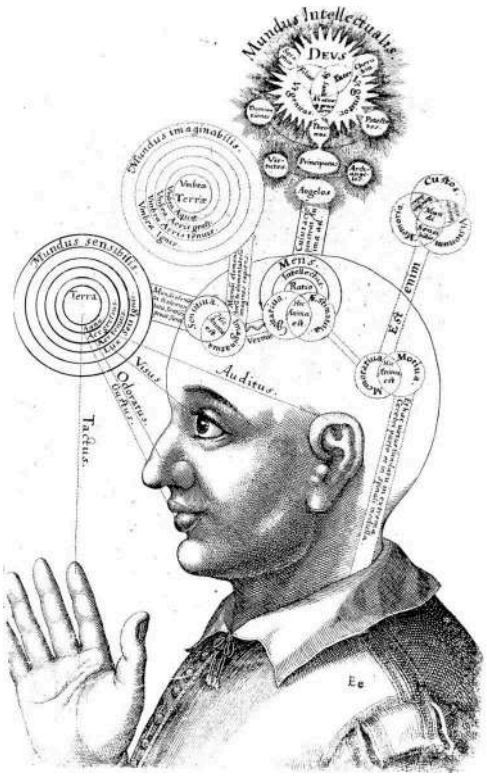


Figure 3. The imagined World by the Spiritual Brain - Robert Fludd. Source: Utriusque Cosmi Historia Book (1617).

Regeneration can be a process that brings together some important points that are usually seen as opposite, but are in fact complementary (just as cities and Nature). For example, empathy and technology - a collective evolution shall permeate any kind of action leading to regeneration - if part of humanity is still suffering or dealing with basic needs deficiency, the other party won't achieve higher levels of satisfactory results. Everyone must increase its life in conditions in order to regenerate the planet - including Nature - because everything is connected. A change in a forest or river course in one continent can change the behaviour of a forest in another one.

This is how Fourth Nature brings up a path: focusing on how technology can be a great partner in summarising data and reading layers of historic change to restore conditions according to each region and to its culture. As well as reaching distant places, to help improve their lives with the conditions and the features existing locally - allowing them to flourish, again, going back to basic, uncomplicating life.

Ancestral knowledge and a new era consciousness: it is essential that we rescue the knowledge that was lost in order to understand the places and how we as co creators can deal and connect to its movements. There is a huge amount of it registered in books and manuscripts. A new era consciousness is exactly about perceiving that for a future to exist, we must reallign and understand our position at this moment - not as Anthropocene villains, but as conscious beings that know where we want to go.

The Earth does not need us to save it, it needs us to evolve.

Local intelligence and cosmic wisdom: each place on earth has different characteristics. Reviewing our demands permits slowing down growth in order to match local needs - it is fundamental to rescale the economy to more coherent levels. The results can be surprising: what about making communities regain

confidence to rescue the values and the wisdom of their ancestors, when life was healthier. This knowledge has a high impact in moving our brains again in order to be creative and innovative, thinking about solutions that can be simple and effective.

As shown on figure 3 - the flow of perception, connection and knowledge is a two hand way path. When we have Nature near us and let it influence us, some kind of door opens to a higher feeling inside ourselves- because the universe is perceiving itself through us. On the other hand, the wisdom contained in cosmic consciousness - yes, we are part of a collective consciousness of the planet - can reach our imagination and we get to have new and powerful ideas. Fourth Nature empowers us as true agents of transformation by making us understand we are part of something bigger than ourselves.

5. Some reflections

The emotion of hope requires people who throw themselves actively into what is becoming, to which they themselves belong. Ernst Bloch

It is not time to do more of the same.

The regeneration concept encompasses a lot more than harm reduction, it is about changing systems to bring back what was lost. To restore and re-establish our presence on the planet in a more equitable way - through different sectors thinking together - such as agriculture (food systems), industry (valuing handmade local articles), real estate (what, where and how to build) and health (physical and mental health, sense of belonging, joy in life) is the motto of our time.

If we do not have positive perspectives, we have no life.

It is imperative to bring back to each person the power of its own life - Innovative methods can mean ancestral wisdom - we have developed so quickly our technological means that our human means were forgotten. And this is what is missing. How to prioritise regenerative processes that benefits Nature as a whole - the planet, humanity, the ecosystem. Not only now but also the future generations. Why do people live so much longer and healthier in places where they eat local and visit friends?

This approach requires a fundamental change in mindset. Understanding how our lives are functioning today has led us to crisis. More activities are needed and less facilities, more focus on our own power, mental and physical power - rather than depending on something outside us or outside our cities. This is the main path proposed by Fourth Nature. We are talking about a complete rethinking from energy consumption to the way goods are produced and delivered to consumers - beginning in the change of the consumers consciousness.

The moment has come for this change - what is all data collected and analysis made for, if we do not see the real target? Let's stop discussing the medicine we should take for the fever, let's heal the cause, the illness. We are absolutely capable of this.

What kind of experience are we allowing ourselves in our existence? Bloch (1995) regards history as a repository of possibilities that can help us to realise the unrealised potentialities - “what we learn from the past are tools for reconstructing the present, not from scratch, not from a point outside of it, but from within its ongoing process”.

We carry in us enough good ingredients to engage in a good future - we are ready to reinvent ourselves as a civilization.

6. References

Bloch, E. (1995) 'The Principle of Hope' in Nasser, M. (2019) *The Path to New Hermopolis.* Auckland: Rubedo Press.

Calvino, I. (1997) 5.Ed. *Invisible Cities*. New York: Vintage Books Random House Publishers

Capra, F. (1982) *The Turning Point - Science, Society and the Rising Culture.* New York: Bantam Books.

Ellcock, S. (2022) *The Cosmic Dance - Finding Patterns and Pathways in a Chaotic Universe.* London: Thames and Hudson.

Fludd, R. (1617) 'Utriusque Cosmi Historia' in Godwin, J. (1979) *Robert Fludd - Hermetic Philosopher and Surveyor of Two Worlds.* London: Thames and Hudson.

Gleiser, M. (2023) *The Dawn of a Mindful Universe - A Manifesto for Humanity's Future.* San Francisco: Harper One.

Hunt, J.D. (1992). *Gardens and the Picturesque.* Cambridge: MIT Press.

Lazlo, E. (2018) *A Plenitude do Cosmos - A Revolução Akáshica na Ciência e na Consciência Humana. Original Title: The Self-Actualizing Cosmos.* São Paulo: Pensamento-Cultrix Ltda.

Prochnow, S. (2024) 'Fourth Nature - Regenerating Cosmicity' *, 29th Real Corp Conference Archives,* (online). Available at: https://corp.at/archive/CORP2024_122.pdf (accessed 10 July 2024)

Von Bingen, H. (1151) 'Wisse die Wege', in (1954) Neu bearbeitete Auflage mit Farbdrucken der Kodex Tafeln. Salzburg: Otto Müller Verlag.

Wulf, A. (2016) *The Invention of Nature - Alexander von Humboldt's New World*. New York: Vintage Books.

Research Paper

Design Strategies for the Regeneration of Existing Hospitals in Cold Cities with the Aim of Sustainability and Regionalism

A Case Study in China

Kexin LIU, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology; The Architectural Design and Research Institute of HIT Co., Ltd (HITAD), China

Jianfei CHEN, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Yu BAN, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Abstract

Urban regeneration is a continuous process of adapting urban spaces to the evolving needs of communities. Healthcare buildings, as essential components of the urban environment, play a vital role in the growth and well-being of cities. However, renewing these buildings presents several challenges as demands change. This renewal requires not only optimizing internal functions to accommodate modern healthcare needs and public expectations but also redesigning existing structures to better integrate with inclusive societal needs. This study uses a large-scale general hospital renewal project in Harbin as an empirical case. The main objective is to explore how to effectively incorporate new functions into the existing hospital environment and manage the coordination between buildings from different historical periods, including those with heritage protection, in line with policies for establishing a national regional medical centre. The study aims to achieve a comprehensive and organized renewal under the broader framework of sustainable urban development. This study presents a new design framework for urban hospital renewal and proposes specific techniques for such projects. The framework serves as a valuable reference for renovating medical buildings in the context of urban regeneration and effectively guides the refurbishment of existing structures and urban renewal efforts.

Keywords

Urban regeneration, General hospital, Cold region, Sustainability

1. Introduction

1.1. Research Background

The process of urbanization has posed significant challenges to human health, including environmental degradation, increased risks of chronic diseases, heightened psychosocial stress, and a rise in mental

health issues(Baker et al., 2020; Wang, Mao and Wang, 2023). In response to growing concerns and demands for health, the World Health Organization's (WHO) concept of health has evolved from merely the absence of disease to a broader focus on disease prevention, health promotion, and the attainment of holistic human well-being. The concept of the "Healthy City" was first introduced in 1984, marking a pivotal shift in urban planning with health promotion becoming a central objective(Lawrence, 2022). At the core of the Healthy City concept is the recognition of the potential of architecture and urban spaces to influence health outcomes. This expands the responsibility for health beyond traditional medical and healthcare institutions, addressing it on a broader urban and social scale.

As a crucial component of Healthy City development, the design of hospital buildings must align with the urban environment and function as part of the larger urban continuum(Moscelli et al., 2016). Architects must consider not only the visual aesthetics of hospital buildings but also their internal functionality and purpose, aiming to create spaces conducive to both living and healthcare needs(Castro, Mateus and Braganca, 2013; Cervinka, Roederer and Haemmerle, 2014; Tajudin and Amat, 2022; Sabir and Mustafa, 2023).

This study focuses on large general hospitals in urban environments to examine issues of urban renewal based on three key considerations. First, hospitals, as core urban structures, coexist and evolve alongside cities, serving as vital components of the urban health system(Kara and Bilgic, 2021). Second, the development of a Healthy City strategy, which integrates health considerations into broader urban and social frameworks, has become an effective means of promoting public health in many countries(Brown, 2020). Third, exploring the potential of architecture and urbanism to extend health promotion beyond healthcare institutions to the entire city can help achieve a low-cost, high-efficiency health promotion model.

1.2. Study Area

The project is located in Harbin, a renowned historical city known for its unique blend of traditional and modern elements. Harbin's cityscape reflects a harmonious fusion of ancient, elegant architecture with dynamic, contemporary styles, showcasing a blend of Eastern and Western cultures(Musgrove, 2007; Xie *et al.*, 2016).

The project site is located in the south of Harbin Central city, about 3.5 km away from Harbin West Railway Station, with a very convenient transport environment (Figure 1). The hospital in this study is located in the urban environment, and the surrounding area has formed very mature support functions, including residential areas, schools, office buildings, etc (Figure 2).As can be seen from the aerial photos of the project, the hospital itself has a good ecological environment, which is an important part of the urban memory and people's living space (Figure 3).

Figure 1. Location of the project in Harbin. Source: HITAD.

Figure 2. The urban environment surrounding the site. Source: HITAD.

Figure 3. Current environment of the site (pre-construction) . Source: HITAD.

2. Case Study

2.1. Project Background

The hospital under study is a large, comprehensive tertiary level hospital with a total site area of approximately 500,000 square metres. The entire hospital area is planned in a square and orderly manner, with a symmetrical layout. The architectural style is based on the ancient and elegant Chinese style, inheriting a long history. The existing hospital area is divided into six different functional areas: the medical area is located on the west side of the base, near Xuefu Road; the landscape area is located on the north side of the base on the central axis; the teaching area is located in the northeast corner; and the scientific research area, residential area and logistics area are located on the south side of the base, which is also the main area where the scope of construction is located.

The hospital boasts a long history of over 80 years, and many of its buildings have been designated as heritage sites by the government (Figure 4). Strict regulations are enforced within the conservation area to ensure the preservation and protection of these historically significant structures.

Figure 4. Existing buildings of different styles in the existing hospital compound . Source: HITAD.

2.2. Research Framework

In the early stages of hospital design, establishing a comprehensive and clear top-level design is crucial, as it plays an essential role in both new hospital projects and the renewal of existing facilities. The renewal of urban hospitals should be approached from a macro-level perspective that aligns with the hospital's strategic development goals, ensuring comprehensive coordination and scientific planning. This approach necessitates consideration of national policies, such as the hierarchical diagnosis(Wang *et al.*, 2024) and treatment system and the policy on close medical associations, to accurately guide the direction of hospital renewal.

Furthermore, the renewal of hospitals should be considered within the framework of the specific medical planning of a city, i.e. the renewal of hospitals should be closely coordinated with the specific medical

planning of the city in order to determine the appropriate positioning of hospitals (bed size and specialisation composition, etc.).

The innovation of this paper is to construct a design guidance framework for urban hospital renewal (Figure 5). The framework not only focuses on the improvement of medical efficiency, which is the basic requirement for the core function of medical services, but also skilfully integrates the preservation and inheritance of history and culture, the optimisation of the external environment and other broad and profound social dimensions, showing a high degree of comprehensiveness and innovation.

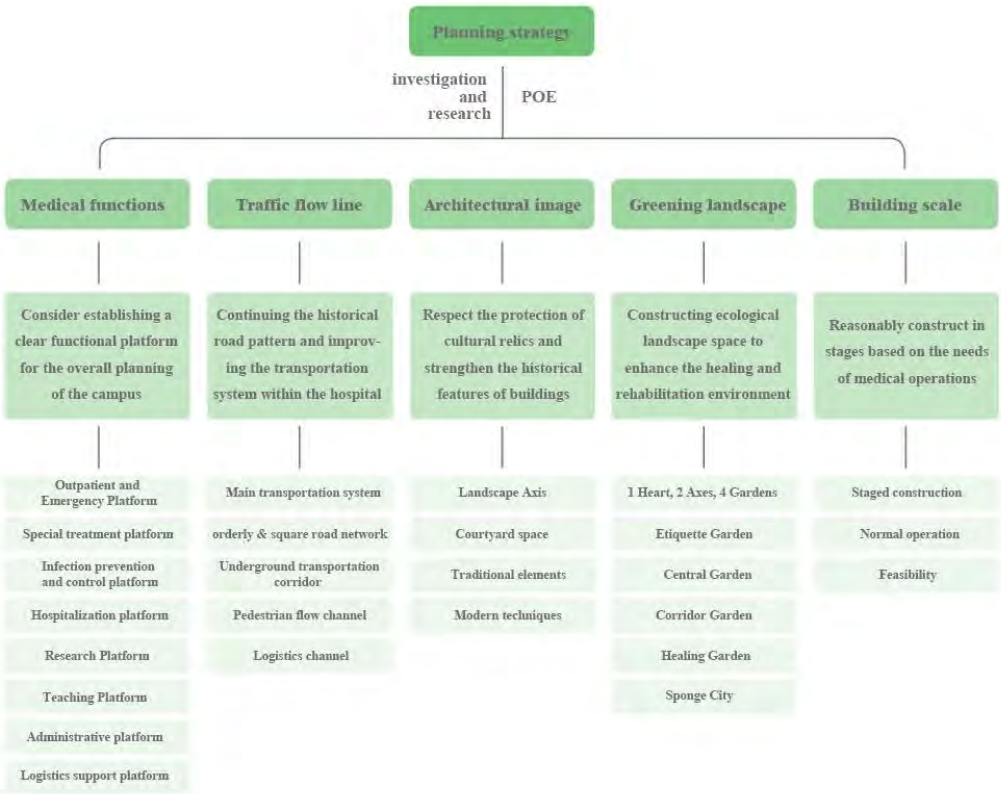


Figure 5. Guidance framework for urban hospital renewal and transformation. Source: HITAD.

3. Project Renewal Strategy

3.1. Establishment of a clear functional organisational platform

The design of the renewal of the existing hospital required a comprehensive review and integration of the hospital's development objectives, the adoption of modern healthcare process concepts(Jonek-Kowalska, 2022), and a systematic reorganization and planning of the entire campus. This process required a careful balance between new and existing functions to optimize the overall layout and facilitate advanced and efficient healthcare workflows. Firstly, a detailed statistical study of the hospital's current building needs was carried out, and the data was then analysed against relevant building and development standards (Figure 6) to accurately determine the functional areas needed to be updated and the corresponding building sizes. A comprehensive assessment was also carried out for old buildings with unsatisfactory general layouts, floor plans and heights, but within their normal life cycle (Figure 7). The comparative analysis shows that demolition and redevelopment of these buildings makes more sense in terms of

optimising workflows and adapting functional layouts, and is more economical in terms of cost control, than retention and refurbishment. It is therefore recommended that a demolition and redevelopment strategy be adopted for these buildings.

Department	The proportion of seven types of rooms to the average floor area per bed	The measure of area		Present situation	Newly build	Total	Difference
		lower limit	upper limit				
Emergency department	3~6	20328	40656	19693	0	19693	635
Outpatient department	12~15	81312	101640	34046.5	0	34046.5	47265.5
Inpatient Department	37~41	250712	277816	121958	85600	207558	43154
Medical Tech Department	25~27	169400	182952	58084	52400	110484	58916
Support system	8~12	54208	81312	30369.5	18629.73	48999.23	5208.77
Business management	3~4	20328	27104	17167	0	17167	3161
In hospital life	3~5	20328	33880	2614	5000	7614	12714
Total	91~110	616616	745360	283932	161629.73	445561.73	171054.27

Sub item	Research, teaching, and training area (5850 beds according to national standards)	Current research and teaching building area								Area of research and teaching rooms in the newly-built comprehensive building	Total	Difference
		13 # Animal Experiment Building	15 # General Practitioner Building	17# Teaching Building	18 # Nursing College	19 # Pharmacy Dept.	20 # First Student Apartment	5 # Fourth inpatient dept. converted into student apartments	Total			
Experiment	55500	10000							10000	4500		
Train	23000	9950	22417	5020	736	7626			45749	2000		
Dormitory	9600						4286	16000	20286			
Total	88100	19950	22417	5020	736	7626	4286	16000	76035	6500	82535	5565

Figure 6. Statistical analysis of area indicators for existing buildings. Source: HITAD.

Figure 7. Functional connection analysis and Demolition and renovation plans. Source: HITAD.

3.2. Preservation and respect for historical heritage

In studying the history of this hospital, we have fund a historically significant central axis in the middle of the site, on which several historic buildings from different periods are landed. So in the master plan, we strengthened this historic axis so that the buildings on the axis form a consistent courtyard.This layout plan provides a better connection between the old buildings and the new ones. At the same time, the heights of the new buildings around the historic buildings are strictly controlled to reduce the impact of the new buildings on the existing environment.

In the design of the outlook of the buildings, we have kept the unity of the old and new buildings in spatial form, building height and appearance. Based on the above preservation strategies, the new

hospital has both historical characteristics and sense of modernity, so that the whole hospital environment presents a natural unity.

3.3. Enhancing the quality of ecological healing environments

In today's global trend towards green hospital design, more and more people are beginning to realise that hospital buildings should be used as an important part of a community's public life(Salehi and Eslami, 2010). Such hospitals are not only medical facilities, but also welcoming urban public spaces where the social atmosphere is effective in reducing patient stress and promoting harmonious community coexistence.

Scholars from different countries have found that the natural landscape can help patients recover from their illness(Reeve, Nieberler-Walker and Desha, 2017; Allahyar and Kazemi, 2021; Wang *et al.*, 2022). Therefore, we have not only built many natural courtyards, but also opened up the hospital's public green space to the city. In this way, we provide opportunities for patients and healthy citizens to communicate freely, which helps their recovery.

In the landscape design of the hospital renewal, we have arranged a number of easily accessible courtyards between the buildings, to provide space for patients and doctors to rest(Figure 8). In addition, we have also developed a rainwater harvesting system with the help of roof structural features, so that the rainwater falls on the roof can be collected in these courtyards. These strategies not only improve the environmental quality, but also respond to the sustainable urban development.

Figure 8. Natural landscape and public open space analysis. Source: HITAD.

3.4. Increasing adaptation to territorial climate

Due to the unique climatic conditions of cold regions(Caili *et al.*, 2024), the scale and spatial layout of hospitals must be designed to be more compact and efficient. It is necessary to use a reasonable spatial layout to withstand bad weather and ensure a pleasant and comfortable space for medical services. Compared with hospitals in other regions, large general hospitals in cold climate regions have more stringent and specific requirements for transformation and future development. In order to effectively address these challenges, a comprehensive analysis of the hospital's outdoor environment was carried out in this study using environmental simulation software(Ries and Mahdavi, 2001; Abaglo, Bonalda and Pertusa, 2017), with the aim of creating a high-quality outdoor space to facilitate the physical and mental rehabilitation of patients (Figure 9).

In addition, in order to reduce the negative impact of extreme winter weather, we designed an innovative underground pedestrian walkway system. This approach significantly improves the efficiency and convenience of daily access for medical staff and patients by connecting all buildings (Figure 10).

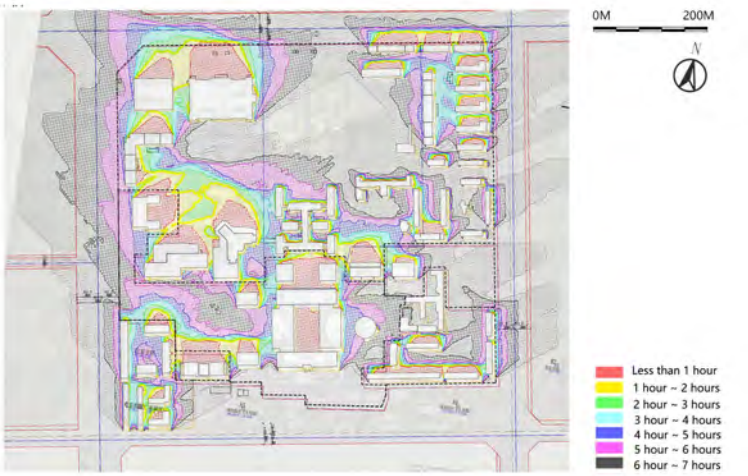


Figure 9. Natural environment modelling analysis. Source: HITAD.

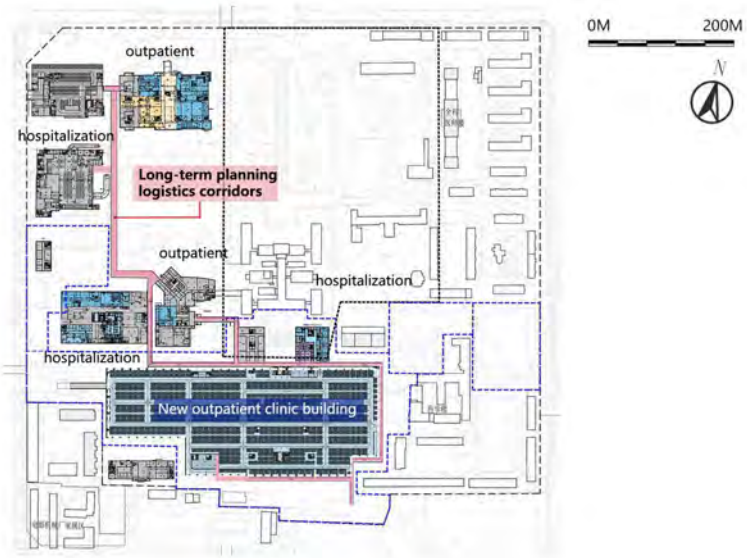


Figure 10. Indoor Underground Pedestrian System. Source: HITAD.

3.5. Developing sustainable development programs

There is a significant difference between updating an existing hospital and building a new one, mainly due to the need to ensure the safe and stable operation of the hospital while achieving hospital renewal. At every stage, the integrity of the hospital's core functions must be strictly maintained to avoid disruption to daily running. During the planning stage, careful strategies are needed to minimise negative impacts such as traffic congestion and noise disturbances during construction. Therefore, the renewal design of the hospital requires a precise phased construction plan.

From the broader perspective of urban sustainability, we have developed a detailed renewal plan to ensure that the hospital continues to contribute to the city. The plan consists of two phases with detailed timelines for new construction, relocation, demolition, and redevelopment (Figure 11). The plan aims to balance the preservation of historic buildings with the current stage of medical needs, taking the city to a higher level of quality and sustainability.

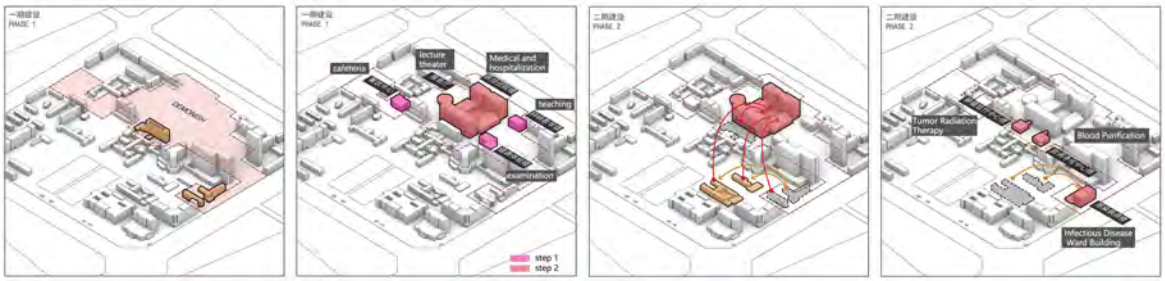


Figure 11. Phased construction plan. Source: HITAD.

4. Discussion

4.1. Summary of Case Characteristics

Guided by this renewal design framework, the proposed design scheme has been successfully completed. The scheme adheres to a human-centred design concept and follows the overall layout principle of "inheriting the essence of the university's culture and integrating the atmosphere of the sunny courtyard," aiming to create a harmonious and symbiotic healing environment. It combines this with the rational spirit of rigor and pragmatism in life sciences, thus achieving a seamless fusion of these two elements.

In the planning layout, the two existing north-south arterial roads were extended into the new site. An east-west road was constructed adjacent to the main entrance on the west side, forming a 'two longitudinal and one horizontal' main road system with the existing ones. This road system effectively connects the existing medical area, the new medical area and the teaching area, forming an efficient traffic network(Figure 12). Sunny and vibrant courtyards have been built between the buildings. These courtyards not only create a positive environment for patients to promote recovery, but also reflect the hospital's humanistic approach(Figure 13).

Figure 12. Master plan of the hospital in the long term. Source: HITAD.

Figure 13. Aerial view of the hospital in the long term. Source: HITAD.

With the help of the project practice, our research has developed a systematic and comprehensive design framework for hospital renewal. This framework has several clear advantages over previous: First of all, it grants equal importance to both the existing layout and the development needs of the hospital. Secondly, by taking patient health needs into account, it enhances the hospital's societal contribution. Thirdly, it improves the environmental quality while preserving the hospital's cultural heritage, so that the hospital can integrate with the current urban environment well. Above all, this design framework has a wide range of applicability and can solve similar design challenges.

4.2. Future prospects

In the following research plan, we hope to use some new quantitative research methods, such as, spatial and temporal big data analysis and spatial behaviour simulation, so that our research will become more scientific. We will also pay more attention to hot issues in urban regeneration such as preservation and usage of cultural heritage, optimisation of building efficiency and improvement of outdoor environmental quality. With all of the above efforts, we hope to enrich the renewal design strategy of existing hospitals in cold cities.

5. Conclusion

General hospitals with a long history have grown along with the city and have made a significant contribution to the city's public health. In the current new wave of urban regeneration, these hospitals are about to enter a new life cycle and become an important part of urban development. It is the responsibility and mission of every architect to improve the quality of hospital buildings through more scientific hospital renewal strategies. We hope that our efforts, combined with the refined hospital management model, will better meet the public's expectations for healthy and efficient healthcare services.

Acknowledgement

This paper is supported by the National Natural Science Foundation of China (52378012),and all project data and images in this article are copyrighted by The Architectural Design and Research Institute of HIT Co., Ltd (HITAD).

6. References

Abaglo, A.J., Bonalda, C. and Pertusa, E. (2017) 'Environmental digital model: Integration of BIM into environmental building simulations', *Energy Procedia*, 122, pp. 1063–1068.

Allahyar, M. and Kazemi, F. (2021) 'Effect of landscape design elements on promoting neuropsychological health of children', *Urban Forestry & Urban Greening*, 65. [online] Available at: https://doi.org/10.1016/j.ufug.2021.127333 (Accessed: 2 September 2021)

Baker, E. et al. (2020) 'New evidence on mental health and housing affordability in cities: A quantile regression approach', *Cities*, 96. [online] Available at: https://doi.org/10.1016/j.cities.2019.102455 (Accessed: 6 September 2019)

Brown, D. (2020) 'The strengths and limitations of using hospital records to assess environmental health in karonga, malawi', *Environment And Urbanization*, 32(1), p. 233–256.

Caili, L. et al. (2024) 'Cold city outdoor space utilisation patterns and constraints: A systematic review of empirical evidence', *Urban Forestry & Urban Greening*, 99. [online] Available at: https://doi.org/10.1016/j.ufug.2024.128439 (Accessed: 17 July 2024)

Castro, M. de F., Mateus, R. and Braganca, L. (2013) 'Indoor and outdoor spaces design quality and its contribution to sustainable hospital buildings', in P. Hajek et al. (eds) *SUSTAINABLE BUILDING AND REFURBISHMENT FOR NEXT GENERATIONS. Conference on Central Europe Towards Sustainable Building (CESB13)*, Prague 6: Czech Technical Univ Prague, pp. 519–522.

Cervinka, R., Roederer, K. and Haemmerle, I. (2014) 'Evaluation of hospital gardens and implications for design: Benefits from environmental psychology for architecture and landscape planning', *Journal of Architectural and Planning Research*, 31(1), pp. 43–56.

Jonek-Kowalska, I. (2022) 'Health care in cities perceived as smart in the context of population aging-a record from poland', *Smart Cities*, 5(4), pp. 1267–1292.

Kara, C. and Bilgic, S. (2021) 'Hospital trip production and attraction modeling for future predictions', *Journal of Urban Planning and Development*, 147(4). [online] Available at: https://doi.org/10.1061/(ASCE)UP.1943-5444.0000754 (Accessed: 13 August 2021)

Lawrence, R.J. (2022) 'Co-benefits of transdisciplinary planning for healthy cities', *URBAN PLANNING*, 7(4), pp. 61–74.

Moscelli, G. et al. (2016) 'Location, quality and choice of hospital: Evidence from England 2002-2013', *Regional Science and Urban Economics*, 60, pp. 112–124.

Musgrove, C.D. (2007) 'Creating a Chinese harbin: Nationalism in an international city, 1916-1932.', *Journal of Urban History*, 33(4), pp. 620–632.

Reeve, A., Nieberler-Walker, K. and Desha, C. (2017) 'Healing gardens in children's hospitals: Reflections on benefits, preferences and design from visitors' books', *Urban Forestry & Urban Greening*, 26, pp. 48–56.

Ries, R. and Mahdavi, A. (2001) 'Evaluation of design performance through regional environmental simulation', in B. DeVries, J. VanLeewuen, and H. Achten (eds) *COMPUTER AIDED ARCHITECTURAL DESIGN FUTURES 2001, PROCEEDINGS. 9th International Conference on Computer Aided Architectural Design Futures 2001*, Dordrecht: Springer, pp. 629–642.

Sabir, B.M. and Mustafa, F.A. (2023) 'Performance-based building design: Impact of emergency department layout on its functional performance efficiency-the case of erbil hospitals', *Open House International-Sustainable & Smart Architecture and Urban Studies*, 48(4), pp. 840–862.

Salehi, F. and Eslami, S.V. (2010) 'Green strategies of healthcare design: Case studies of medical centers', in S. Lehmann, H. AlWaer, and J. AlQawasmi (eds) *Sustainable Architecture and Urban Development (SAUD 2010), VOL III. 2nd International Conference on Sustainable Architecture and Urban Development (SAUD),* Amman: Csaar Press-Center Study Architecture Arab Region, pp. 431–446.

Tajudin, N.F.S.A. and Amat, R.C. (2022) 'The covid-19 pandemic: Impacts on the hospital environment and spatial design', *International Journal of Built Environment and Sustainability*, 9(2–2), pp. 5–14.

Wang, P. et al. (2022) 'Understanding the relationship between small urban parks and mental health: A case study in shanghai, China', *Urban Forestry & Urban Greening*, 78. [online] Available at: https://doi.org/10.1016/j.ufug.2022.127784 (Accessed: 7 November 2022)

Wang, X. et al. (2024) 'The selection of hospital sites and adaptive medical resource planning in the post-COVID era: Navigating public health crises in China?', *Town Planning Review*, 95(5), pp. 505–525.

Wang, Y., Mao, Z. and Wang, D. (2023) 'Housing affordability and mental health in urban China: A cross-sectional study', *Housing Studies*, 38(3), pp. 484–504.

Xie, L. et al. (2016) 'Harbin: A rust belt city revival from its strategic position', *Cities*, 58, pp. 26–38.

Research Paper

Associations between neighborhood built environment and social health among older adults in Harbin, China

Jiahui ZHU, School of Architecture, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Wei DONG, School of Architecture, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Yu DONG, School of Architecture, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Yuelei ZHAO, School of Architecture, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Xiaohan LIANG, School of Architecture, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

Amid rapid urbanization and renewal, community social spaces are being restructured, posing adaptation challenges for the elderly due to physical aging and entrenched beliefs. The decline in social functions and participation exacerbates their social and health risks. It has been shown that community space, as the most frequently used spatial vehicle in the daily lives of older people, has an active intervention value for the physical and mental health of older people, yet fewer studies have discussed the relationship between the built environment and the social health of older residents. The study begins with the social dimension of health and attempts to proactively intervene in the social health crisis of old age from the perspective of the community environment. Combined with the rootedness theory, it reveals the role of the community built environment on the social health of the elderly, and proposes a theoretical model of 'environment-interaction-social health'.

Keywords

Built Environment, Social Health, The Elderly, Impact Relationship, Community, Theoretical Model

1. Introduction

China is one of the most rapidly ageing countries in the world. At the end of 2023, the proportion of older persons aged 65 and above will reach 217 million, accounting for 15.4 percent of the total population. (Wang, 2024). According to the relevant international standards, a moderately ageing society has been entered. However, to date, society has yet to form a relatively comprehensive understanding of the problems and challenges posed by an ageing population and develop mature coping strategies. The elderly population has greater health vulnerability, with a sharp increase in the prevalence of chronic diseases and a significantly higher risk of multiple organ ageing, declining immunity and disability and dementia. In

addition, retirement brings with it the loss of social roles, and the large population movements caused by urban construction and stock renewal destroy native social networks, leaving older people with fewer and fewer 'networks of acquaintances', and a growing sense of isolation and a crisis of social health. Healthy ageing is a common choice of the international community, which requires all subjects to work together for a high quality of ageing in health, dignity, socialisation, sociability, self-fulfilment and access to security to achieve the best results(Wang, 2023)。

Under the long-lasting influence of the family planning policy, the size of families in China has become increasingly small.(Ma, 2023). The average household size in China (mainland) in 2020 will be only 2.62 persons. At present, the elderly often choose to live separately from their younger generation, and the number of 'empty-nest' families is increasing. The role of the family in supporting the elderly has greatly diminished, while the demand for community support has increased significantly. At the same time, the combination of diminishing contact with members of the social network and declining physical and cognitive functioning has led to a reduction in the scope of travelling among older persons. The community becomes the main place for daily activities. In addition to health care coverage, the built environment of the community plays a key role in influencing their daily behaviours and health. A large number of studies have focused on the relationship between the community environment and the impact of physical and mental health of older adults, but more research findings are still needed to examine healthy communities from a social dimension.

2. Literature review

Social health is the same concept as social well-being, which is defined by the World Health Organisation (WHO) as one of the three dimensions of human health, along with physical health and mental health. In 1951, the American sociologist Parson first introduced the concept of social health, which refers to 'the state of the individual in his or her dealings with others and interactions with the social environment' (Parsons, 1951). This requires individuals to have good social adaptability and harmonious social relationships; otherwise, they will not be able to communicate and co-operate smoothly in society, resulting in tensions in interpersonal relationships, which in turn will have an impact on their physical and mental health. In recent years, the fields of sociology, psychology, medicine and behaviour have provided a multidimensional interpretation of social health. A range of concepts such as 'social adaptation, social support, social networks, social participation, social functioning, social integration, social identity, social cohesion, meaningful social contact' have emerged. Actually, social health in a broader sense encompasses both cohesion , mutual trust and support at the collective level, as well as healthy social relationships and interactional behaviours at the individual level. Also, the formation of good social support among individuals will help to promote collective self-identity , providing more possibilities for group social health. (Lin et al., 2016; Dong et al., 2023). This study focuses on the elderly population, that is, the social health at the individual level, which mainly includes two dimensions of individual social function and social relationship (Hahn et al., 2010). It can be understood as the ability to adapt well to the environment, to have harmonious social network relationships and to have the ability to participate in social activities.

Social relations owned by residents are essentially a kind of social resources, which are directly related to their socio-economic status, personality characteristics and living environment. Social adaptability increases with age, and people aged 30-65 tend to have a high level of social health due to their strong adaptability to social participation, career and family life. After retirement, people quickly leave the workplace role, interpersonal activities are greatly reduced, social participation is reduced, and the level of social health tends to decline(Renne, 1974). The loss of social value and the loneliness that comes with shopfronts threaten the physical and mental health of the elderly population, and they need a flexible and

constantly evolving living environment to compensate for these changes. In 2003, Mary E. Northridge and others joined with scholars in the fields of urban planning and public health to summarise the social and environmental factors that influence health, forming a framework for influencing human health and well-being(Figure 1) (Northridge et al., 2003). Considering that the natural environment is a contextual factor that influences the health outcomes of all living things, including urban dwellers. Whereas the built environment (including the artificially created physical environment of buildings, transport systems and development space) is the prospective factor and an important intermediate level factor, and is considered to be the level most vulnerable to active policy intervention. So clarifying the relationship between the built environment and health outcomes is a necessary part of the solution.

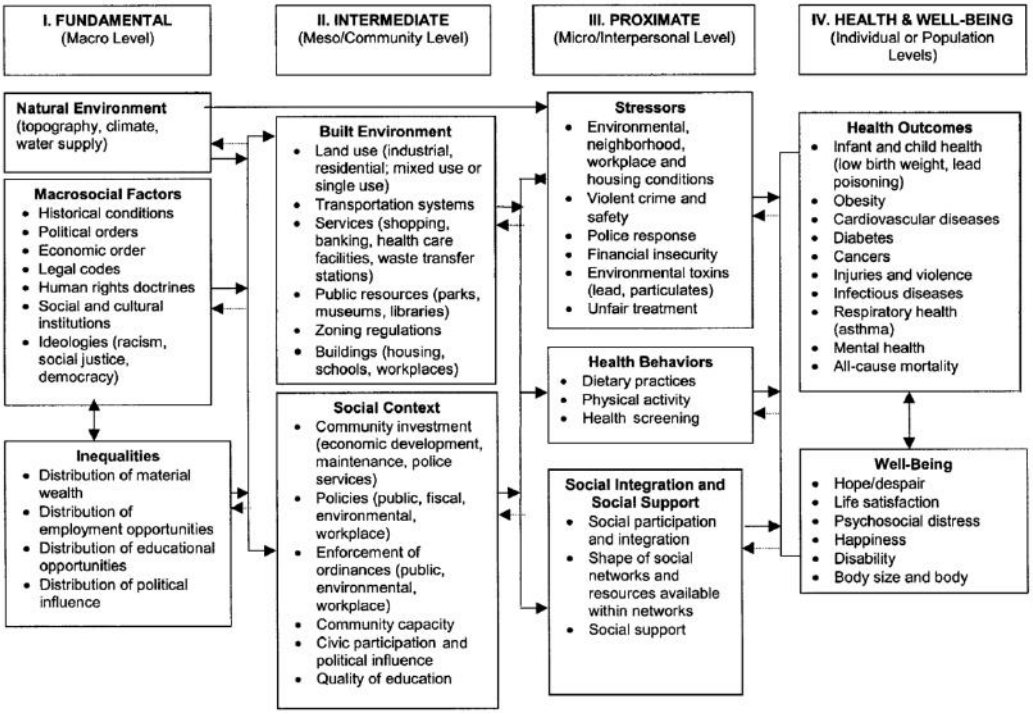


Figure 1 The Social and Environmental Determinants of Health Promotion. Source: Northridge et al., 2003

The community built environment is an important physical spatial vehicle for residents to carry out social activities, which affects the social health of individuals, and the Interactive behaviors generated in space are important influence ways. Residents' daily shallow social interactions and survival necessity behaviours take place mainly in the community and the surrounding places such as shops, supermarkets, food courts, roadside stalls, etc. The number, accessibility, diversity, walkability, and landscape environment of these types of places all have an impact on interaction behaviours and social support(Chen et al., 2020; Yang and Sui, 2021). Libraries, schools, community parks, community centres, etc. are necessary places in the community where collective behaviour takes place, which promotes social cohesion in the community and enhances a friendly atmosphere in the community(Cohen et al., 2008; Mazumdar et al., 2018). Due to the small activity radius of the elderly, a favourable community environment and supportive public resources are conducive to the promotion of physical and social activity among older residents and to the avoidance of social isolation(Levasseur et al., 2015). The built environment can also have an impact on the social health of residents by influencing their subjective perceptions. Perceived good spatial quality of recreational areas, satisfaction with the landscape environment, etc. will to some extent mobilise residents' willingness to travel and provide more opportunities for interpersonal exchanges(Yang and Sui, 2021). A favourable community atmosphere will provide residents with more emotional, informational and

instrumental support, thereby enhancing the sense of community and collective effectiveness. In addition, the equitable distribution of public resources in the community contributes to a more positive social environment, where good norms, order and social consensus are necessary to ensure the sustainability of collective behaviour and contribute to mutual trust and reciprocity among individuals and social groups and to the development of a climate of inclusiveness that fosters community cohesion (Brueckner and Largey, 2008; French et al., 2014).

At present, most of the research focuses on the relationship between the environment and the physical and mental health of the elderly, and the research on the relationship between the built environment and the social connection of the elderly residents is still in its infancy, and most of the research stays in the effect of the open space, public green space, etc. on the social interaction of the crowd, but the deeper mechanism of the role of the mechanism and the path of regulation has not yet been clarified. The reason for this is, on the one hand, the complexity of social health measurement standards and the fact that conceptual definitions and dimensions have not yet been harmonised. On the other hand, most of the studies lack a systematic collation of built environment indicators. Based on the above analyses, this study, on the basis of further clarifying the concept of social health of the elderly population, through in-depth research and analyses, adopts the theory of rootedness, clarifies the system of influencing elements of the built environment of the community, and finally puts forward the theoretical model of 'community environment - social health of the elderly'.

3. Research design

Because of the significant differences between China's socio-cultural background, urban construction methods, and community management modes and those of Western countries, the results related to foreign social health and its environmental influences cannot be fully applied to China's local communities. The study used the data collection method of semi-structured interviews to conduct in-depth interviews with elderly residents in the downtown area of Harbin. Using a combination of transcripts and audio-recorded interviews, based on the theoretical foundations of environmental-behavioural relationship theory, social interaction theory and established research foundations such as the relationship between the environment and social health. The four dimensions of respondents' basic information, perceived community environment, social interaction, and social health were used as entry points for information acquisition. And the three-stage translation and coding using the rootedness theory, to clarify the composition of the community environmental influence elements of the social health of the elderly in the downtown area of Harbin.

3.1. Survey design

Selection of in-depth interview sample areas: The Urban Statistical Yearbook and other relevant data indicate that the proportion of elderly residents in the Harbin metropolitan area will be 25.5 percent at the end of 2022. Considering the location, the built environment, the population base and the distribution of the elderly, the four central urban areas of Daowai, Doli, Xiangfang and Nangang (with the proportion of the elderly population at 30.5%, 28.9%, 26.0% and 23.4% respectively) were selected as the pre-study areas because of their representativeness. First-hand information on the research subjects was obtained through interviews with the residents and relevant workers involved in the region, as well as the collection of relevant policy documents, press releases and statistical yearbooks through the Internet. Based on the pre-survey, the interview sites were finally selected in parks, squares, community micro-activity spaces, green spaces, activity centres, shopping malls, fresh food supermarkets and other places in typical communities in the four urban areas.

Semi-Structured Interview Design: The study focused on the design of the interview outline in terms of four dimensions: respondents' basic information, perceived community environment, social interaction and social health. **Socio-economic Information:** This section mainly relates to the relevant socio-economic characteristics of the respondents and their families. **Perceived Community Environment:** This section includes respondents' perception and evaluation of the multi-dimensional community environment, and the respondents are asked to put forward the environmental factors that will affect the process of going out to communicate (on the way and at the destination), and finally the overall perception of the community environment and suggestions for optimization and improvement. **Social Interaction:** This section explores the law of outdoor interaction activities of the respondents, the characteristics and importance of interaction with different objects. **Social Health:** This dimension mainly includes self-evaluation of respondents' social function and social relationship. Social function includes participation in and satisfaction with social activities. Social relationships, including emotional support, instrumental support, informational support, and companionship.

Table 1. Interview Objectives and Content. Source：Author's own research

Interview Objective	Interview Content	
Socio-economic Information	Personal Attributes	Age, education level, pre-retirement occupation, economic income, health status, etc.
	Household and Community Attributes	Residential neighborhood, length of residence, living arrangements (family members), household responsibilities, etc.
Perceived Community Environment	Activity Venues	Most frequented social activity venues, variety and accessibility of venues, etc.
	Community Environment	Walkability, housing conditions, public transportation facilities, service facilities, public spaces, environmental safety and comfort, etc.
	Spatial Quality	Green spaces, sanitation, seating availability, accessibility facilities, etc.
Social Interaction	Types of Social Activities	Content and preferences, reasons for preferences, travel modes, travel needs, etc.
	Social Interaction and Perception	Modes, frequency, satisfaction, and importance of interactions with family, relatives or friends, neighbors, and service providers.
Social Health	Social Function	Participation in social activities (family events, recreational activities, interactions with friends, etc.) and satisfaction with social activities (household chores, helping friends, handling daily affairs, etc.).
	Social Relationship	Emotional support (trusted confidants, feeling valued, etc.), instrumental support (caregiving, accompanying to medical visits, errands, etc.), informational support (help with problem-solving, provision of important and useful advice, etc.), companionship (people to enjoy entertainment and relaxation with, etc.).

Interviewer training: Conduct professional training for the interviewers to ensure that the core meaning of the interviewers remains unchanged during the interview process, and obtain sample data flexibly.

3.2. Methods

Grounded theory is one of the most scientific methodologies through the qualitative approach to theory building. Theories constructed through standardized and rigorous research procedures are firmly rooted in empirical data, and their research can be retroactively examined and even repeated to a considerable extent. Therefore, it is also considered to be the most suitable method for theoretical construction among

traditional sociological research methods(Jia and Tan, 2010). This study mainly draws on the coding construction logic of grounded theory, and uses the coding analysis to analyze the factors affecting the social health environment of the elderly.

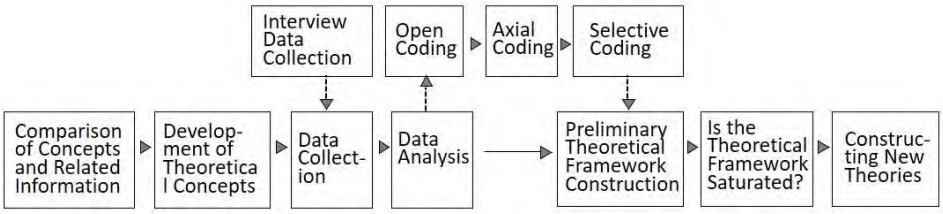


Figure 2 Analytical Approach Based on Grounded Theory Source: Author's own research

The textual information collected from the interviews was coded and analysed using NVivo11 to extract the core content, to further accurately interpret the connotation of social health of the elderly residents and its environmental impact elements, and to determine the relationship among them.(Figure 2).

3.3. Data collection

In-depth interviews were conducted in accordance with the principle of theoretical saturation, starting with the selection of a typical community in each of the four urban areas of the centre as a research unit, and the random sampling of research subjects within the unit. Then the sample data is coded and analyzed, and the next research unit is interviewed according to the analysis results, and the interview is stopped until there are no new concepts. Each interviewee was interviewed for 10-30 minutes. The researchers asked and interacted with the interviewees to different degrees according to their answers. The whole process was recorded with the consent of the interviewees.

4. Relationship between the neighborhood environment and elderly social health

Based on the above research ideas, the interview research was conducted from 18 December 2023 to 25 January 2024, and a total of 28 respondents were interviewed (Table 2). The total interview time was 7 hours and 46 minutes, with an average interview time of 16 minutes and 39 seconds per respondent. The entire audio file was transcribed into the corresponding textual material, resulting in a 106,000-word transcript.

Table 2. Demographic Information of Semi-Structured Interview Respondents. Source: Author's own research

No.	Gender	Age	District	Length of Residence (Years)	Living Arrangement	Recording Duration (min: sec)
F1	Female	81	Xiangfang	5	With grandchildren	17:36
F2	Female	84	Xiangfang	5	Alone	10:45
F3	Female	74	Xiangfang	4	Alone	19:13
F4	Female	83	Xiangfang	4	Alone	18:18
F5	Female	72	Xiangfang	15	Alone	13:31
F6	Female	71	Nangang	9	With spouse	17:39
F7	Female	80	Nangang	23	With children	12:20
F8	Female	76	Nangang	20	With children and grandchildren	11:38
F9	Female	68	Nangang	22	With spouse	21:52
F10	Female	69	Nangang	1	With spouse	15:51
F11	Female	67	Daoli	12	With spouse	10:42
F12	Female	72	Daoli	30	With spouse	13:21

No.	Gender	Age	District	Length of Residence (Years)	Living Arrangement	Recording Duration (min：sec)
F13	Female	72	Daoli	3	With Spouse and grandchildren	16:58
F14	Male	70	Xiangfang	3	With spouse	16:19
F15	Male	65	Nangang	6	With spouse, children, and grandchildren	13:07
F16	Male	85	Nangang	26	With Spouse and grandchildren	24:45
F17	Male	84	Nangang	9	Alone	21:49
F18	Male	76	Nangang	21	With spouse	24:00
F19	Male	66	Daowai	60	With spouse, children, and grandchildren	26:11
F20	Male	68	Daowai	16	With spouse	16:14
F21	Male	63	Daowai	20	With spouse	17:06
F22	Male	68	Daoli	11	With spouse	16:20
F23	Male	73	Daoli	3	With spouse	17:34
F24	Male	75	Daoli	20	With mother	13:44
F25	Male	65	Daoli	12	With spouse	11:48
F26	Male	79	Daoli	10	With spouse	16:14
F27	Male	61	Daoli	5	With spouse, children, and grandchildren	11:23
F28	Male	75	Daoli	10	With spouse	19:55

4.1. Open coding

Open coding encompasses conceptualization and preliminary categorization. It involves analyzing the collected data to identify key concepts and categories through textual analysis. By systematically examining and comparing the data, the content is categorized and named, revealing the underlying concepts to accurately reflect the material's essence. These abstracted concepts are then employed to present the data effectively.

Table 3. Examples of Open Coding Analysis(Only selected content is presented). Source： Author's own research

Original Interview Text (28 interview recordings)	Labeling **a** (1,091 labels)	Preliminary Conceptualization **A** （175 concepts）
I live by myself, but when my granddaughter comes back, I stay with her. (F1-1) My daughter lives close by, and my kids and granddaughter usually drop by two or three times a week. (F1-2) Sometimes, my daughter helps me with the cleaning. (F1-3) I chat a lot with my kids on WeChat; we mostly just message each other whenever something comes up. (F1-4) …… In our neighborhood, we all go out for walks together regularly. Whether it's summer or winter, we like to stroll around the yard. (F1-5) We don't go to the park or the square because it's too far and the air isn't great there. It's way better here; the environment is nice, and it really keeps us healthy. (F1-6) In the winter, we don't go out much, but in the summer, we can walk further, like down to the ecological park where there's a place called Dai Xiu Lake Park. (F1-7) We usually just walk around close by. We hang out in the yard for about half an hour, not going too far, and we don't bother taking a car. (F1-8) We don't even use our senior cards; why would we need to take the bus? Everything we need is nearby, and that big supermarket is super close. (F1-9) At our age, why keep taking the bus? What if we trip or fall? It just doesn't make sense, right? (F1-10)	a1 Living with granddaughter a2 Frequency of interaction with children a3 Children helping with household chores a4 Frequent online socializing a5 Activities in the community yard a6 Community environment evaluation a7 Parks and squares a8 Generally enjoy walking a9 Commercial facilities and nearby neighborhoods a10 Concern for safety	A1 Living Arrangement (a1…) A2 Intergenerational interaction (a2, a3…) A3 Online Socializing (a4…) A4 Outdoor Social Activities (a5, a7, a8, a9…) A5 Perception of Community Environment (a6) A6 Community Service Facilities (a7, a9…) A7 Preferences of Elderly Individuals (a10, …)

Initially, a labeling approach was employed to abstract and extract interview data, summarizing the material sentence by sentence and assigning labels using Ax (1,091 instances in total). These labels were then categorized, named, and conceptually refined, resulting in preliminary conceptual coding represented by Ax (175 instances). Finally, through clustering and categorization, relationships among concepts were identified, leading to the formation of categories represented by AAx (26 instances). Examples of the open coding process are presented in Tables 3 and 4.

Table 4. Examples of Open Coding Categorization. Source：Author's own research

Category (AA)	Corresponding Concept (A)
Activity Facilities	Parks, squares, senior activity centers, community activity rooms, community canteens, senior universities, accessibility and diversity of facilities, etc.
Commercial Facilities	Morning and night markets, farmers' markets, restaurants, supermarkets, shopping malls, convenience stores, etc.
Service Facilities	Banks, senior universities, community clinics, hospitals, etc.
Public Transportation	Buses, subways
Walking Environment	Sidewalks, connectivity, parked vehicles, speed safety.
Spatial Quality	Landscape, fitness facilities, safety, environmental hygiene, benches, accessibility facilities, facility maintenance, satisfaction with outdoor spaces.
Housing Conditions	New /old neighborhoods, community demographic composition, length of residence, multi-story/high-rise neighborhoods.
Community Atmosphere	Familiarity/unfamiliarity among neighbors, mutual assistance, reciprocity, friendliness, alienation, stress
Living Arrangement	Living alone, with a spouse, with children, with grandchildren, with three generations.
Community Management	Property management, neighborhood renovation, gated management.
Intergenerational Interaction	Interaction with children/ grandchildren/ other relatives, family activities.
Like-minded Interaction	Former colleagues, walking buddies, sports partners/card friends, confidants, trusted individuals, old friends, mutual assistance, gatherings, interaction frequency, phone contacts, satisfaction with friendships.
Neighbor Interaction	Casual acquaintances, chance encounters, frequent chatting, traveling together, interaction frequency, familiarity among neighbors in older neighborhoods, satisfaction with neighbor relationships
Service Interaction	Shopping, vendors, banking services, business ownership, re-employment after retirement.
Other Outdoor Social Activities	Playing cards, mahjong, dancing, singing, swimming by the river, ball sports, photography, playing chess, watching the lively scene.
Ability to Participate	Engaging in social activities, leisure and entertainment, doing household chores, daily work, friend activities.
Satisfaction with Participation	Household skills, helping friends, managing daily affairs, entertainment.
Emotional Support	Confiding, trust, appreciation, comfort.
Instrumental Support	Care during illness, accompanying to medical appointments, helping with household chores, running errands.
Informational Support	Crisis advice, problem-solving, information needs, important matters.
Companionship	Enjoying entertainment/ relaxing together, companionship.
Daily Behavior Preferences	Enjoy walking, prefer strolling alone, online socializing/shopping, slow to accept new things, content mindset, emphasize customs and traditions.
Preference for Solitude	Enjoy being alone, prefer quiet, reading the news, reading poetry, strong self-care ability when living alone, not fond of visiting others.
Impact of Work Experience	Served in the countryside, historical background, worker, employee community, professor, campus experience, etc.
Personal Characteristics	Age, gender, profession before retirement, education, health.
Socioeconomic Characteristics	Monthly income, community, religious beliefs, etc.

4.2. Axial coding

Axial coding identifies core categories by examining the underlying relationships between various categories based on theoretical frameworks. This process establishes hierarchical relationships, summarizing core categories and their subcategories. In this study, the analysis of 26 categories revealed

six main categories: **Perceived built environment, Perceived social environment, Social interaction, Social health, Preferences of the elderly, and Individual and socioeconomic characteristics.** Table 5 presents these main categories along with their corresponding subcategories and specific meanings.

Table 5. Main Categories and the Corresponding Subcategories. Source: Author's own research

Main Categories (AAA)	Subcategories (AA)	Connotations
Perceived Built Environment	Activity Facilities	Subjective evaluation of recreational facilities frequently utilized in the community and surrounding areas.
	Commercial Facilities	Subjective evaluation of commercial establishments frequently utilized in the community and surrounding areas.
	Service Facilities	Subjective evaluation of other essential service facilities frequently utilized in the community and surrounding areas.
	Public Transportation	Subjective evaluation of daily public transportation usage.
	Walking Environment	Subjective evaluation of environments involved in daily walking activities.
	Spatial Quality	Subjective evaluation of outdoor environments and public resource utilization within the community.
Perceived Social Environment	Housing Conditions	Subjective evaluation of current housing and residential community.
	Community Atmosphere	Subjective assessment of neighborly relations within the current living environment.
	Living Arrangement	Objective description of cohabiting family members.
	Community Management	Subjective evaluation of community operations and management.
Social Interaction	Intergenerational Interaction	Interaction behaviors with immediate and extended family members.
	Like-minded Interaction	Interaction behaviors with peers who share similar interests.
	Neighbor Interaction	Interaction behaviors among residents within the same community.
	Service Interaction	Interaction behaviors occurring during daily contact with service personnel.
	Other Outdoor Social Activities	Interaction behaviors for leisure and entertainment purposes.
Social Health	Ability to Participate	Perceived ability to engage in social activities.
	Satisfaction with Participation	Level of satisfaction regarding one's capability to participate in activities.
	Emotional Support	The experience of being valued and cared for.
	Instrumental Support	Assistance received in completing daily tasks.
	Informational Support	Access to useful advice and information.
	Companionship	Having individuals to enjoy pleasant social activities with.
Preferences of the Elderly	Daily Behavior Preferences	Stable behavioral tendencies or preferences exhibited by elderly individuals in daily life.
	Preference for Solitude	The tendency among certain elderly individuals to minimize external interactions.
	Impact of Work Experience	Influence of past life and work experiences on social relationships and behavioral preferences.
Individual and Socioeconomic Characteristics	Personal Characteristics	Self-awareness and evaluation of individual attributes.
	Socioeconomic Characteristics	Objective assessment of one's socioeconomic conditions.

4.3. Selective coding

Selective coding identifies core categories and their relational structures. Using theoretical foundations and empirical data, the researcher discerns core categories from primary categories, interpreting their logical relationships through an overarching "storyline." This storyline reflects the researcher's analysis of the data, clarifying the interconnections among the main categories. An in-depth analysis of the 26 categories and 6 main categories, along with a thorough review of the original text and field survey data, led to the development of a core model for the elderly: "Community Built Environment-Interactive Behavior-Social Health"(Figure 3).

Main Implications of the Model: The model highlights that the community built environment, encompassing both physical and social elements, shapes individuals' perceptions. Through various interactions—such as intergenerational, neighborly, and service-related—individuals engage with the objective built environment, influencing their perceptions and, in turn, affecting multiple dimensions of social health among the elderly. Socioeconomic characteristics and personal preferences also play a significant role, influencing all pathways based on individual attributes and life experiences. This variability is reflected in the diverse perspectives expressed by respondents during interviews.

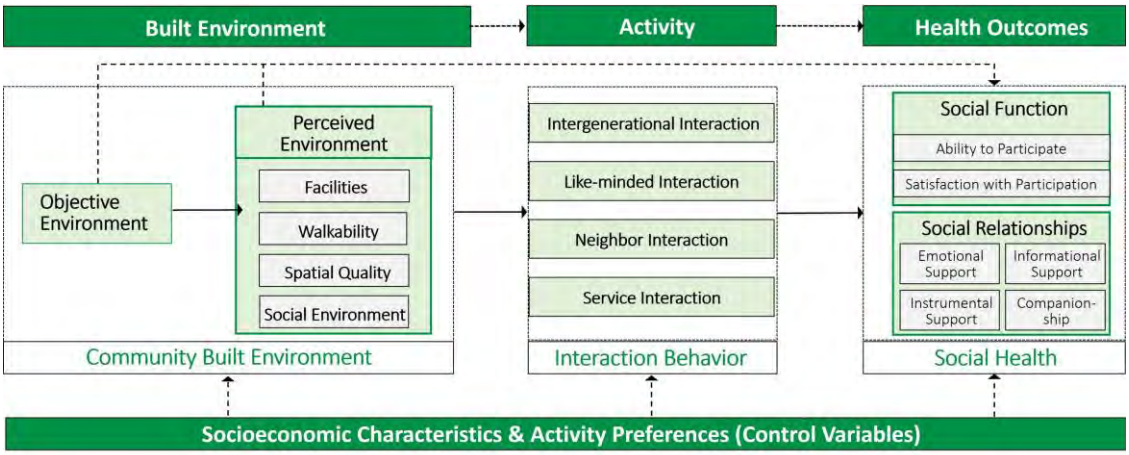


Figure3. Core Model of "Community Built Environment-Interactive Behavior-Social Health."

Source: Author's own research

4.4. Key findings

Based on the analysis and relevant theoretical insights, factors affecting the social health of elderly residents can be divided into two main categories: community built environment elements and social interaction factors.

Community facilities are the factors of the physical space. In summary, the use of high-frequency activity places for elderly residents is very obvious, and most communications occur in shopping scenes and leisure scenes. The top five most frequently used activity places in daily life are 1) morning and night markets, mobile vendors, and farmers' markets; 2) retail stores such as convenience stores/fruit and vegetable stores; 3) parks and squares; 4) community centers/senior activity centers; and 5) large shopping malls. The number, convenience, service, consumption and richness of these facilities are the main factors affecting the social interaction and social health of the elderly. The existence of these facilities will increase the opportunities for social interaction among elderly residents, and the attraction attached to the functional attributes of the facilities themselves will also encourage communication among residents. Through contact, a large amount of social support will be obtained, which will be beneficial to social health(Dong et al., 2023). At the same time, older residents like to patronise more familiar and safer activity venues, which have a stronger 'stickiness', and older people with the same behavioural preferences will form a relatively fixed 'circle of interaction', which will provide them with more opportunities for chatting and bonding.

In addition to the attraction of social places, **the community walking environment** is also an important factor affecting the physical space, which includes good destination accessibility and walkability. Previous studies have confirmed that there is a significant positive correlation between destination walkability and social cohesion(Jun and Hur, 2015; Moogoor et al., 2022). Similarly, this study found that more pedestrian-friendly, better-connected neighborhoods were more likely to increase neighborhood knowledge and

social engagement. This is especially true for the older population. Older people are more likely than younger people to travel on foot, tend to walk for exercise as their main leisure activity, and use walking spaces near their homes more frequently. As such, building age-friendly walking environments is an important part of enhancing the health of our society.

Spatial quality is also an important environmental factor. Landscape, safety and comfort, hygiene, and barrier-free design are all elements of the environment that are of particular concern to older residents in their leisure interactions. A higher quality community outdoor environment or neighborhood green space will enhance people's willingness to meet friends, enjoy fitness and recreation. Compared with ordinary people, the activity radius of the elderly is smaller, and the dependence on the community and surrounding environment and resources is stronger. For wheelchair users and people with mobility problems such as those with sequelae of cardiovascular disease, better accessibility in the community can provide opportunities for independent travel. Convenient, safe, comfortable, aesthetical, and enriched community built environments are important factors in encouraging inter-age and inter-generational interactions among older adults(Moogoor et al., 2022; Zhang and Yao, 2022).

The social environment elements are non-physical soft environmental elements. These mainly involve housing conditions, community atmosphere, living style, community management services and so on. In recent years, the housing reform and urban renewal have caused a large number of urban residents to move, which has a certain impact on the original geographical stability of social relations. Closed residential areas and apartment-style houses have reduced the opportunities for neighborhood communication to some extent. In this case, the abundance of amenities and activity options offered by urban communities creates opportunities for contact, thus easing neighborhood strangeness. A friendly community atmosphere and high quality management services will enhance residents' sense of community belonging and cohesion. Where and how older people live, such as whether they live with or near their children, will directly affect their social support and social networks.

Social interaction is an intermediate factor between community environment and social health outcomes. Whether people want emotional or instrumental social support, it is achieved through the act of interacting with others. In terms of deep interaction, older persons interact most frequently with family members, followed by familiar neighbors. The level of interaction with relatives and friends is mostly 1-3 times a year, mainly at parties. The average length and importance of interactions for most older people was ranked in order of family, relatives, friends and classmates. Shallow interactions, however, tended to be with pleasant neighbors, casual friends and service personnel. According to statistics, the interaction behavior of the elderly mostly stems from social needs with emotion and belonging. Different needs and preferences will stimulate different types of communications and correspond to different objects. Based on the existing research and analysis, we believe that the interaction of the elderly can be divided into four categories according to the objects of communication: **Like-minded Interaction** (leisure and entertainment, community participation and continuing education), **Intergenerational Interaction** with family, **Neighbor Interaction** (neighborhood pleasantries, chats, and mutual assistance), and **Service Interaction** with staff at the service place.

In addition to the above-mentioned core factors, there are still other factors affecting the social health of the elderly. Such as whether residents use online platforms for social, online communication frequency , adult children's economic status, religious beliefs, etc. Although these impact can hardly be ignored, the focus of this study is to explore the mechanism of the impact of community built environment on the social health of the elderly, so the factors with weak connection are not included in our model.

5. Conclusions

Starting from the social dimension of health, this study aims to improve the age friendliness and inclusiveness of the built environment in the community, explore the relevant influencing factors and clarify the paths. Primary data was collected in the form of in-depth interviews, coded using grounded theory methodology, and data was analysed using NVivo software. Six core categories were identified: perceived built environment, perceived social environment, social interaction, social health, elderly preferences, and individual and socioeconomic characteristics. Additionally, 26 subcategories were identified, including activity and commercial facilities, walkability, spatial quality, community atmosphere, and intergenerational interaction. These formed a comprehensive framework of factors influencing elderly social health within the community environment. This framework highlights critical environmental factors affecting elderly social health and offers targeted strategies for community planning and renewal that promote healthy aging. Although this study provides qualitative results, future research will explore quantitative analysis of environmental factor weights and their influence pathways.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Acknowledgements

This study is funded by the National Natural Science Foundation of China under the programme 'Study on built environment elements and planning regulation mechanism to promote community social health' (Grant No.5227080991).

6. References

Brueckner, J. K. and Largey, A. G. (2008) 'Social interaction and urban sprawl', *Journal of Urban Economics*, 64(1), pp. 18–34.

Chen, C., Zhang, N. and Yu, L. (2020) 'The levels of social interaction among the elderly and the reconstruction of the built environment in communities', *Urban Development Studies*, 27(4), pp. 30–42.

Cohen, D. A., Inagami, S. and Finch, B. (2008) 'The built environment and collective efficacy', *Health & Place*, 14(2), pp. 198–208.

Dong W., Zhu J. H. and Li H. Z. (2023) 'The influence of community built environment on social health: review and enlightenment', *Shanghai Urban Planning Review*, (3), pp. 1–7.

French, S., Wood, L., Foster, S. A., et al. (2014) 'Sense of community and its association with the neighborhood built environment', *Environment and Behavior*, 46(6), pp. 677–697.

Hahn, E. A., Devellis, R. F., Bode, R. K., et al. (2010) 'Measuring social health in the patient-reported outcomes measurement information system (PROMIS): item bank development and testing', *Quality of Life Research: An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation*, 19(7), pp. 1035–1044.

Jia X. D. and Tan X. H. (2010) 'The classical grounded theory and its relevance to Chinese management research', *Chinese Journal of Management*, 7(5), pp. 656–665.

Jun, H. J. and Hur, M. (2015) 'The relationship between walkability and neighborhood social environment: the importance of physical and perceived walkability', *Applied Geography*, 62, August, pp. 115–124.

Levasseur, M., Cohen, A. A., Dubois, M.-F., et al. (2015) 'Environmental factors associated with social participation of older adults living in metropolitan, urban, and rural areas: The NuAge Study', *American Journal of Public Health*, 105(8), pp. 1718–1725.

Lin, Y., Zhang, Q., Chen, W., et al. (2016) 'Association between social integration and health among internal migrants in ZhongShan, China', *PLOS ONE*, 11(2), e0148397.

Ma, G. Q. (2023) 'Changes in contemporary Chinese families: characteristics, trends, and prospects', *Population Research*, 47(1), pp. 43–57.

Mazumdar, S., Learnihan, V., Cochrane, T. et al. (2018) 'The built environment and social capital: a systematic review', *Environment and Behavior*, 50(2), pp. 119–158.

Moogoor, A., Močnik, Š. and Yuen, B. (2022) 'Neighbourhood environmental influences on older adults' physical activities and social participation in Singapore: A photovoice study', *Social Science & Medicine*, 310, October, 115288.

Northridge, M. E., Sclar, E. D. et al. (2003) 'Sorting out the connections between the built environment and health: a conceptual framework for navigating pathways and planning healthy cities', *Journal of Urban Health: Bulletin of the New York Academy of Medicine*, 80(4), pp. 556–568.

Renne, K. S. (1974) 'Measurement of social health in a general population survey', *Social Science Research*, 3(1), pp. 25–44.

Wang, P. P. (2024) 'Wang Pingping: The total population has declined, and high-quality population development has achieved results', *National Bureau of Statistics*. [Online]. Available at: https://www.stats.gov.cn/xxgk/jd/sjjd2020/202401/t20240118_1946711.html. (Accessed: 8 October 2024)

Wang, Y. L. (2023) *A study on the social activities of the elderly in China and their influence*. PhD dissertation. Jilin University.

Yang, D. F. and Sui, X. (2021) 'Identification and optimization strategies of residential environment elements for social support of the elderly: a perspective based on perception survey', *Urban Development Studies*, 28(3), pp. 123–132.

Zhang, Y. and Yao, E. (2022) 'Exploring elderly people's daily time-use patterns in the living environment of Beijing, China', *Cities*, 129, October, 103838.

Research Paper

Built environment and social health of the elderly in Harbin:

A comparative study of communities built before and after housing reform

Jiahui ZHU, School of Architecture, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Wei DONG, School of Architecture, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Yu DONG, School of Architecture, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Jingwen LIANG, School of Architecture, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

China's housing reform and urban renewal have changed the spatial structure and social relations of urban communities, and the original ties between people and places have gradually dissolved, with the elderly facing more adjustment difficulties in the new environment. Taking Harbin, China as an example, this study focuses on the work-unit community and commercial housing community built before and after the housing reform, compares the basic characteristics of the two environment and elderly residents, and impacts on the social health of the elderly. The results showed that there were significant differences in environmental perception and social health between them. In terms of the influence relationship, the accessibility of facilities such as parks, supermarkets and public canteens has a significant positive impact on the social functioning level of the elderly, while the accessibility of medical facilities, retail stores and bus stops has a significant positive impact on the social support. A safe and smooth walking environment is more beneficial for the elderly to obtain social support. The proportion of the elderly, the level of community service, community cohesion and community type are all important factors affecting the social health. The two types of communities should formulate refined development strategies based on different environmental characteristics and population attributes, so as to enhance the sense of social integration and overall happiness of elderly residents.

Keywords

Built Environment, Social Health, the elderly, Impact Relationship, Community, Harbin

1. Introduction

China is entering an aging society at the fastest rate in history, and by 2027, China will transform from an 'aging' society to an 'aged' society, and the promotion of healthy aging has become an urgent task and a serious challenge for national development and construction. Ageing causes changes in the physical and mental aspects of the human body, which in turn leads to a slight deterioration in hearing, vision, dexterity, agility and memory, thus increasing the health vulnerability of the older population. At the same time, the contact between retired older people and their social networks gradually decreases, and the combination

of these factors leads to a narrowing of the scope of travelling, with the community becoming the main place for their daily activities (Huang et al., 2019). Under the influence of rapid urbanisation and housing reforms, the construction patterns， demographic and environment changes have led to huge changes in the original social space and sense of identity that residents had established with their ‘place’ (Cheng and Li, 2022). Older people face more difficulties in adjusting to this rapidly changing environment.

The community environments are important in facilitating social interactions and enhancing the quality of life and social health of older adults (Small and Adler, 2019). With the increase of age, the health and cognitive level of the elderly are gradually declining, and the degree of social adaptation and participation is deteriorating. The need to adjust emotions, improve health and relieve loneliness through social activities is increasing. In addition to the medical and health field, the built environment in the community has a great influence on its daily behavior and quality of life(Rosso et al., 2011; Huang et al., 2019; Dong et al., 2021; Moogoor et al., 2022; Zhang and Yao, 2022). Integrating resources at the community level and exploring ways to optimise the environment for older people's living, travelling, healthcare and nourishment to create a safe, convenient, comfortable and barrier-free livable environment for older people is an urgent issue under the goal of active ageing.(National Health Commission of the People’s Republic of China, 2019)

2. Literature review

Social health is one of the three dimensions of health defined by the World Health Organisation, which requires people to adapt to social life, play social roles and perform social functions effectively(Dong et al., 2023). The social health of an individual is closely related to the level of education, social culture, family, career and relationships, and is a higher level of health status based on physical and mental health. Studies have shown that people who are better integrated into the community tend to live longer and have stronger resilience when encountering accidents such as diseases. The stress buffering model suggests that the supportive strengths provided by social relationships buffer the negative effects of stress on health.The main effects model also proposes that social relationships confer richer roles and meaning to people's lives, thus encouraging healthy behaviours (Holt-Lunstad et al., 2010). In contrast, social isolation is a significant risk factor for the disease and has even surpassed other risk factors such as physical inactivity and obesity(Holt-Lunstad et al., 2010, 2015). Exposure to loneliness can be seen as a social form of ‘pain’ with a significant impact on well-being. Throughout the life course, older age is characterised by a higher risk of social isolation and greater health vulnerability(Svensson et al., 2022).

Urban communities are integrated spatial vehicles for the daily lives and social interactions of older persons. The overall character of China's social transformation over the past three decades can be summarised by the shift from the ‘unit state’ to the ‘community state’. This transformation does not only mean a shift in living space, but also a transformation of social composition and interaction, and a transformation of the social governance system(Zhao and Hu, 2009). Harbin, as a city with a long history, has a large number of old unit communities. These communities are mainly the products of settlements formed under the First and Second Five-Year Plans in the course of industrialisation, and are used to house workers and their families, with obvious unit and historical features. Most of the residents of the community work in the same organisation and have experienced the development of the community together. This long-term experience creates a deep emotional bond between neighbours, based on which a good neighbourhood atmosphere is formed. After the housing reform, a large number of closed commercial housing have been built rapidly. These residential areas often emphasize the safety and environmental grade unilaterally in isolation, but bring other harms.such as the disruption of the spatial hierarchy, lossing control at various scales and the destruction of native human-land relationships(Zhao

and Hu, 2009). Living in unfamiliar and unsafe environments affects older people's willingness to get out and may make them more vulnerable to loneliness and depression(Svensson et al., 2022; Zhang and Yao, 2022). Therefore, it is crucial to study the social health of elderly residents in the community and the patterns of influence of the community environment on them in the context of different periods of time, in order to implement targeted planning interventions for age-friendly communitys.

The community environment provides many of the essential elements for social connections for older residents. Well-developed transport offers more possibilities to get around and visit friends and relatives, while homes, restaurants, libraries, parks, fitness trails, fairs, etc. provide more opportunities for encounters and interactions(Small and Adler, 2019). It has also been found that places with more pedestrian-friendly environments provide more opportunities for beneficial or unintentional interactions for community members, as well as more mobility possibilities and social connections for people with disabilities(Kwon et al., 2017; Pfeiffer et al., 2020; Kim et al., 2024). Neighborhood green space can improve the mental health and social participation through the sense of place experience in public space(Enssle and Kabisch, 2020). However, public space design details, such as safety hazards like pavement obstructions and poorly maintained fitness facilities, can discourage older people from outdoor activities, whereas high-quality leisure environments that are both comfortable and pleasing are more conducive to mobilising willingness to travel(Kweon et al., 1998; Dong et al., 2020; Enssle and Kabisch, 2020). It is clear that the social health of older people is closely related to the multiple built environments in the community, but it is not yet possible to determine the relationship between the different dimensions of the built environment and social health.

Based on the above analyses, this study is oriented towards social health, with older people as the main body, and by analysing the built environment and social health of older people in the two types of communities formed before and after the housing reform. Identifying relevant environmental indicators and revealing patterns of influence in order to clarify the differences and commonalities between different types of communities in their social health support systems for older persons. To help develop more accurate age-friendly planning intervention strategies and build a more inclusive community environment.

3. Methods

3.1. Data collection

The study selected 14 representative communities in the central urban area of Harbin, including 7 old unit-based communities (built before 2000) and 7 new commercial housing communities (built after 2000). The questionnaire scale was designed with 5-level Likert scale method. Questionnaire interviews were conducted in the field with randomly selected older residents aged 60 years and above, specifically focusing on the evaluation of the multidimensional community environment representations proposed above, social interaction preferences, and social health(from the PROMIS Adult Self-Reported Social Health scale (v2.0), including the core dimensions of social function and social relationship)(Hahn et al., 2010, 2014) and information on the socioeconomic attributes of the older adults interviewed. The number of questionnaires in each community was basically limited to about 30 to ensure a reasonable sample distribution.

The research team carried out the questionnaire distribution work in April-July 2024, and finally 440 questionnaires were recovered, 21 incomplete and untrue questionnaires were excluded, and finally 419 valid questionnaires were obtained, with a valid recovery rate of 95.23%. The respondents included 246 female older persons (58.7%) and 173 male older persons (41.3%) (Table 1).

More than half of the respondents have an education level of junior high school and below, and most of their incomes are clustered between 2,000 and 5,000 yuan. 71.1 percent of the elderly choose to live with their spouses or children, while 17.9 percent live alone.

Table 1. Socio-demographics of respondents (N = 419). Source：Author's own research

Variable	Category	Number	Proportion (%)	Variable	Category	Number	Proportion (%)
Gender	Female	246	58.7	Education Level	Primary school and below	103	24.6
	Male	173	41.3		Middle school	154	36.8
Age	60-64	94	22.4		High school	110	26.3
	65-69	108	25.8		College	36	8.6
	70-74	93	22.2		Bachelor's degree and over	16	3.8
	75-79	69	16.5				
	⩾80	55	13.1	Living Arrangement	Alone	75	17.9
Pension Income	Below 2k	79	18.9		With spouse	226	53.9
	2k-5k	256	61.1		With children	73	17.4
	5k-10k	81	19.3		With spouse and children	41	9.8
	10k-30k	3	0.7		Other	4	1.0

3.2. Data analysis

Factor Analysis. In order to avoid the problem of possible covariance between the variables, the data analysis stage began with an exploratory factor analysis of each dimension of the community environment factor, the essence of which is to find as many composite variables as possible that reflect the original information and are independent of each other. The results are shown in Table 2 and the KMO (Kaiser-Meyer-Olkin) values indicate that the use of factor analysis is appropriate. The cumulative variance contribution of the factors indicates that the new variables reflect the information of the original variables better. Factor loadings were generated using principal component analysis and varimax rotation, while factors with factor loadings less than 0.5 were excluded(Hu et al., 2021).

Multiple Regression Analysis. The common factor obtained from the above exploratory factor analysis was used as the independent variable, and the six sub-dimensions of social health level were used as the dependent variables. Controlling for socio-economic characteristics such as age, education level, pre-retirement occupation, residence mode, monthly income, online social frequency and physical limitation status, multiple linear regression analyses were conducted, and a total of six models were obtained for the influence of community environment on the dimensions of social participation, satisfaction, emotional support, instrumental support, informational support, and companionship (Model 1–6). The value of R^2 in the model shows an acceptable model fit and the results of regression analysis are shown in Tables 5 and 6.

4. Results

4.1. Characteristics of the community environment

Based on the results of factor analysis and multiple linear regression, three key dimensions of the community environment were identified: facility, spatial design, and social environment. 14 secondary factors such as small commercial facilities, outdoor activity facilities, environmental quality, walkability, and community cohesion and 42 tertiary factors were recognized（Table 3）.

Table 2. Factor Analysis of community environment. Source: Author's own research

Community Environment	Common Factor	Dimension	Indicator	Factor Loading
Facilities	X1	Small Commercial Facilities	Number of restaurants	0.829
			Accessibility of restaurants	0.779
			Number of pharmacies/clinics	0.679
			Accessibility of convenience stores	0.632
			Accessibility of pharmacies/clinics	0.619
			Number of convenience stores	0.605
	X2	Outdoor Activity Facilities	Number of squares	0.831
			Number of parks	0.811
			Accessibility of parks	0.774
			Accessibility of squares	0.773
	X3	Financial Service Facilities	Accessibility of banks/post offices	0.863
			Number of banks/post offices	0.836
	X4	Indoor Activity Facilities	Accessibility of activity centers/rooms	0.870
			Number of activity centers/rooms	0.853
	X5	Public Transport Facilities	Number of bus stops	0.841
			Accessibility of bus stops	0.812
	X6	Comprehensive Commercial Facilities	Accessibility of supermarkets	0.917
			Number of supermarkets	0.890
	X7	Public Canteens	Accessibility of public canteens	0.928
			Number of public canteens	0.923
	KMO		0.719	
	Cumulative Explained Variance/%		79.44%	
Spatial Design	X1	Environmental Quality	Regular maintenance	0.782
			Rest facilities	0.697
			Fitness facilities	0.681
			Landscape	0.639
			Barrier-free facilities	0.630
			Housing quality	0.628
			Lighting	0.592
			Sanitation	0.515
	X2	Park and Square Design	Activity facilities	0.882
			Infrastructure	0.840
			Greenery	0.830
	X3	Walkability	Street connectivity	0.821
			Pedestrian infrastructure	0.796
			Safety and smoothness	0.509
	KMO		0.885	
	Cumulative Explained Variance/%		63.44%	
Social Environment	X1	Community Cohesion	Neighborhood trust	0.924
			Neighborhood atmosphere	0.889
			Neighborhood identity	0.848
	X2	Community Services	Community organizations or activities	0.872
			Property management	0.772
	X3	Population Structure	Proportion of elderly population	0.783
	KMO		0.706	
	Cumulative Explained Variance/%		79.72%	

Note: Principal component analysis was used for factor extraction, with orthogonal rotation using Kaiser normalization. Factors with loadings below 0.5 were excluded.

Table 3. Comparison of the two types of community environments. Source: Author's own research

	Old work-unit communities (n=209)		New commercial communities (n=210)		Independent t-Test	
Community Environment	Mean	S.D.	Mean	S.D.	t 值	Sig. (2-tailed)
Facilities						
Parks No. (Number)	3.78	1.083	2.77	1.262	8.778	0.000***
Squares No.	3.64	1.18	3.28	1.22	3.114	0.002***
Convenience Stores No.	4.32	0.886	4.23	0.93	0.931	0.352
Supermarkets No.	3.28	1.38	2.66	1.22	4.903	0.000***
Restaurants No.	4.15	0.928	4.09	1.01	0.712	0.477
Activity Centers No.	2.05	1.28	2.27	1.35	-1.707	0.089*
Public Canteens No.	1.10	0.326	1.29	0.78	-3.260	0.001***
Pharmacies/Clinics No.	3.96	1.06	4.05	0.83	-0.974	0.331
Banks/Post Offices No.	3.69	1.127	3.57	1.04	1.198	0.232
Bus Stops No.	4.14	1.01	3.86	0.74	3.296	0.001***
Parks Access	3.79	1.033	2.96	1.33	7.167	0.000***
Squares Access	3.92	1.10	3.74	1.18	1.618	0.106
Convenience Access	4.28	0.909	4.17	0.86	1.281	0.201
Supermarkets Access	3.12	1.44	2.56	1.23	4.349	0.000***
Restaurants Access	4.17	0.933	4.03	1.03	1.446	0.149
Activity Centers Access	2.18	1.43	2.51	1.53	-2.261	0.024**
Public Canteens Access	1.16	0.587	1.39	0.92	-3.017	0.003***
Pharmacies/Clinics Access	3.96	1.07	4.02	0.89	-0.596	0.551
Banks/Post Offices Access	3.62	1.215	3.47	1.13	1.353	0.177
Bus Stops Access	4.00	1.13	3.83	0.82	1.725	0.085*
Overall Facility satisfaction	3.79	0.680	3.53	0.73	3.796	0.000***
Spatial Design						
Park/Square Greenery	3.85	0.76	3.39	1.12	4.904	0.000***
Park/Square Activity facilities	3.66	0.835	3.19	1.08	5.047	0.000***
Park/Square Infrastructure	3.66	0.78	3.33	1.02	3.700	0.000***
Pedestrian infrastructure	3.70	0.797	3.73	0.82	-0.440	0.660
Street connectivity	3.99	0.76	4.01	0.71	-0.333	0.739
Safety and smoothness	3.42	0.99	3.30	1.08	1.197	0.232
Lighting	3.70	1.074	3.80	1.17	-0.882	0.378
Rest facilities	3.38	1.18	3.26	1.19	1.099	0.273
Fitness facilities	3.48	1.29	3.11	1.04	3.188	0.002***
Regular maintenance	2.64	1.36	2.78	1.12	-1.152	0.250
Barrier-free facilities	2.05	0.903	2.60	1.17	-5.396	0.000***
Housing quality	3.14	1.05	3.42	0.89	-2.940	0.003***
Landscape	3.40	1.08	3.45	1.07	-0.479	0.632
Sanitation	3.45	1.147	3.37	1.13	0.703	0.483
Social Environment						
Proportion of the elderly	4.29	0.74	4.30	0.84	-0.167	0.868
Community organizations or activities	2.06	0.97	2.04	0.98	0.203	0.839
Neighborhood atmosphere	3.74	0.941	3.81	0.77	-0.808	0.420
Neighborhood trust	3.75	0.93	3.61	0.79	1.570	0.117
Neighborhood identity	3.66	1.07	3.54	0.85	1.246	0.213
Property management	2.60	1.312	2.82	1.03	-1.957	0.051*

***p < 0.1, **p < 0.05, ***p < 0.01.**

According to the statistics, in terms of the facilities, both types of neighbourhoods demonstrate a high abundance and good accessibility of retail shops, medical facilities and public transport facilities (average score above 4). However, it is worth noting that both types of communities are notably lacking in facilities such as activity centres and communal canteens, a finding that contrasts with the high demand for such facilities among the older resident groups. By further comparing the differences, the old communities show obvious advantages in the number and accessibility of parks and supermarkets, and the rich Settings of square space and bus stops contribute to their high overall facility satisfaction. This suggests that, despite aging infrastructure, older communities maintain unique strengths in the layout of amenities that enhance daily leisure and shopping convenience. In contrast, new residential communities excelled in the number and accessibility of activity centers and public canteens, likely reflecting forward-thinking planning that addressed residents' diverse lifestyle needs.

In terms of public space design, new residential communities demonstrate a more pedestrian-friendly design, with superior housing quality compared to old work-unit communities, providing safer and more convenient mobility for elderly residents, especially those with limited mobility. In contrast, old work-unit communities excel in green space layout and recreational facilities, offering a rich environment for leisure and fitness, reflecting a long-term commitment to improving residents' quality of life. Both types exhibit good street connectivity, but they lack sufficient barrier-free design and regular maintenance of outdoor facilities.

Additionally, In the social environment, elderly residents perceived a higher proportion of older populations generally, reflecting the broader trend of societal aging. Old work-unit communities, with their historical background and close-knit structure, demonstrated higher levels of neighborhood trust and cohesion, though not statistically significant, offering insights into social capital accumulation across different community types. New residential communities, with modern management and efficient operations, excelled in property management. However, both types show potential for improvement in community vitality and resident engagement.

4.2. Characteristics of social health of the elderly

Elderly residents in both community types reported higher levels of instrumental and informational support (above 50 points), surpassing emotional support and companionship. This may be attributed to family, neighborly help, community services, or government policies that address practical challenges and information gaps. Work-unit communities showed higher social participation, with stronger perceptions of

Table 4. Comparison of social health evaluation results. Source: Author's own research

	Old work-unit communities（n=209）		New commercial communities（n=210）		Independent t-Test	
Social health	Mean	S.D.	Mean	S.D.	t 值	Sig.(2-tailed)
Social Function						
Ability to Participate	48.55	6.11	47.91	5.52	1.14	0.256
Satisfaction with Participation	48.68	4.91	48.39	5.08	0.61	0.543
Social Relationships						
Emotional Support	47.67	6.34	47.00	6.00	1.10	0.272
Instrumental Support	52.62	5.99	54.36	6.33	-2.89	0.004***
Informational Support	52.99	6.23	54.48	6.46	-2.41	0.017**
Companionship	47.98	7.06	47.48	6.38	0.77	0.443

***p < 0.1, **p < 0.05, ***p < 0.01.**

emotional support and companionship, though no significant intergroup differences were found. However, instrumental and informational support was significantly higher in newly developed commercial housing, likely due to better facilities and more efficient management systems(Table 4).

4.3. Effect of neighbourhood characteristics on social health

Community facilities. In terms of facilities, the study selected the number and accessibility of facilities to characterise the abundance and convenience of facility provision. We found that the number of parks, restaurants, and bus stops around the community had a significant impact on both social health dimensions, social function and social relationships; It is worth exploring whether too many of these facilities can have a negative impact on instrumental support or informational support. It may be that because settlements accompanied by a large number of parks, restaurants and other amenities in the surrounding area will attract a large number of people who are not from their own neighbourhoods, with a high level of disruption and safety concerns for the senior population, they will avoid moving around in densely populated areas. More bus stops will provide easier travelling conditions, with more choices to travel and a wider range of activities, which will promote older people's participation in activities.

Accessibility to parks, hypermarkets, and public canteens has a significant positive effect on the level of social function only; Older residents who have better access to parks are more likely to engage in recreational behaviours such as walking and talking in parks, as well as forming relatively fixed ‘circles’ of interaction, thus receiving more instrumental support; Settlements close to large supermarkets tend to be in relatively busy and convenient, with more opportunities for socialising; The availability of public canteens is a strong attraction for elderly residents, who are willing to eat there, and many of them eat regularly in groups, resulting in a better satisfaction of social participation.

The number of pharmacies or clinics, accessibility to stores and bus stops have a significant positive effect on social support, and overall facility satisfaction also has some positive effect on residents' social support. That easy access to public transport contributes significantly to all four types of social support. Older adults in neighbourhoods with better retail accessibility and higher facility satisfaction tend to have more instrumental support. That is, they often have trusted people to help them with errands, chores and care.

Spatial desigh. The design of public spaces, walking environments, and spatial quality influence the social relationships of the elderly significantly. The safe and smooth walking environment has the strongest positive influence on social support. In contrast, public spaces with better infrastructure tend to offer lower levels of emotional and informational support, as such spaces are typically found in newer residential areas with weaker neighborly ties. However, housing quality, landscaping, and sanitation have a positive effect on social relationships, as higher environmental quality encourages the elderly to engage in outdoor activities, providing more opportunities for social interaction and fostering friendships.

Social environment. The social environment significantly influences the social health of the elderly. Key factors include the proportion of elderly residents, community services, cohesion, and community type. Communities with a higher elderly population see greater social participation, as members of the same age group share common interests and concerns, which facilitates lasting friendships. Frequent community activities and a welcoming atmosphere enhance community identity, providing emotional support and companionship, and preventing social isolation, which improves social health. However, property management shows a negative correlation with social health: older communities with less effective management often foster closer neighborly ties, while newer communities with better management tend to have more distant relationships among residents.

Sociodemographic characteristics. The study found that advancing age has a negative effect on the participation in social activities among older people, but due to physical limitations, older people tend to

receive more attention or be cared for by their loved ones. In terms of literacy, people with bachelor's degrees tend to be supported by more tools as they have a greater knowledge base and more technical types of occupations. Those who are self-employed had lower levels of social participation because they spend a great deal of their time in the shops they operate, taking up time and energy for other social participation.

In terms of mode of residence, those living with couple or children have better social health than those living alone. In terms of income, seniors at higher income levels (more than 5k yuan per month) also have better social health. People with limited outdoor walking, public transport and interactions tend to have significant negative impacts on their social functioning. In terms of online social, the elderly who do not use the Internet and those who use online social interaction many times a week have a better level of social activities. The former prefers face-to-face communication, while the latter communicates with relatives and friends because of making good use of the Internet.

In addition, in terms of community types, the level of tool support and information support for the elderly in the newly-built commercial housing community is higher than that in the old unit. They generally have a good economic foundation, and most of them live in husband and wife, or go to their children's residence to help look after their grandchildren, so they will be more likely to get advice and help from their relatives when they are in trouble.

5. Discussion and conclusion

Amid rapid urban and community changes, the social health challenges of the elderly require attention. This study, using survey data, highlights differences in the built environment and social health between communities developed before and after housing reform. Factor analysis and multiple regression identify key environmental factors influencing elderly social health, including facility quantity and accessibility, walking conditions, public space design, and the social environment. Overall, elderly residents in older work-unit communities perceive stronger neighborhood trust and sense of belonging, with better facilities. However, community services and spatial quality still require improvement. In contrast, commercial housing communities offer more comprehensive services, property management, and user-friendly designs, providing greater instrumental and informational support. However, neighborly relationships tend to be weaker, highlighting the need for a warmer environment. To address the diverse spatial resources and heterogeneous needs, various renewal strategies are necessary to create more elderly-friendly community environments.

This study is , of course, limited by the subjectivity of data collection, and the scientific rigor of the scales and questionnaires can still be further improved. Future research should focus on the following areas, with an emphasis on the social dimensions of healthy cities. First, the interaction effects between different aspects of the built environment on social health need further investigation. For instance, activity spaces may mitigate the impact of spatial proximity. Moreover, the influence of various spatial design elements on social relationships may not be independent, highlighting the need for a comprehensive analysis of multiple dimensions of the built environment to better understand these complex interactions. Second, it is important to explore the marginal utility of the built environment on social health. Some studies suggest that factors like population density may have threshold effects on social activities. Understanding these nonlinear relationships can lead to more targeted and practical strategies. Finally, future research should explore these dynamics across various population groups and cultural contexts.

Table 5. Associations between community environment and elderly individuals' social health (Model 1 - Model 3). Source: Author's own research

Variable		Model 1		Model 2		Model 3	
		R2	0.510	R2	0.593	R2	0.468
		B	S.E.	B	S.E.	B	S.E.
Constant		32.834***	4.230	41.579***	3.312	18.704***	4.674
Number of facilities	Park	-0.687**	0.339	-0.658**	0.265	-0.498	0.374
	Plaza	0.163	0.346	-0.079	0.271	-0.307	0.382
	Convenience store	-0.735	0.486	-0.015	0.381	-0.559	0.538
	Mall/supermarket	-0.341	0.343	0.180	0.269	0.665*	0.379
	Restaurant	-0.914**	0.424	-0.244	0.333	-0.536	0.468
	Active center	-0.045	0.409	-0.549*	0.320	-0.043	0.452
	Public canteen	-0.378	0.668	-0.190	0.524	0.404	0.738
	Clinic/Pharmacy	0.702	0.439	-0.391	0.344	0.418	0.485
	Bank/Post Office	0.488	0.403	0.395	0.316	0.092	0.446
	Bus station	0.889**	0.422	0.497	0.332	0.173	0.466
Accessibility of facilities	Park	0.599*	0.340	0.710***	0.266	0.423	0.375
	Plaza	-0.074	0.331	-0.128	0.259	-0.026	0.366
	Convenience store	0.422	0.472	0.331	0.370	0.173	0.522
	Mall/supermarket	0.875***	0.338	0.243	0.265	0.032	0.374
	Restaurant	0.504	0.390	-0.181	0.307	0.449	0.431
	Active center	-0.265	0.356	0.041	0.279	-0.204	0.393
	Public canteen	1.169**	0.547	0.726*	0.430	0.159	0.605
	Clinic/Pharmacy	0.049	0.423	0.485	0.332	-0.133	0.467
	Bank/Post Office	-0.386	0.374	-0.322	0.294	0.066	0.413
	Bus station	-0.259	0.393	0.346	0.309	1.230***	0.434
	Overall satisfaction	0.494	0.453	0.278	0.357	0.120	0.501
Open space design	Afforestation	0.374	0.460	0.295	0.362	0.875*	0.509
	Activity facility	0.43	0.449	0.185	0.352	-0.164	0.496
	Infrastructure	0.419	0.462	-0.263	0.362	-0.900*	0.510
Walkability	Pedestrian infrastructure	-0.159	0.412	0.269	0.323	0.163	0.456
	Street connectivity	0.466	0.429	0.101	0.336	-0.056	0.474
	Safety leveling	-0.267	0.350	-0.228	0.274	-0.052	0.387
Environmental quality	Lighting	0.217	0.296	-0.213	0.232	-0.156	0.327
	Rest facilities	-0.227	0.363	-0.160	0.286	0.509	0.401
	Fitness facilities	-0.109	0.352	0.188	0.277	-0.003	0.390
	Regular maintenance	0.563*	0.288	0.259	0.226	-0.091	0.318
	Barrier-free facilities	-0.181	0.294	0.330	0.230	0.079	0.325
	Housing quality	-0.221	0.297	0.244	0.233	0.238	0.328
	Landscape	0.386	0.359	0.057	0.281	-0.060	0.397
	Sanitary	-0.203	0.304	-0.179	0.239	0.730***	0.336
Pop. Structure	Old population proportion	0.699***	0.352	0.083	0.276	0.042	0.389
Community service	Organizations/Activities	0.492*	0.288	0.227	0.226	0.517	0.319
	Property management	-1.064***	0.317	0.259	0.249	-0.373	0.350
Community cohesion	Neighborhood Atmosphere	0.365	0.477	0.537	0.377	1.379***	0.527
	Trust	0.396	0.504	0.310	0.395	0.076	0.556
	Community identity	0.415	0.392	0.140	0.308	0.852	0.434
Age		-0.043	0.040	-0.091***	0.031	0.096**	0.044
Education Level	Primary School or Below	0.000	--	0.000	--	0.000	--
	Junior High School	-0.647	0.706	0.015	0.553	0.933	0.780
	Senior High School / Technical School	0.35	0.832	0.160	0.652	1.811**	0.919
	Junior College	0.019	1.232	-0.250	0.966	1.561	1.362
	Bachelor's Degree or Above	1.614	1.451	1.832	1.138	2.117	1.603
Pre-retirement occupation	Management Staff of Enterprises	0.000	--	0.000	--	0.000	--
	Government Staff	-0.504	1.092	-1.626*	0.855	-2.618**	1.206

Variable		Model 1		Model 2		Model 3	
		B	S.E.	B	S.E.	B	S.E.
	Professional Staff (Doctors, Teachers, Lawyers, etc.)	-0.802	0.878	-1.066	0.688	-1.679*	0.970
	Self-employed	-2.226*	1.259	-0.962	0.986	0.043	1.391
	Commercial/Service Industry Workers	0.017	1.128	-0.784	0.884	-0.560	1.247
	Migrant Workers	-0.247	1.024	-0.447	0.802	-0.637	1.132
	Unemployed	-0.01	1.544	-0.623	1.209	-1.612	1.706
	Other Occupations	-1.07	1.538	-3.105***	1.204	-2.867*	1.699
Living Arrangement	Alone	0.000	--	0.000	--	0.000	--
	With Spouse	0.939	0.704	0.687	0.552	2.824***	0.778
	With Children	-0.044	0.811	1.633**	0.635	2.343***	0.896
	With Spouse and Children	0.73	1.012	0.983	0.792	3.309***	1.118
	Other	3.933	2.504	3.820*	1.961	-2.008	2.767
Monthly Income(Pension)	Below 2k	0.000	--	0.000	--	0.000	--
	2k-5k	0.741	0.790	0.563	0.619	-0.086	0.873
	5k-10k	-0.052	1.077	1.115	0.846	1.015	1.190
	10k-30k	6.623*	2.939	1.518	2.302	2.073	3.248
Online Social Frequency	Never	0.000	--	0.000	--	0.000	--
	Rarely	0.661	0.837	1.434**	0.659	-0.438	0.925
	Once a Month	0.543	1.597	1.300	1.251	-3.915**	1.764
	Weekly or More Frequently	1.062	0.738	1.145**	0.578	0.295	0.816
Physical Limitations	Limited Outdoor Walking	-3.585***	1.091	-2.623***	0.855	-0.327	1.205
	Limited Use of Public Transport	-2.57***	0.928	-2.202***	0.728	-1.937*	1.026
	Limited Outdoor Socializing	-0.5	1.333	-3.714***	1.044	-0.452	1.473
Length of Residence		0.016	0.020	0.003	0.016	0.044*	0.022
Community Type		0.942	0.686	0.104	0.538	0.534	0.758

***p<0.1(weak correlation), **p<0.05(moderate correlation), ***p<0.01(strong correlation)**

Table 6. Associations between community environment and elderly individuals' social health (Model 4 - Model 6). Source: Author's own research

Variable		Model 4		Model 5		Model 6	
		R2	0.405	R2	0.408	R2	0.501
		B	S.E.	B	S.E.	B	S.E.
Constant		36.971***	4.969	34.798***	5.103	19.189***	4.929
Number of facilities	Park	-0.681**	0.398	-0.810**	0.408	-0.069	0.395
	Plaza	-0.160	0.406	-0.514	0.417	-0.286	0.403
	Convenience store	-0.615	0.571	-1.099*	0.587	-0.378	0.567
	Mall/supermarket	-0.123	0.403	0.581	0.414	0.409	0.400
	Restaurant	-0.732	0.498	-1.252**	0.511	-0.119	0.494
	Active center	-0.054	0.480	-0.459	0.493	-0.580	0.476
	Public canteen	0.147	0.785	-0.167	0.806	0.819	0.778
	Clinic/Pharmacy	0.195	0.516	-0.131	0.529	1.038**	0.511
	Bank/Post Office	-0.459	0.474	-0.563	0.487	-0.329	0.470
	Bus station	-0.819*	0.496	-1.066**	0.509	0.147	0.492
Accessibility of facilities	Park	0.671*	0.399	0.331	0.410	0.318	0.396
	Plaza	-0.527	0.389	-0.238	0.399	-0.110	0.386
	Convenience store	1.183**	0.555	0.924	0.570	-0.199	0.550
	Mall/supermarket	0.406	0.397	-0.229	0.408	0.047	0.394
	Restaurant	-0.161	0.458	0.187	0.471	0.180	0.455
	Active center	0.029	0.418	0.032	0.430	0.170	0.415
	Public canteen	-0.623	0.643	0.420	0.660	-0.138	0.637
	Clinic/Pharmacy	-0.813	0.497	-0.034	0.510	-0.600	0.493
	Bank/Post Office	0.518	0.440	0.338	0.451	0.380	0.436
	Bus station	1.149**	0.462	1.555***	0.474	1.533***	0.458
	Overall satisfaction	1.279**	0.532	0.638	0.546	0.539	0.528

Variable		Model 4		Model 5		Model 6	
		B	S.E.	B	S.E.	B	S.E.
Open space design	Afforestation	-0.476	0.541	0.254	0.555	0.997*	0.536
	Activity facility	0.686	0.527	0.597	0.542	-0.523	0.523
	Infrastructure	-0.761	0.543	-1.109**	0.557	-0.808	0.538
Walkability	Pedestrian infrastructure	0.303	0.485	0.232	0.498	0.476	0.481
	Street connectivity	-0.581	0.504	-0.061	0.517	-0.188	0.500
	Safety leveling	0.671	0.411	1.173***	0.422	0.277	0.408
Environmental quality	Lighting	-0.055	0.347	0.333	0.357	-0.076	0.344
	Rest facilities	0.277	0.427	0.531	0.438	0.616	0.423
	Fitness facilities	-0.266	0.414	-0.149	0.425	-0.219	0.411
	Regular maintenance	0.166	0.338	0.082	0.347	0.065	0.335
	Barrier-free facilities	-0.647*	0.345	-0.496	0.354	-0.345	0.342
	Housing quality	0.451	0.349	0.870**	0.359	0.033	0.346
	Landscape	0.899**	0.422	0.329	0.433	0.635	0.418
	Sanitary	0.091	0.358	0.489	0.367	-0.113	0.355
Pop. Structure	Old population proportion	0.267	0.414	0.044	0.425	0.146	0.411
Community service	Organizations/Activities	-0.159	0.339	0.125	0.348	0.663**	0.336
	Property management	-1.072***	0.372	-1.034***	0.382	-0.440	0.369
Community cohesion	Neighborhood Atmosphere	0.586	0.560	0.836	0.575	0.456	0.556
	Trust	-0.278	0.591	-0.101	0.607	0.714	0.587
	Community identity	0.347	0.461	0.384	0.473	0.900**	0.457
Age		0.089*	0.047	0.120**	0.048	0.068	0.046
Education Level	Primary School or Below	0.000	--	0.000	--	0.000	--
	Junior High School	1.333	0.829	0.065	0.852	0.823	0.823
	Senior High School / Technical School	1.356	0.977	0.767	1.004	1.486	0.969
	Junior College	1.644	1.448	0.739	1.487	1.014	1.436
	Bachelor's Degree or Above	3.390**	1.705	2.100	1.750	1.784	1.691
Pre-retirement occupation	Management Staff of Enterprises	0.000	--	0.000	--	0.000	--
	Government Staff	-1.643	1.283	-2.642**	1.317	-3.610***	1.272
	Professional Staff (Doctors, Teachers, Lawyers, etc.)	-1.273	1.031	-1.080	1.059	-2.055**	1.023
	Self-employed	2.271	1.479	1.385	1.518	-0.025	1.467
	Commercial/Service Industry Workers	0.948	1.326	-0.946	1.361	-1.167	1.315
	Migrant Workers	1.667	1.203	1.298	1.235	0.375	1.193
	Unemployed	-1.656	1.814	-2.710	1.863	-2.127	1.799
	Other Occupations	-0.244	1.806	-2.245	1.855	-2.239	1.792
Living Arrangement	Alone	0.000	--	0.000	--	0.000	--
	With Spouse	4.354***	0.827	2.302***	0.849	2.265***	0.820
	With Children	6.774***	0.953	5.377***	0.978	2.109**	0.945
	With Spouse and Children	5.712***	1.189	4.320***	1.221	2.741**	1.179
	Other	-0.084	2.942	0.451	3.021	-2.671	2.918
Monthly Income(Pension)	Below 2k	0.000	--	0.000	--	0.000	--
	2k-5k	0.281	0.928	0.853	0.953	0.194	0.921
	5k-10k	2.730**	1.265	2.818**	1.299	1.271	1.255
	10k-30k	0.906	3.453	4.472	3.546	6.684	3.425
Online Social Frequency	Never	0.000	--	0.000	--	0.000	--
	Rarely	1.152	0.983	0.938	1.010	0.870	0.975
	Once a Month	-0.051	1.876	-0.678	1.926	-3.826**	1.860
	Weekly or More Frequently	0.468	0.867	0.203	0.890	1.104	0.860
Physical Limitations	Limited Outdoor Walking	-0.044	1.281	-0.353	1.316	-1.718	1.271
	Limited Use of Public Transport	0.261	1.090	-1.674	1.120	-1.859*	1.082
	Limited Outdoor Socializing	0.062	1.566	0.680	1.608	-2.167	1.553
Length of Residence		-0.009	0.024	-0.007	0.024	0.039*	0.024
Community Type		2.338***	0.806	1.365*	0.827	1.194	0.799

***p<0.1(weak correlation), **p<0.05(moderate correlation), ***p<0.01(strong correlation)**

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve language. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Acknowledgements

This study is funded by the National Natural Science Foundation of China under the programme 'Study on built environment elements and planning regulation mechanism to promote community social health' (Grant No.5227080991).

6. References

Cheng, P. H. and Li, Z. G. (2022) 'A review of international literature on the impacts of neighborhood changes upon residents' health', *Urban Planning International*, 37(5), pp. 98–106.

Dong, W., Chen, S. Y. and Dong, Y. (2021) 'Research progress on factors affecting the mobility of elderly people's living spaces', *Science & Technology Review*, 39(8), pp. 26–35.

Dong, W., Zhu, J. H. and Li, H. Z. (2023) 'The influence of community built environment on social health: review and enlightenment', *Shanghai Urban Planning Review*, (3), pp. 1–7.

Dong, Y. P., Liu, H. L. and Qi, J. (2020) 'Progress of studies on the relationship between urban green space and public health', *Urban Planning International*, 35(5), pp. 70–79.

Enssle, F. and Kabisch, N. (2020) 'Urban green spaces for the social interaction, health and well-being of older people— an integrated view of urban ecosystem services and socio-environmental justice', *Environmental Science & Policy*, 109, July, pp. 36–44.

Hahn, E. A., Devellis, R. F., Bode, R. K., et al. (2010) 'Measuring social health in the patient-reported outcomes measurement information system (PROMIS): item bank development and testing', *Quality of Life Research: An International Journal of Quality of Life Aspects of Treatment, Care and Rehabilitation*, 19(7), pp. 1035–1044.

Hahn, E. A., DeWalt, D. A., Bode, R. K., et al. (2014) 'New English and Spanish social health measures will facilitate evaluating health determinants', *Health Psychology*, 33(5), pp. 490–499.

Holt-Lunstad, J., Smith, T. B., Baker, M., et al. (2015) 'Loneliness and social isolation as risk factors for mortality: a meta-analytic review', *Perspectives on Psychological Science: A Journal of the Association for Psychological Science*, 10(2), pp. 227–237.

Holt-Lunstad, J., Smith, T. B. and Layton, J. B. (2010) 'Social relationships and mortality risk: a meta-analytic review', *PLOS Medicine*, 7(7), e1000316.

Hu, Y. T., Yu, Y. F. and Zhang, Q. L. (2021) 'Urban green space feature and its impacts on elderly people's social life: evidence of GPS tracking and social investigation in Shanghai', *Shanghai Urban Planning Review*, (2), pp. 96–103.

Huang, J. Z., Zhang, R. Q. and Hu, G. Y. (2019) 'A research of the elderly's daily life circle based on spatial-temporal behaviors: analysis of place recognition and spatial features', *Urban Planning Forum*, (3), pp. 87–95.

Kim, Y., Yeo, H. and Lim, L. (2024) 'Sustainable, walkable cities for the elderly: Identification of the built environment for walkability by activity purpose', *Sustainable Cities and Society*, 100, January, 105004.

Kweon, B. S., Sullivan, W. C. and Wiley, A. R. (1998) 'Green common spaces and the social integration of inner-city older adults', *Environment and Behavior*, 30(6), pp. 832–858.

Kwon, M., Lee, C. and Xiao, Y. (2017) 'Exploring the role of neighborhood walkability on community currency activities: A case study of the Crooked River Alliance of TimeBanks', *Landscape and Urban Planning*, 167, November, pp. 302–314.

Moogoor, A., Močnik, Š. and Yuen, B. (2022) 'Neighbourhood environmental influences on older adults' physical activities and social participation in Singapore: A photovoice study', *Social Science & Medicine*, 310, October, 115288.

National Health Commission of the People's Republic of China (2019) 'Healthy China Initiative (2019–2030)', 15 July [Online] Available at: https://www.gov.cn/xinwen/2019-07/15/content_5409694.htm. (Accessed: 27 September 2024).

Pfeiffer, D., Ehlenz, M. M., Andrade, R., et al. (2020) 'Do neighborhood walkability, transit, and parks relate to residents' life satisfaction?: insights from Phoenix', *Journal of the American Planning Association*, 86(2), pp. 171–187.

Rosso, A. L., Auchincloss, A. H. and Michael, Y. L. (2011) 'The urban built environment and mobility in older adults: a comprehensive review', *Journal of Aging Research*, 2011, 816106.

Small, M. L. and Adler, L. (2019) 'The role of space in the formation of social ties', *Annual Review of Sociology*, 45(1), pp. 23.1–23.22.

Svensson, M., Rosso, A., Elmståhl, S. et al. (2022) 'Loneliness, social isolation, and health complaints among older people: A population-based study from the "Good Aging in Skåne (GÅS)" project', *SSM - Population Health*, 20, December, 101287.

Zhang, Y. and Yao, E. (2022) 'Exploring elderly people's daily time-use patterns in the living environment of Beijing, China', *Cities*, 129, October, 103838.

Zhao, H. Y. and Hu, X. M. (2009) 'Urban residential area spatial transformation from the perspective of neighborhood capital', *Urban Problems*, (5), pp. 2–6.

Research Paper

Main Title
Iranian Mosques, an icon in identity of Iranian cities

Nasim IRANMANESH , Department of architecture & urban planning, east Tehran branch, Islamic Azad University, Tehran, Iran
Sepideh ETAATI , Faculty of Electrical Engineering, K. N. Toosi University of Technology, Tehran, Iran

Abstract
Mosques is the place of praying of Muslims. The common elements of mosques are entrance, Shabestan (a covered hall with numerous columns in mosques and the main space for praying), Ivan (a semi open space between yard and Shabestan), Minarets, yard, doom and so on.
There are various kinds of mosques, for example Jameh mosque (which is the most important mosques in the city), mosques of a residential district, mosques of cemetery and mosque- school.
Revolution of mosques in Iran can be divided to some periods. Mosques have been evolved during the history, first Iranian mosques had just a Shabestan and a courtyard but Ivan was added to mosques and mosques with one Ivan and after Mosques with four Ivan were appeared.
Mosques (specially Jameh mosques) have effective impacts in cityscape of Iranian cities, the doom and minaret of mosques play as effective landmarks in cityscape of the city.
The ornamented entrance of a mosque is an effective point in the elevation of streets as well. In the other hand the courtyard of mosque can be used as an urban space as well.
This paper will explain about the effects of mosques in the cityscape of Iranian city and how this effect can be reinforced in the best way to lead the city toward a mentionable and remarkable city.

Keywords

Mosque , skyline , Elements of mosques , cityscape

Introduction
Urban designing is an art which should be admired by million visitors and citizens. In past Iranian cities had high physical quality but in revolution of modernization its physical quality was declined a lot.
Improving the physical quality of Iranian cities should be considered in recent urban planning programs. Although fulfilling it will take a long time.
Each city needs a pleasant and qualified cityscape and beautiful skyline to be considered as an in shaped and remarkable city.
Mosques in Iranian cities have a great impact in the physical elements of Iranian cities such as cityscape, skyline, roofscape and roofline.
This paper will discuss about the impact of Iranian mosques on physical quality of Iranian cities and how it can improve the image of city.

1. Elements of the physical image of city

The physical aspects of each city are numerous and the most important elements of it are: skyline, roofline, roofscape. Below is a brief explain about each element.

1.1. Skyline

The skyline can be defined as “a line which exists in the intersection of sky and land”. The skyline is the crown of the city and this crown will be decorated by gems which they are actually the land marks. With putting more gems with a good order on the crown, we can have more beautiful cityscape and skyline in the city. Skyline can create an individual and unique character in the city.

Figure 1. Jameh mosque (great mosque) in Ardestan city

Figure 2. The skyline of historical city of Yazd

1.2. Roofscape

It is the scape of roofs which can be seen from higher buildings or other high places. Roofscape needs to be decorated to form a remarkable and noticeable city.

Figure 3. Roofscape of Jameh mosque of Isfahan

1.3. Roofline

The difference between skyline and roofline is that skyline can be seen from a long distance and roofline can be seen from the inside the urban space. So, we can see the roofline from the near distance.

Figure 4. Naghshe – Jahan square roofline

2. Iranian mosques and its features

Mosques in Islamic cities is the main landmark in an Islamic society. The shape of mosques, doom, high minaret and location of mosque become it to a landmark in the Iranian cities. In traditional Iranian cities bazars and districts were formed around the Jameh mosques. Jameh mosque (great mosque) is a main and the most important building in the city. In the second scale we have mosques for districts for local prayers, these mosques are smaller with lower ornaments.

Mosques have several elements and in follow we will review the most general elements in an Iranian mosque.

3. Elements of mosques

3.1. Entrance

The entrance of a mosque includes entry, the minaret above the entry, the door, stone bench, Hashti and corridor. The entrance of the mosque usually is decorated with tile work and plastering.

Figure 5. Imam Mosque in Bazar of Tehran

Figure 6. Imam mosque in Isfahan

3.2. Courtyard

it is the main open space of the mosque. The access to the Ivans, Shabestan, and stairs of roof and Minarate is possible by courtyard. Often a pool has been located in the middle of courtyard for cleaning purposes and getting Vuzo.

3.3. Ivan

this space is a semi opened between courtyard and Shabestan. The history of it goes back to Iranian architecture in Ashkanian and Sasanid era.

Figure 7. The courtyard of Agha Bozarg mosque in Kashan city

3.4. Minaret

This element usually located on top of entrance or roof of the mosque. Minaret was used for standing the singer of Azan (sing for inviting prayers to pray)

Figure 8. Sepahsalar Mosque in Tehran

Figure 9. Jameh mosque in Yazd city

3.5. Doom

it is an arched structure of the roof of mosques which can be identified as a landmark like minaret. Many Dooms in mosques have been decorated by tiling.

Figure 10. Agha Bozorgh Mosque in Kashan

Figure 11. Jameh mosque in Yazd city

3.6. Shabestan

a covered hall with numerous columns in mosque and it is the main space for praying and meeting.

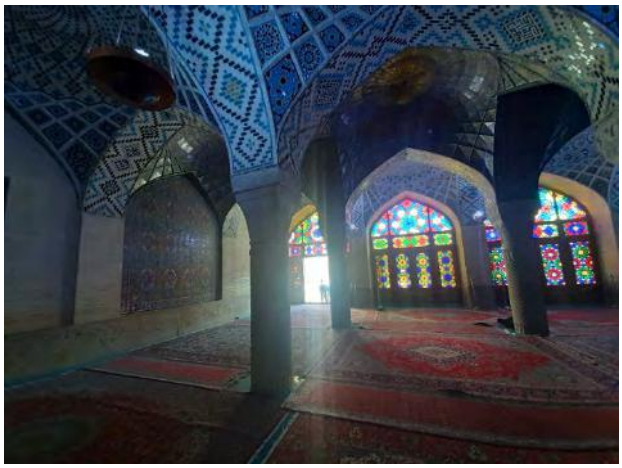


Figure 12. Shabestan of Nasirolmolk Mosque in Shiraz

4. conclusion

Iranian cities have lost their physical values during modernization but it can be improved by some strategies. One of the effective strategies is considering the impact of mosques in the roofscape and skyline of the city. Masques can be considered as a landmark in the Iranian cities, the doom, Minaret , entrance and other similar elements of mosques can have positive impacts in the skyline , roofline and roofscape of the Iranian cities.

Specially Minaret and after that the doom of mosque can have a great influence in the skyline and roofscape of city.

We have good example of this kind in some Iranian cities and this should be improved in other Iranian cities. During the making shape of the city this landmark can enrich the physical impact of Iranian cities.

Figure 13. Mosalla (mosque for doing ceremonial prays) of Tehran

Figure 14. Roofline of the square of Amir Chaghmagh in Yazd city

Istanbul in Turky is a good and noticeable example of it. This city has the beautiful image because of its Mosques.

Figure 15. Roofline in Istanbul

Even smaller mosques have their effect in the image of city in smaller scale. Presenting a good image of district mosques can improve the image of that district of city.

Figure 16. A district mosque in Dubai

Authorities of urban planning in Iran can improve the image of city by issuing some good legislation in designing of mosques according their scale. For examples issuing some codes for the height of doom and minaret for future mosques, the skyline and its character of city can be improved.
An important fact in Iranian urban plans is that most of plans just have been prepared in two dimensions. The comprehensive plan for Iranian cities has been created as a two-dimensional plan, so the third

dimension hasn't been considered in this plan. Because of this character the future skyline of the city has no legislation.

This means that urban plans should be created in three dimensional the height of building should be considered in each landuse and any zone. So, the future skyline and cityscape of city can be created more better with a defined program.

Finally, it can be said that providing three-dimensional plan for Iranian cities with considering important landmarks specially mosques can create a more considerable and noticeable cities.

Figure 17. Goharshad mosque in Mashad city

4. References

Hedman , R (1985) Fundamental of Urban design . London :Routledge .

Moughtin, C (1999) Urban design: ornament and decoration. London : Architectural press .

Moughtin, C (2003) Urban design: Street and Square . London : Architectural press.

Prochazka, A (1994) Architecture of the Islamic cultural sphere Mosques. Tehran: Amir Kabir publication organization .

Ghobadian, V (2003) Climatic Analysis of the traditional Iranian buildings. Tehran: University of Tehran press.

Pirniya, M (2003) Introducing the Islamic architecture of Iran . Tehran: Elm-o-Sanat university press .

Esfandiyari, M; Esfandiyari, Z; Haghighatbin, M (2018) Quantitative assessment of the skyline in urbanscapes as the edge of the city (Emphasizing the modern tools of urbanscape analysis) , Maremate- E Asar & Baft-haye Tarikhi-Farhagi , no. 16

Research Paper

The Correlation between Loneliness and Community Third Space for Young People Living Alone in Shenzhen

A case study of youth community in Shenzhen

Jian Dai, School of Architecture, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Xiaokai Mi, School of Architecture, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Zhiqing Zhao, School of Architecture, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

Youth are pivotal in urban development, with youth-friendly city construction gaining traction. Yet, research frequently neglects urban space construction linked to youth. Shenzhen, a city oriented towards youth development, has a population where young people constitute a majority. Many of them are solitary " drifters," facing loneliness due to their fast-paced lifestyle and limited social opportunities. Based on this background, this study takes Shenzhen's solitary youth group as the research object to carry out specific research, The research content mainly includes four aspects: First, using the methods of crowd interview and field observation, to define and classify the third space in the research area; Second, through questionnaire survey and in depth interview, the preference information of young people living alone in the use of third space was collected; Third, the UCLA scale was used to quantitatively assess the loneliness of them. Fourth, SPSS was used to analyse the correlation between loneliness and community preference for using third space. Results indicate: (1) High levels of loneliness among solitary youth; (2) Regular and prolonged engagement with third spaces significantly reduces loneliness; (3) Social leisure spaces exhibit the strongest influence in mitigating loneliness among solitary youth.

Keywords

Young people living alone, Loneliness, The third space, Preference for using third space

1. Introduction

In today's context of globalization and rapid urbanization, the policy orientation of building a youth-friendly society at the national level has not only provided an unprecedented opportunity for the growth and development of youth groups, but also spawned a series of new policies aimed at promoting youth integration into society and stimulating innovation. "Youth" has become a frequent word in Shenzhen's "14th Five- Year Plan" outline. Shenzhen Youth League Committee will always adhere to "youth-centered" and take "youth development-oriented city" as a major strategy Shenzhen, as the frontier of China's reform and opening up and a special economic zone, has a large youth population, which is quite representative in the whole country and even the world. As a well-known "City of youth" in China, Shenzhen has a permanent population of 8.019 million young people aged 14-35, accounting for 45.66% of the city's

permanent population. The average age of the permanent population is 325 years old, which highlights the significance of building a developing-oriented city for youth.

With the development of urbanization and the increase of housing costs, young people are facing more and more housing pressure, and young people have made great changes in their working and living styles[1][2]. Under this background, the rental housing market in Shenzhen has developed rapidly, and a number of brand apartments for young people have appeared. Compared with traditional housing, youth apartments provide a public space for youth groups to meet their diverse living needs.

With the continuous gathering of youth population in Shenzhen, social problems concerning youth groups have gradually surfaced, among which the phenomenon of "empty-nest youth" is particularly concerning[3]. According to the preliminary prediction, in 2030, the number of young people living alone may reach 40 million to 70million. Among them, Dongguan and Shenzhen have a solo rate of nearly 40 percent. "Empty-nest" young people come to a foreign land alone, their life focus on work, lack of opportunities to participate in social activities, lack of face-to-face communication with people, resulting in a certain sense of loneliness[4]! According to the survey report on the Health of Young Men and Women 2021, 71.2 percent of Chinese young men and women (aged 18-35) feel lonely.

Based on this, this study connects loneliness of young people living alone with community third space, explores the correlation between loneliness degree and preference for using community third space, and takes Shenzhen youth community as an example to conduct investigation and research, in order to further enrich the theory of building youth-friendly cities and provide references for the construction of youth-friendly cities.

2. Framework and methods

2.1. The study area

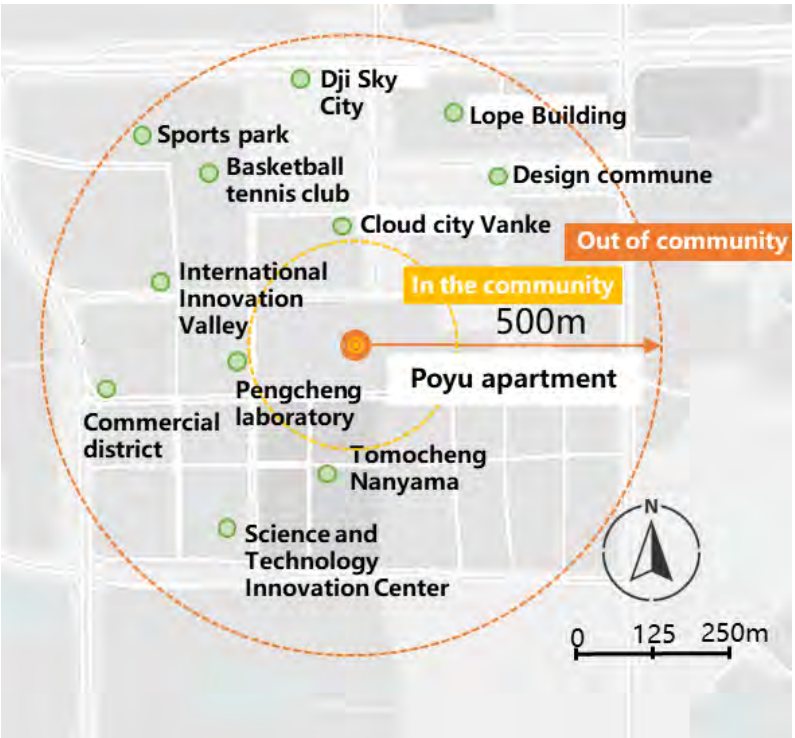


Figure 1 Study area. Source: drawn by authors.

The research area should be centered on the flagship store of Cloud City of Poyu Apartments with a radius of 500 meters. Cloud City Flagship Store is a typical youth community. It is the largest long-term rental apartment in Shenzhen, with more than 6,000 young people gathering here. There are many types and quantities of third space in this area(Figure 1).

2.2. Study objects

At present, there is no clear definition on the meaning of "empty-nest youth". The people studied in this study are single young people in the study area, aged 18-35 years old, working in Shenzhen, living alone or sharing an apartment with strangers, far away from home.

2.3. Data sources

The data needed for this research comes from questionnaire survey, including field survey and network survey. The research time is concentrated on the weekend from June 22 to June 30, 2024which is the time when a large number of youth in the community are located in the community, and also the time when a large number of them use the third space, so it is more representative to conduct the survey during this period. A total of 211 questionnaires were issued in this survey, of which 205 were valid, with an effective rate of 97%.

2.4Research methods

(1) Field observation method

According to the characteristics of the third space proposed by Oldenburg, from the five dimensions of sociability, fairness, accessibility, stability and comfort, through field observation and interviews with young people living alone and community managers, the third space is identified within a 500-meter radius centered on the Porto apartment.

(2) Questionnaire survey method

Through the questionnaire survey, the basic information of the subjects, the degree of loneliness and the preference of using the third space were collected.

The questionnaire mainly includes three parts:① The first part is to collect basic information about the young people living alone. Eight questions are used to collect the age, sex, length of living alone, education level, work industry, disposable income, reasons for living alone and reasons for limiting the expansion of social circle of the youth. ②The second part is to collect the third space use preference. Four questions are used to collect the types of third space often used by the youth, the frequency, the duration of each use, and the types and quantities of the third space used. ③The third part is to investigate the degree of loneliness. The third edition of the UCLA Loneliness Scale, developed by Russell et al., was used to evaluate loneliness, consisting of 20 items

Quality control was applied to the questionnaire, the purpose and significance of the study was explained in writing to the respondents, the confidentiality of the data was emphasized and only used for scientific research, and informed consent was obtained before answering the questions. Short answer time and obvious random answers were deleted before data analysis.

(3) Statistical methods

Quantitative analysis was carried out on the research data, and SPSS 24.0 software was used for statistical analysis. Firstly, the sample characteristics were statistically analysed, then the loneliness and their

preference for using the third space were statistically analysed, and finally, the correlation between the degree of loneliness of the respondents and their preference for using the third space was analysed.

2.5 Research framework

The first step is to analyze the basic characteristics of the the respondents in Shenzhen, and clarify the characteristics of them.

The second step is to analyze the degree of loneliness of them. The UCLA scale is used to evaluate and analyze the loneliness.

Figure 2 Learning entrepreneurship space. Source: Self-portrait by the author.

Figure 3 Social and leisure space. Source: Self-portrait by the author.

Figure 4 Sports and fitness space. Source: Self-portrait by the author.

Figure 5 Public service space. Source: Self-portrait by the author.

Figure 6 Outdoor leisure space. Source: Self-portrait by the author.

The third step is to classify the identified third space into different levels and types. In terms of hierarchy, according to the applicable population and distance, the third space is divided into two levels. The first level is the third space configured in the Pu apartment community, which is only open to community residents; The second level is the commercial supporting facilities around the community, the users include not only the residents of the Pu apartment, but also other users. According to the interviewee's preference types and functions on the use of the third space, the identified third space is subdivided into five types: l: ① learning entrepreneurship space, including the Goethe library, business incubation center and self-study room in the community; Bookstores in shopping malls, paid study rooms around them, etc (Figure 2).② social and leisure Spaces, including video and audio rooms and game and entertainment areas in the community; Surrounding coffee shops (Figure 3). ③ Sports and fitness Spaces, including gymnasiums, badminton courts， billiards rooms and other sports venues inside and outside the community; Dance studio, gym, etc.in shopping malls (Figure 4). ④public service Spaces, including service desks, express delivery points, public kitchens, meeting rooms in the community; Party and mass service centers and other community service facilities outside the community (Figure 5). ⑤ Outdoor leisure Spaces, including atriums and terraces within the community; Street parks, small squares, etc., outside the community. At the same

time the third space use preference of young people living alone was investigated, including: duration of use, frequency of use, type of use and number of types of use (Figure 6).

The fourth step is to analyze the correlation between the degree of loneliness of the respondents and their preference for using third space by using SPSS24.0 statistical software tool.

The fifth step is to explore the problem, from three aspects, the first is to analyze the source of loneliness from the internal and external causes; Then analyze the shortage of the third space; And to understand the third space needs through interviews.

The sixth step is based on the above analysis, to put forward the third space optimization strategy to alleviate the loneliness of young people living alone (Figure 7).

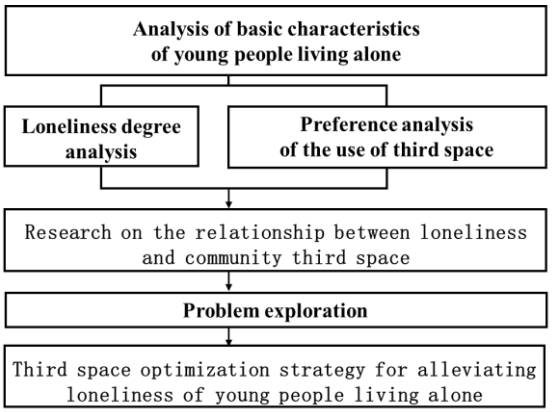


Figure 7 Research framework. Source: drawn by authors.

3. Results

3.1. Sample characteristics

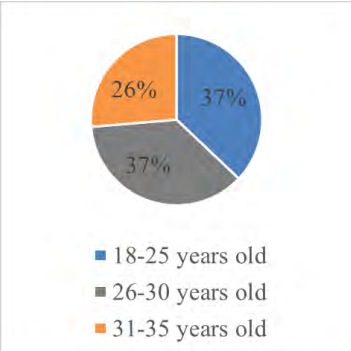


Figure 8 Age proportion. Source: drawn by authors.

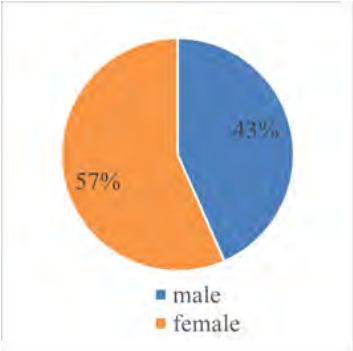


Figure 9 Gender proportion. Source: drawn by authors.

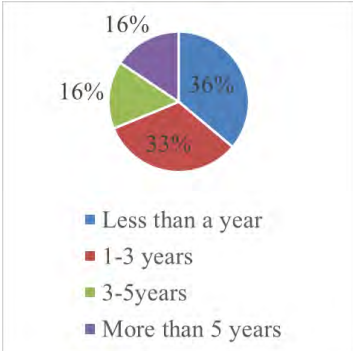


Figure 10 The proportion of time spent living alone. Source: drawn by authors.

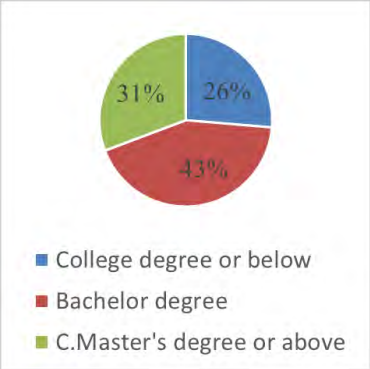


Figure 11 Educational background. Source: drawn by authors.

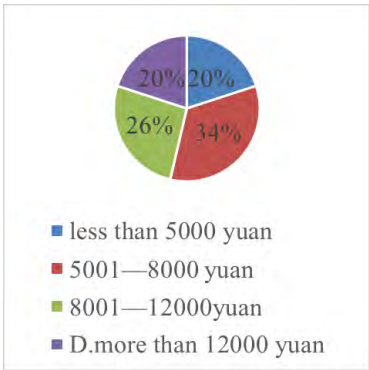


Figure 12 Proportion of disposable income. Source: drawn by authors.

In terms of age, young people living alone are mainly aged 18-25 and 26-30. In terms of gender, the proportion of female respondents is slightly higher than that of male respondents; Respondents lived alone for less than 3years; Nearly 74% of the respondents had a bachelor's degree or above, indicating a high level of overall education. In terms of individual disposable income, people with a disposable income of 5,001 to 12,000 yuan are the main group. From the perspective of working industries, the number of people engaged in education, service industry and financial securities industry is relatively high(Figure 8-12).

3.2 Analysis on the degree of loneliness

In order to clarify the degree of loneliness of the respondents, the general situation of loneliness of them was analysed. The full score of loneliness is 80 points the higher the score, the higher the level of loneliness. In this study, the total score of them ranges from 24 to 73 points, with an average score of 44.48, higher than the threshold of 44 points for high loneliness, indicating that the overall loneliness is relatively high.

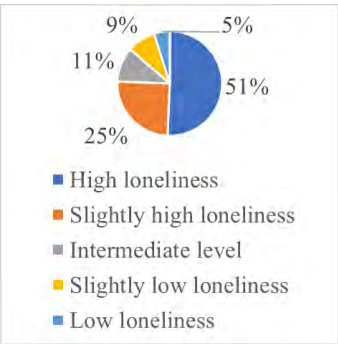


Figure 13 The proportion of loneliness. Source: drawn by authors.

The distribution of different levels of loneliness in this study is shown in the table below. 51% experienced high levels of loneliness, and 25% experienced average loneliness. High loneliness accounted for 76% of the total sample, indicating that most have a high degree of loneliness (Figure 13).

3.3 Analysis of third space use preference

In the survey of the third space preference of the respondents, the duration of third space use, the frequency and the type were respectively used to measure the third space use preference of young people living alone.

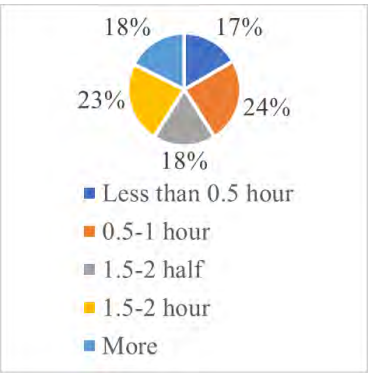


Figure 14 The usage time. Source: drawn by authors.

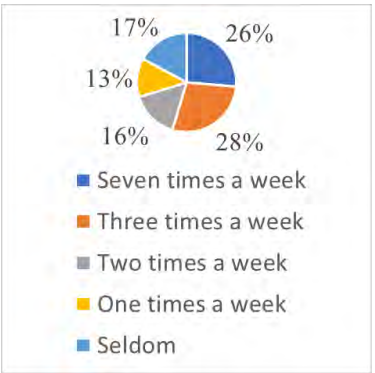


Figure 15 The use frequency. Source: drawn by authors.

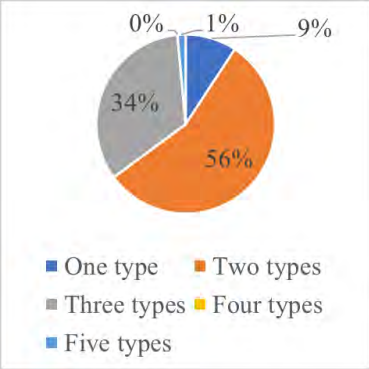


Figure 16 The number of types. Source: drawn by authors.

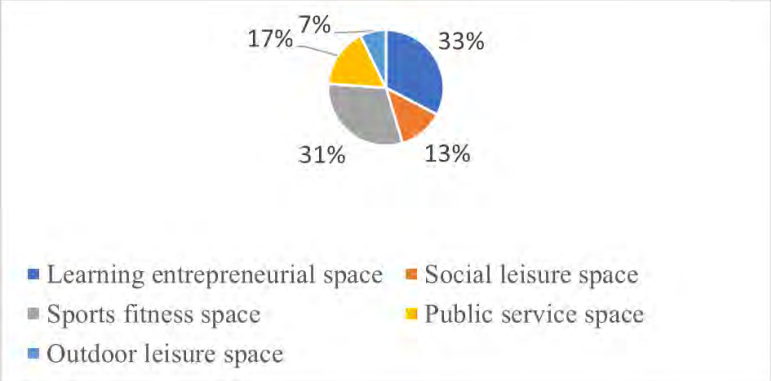


Figure 17 The type. Source: drawn by authors.

(1) Third space use duration

From the perspective of the duration, the proportion of the third space use time of young people living alone is relatively uniform, among which "half an hour to one hour" and "half an hour to two hours" account for a slightly higher proportion, accounting for 24% and 23% of the total number respectively (Figure 14).

(2) Third space use frequency

From the perspective of the frequency of using the third space, the frequency of young people living alone using the third space is mainly concentrated in "once a day" and "three times a week" (Figure 15).

(3) The types of third space use of

In terms of the number of third space use types, only few people use only one type, and most people choose to use two or three third Spaces(Figure 16). From the perspective of the third space use type, young people living alone prefer to use the space for learning and entrepreneurship and the space for sports and fitness, accounting for 33% and 31% of the total samples respectively (Figure 17).

3.4 Correlation between degree of loneliness and preference for the use of third space

In order to explore whether there is a correlation between the degree of loneliness of the respondents preference for using the third space in the community, a correlation analysis was conducted between the degree of loneliness and "duration of use of the third space", "frequency of use of the third space", "type of use of the third space" and "quantity of type of use of the third space", and the following results were obtained (Table 1).

Table 1 The results of the Pearson correlation analysis between loneliness degree and various dimensions

dimension	use time	frequency of use	usage type	number of types
	Pearson correlation			
loneliness degree	0.335**	0.343**	0.282**	0.183**

**. At the 0.01 level (two-tailed), the correlation is significant.

(1) Correlation analysis between the degree of loneliness and the duration of using the third space

In order to test the relationship between the degree of loneliness of the respondents and the duration of using the third space, a correlation analysis was made between the duration of using the third space of "them" and the degree of loneliness of them. The results show that the correlation is between the duration of using the third space and the degree of loneliness is significant, And the two showed a negative correlation, the longer the use of the third space, the lower the loneliness.

(2) Correlation analysis between the degree of loneliness and the frequency of using the third space

In order to test the relationship between the frequency and the degree of loneliness, a correlation analysis was made. The results showed that there was a significant correlation. And the two showed a negative correlation, the higher the frequency of using the third space, the lower the loneliness.

(3) Analysis of the correlation between the degree of loneliness and the use type of the third space

In order to test the relationship between the type of using the third space and the degree of loneliness, a correlation analysis was made between the type of "solitary youth" using the third space and the degree of loneliness. The results showed that there was a significant correlation. Among them, the loneliness who use social leisure space and outdoor leisure space is generally low, mainly because the community will hold various social activities in the social leisure space and outdoor leisure space such as music festival, "parking reading party" and "parking outdoors", which promote the social interaction of young people living alone and provide rich opportunities for making friends.

(4) Analysis of the correlation between the degree of loneliness and the number of types of third space use

In order to test the relationship between the number of types of "solitary youth" using the third space and the degree of loneliness, a correlation analysis was made. The results showed that there was a significant correlation. And the more types of third places used, the lower the loneliness.

4. Question exploration

4.1 Analysis from the perspective of population

Because of the two characteristics of living alone and being single, their loneliness is easily amplified. This study analyses the sources of loneliness from the aspects of internal and external factors that restrict their social circle.

Figure 18 Reasons for limiting social interaction among young people living alone. Source: drawn by authors.

Figure 19. The proportion of reasons for choosing to live alone. Source: drawn by authors.

(1) The internal causes of limiting the social circle

According to the results of the questionnaire, the main reason for restricting the social circle of the respondents is lack of time (Figure 18). Due to the high work pressure, crowding out the time. There is also a situation that the third space is far from the working place and the living place, resulting in a longer time to go to the third space, there is also a lack of "shallow social" in the third space, the current situation of the third space to socialize needs to invest a long time cost. Secondly, the internal factors that restrict the social interaction of young people living alone include their own lack of executive power and arrangement, as well as psychological factors (such as shyness, fear of embarrassment, disinterest and inferiority). This shows that the existing third space is used passively, with low inclusiveness and lack of activities and facilities to actively guide young people living alone to use the third space.

(2) The external causes that restrict the social circle

Through the interview, it is concluded that the external reasons limiting the social circle of the respondents mainly include: lack of inheritance of the relationship of the father; The space cannot meet the social needs of them in the fast-paced society; Life shows a monotonous work.

Under the background of modernization transformation, the change of social structure promotes the evolution of social relations, and the traditional social communication faces the double barrier of time and space. From the perspective of space barrier, the traditional Chinese society has the characteristics of' stable land relocation and generation stability. In the daily production and work an acquaintance society based on the pattern of difference has been formed. With the deepening of modernization, the social division of labour tends to be refined, the whole society is filled with a variety of occupational types, the pace of modern life has a large heterogeneity, and it is precisely the heterogeneity of this, which restricts the formation of contemporary youth deep social relations. Even if they are not far away from their friends, the pace of life is different. When they finish their work and enjoy socializing, their friends are working overtime, and the rest day happens to be their working day. It is difficult to have friends with them every time they fall into loneliness. Most of the youth in Shenzhen are divorced from their native growth environment, and cannot quickly integrate into the new environment, unable to get a sense of belonging, thus extending the sense of loneliness.

The existing third space cannot meet the needs of young people in the fast-paced society. Compared with the traditional third space of restaurants and physical stores, young people living alone prefer to use

takeout and express delivery to meet their eating and shopping needs, which reduces a lot of face-to-face socializing and is also one of the sources of loneliness for young people living alone.

The main reason why they choose to live alone in big cities is to get better job opportunities. However, long working hours and long commuting time result in a single, work-based life for most young people (Figure 19).

4.2 Analysis from the perspective of third spaces

Through the interview, it is found that young people living alone have a higher utilization rate in the community, but a lower utilization rate around the community, mainly due to the serious homogeneity of the third space outside the community and random service groups. However, the third space in the community is designed for the respondents and meets their needs. At the same time, the community is closed management, and the service group is relatively fixed, which is more conducive to forming a fixed social relationship network and promoting the use of the third space by young people living alone.

(1) The third space outside the community is seriously homogenized and has a single function

Through the interview, it is found that the dissatisfaction factors are mainly concentrated in the aspects of "single function", "single type of facilities" and "'unattractive", indicating that the existing third space cannot fully meet the them for the use of the third space. Through field observation, it is found that the existing third space follows the traditional community setting and configuration standards, is equipped with template facilities and equipment, is seriously homogenized, lacks innovation and characteristics, and runs contrary to the interests of them. It is difficult to meet the needs of them for diversified and personalized space, and it is difficult to stimulate the interest and enthusiasm of them, resulting in a decrease in the frequency of use. Which further aggravates their loneliness and lack of social interaction.

(2) The third space outside the community serves the population randomly

Field observation shows that the third space outside the community, such as shopping malls, parks, etc., serves people of all ages, including the elderly, middle-aged, young people, etc. At the same time, people appear in the form of families or other groups, which has a strong randomness. Young people living alone cannot have effective social behaviours in such third space, which enhances the sense of isolation of young people living alone. Therefore, young people prefer to meet their needs by online shopping and take-out rather than offline physical space.

4.3 Analysis of the needs for the third space

(1) Targeting the need of young people

Through the interview, it is found that young people living alone frequently use words such as "minority treasure", "concert", "slow space", "coffee" and "socializing" in their expectations for the improvement of the third space. Young people living alone hope to relax in the fast-paced life through the third space; They hope to take their own interests as the starting point, find a suitable third space, and carry out social activities based on interests.

(2) Forming a relatively stable social relationship

Through the interview, it is found that young people living alone generally hope to have a "partner" when using the third space. They have the same interests and needs, and can accompany each other when using the third space. Similarity plays an important role at the beginning of interpersonal relationship, and interests and hobbies are the main sources of similarity between people. A "partner" is formed based on

precise personal interests or needs, meeting the diverse needs of interpersonal relationships and enabling young people to be accompanied in different areas of work and life.

5. Discussion

Based on the analysis of respondents' needs at the population level, spatial level, and third-space level, the author proposes strategies to improve the design and construction of third spaces in youth communities and surrounding areas:

(1) Policy formulation level

Introduce policies supporting youth community construction and third-space development. These policies should emphasize the importance of third spaces in community planning and encourage developers and managers to provide more diverse, high-quality third spaces[5].

Improve youth community construction guidelines and standards. These should fully address young people's needs, clarify the positioning and goals of youth communities, and provide direction for third-space development.

Establish incentive mechanisms, such as tax benefits or rewards, for communities and businesses that create outstanding third spaces, thereby encouraging broader societal participation.

(2) Planning and design level

Enhance spatial functionality and facilities to accommodate social events of varying scales and types. Within limited spaces, adopt the "spatial compounding principle" or the "multi-scene adaptability principle", allowing flexible adjustments to meet different functional and activity needs.

Create an atmosphere that fulfills emotional needs, fostering psychological cues that promote social interaction. Incorporate unique design elements aligned with young people's preferences, such as distinctive colours and materials, to establish memorable spaces that attract engagement.

(3) Community management level

Beyond maintaining third-space facilities, organize diverse social activities, including interest groups, outdoor adventures, cultural exchanges, and volunteer services—not just traditional gatherings. Regular events can provide platforms for young people to connect, share experiences, and grow together, reducing loneliness and strengthening community bonds.

6. Funding

The study was supported by Heilongjiang University Think Tank (Provincial Innovation and Entrepreneurship Think Tank) Open Project (Grant No. ZKKF2022187).

7. References

He,S. 'Multidimensional interpretation of "empty nest youth" group', *Chinese youth social science,*36(03),p40-45.

Zhu, Z. (1989). *Dictionary of psychology.* Beijing: Beijing Normal University Press.

Bao, H. 'From "empty nest" to "real heart": A discussion on the problem of "empty nest youth" in our country in the new era'. *Chinese Youth Studies,* 31(04), p40-46.

Feng, J., Zhen, F.and Wang, J. 'Research on the third space of western cities and its planning'. *International Urban Planning*, 30(05), p16-18.

Wei, C. and Yu, Y. '"Third space" to ease the path of modern people's mental dilemma'. *Architecture and Culture,* 32(05), p189-190.

Rapporteurs:

- ***Carlo Castelli,*** *Founder Urban Purpose and Chief Technical Advisor UNDP, United Kingdom*
- ***Funmilayo Modebola-Fadimine****, Assistant Director, Ministry of Physical Planning and Urban Development/ GIS Officer, NEWMAP-EIB, Ondo State, Nigeria*
- ***Sofia Morgado****, Professor Dr, Faculdade de Arquitetura, Universidade de Lisboa, Portugal*

1. Introduction

The Sustainable Urban Density - Track 4 - examined approaches to sustainable urban density, balancing population growth with green spaces and sustainable design principles to create livable and resilient urban environments.

This report synthesizes insights from Track 4, which includes five sub-themes and identifies key challenges, findings, and recommendations for regional and city planning as well as related governance. Presented abstracts, research contributions, and countrywide experiences provide a very interesting insight and comprehensive outlook on the future of density and urban development, addressing issues of equity, data and evidence, normative definition, sustainability, and communty engagement. The presentation also highlighted possibilities of future investigations and research needed.

2. Core Objectives

Track 4 focuses on five primary objectives that are crucial to the future evolution of urban spaces:

1. **Enhancing Urban Mobility and Efficiency** – Improve transportation systems to optimize urban connectivity and accessibil timize urban connectivity and accessibility, aiming for a more efficient and sustainable urban environment.
2. **Discovering Innovative Solutions for Urban Revitalization** – Focus on revitalizing cities and metropolitan areas to enhance economic vibrancy and social inclusiveness.
3. **Promoting Equity and Inclusiveness through Urban Planning** – Implement spatial planning that fosters fairness, inclusivity, and collaboration within diverse urban communities.
4. **Implementing Technological Advancements for Urban Modernization** – Explore digital innovations for urban management,

enhancing service delivery and supporting smart city infrastructure.

5. **Supporting Sustainable Urban Development** – Encourage planning practices that align with environmental sustainability and efficient use of resources.

3. Sub-Themes

To better manage these objectives and contextualise concepts and case-studies, five (5) sub-themes were defined:

1. **Climate change, Resilience, Adaptation**
2. **Morphology, Parametrics, Densities**
3. **Everyday Life: Housing, Place-Making, Neighborliness**
4. **Urban Infrastructure, Environment and Health**
5. **Connectivity, TOD and Land Use**

4. Data Summary

Based on the 72 abstracts presented and accepted, 53 presentations were registered, covering 11 sessions under five sub-themes. Seven authors were accepted for the poster exhibit. Research contributions came from 20 countries, including Belgium, Brazil, China, Denmark, Ecuador, France, Germany, India, Iran, Italy, Jordan, Korea South, Nigeria, Poland, Portugal, South Africa, Spain, Turkey, United Kingdom, and United States.

5. Key Findings

Identified issues include urban polarization, marginalization of rural areas, population shrinkage, high urban service demands, fragmented governance, and the impacts of climate change. In particular, from the presentations emerged the following key findings:

- **Densities – Perceptions and Realities**
- **Moving and Dynamic Definition of Density, Time-Related**
- **Evidence is Key - social, cultural and environmental outcomes**
- **Move Beyond Buzzwords**
- **Innovative Multi-Agency Governance – Powers and Funding**
- **International Cooperation Orgs not al ways aligned with local needs**
- **Nature and Built Urban Form must co-exist in renewed mix**
- **People-centred, multi-scalar, neighbourhood-based approaches**

6. Identified Challenges

- **There is no 'one density fits all'** Commentary
- **Mismatch of goals and objectives across levels of governance**
- **Fragmented Governance National and Sub-national levels**
- **Lack of linkages between Policy and Planning**
- **Lack of diversity of voices in the planning process**

7. Recommendations

- **Innovative approaches to integrated strategic policy, planning and design tools**
- **Research by Design**
- **Place-Based Visions associated with implementation strategy**
- **Redefine Value Creation through focus upon environmental, social and cultural considerations**
- **Communication, illustration and engagement with communities**
- **Active Listening**

8. Conclusion

Track 4, Sustainable Urban Density, gave rise to much broader and richer debates than expected, particularly in workshop-based activities in a more participatory way.

Research Paper

Beyond the Buzzwords:

Examining perceptions of climate change resilience and adaptation in Jordanian municipal planning.

Yasmein OKOUR, Jordan University of Science and Technology, Jordan

Abstract

Addressing the diverse impacts of climate change is a significant challenge to cities and urban planners. In recent years, climate action has encompassed a substantial portion of municipal planning practice. As a result, new climate lexicons such as sustainability, resilience, mitigation, adaptation, risk, and vulnerability have engulfed municipal planning and policy discourse. Despite their prominence, such terminologies and concepts are often deemed ambiguous, used interchangeably, and conceptualized differently by various stakeholders. Focusing on two municipalities in Jordan as a case study, Irbid and Amman, the study examines the recent surge of resilience and adaptation reports, initiatives, and projects emerging from Jordanian public authorities. Using semi-structured interviews with municipal environmental and urban planners, this paper explores how municipal planners navigate the intricate lexicon of climate action. The findings illustrate that climate lexicons are perceived as new development buzzwords promoted by international development funding schemes. Specifically, adaptation and resilience work is seen as reactive to the funding priorities of international agencies rather than proactive actions driven by local municipalities. The translation of the global climate action lexicon into Arabic thus emerges as a significant issue. However, the analysis suggests that municipal planning practices in Jordan are driven by an understanding and belief of the overarching benefits of adaptation and resilience and other climate actions regardless of the conceptual ambiguities or the absence of well-understood and translated definitions. Overall, this study calls for further research that examines the impact of international climate action work and lexicon on climate adaptation and resilience efforts in the Global South.

Keywords

Climate Action, Adaptation, Resilience, Municipal Planning, Jordan

1. Introduction

1.1. Climate Action Lexicon: A Global Challenge

Research on the role of cites in driving global climate change response is growing (While & Whitehead, 2013). Climate action implemented by local municipal and planning authorities encompasses a wide range of strategies, including concepts such as climate change adaptation, and mitigation, disaster risk reduction, and urban climate resiliency (Hallegatte, 2009; Jabareen, 2013; Ribeiro & Goncalves, 2019). Climate change mitigation strategies refer to multi-sectoral actions cities take to reduce greenhouse gas emissions, while adaptation attempts to reduce the vulnerably of cities and residents to climate hazards (Seto *et al.*, 2014; Carter *et al.*, 2015; Araos *et al.*, 2016; Sancino *et al.*, 2021). On the other hand, researchers have described

urban resilience as the ability of interconnected urban systems to adapt and transform or bounce forward in the face of climate change. (Meerow et al., 2016; Rockefeller Foundation, 2019; Woodruff, 2021).

Cities and municipalities have also mobilized funding and research towards other complementary strategies and frameworks such as sustainable cities, green cities, smart cities, nature-based solutions, and green infrastructure that aim to support the long-term well-being of communities (Graute, 2016). Indeed, as cities are recognized as key actors in climate action, conceptual frameworks such as "resilience," "adaptation," "mitigation," and "sustainability" are increasingly dominating local urban policy and planning (Jabareen, 2013; Carter *et al.*, 2015; Graute, 2016).

However, climate action strategies are generally considered interconnected and effective implementation requires a thorough assessment of potential conflicts and co-benefits between various strategies. Indeed, researchers have criticized the lack of consistencies in conceptual definitions and applications in national and local planning policy (Moser *et al.*, 2019). Urban planning professionals and municipal climate action frameworks often use resilience, sustainability, and adaptation interchangeably or define strategies differently based on the stakeholders involved (Davoudi & Porter, 2012; Meerow *et al.*, 2016). While definitions, climate lexicon, and climate action literature continue to grow, such conceptual discrepancies create significant challenges to municipal planners in developing and implementing coherent climate urban polices.

1.2 Climate Action in Jordan

Jordanian cities face many challenges, including rapid urbanization, high refugee influx, depletion of water resources, and increasing climate change impacts (Higgitt, 2009; UN-Habitat, 2023). The landscape of climate action in Jordan is growing. At the local and national levels, several plans and frameworks have been developed to promote climate change strategies in the country and reduce climate-related risks facing Jordanian communities, including:

1. National efforts:
    - The National Climate Adaptation Plan of Jordan (NAP)
    - National Climate Change Policy of Jordan (NCCP)
    - A National Green Growth Plan for Jordan
    - National Climate Change Health Adaptation Strategy of Jordan
    - Jordan's National Urban Policy
    - National Green Growth Plans for various sectors (Agricultural, Energy, Transportation)
2. Local efforts:
    - Sustainable Energy and Climate action plans for six cities (Irbid, Dier Alla, Busiara, Karak, Jerash, Aqaba)
    - Amman Climate Action Plan
    - Amman Resilience Strategy
    - The Amman Climate Plan
    - Amman Green City Action plan

1.3 Objectives of the paper

This research examines how Jordanian municipal planners navigate the intricate lexicon of climate action. First, the study explores municipal planners' motivations behind promoting climate change adaptation and climate urban resilience in two Jordanian cities. Second, the research identifies municipal processes taking

place that aim to minimize and address conceptual ambiguities related to climate action. Specifically, the study attempts to answer the following questions: How do Jordanian municipal planners navigate the intricate lexicon of climate action? Overall, the study highlights the experiences of municipal planners in the Global South as they struggle to localize global climate action lexicon, while at the same time adopt the climate action language emerging from the Anglosphere to communicate their climate objectives and align them with international funding streams.

2. Methodology

To achieve the research objectives, this study utilized a qualitative approach by conducting semi-structured interviews with municipal planners in two Jordanian municipalities, the Greater Irbid Municipality (GIM) and the Greater Amman Municipality (GAM). The interviewee sample consisted of municipal planners and actors working in diverse departments and units within the municipalities. The sampling process aimed to identify participants involved in local development projects, land use planning, comprehensive planning, transportation planning, recreational planning, environmental planning, and local climate and urban policy development. Targeting diverse departments within the municipalities ensured a comprehensive exploration of how different municipal sectors navigate the emerging climate action lexicon in Jordan. A snowball sampling technique was used to identify key stakeholders and consultants of relevance to municipal climate action. Semi-structured interviews continued until data saturation was achieved. In total, 21 participants were interviewed (see Table 1).

Table 1. Participant distribution in municipal departments. Source: Author.

Department/Division	Greater Amman Municipality (GAM)	Greater Irbid Municipality
Comprehensive planning division	4	4
Municipal strategic planning division	1	1
Resilient Amman unit	2	-
Municipal communication division	1	-
International projects department	1	1
Social development department	1	-
Municipal planning consultants	3	2
Total	13	8

An interview guide was designed based on the research objectives. The questions within the guide were categorized into three main sections:

1. Background questions to examine their experience with climate action work
2. Questions to examine motivations behind adopting climate action strategies, including resilience and adaptation.
3. Questions to explore how municipal planners navigate and address conceptual ambiguities and linguistic barriers within municipal climate action.

The interviews ranged from 40-60 minutes in length and were conducted in Arabic. Verbal consent was collected from all participants, and interviews were recorded and transcribed. The analysis of the qualitative data from the semi-structured interviews consisted of thematic coding using NVivo software (Baralt, 2011).

3. Results and Discussion

3.1. Climate Action in Jordan: International Development Buzzwords?

To understand how municipal planners navigate diverse climate action lexicon, it is first essential to examine the motivation behind adopting climate-related strategies. One crucial finding of this study was the influence of international development funding schemes on local municipal climate action. Specifically, the participants highlighted that funding sources shape local climate priorities and goals. Due to limited financial resources, municipalities seek funding for local development projects from international development funding agencies such as the United States Agency for International Development (USAID), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the Austrian Development Agency, the Swedish International Development Agency (SIDA), the Japan International Cooperation Agency (JICA), the Canadian International Development Agency (CIDA), and the French Agency for Development (AFD).

As a result of fiscal limitations, municipal climate action is continuously reshaped and reframed to align with emerging international funding priorities, as one participant explained:

> "Last year, adaptation is what everyone was working on. This year, it's all about smart cities…. because that's what international funding grants are focusing on" (Comprehensive Planning Department, GIM).

> "The USAID is about to launch a multi-million urban resilience project proposal in Amman; everyone will be talking about and working on resilience next year" (Resilient Amman Unit, GAM).

Thus, when funding opportunities are linked to themes of climate change mitigation for instance, municipal planners work on developing relevant project proposals, even if other areas of climate action are of priority to the local community. This international funding-driven format of climate action often overwhelms municipal planners who have to navigate new terminologies within calls for funding and can lead to misplaced efforts. At the same time, participants expressed their frustrations with the evolving lexicon of climate action. Funding agencies may define terminologies differently, and the interchangeable use of terms like resilience, adaptation, and sustainability creates confusion among municipal planners and can hinder the coordination efforts between various stakeholders.

On the other hand, participants critiqued the global climate action lexicon as never-ending buzzwords that are disconnected from the socio-economic realities of cities, particularly cities in the Global South. Municipal planners emphasized that while thinking globally is important, the climate action lexicon must be defined and refined locally. This issue is exacerbated by the need to translate terminologies often introduced in English into Arabic. Rather than burdening planners with the task of translating terminologies developed in the Anglosphere to the local language, international funding agencies that aim to support meaningful local climate action must consider the sensitivities of the local climate lexicon. Multilingual climate action work thus complicates the implementation of diverse climate-related strategies. Indeed, it is important to recognize that the climate lexicon within international development funding schemes may be disrupting local climate action work rather than supporting it.

Despite conceptual ambiguities and translation challenges, Jordanian municipal planners recognize the importance of various strategies, such as resilience and adaptation, in addressing the country's climate vulnerabilities and are motivated by an overarching belief in the benefits of climate action. As one participant stated:

> "Even if there is confusion about the terms and strategies, everyone in the municipality knows why they are important, and everyone is motivated to implement meaningful climate action" (Comprehensive Planning Department, GAM).

3.2. Navigating Climate Lexicon

As new climate action terms are introduced into local municipal planning, understanding how participants navigate diverse climate lexicon is important. Specifically, this allows the identification of specific factors or processes that help municipal planners understand new terminologies, overcome potential ambiguities, and thus enhance local resilience and adaptation efforts. The framework presented in Figure 1 illustrates the main variables that shape how planners navigate intricate climate lexicon: Driving forces, Disruption forces, and Stabilizing processes.

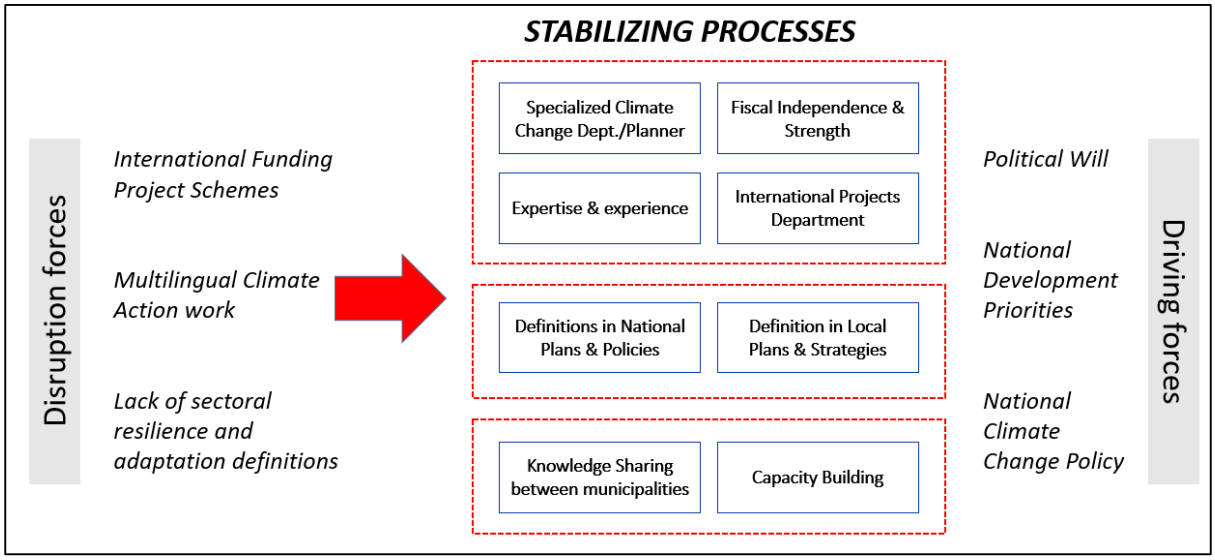


Figure 1. Navigating the Global Climate Lexicon in Jordan Framework. Source: Author.

Driving forces:

Participants discussed three main factors crucial to the navigation of the climate lexicon. Such driving forces are considered the foundation for implementing meaningful climate action and overcoming conceptual ambiguities. First, political will at the national and municipal levels is important. Municipal planners emphasized that decision-makers who recognize the urgency of climate change can promote the incorporation of climate action in municipal urban policy and allocate resources to support municipal planners in overcoming the challenges they face, including dealing with intricate climate lexicon. For instance, cities whose mayors are active members of global climate networks, such as C40 Cities or the Global Covenant of Mayors for Climate and Energy, tend to be more successful in adopting and implementing progressive climate policies.

At the same time, incorporating climate lexicon in national development priorities and frameworks is important. Municipal planners emphasized that climate action at the national level is the overarching framework that guides local municipal planning operations. Climate goals, indicators, and funding mechanisms established by national climate policies can be leveraged by municipalities to effectively incorporate climate action at the local level, and thus potentially reduce some conceptual ambiguities. At the same time, national development priorities can be used to align climate action work across municipal

sectors and foster a shared understanding of various climate change strategies and concepts among diverse stakeholders.

Disruption forces:

Municipal planners identified three main variables that create significant challenges to navigating the climate lexicon. As discussed in the previous section, international funding project schemes can disrupt municipal climate action and introduce new terminologies and diverging definitions. Similarly, multilingual climate action work imposed by the need for international grants to fund local development projects overwhelms municipal planners. Participants emphasized the need to focus on developing a coherent Arabic climate lexicon and building a shared understanding of climate-related risks and strategies across sectors, rather than waste time on translation. Some participants also pointed out how Arabic translations of climate concepts such as resilience and adaptation are not consistent between Arabic-speaking countries. This can also hinder resilience and adaptation to regional coordination and collaboration efforts within the Arab world.

On the other hand, some participants emphasized that while developing coherent Arabic definitions of adaptation and resilience is important, effective climate action also requires sectoral definitions of climate strategies. As one participant explained:

> "At the end of the day, a transportation planner will ask you: tell me what resilience means to my sector and to my work" (International Projects Department, GIM).

Stabilizing processes:

Stabilizing processes represents existing municipal capacities and infrastructure, knowledge and information, and initiatives that support municipal planners' efforts in mitigating conceptual ambiguities of climate lexicon. First, both Irbid and Amman municipalities have specialized department tasked with seeking international funding. The international projects departments in both municipalities, as well the Resilience Amman Department in GAM play a leading role in fostering a shared understanding of climate lexicon. Because both departments are implementing diverse climate initiatives and projects, they play a pivotal role in fostering inter-departmental collaboration within the municipality, which supports cross-sector knowledge sharing and facilitates a consistent interpretation of key concepts among stakeholders. At the same time, participants also explained, that the long and extensive experience of GAM in implementing local climate action, can mitigate potential ambiguities that may emerge as climate lexicon continues to evolve.

Second, existing efforts to define various climate-related terms at the national and local levels are important. Definitions provided in local climate action plans and national documents, such as Jordan's National Climate Change Policy and the National Adaptation Plan, act as standardized references that municipal planners can utilize and expand when developing climate strategies that meet their local needs. Such information ultimately supports the alignment of national priorities with local climate goals.

Third, participants indicated the importance of knowledge sharing and capacity building across municipalities. Local planning authorities that work together to share experiences, successes, and challenges with diverse climate action strategies can help municipal planners gain a more nuanced understanding of what, for example, climate resilience means within a Jordanian context and can foster the development of a common climate action lexicon. A collaborative learning process can also support smaller municipalities with limited resources to leverage climate change knowledge and expertise from other localities.

4. Conclusions and Future Research Direction

The urgency to adapt to climatic risks and hazards has exposed municipal planners to complex and evolving climate action lexicon and conceptual frameworks. The findings from this study illustrate how the climate lexicon emerging within international development funding schemes impacts local climate action work and complicates municipal planners' ability to navigate conceptual ambiguities within the climate lexicon. The study emphasizes the need for a unified Arabic Climate Action Lexicon that promotes collaboration between municipalities in Jordan and between Arabic-speaking countries. Despite the challenges, municipal planners' understanding of the benefits of climate change strategies, such as resilience and adaptation, helps mitigates some conceptual ambiguities within local climate action work.

Future studies research that explore international funding schemes effectiveness in promoting urban resilience is warranted. This includes examining how international funding development frameworks can support or potentially disrupt the establishment of a local climate action lexicon driven and co-created by local communities. A comparative assessment of how the climate lexicon is employed by municipalities facing different climatic challenges and resource constraints is also essential. Finally, future research can identify the characteristics of effective climate action knowledge-sharing systems for local Jordanian governance, international non-governmental organizations, higher education, and local community organizations that can foster a shared understanding of the climate lexicon across diverse Jordanian localities.

5. References

Araos, M., Berrang-Ford, L., Ford, J.D., Austin, S.E., Biesbroek, R. and Lesnikowski, A. (2016) 'Climate change adaptation planning in large cities: A systematic global assessment', *Environmental Science and Policy*, 66, p375-382. Available at: https://doi.org/10.1016/j.envsci.2016.06.009.

Baralt, M. (2011). 'Coding qualitative data' in Mackey, A. and Gass, S. M. (eds.) *Research methods in second language acquisition: A Practical Guide*. Chichester: Blackwell Publishing Ltd, pp222-244. Available at: https://doi.org/10.1002/9781444347340.ch12

Carter, J.G., Cavan, G., Connelly, A., Guy, S., Handley, J., and Kazmierczak, A. (2015) 'Climate change and the city: Building Capacity for urban adaptation', *Progress in Planning*, 95, p 1-66. Available at: https://doi.org/10.1016/j.progress.2013.08.001

Davoudi, S. and Porter, L. (2012) 'Applying the Resilience Perspective to Planning: Critical Thoughts from Theory and Practice', *Planning Theory and Practice*, 13(2), p299-333. Available at: https://doi.org/10.1080/14649357.2012.677124

Graute, U. (2016) 'Local authorities acting globally for Sustainable Development', *Regional Studies*, 50(11), p1931-1942. Available at: https://doi.org/10.1080/00343404.2016.1161740

Hallegatte, S. (2009) 'Strategies to adapt to an uncertain climate change', *Global Environmental Change*, 19(2), p240-247. Available at: https://doi.org/10.1016/j.gloenvcha.2008.12.003

Higgitt, D.L. (2009) 'Urbanization and environmental degradation in Jordan', in Sassen, S. (ed.), *Human Settlement Development – Vol 1*. Oxford: Eolss Publishers Co. Ltd, pp350-361.

Jabareen, Y. (2013) 'Planning the resilient city: Concepts and strategies for coping with climate change and environmental risk', *Cities*, 31, p220-229. Available at: https://doi.org/10.1016/j.cities.2012.05.004

Meerow, S., Newell, J. P., and Stults, M. (2016) 'Defining urban resilience: A review', *Landscape and Urban Planning,* 147, p28-49. Available at: https://doi.org/10.1016/j.landurbplan.2015.11.011

Moser, S., Meerow, S., Arnott, J. and Jack-Scott, E. (2019) 'The turbulent world of resilience: interpretations and themes for transdisciplinary dialogue', *Climatic change*, 153(1), p21-40. Available at: https://link.springer.com/article/10.1007/s10584-018-2358-0

Ribeiro, P.J. and Pena Jardim Gonçalves, L.A. (2019) 'Urban resilience: A conceptual framework', *Sustainable Cities and Society*, 50, p101625. Available at: https://doi.org/10.1016/j.scs.2019.101625

Rockefeller Foundation (2019) *Resilient cities, resilient lives: Learning from the (100RC network.)*. Available at: https://resilientcitiesnetwork.org/downloadable_resources/UR/Resilient-Cities-Resilient-Lives-Learning-from-the-100RC-Network.pdf

Sancino, A., Stafford, M., Braga, A., and Budd, L. (2021) 'What can city leaders do for climate change? insights from the C40 cities climate leadership group network', *Regional Studies*, 56(7), p1224-1233. Available at: https://doi.org/10.1080/00343404.2021.2005244

Seto K. C., S. Dhakal, A. Bigio, H. Blanco, G. C. Delgado, D. Dewar, L. Huang, A. Inaba, A. Kansal, S. Lwasa, J. E. McMahon, D. B. Müller, J. Murakami, H. Nagendra, and A. Ramaswami (2014). 'Human Settlements, Infrastructure and Spatial Planning' in Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.) *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, pp923-1000.

UN-Habitat (2023) *Jordan National Urban Policy*. United Nations Human Settlements Programme. Available at: https://unhabitat.org/sites/default/files/2024/02/231231-jnup_en_-final.pdf

While, A. and Whitehead, M. (2013) 'Cities, urbanisation and climate change', *Urban Studies*, 50(7), p1325-1331. Available at: https://doi.org/10.1177/0042098013480963

Woodruff, S., Bowman, A.O.M., Hannibal, B., Sansom, G., and Portney, K. (2021). 'Urban resilience: Analyzing the policies of U.S. cities', *Cities*, 115, p103239. Available at: https://doi.org/10.1016/j.cities.2021.103239

Research Paper

Regional Comprehensive Disaster Prevention System Planning from the Perspective of Resilient Cities: A Case Study of Mentougou District, Beijing Municipality

Yifei XU, School of Landscape Architecture, Beijing Forestry University, Beijing

Chi LI, School of Landscape Architecture, Beijing Forestry University, Beijing

Abstract

Urban ecosystems are increasingly vulnerable to extreme weather events, making resilient city planning vital for disaster prevention and mitigation. This study focuses on Beijing's Mentougou district, identifying high-risk areas for various disasters and quantitatively assessing three major natural hazards and their key influencing factors. It evaluates resilience within regional ecosystems and infrastructure systems to map the district's safety landscape comprehensively. Integrating multi-hazard risk assessments with urban resilience evaluations, the research proposes disaster prevention zones, identifies critical urban life corridors, and incorporates disaster relief nodes, enhancing the spatial organization of disaster management. The findings highlight the distinct roles of urban ecosystem quality and infrastructure in disaster prevention and relief, leading to the development of a comprehensive system tailored to Mentougou's temporal disaster characteristics. This system aims to improve urban resilience, safeguard land use, and support high-quality urban development.

Keywords

Resilient City; Coupling Analysis; Risk Assessment; Disaster Prevention and Mitigation; Mentougou District

1. Introduction

Climate is the fundamental condition for the survival and maintenance of human and natural ecosystems. Since the late 1970s and early 1980s, global warming has become increasingly pronounced, leading to a heightened risk of climate-related disasters, which pose a severe threat to human production and livelihoods. Currently, research in the relevant field primarily addresses two aspects: first, it focuses on the spatiotemporal characteristics(Huang et al., 2020) and patterns(Shen et al., 2022; Li et al., 2014) of climate change, particularly studying the risks of individual extreme events such as flooding and heatwaves(Han et al., 2019; Zhao et al., 2022); second, it conducts comprehensive analyses and evaluations of the resilience development level in study areas, considering factors such as spatiotemporal evolution, spatial differentiation, influencing factors, and optimization paths(Zhang et al., 2022; Li et al.,

2022; Liu et al., 2023). The scale of research is mainly concentrated on urban and watershed levels (Luo et al., 2022; Wang et al., 2023). Although existing research has yielded significant results, it still faces considerable theoretical and practical limitations. From a theoretical perspective, analyses based solely on single-hazard risks or resilience perspectives lack a systematic and scientific coupled assessment framework, as well as a theoretical analysis of the interactive evolution between the two (Wu et al., 2024). From an applied perspective, specialized mitigation measures for individual hazards overlook the trade-offs and synergies among multiple hazard factors, making the actual effectiveness difficult to measure. Therefore, conducting a comprehensive multi-hazard risk assessment from the perspective of resilient cities, identifying the baseline of urban disaster risks, and optimizing the spatial structure of urban disaster prevention is critical to achieving resilient urban development.

In summary, this study selects Beijing's Mentougou District as a case study area. Utilizing Remote Sensing (RS) and Geographic Information Systems (GIS) within the appropriate model framework, we quantitatively assess the geological, flood, and fire disaster risks of the district and systematically evaluate the resilience development levels of regional ecosystems and infrastructure systems. Building upon a comprehensive integration of existing territorial spatial planning outcomes, the research clarifies the city's emergency support nodes, identifies key life corridors, and delineates disaster prevention and control zones from the three dimensions of "point, line, and plane." The findings reveal the spatial misalignment between comprehensive multi-hazard risks and urban resilience patterns in Mentougou District, offering data support and a theoretical basis for disaster risk prevention and resilient urban development in the region.

2. Materials and methods

2.1. Study area

Mentougou district (Figure 1) is located in the mountainous western region of Beijing, covering an area of 1,455 km², with mountains accounting for 98.5% of the total area. As the only fully mountainous district in Beijing, it has uneven vegetation coverage, severe soil erosion, and frequent landslides and debris flows. Additionally, due to the instability of mid-latitude atmospheric circulation and the influence of monsoons, the Mentougou district experiences significant interannual variations in precipitation, with uneven distribution throughout the year. Approximately 85% of the annual rainfall occurs during the flood season, making the area highly prone to major floods and flood-related disasters.

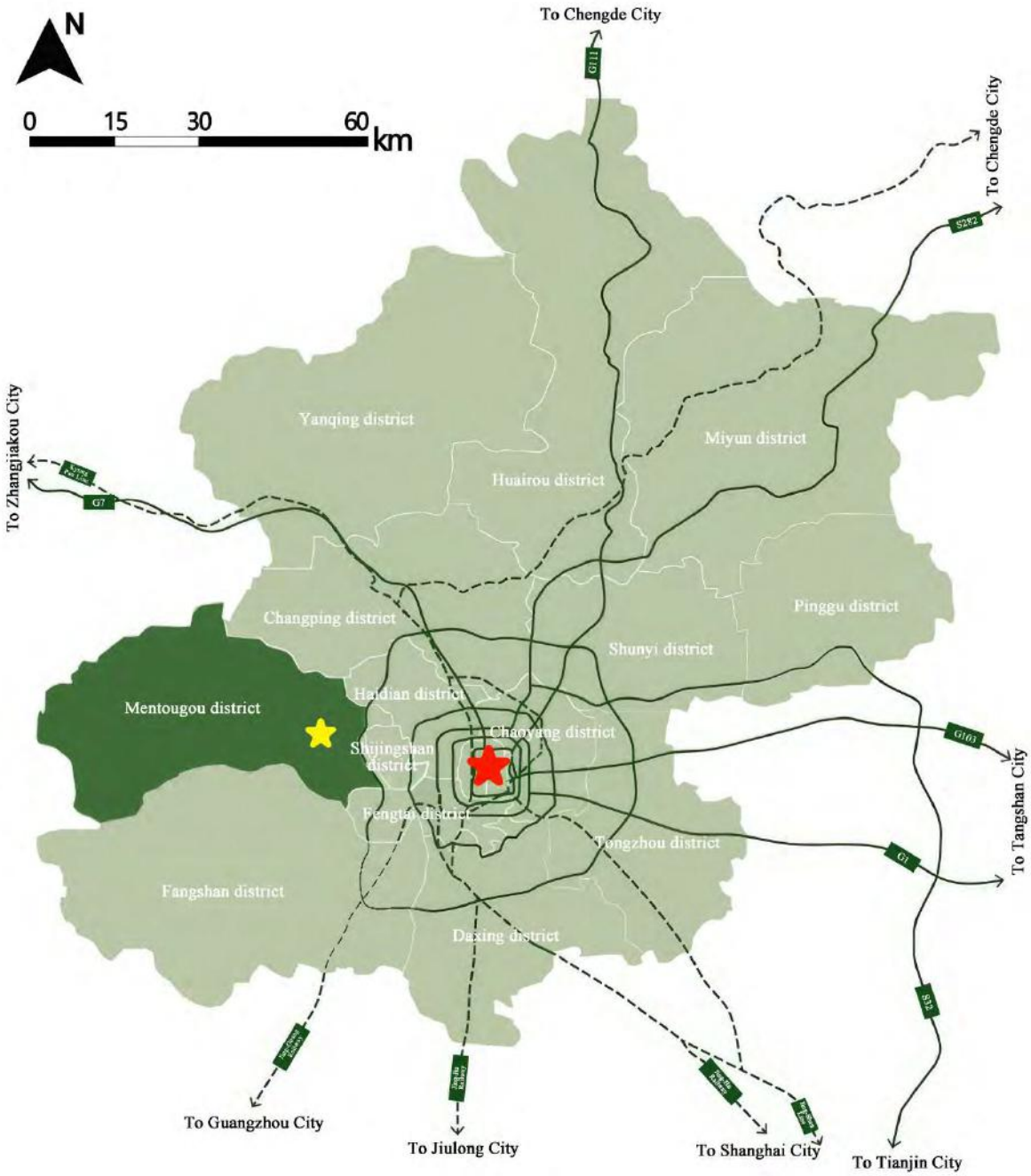


Figure 1. Location analysis of the study area.

2.2. Data

The data used in this study primarily consists of four types: land use data, disaster distribution data, natural environment data, and socioeconomic data (Table 1). To ensure the scientific rigor and consistency of the study, the administrative boundaries of the Mentougou district were used as spatial constraints. All data were projected using the WGS_1984_UTM_Zone_50N coordinate system, with a uniform resolution of 30 meters, and the rows and columns of raster data were aligned accordingly.

Table 1. Data profile and sources.

Data types	Specific data	Data format	Sources of the data (Providers)
Land Use/Cover	China National Land Use/Cover Change Dataset (CNLUCC)	Raster	Resource and Environmental Science and Data Center (https://www.resdc.cn/)
Disaster distribution data	Hazard distribution coordinate data	CSV	Mentougou District Government (http://www.bjmtg.gov.cn/)
Natural environment data	Digital Elevation Data	Raster	Geospatial Data Cloud (https://www.gscloud.cn/)
	Annual NDVI Spatial Distribution Dataset in China	Raster	Resource and Environmental Science and Data Center (https://www.resdc.cn/)
	Annual spatial interpolation data of meteorological elements in China	Raster	Resource and Environmental Science and Data Center (https://www.resdc.cn/)
	Natural element boundary data	Shapefile	National Catalogue Service for Geographic Information (https://www.webmap.cn/)
	Seismically active fault data	Shapefile	Institute. of Geology, China Earthquake Administration (https://www.eq-igl.ac.cn/)
Socio-economic data	Transportation network classification data	Shapefile	OpenStreetMap (https://extract.bbbike.org/)
	Infrastructure distribution data	Shapefile	OpenStreetMap (https://extract.bbbike.org/)
	Administrative boundary data	Shapefile	Resource and Environmental Science and Data Center (https://www.resdc.cn/)
	GDP spatial distribution kilometer grid data in China	Raster	Resource and Environmental Science and Data Center (https://www.resdc.cn/)
	Population Spatial Distribution Kilometer Grid Data in China	Raster	Resource and Environmental Science and Data Center (https://www.resdc.cn/)

2.3. Multi-hazard Comprehensive Risk Assessment

This paper reveals the comprehensive disaster risk level of the study area by coupling the individual risk assessment results of geological hazards, flood hazards, and fires. As shown in Equation (1), the risk of a single hazard consists of two components: hazard risk and susceptibility (Lu et al., 2024). Hazard risk refers to the intensity of hazardous factors and the likelihood of their occurrence. For each type of disaster, this study selected five independent factors with significant influence as evaluation indicators and determined the weight of each factor using expert scoring and public participation methods (Table 2) (Shan et al., 2024; Bai et al., 2024; Li et al., 2024). Susceptibility refers to the spatial density and temporal frequency of disaster occurrences. This study collected historical data on various disasters by reviewing statistical records consulting relevant organizations, and performing spatial visualization based on the GIS platform. Additionally, to eliminate the impact of dimensional differences, all individual factor indicators were standardized (Equation 2).

$$R_f = H_f \times eV_f \tag{1}$$

In the equation, R_f represents the risk level of a single hazard, H_f denotes hazard risk, V_f refers to susceptibility, and e is the proportional coefficient.

$$X' = \frac{(X_i - X_{min})}{(X_{max} - X_{min})} \tag{2}$$

In the equation, $X^{'}$ epresents the standardized result, with values ranging between 0 and 1; X_i is the value of the i-th raster; X_{max} and X_{min} are the maximum and minimum values of the raster, respectively.

Table 2. Indicators and weights for single-hazard evaluation.

Type of disaster	Indicator name	Relevance	Weight
Geological disaster	DEM	Positive correlation	0.2
	Rate of change of slope	Positive correlation	0.25
	Slope	Positive correlation	0.25
	NDVI	Negative correlation	0.2
	Distance from the fault	Negative correlation	0.1
Flood disaster	Precipitation	Positive correlation	0.2
	Rate of change of slope	Positive correlation	0.15
	Slope	Positive correlation	0.15
	NDVI	Negative correlation	0.2
	Distance from the water body	Negative correlation	0.3
Fire disaster	Temperature	Positive correlation	0.2
	NDVI	Positive correlation	0.3
	Distance to timber-framed buildings	Negative correlation	0.15
	Distance from the deflagration risk area	Negative correlation	0.15
	Soil water content	Negative correlation	0.2

2.4. Assessment of the development level of urban resilience

This study uses the completeness of urban roads, power supply facilities, water supply facilities, communication facilities, and fire-fighting facilities as the basic indicators for evaluating the resilience of the urban infrastructure system. The weight of each factor was determined through expert scoring and public participation methods (Table 3).

Table 3. Indicators and weights for single-hazard evaluation.

Code	Indicator name	Relevance	Weight
1	Distance from the road	Positive correlation	0.4
2	Distance from the fire-fighting facilities	Positive correlation	0.15
3	Distance from the power supply facilities	Positive correlation	0.15
4	Distance from the water supply facilities	Positive correlation	0.15
5	Distance from the communications facilities	Positive correlation	0.15

Drawing on previous research, this paper constructs an urban ecological resilience assessment model from three aspects: resistance, adaptation, and restoration (Equation 3) (Xia et al., 2022). Resistance (P) refers to the ability of an urban ecosystem to withstand external disturbances, which in this study is evaluated by calculating the ecosystem service value index of the study area (Equation 4) (Huang et al., 2018; Ren et al., 2000a; Xie et al., 2015). Restoration (R) refers to the ability and potential of an ecosystem to return to its original state after being harmed and is calculated using the ecological resilience model proposed by Peng et al. (Equation 5) (Peng et al., 2015). Adaptation (A) refers to the stability of the landscape structure in the study area, which is assessed using landscape indices from two

aspects: landscape heterogeneity and landscape connectivity (Ren et al., 2000b). The specific secondary indicators and weight distribution are shown in Table 4 (Peterson, 2002; Turner, 1989; Peng et al., 2015).

$$Resilience = \sqrt[3]{A \times P \times R} \quad (3)$$

$$P = ESV = \sum A_k \times VC_{fk} \quad (4)$$

$$R = \sum A_k \times RC_i \quad (5)$$

Table 4. Analysis of landscape pattern factor.

Evaluation indicators	Landscape pattern factor	Weight
Landscape heterogeneity	Shannon Diversity Index	0.25
	Area-Weighted Mean Patch Fractal Dimension	0.25
Landscape connectedness	Landscape Fragmentation	0.5

3. Results

3.1. Mentougou district multi-hazard comprehensive risk

3.1.1. Geological Disaster Risk

Geological disasters in the Mentougou district are primarily sudden-onset, characterized by diversity, clustering, concealment, and concentration. The mountainous areas of Mentougou account for 98.5% of its total area, making the impact of terrain on urban development more pronounced than in other regions. As shown in Figure 2-a, areas with high seismic hazard levels are mainly located in the northwestern mountains and along the Yongding River in the Yanchi, Wangping, and Miaofengshan villages. Additionally, the new city area, Tanzhesi Town, and Junzhuang Town, with a long history of coal mining and large subsidence areas, are also high-risk zones for mine-induced earthquakes. Susceptibility results (Figure 2-b) indicate that Mentougou district contains five high-vulnerability zones, four medium-vulnerability zones, and several low-vulnerability zones, most of the low and medium-vulnerability zones are located in patches. Zhaitang, Qingshui, and Yanchi towns each have over 350 geological disaster points, while Datai subdistrict, Tanzhesi town, and Wangping town have over 150 points. The Longquan area is the location of major geological hazards in the New City.

Overall, the most severe geological hazards in Mentougou district are concentrated in Dong and Xi Wangping villages in Wangping town, Sanjiadian village in Longquan town, and the northwestern mountainous area, with typical cases in Lingshan mountains, Bijingsi village, and Huangtugui village. Medium-scale hazards are concentrated in the northern part of Caodianshui village in Tanzhesi town, the central parts of Shangdamo village, the Xidamoand village, and the eastern parts of Huangta villages in Qingshui town, and the northern part of Huiyu village in Junzhuang town (Figure 2-c).

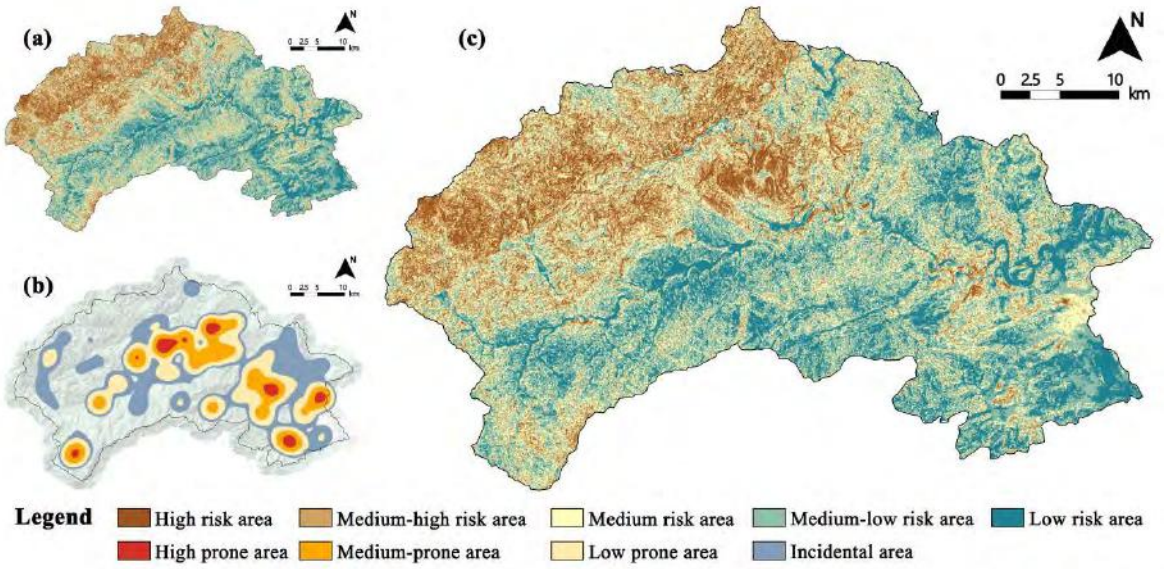


Figure 2. Mentougou district multi-hazard comprehensive risk (Geological disaster). (a)Results of disaster risk assessment. (b)Results of risk susceptibility assessment. (c)Results of multi-hazard comprehensive risk.

3.1.2. Flood disaster risk

Flood disasters in Mentougou district are primarily caused by torrential rain, leading to collapses and waterlogging. As shown in Figure 3-a, areas with high flood risk are concentrated in the mainstream of the Yongding River and its tributaries, including the Qingshui River, Weidiangou, and Jiangou regions. Additionally, due to the low elevation of Mentougou new city area, surrounded by mountains on the north, west, and south sides, the city's main drainage channels are insufficient during heavy rainfall in the flood season, posing certain disaster risks. Susceptibility results (Figure 3-b) show that high-vulnerability flood zones are concentrated along the Qingshui River, from Zhaitang town to Yanchi town along the Yongding River. This region has numerous sharp river bends, causing significant increases in runoff. Three high-vulnerability areas are located in Donghulin village, Taizimu village, and Chengzi subdistrict of Mentougou new city area, with five medium-vulnerability areas and several low-vulnerability zones.

Overall, the most severe flood risks in Mentougou district are concentrated in the northern Yongding River basin section of the new city area, the confluence of water systems in Miaofengshan town and Wangping town, and the area between Zhuwo-Weizishui reservoir area. Medium-scale risks are concentrated in the Zhaitang reservoir and the Tanzhesi section of the Daqing River. Additionally, the southern of the new city area, Junzhuang town, Miaofengshan town, Yanchi town, Zhaitang town, and the central areas of Qingshui town are under significant waterlogging threats (Figure 3-c).

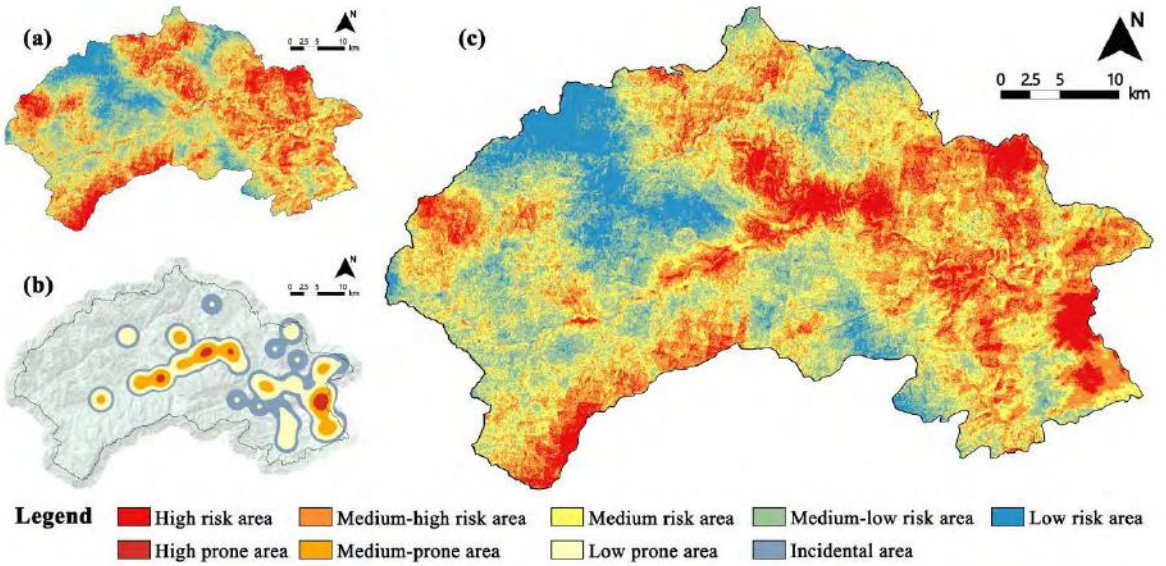


Figure 3. Mentougou district multi-hazard comprehensive risk (Flood disaster). (a)Results of disaster risk assessment. (b)Results of risk susceptibility assessment. (c)Results of multi-hazard comprehensive risk.

3.1.3. Fire disaster risk

Fire hazards in Mentougou district are mainly concentrated in units handling flammable and explosive materials, high-density old urban areas, protected historic buildings, and forest fires. As shown in Figure 4-a, fire risks are highest in the Qingshui River basin and the new city area, with a gradient decreasing from east to west and from the rivers to the forests. Susceptibility results (Figure 4-b) indicate that Mentougou district has three high-vulnerability zones, four medium-vulnerability zones, and several low-vulnerability zones, mostly scattered.

Overall, major fire hazard zones in Mentougou district are concentrated in Junzhuang town, Zhaitang town, and Yanchi town, while medium-risk areas are concentrated in the new city area, Tanzhesi town, Junzhuang town, and Zhaitang town. Fire risks are scattered across various regions in a point pattern (Figure 4-c).

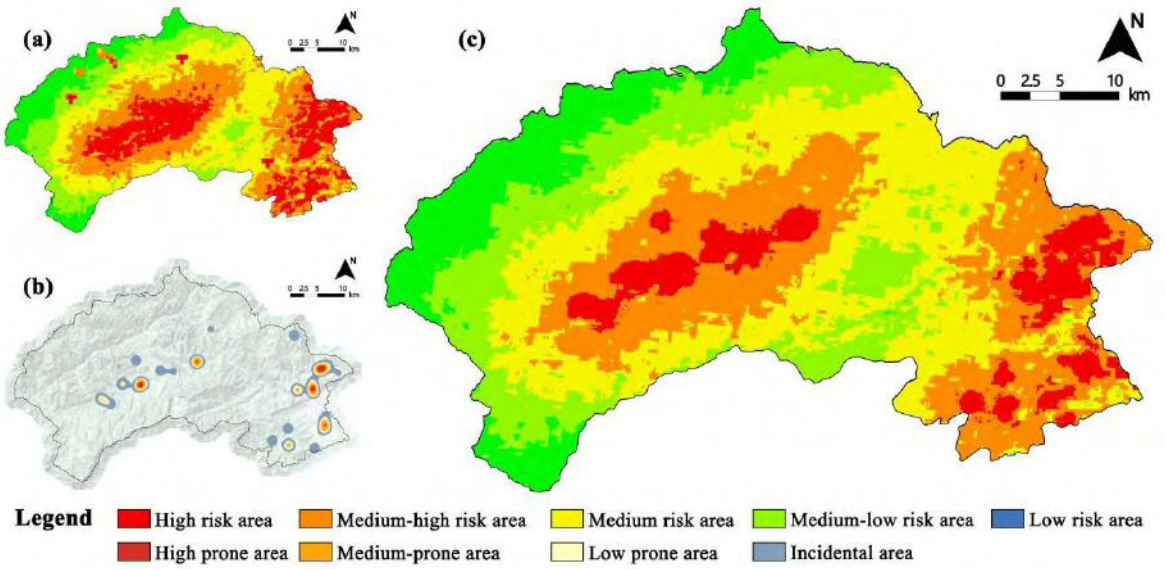


Figure 4. Mentougou district multi-hazard comprehensive risk (Fire disaster). (a)Results of disaster risk assessment. (b)Results of risk susceptibility assessment. (c)Results of multi-hazard comprehensive risk.

3.1.4. Mentougou district multi-hazard comprehensive risk

As shown in Figure 5, areas with high comprehensive disaster risk in Mentougou district are primarily located in the northern section of Chengzi village in the new city area, the southern part of Sanjiadian village, the Seshufen area in Wangping town, the northeastern part of Datai subdistrict, and the Fajiatai and Zhuwuo village areas in Yanchi town. Medium-risk areas are distributed in Chengzi village, Shigang village, and Mentoukou village in the new city area; Dongxin village in Tanzhesi town; the Huiyu village in Junzhuang town; Longjiazhang village in Miaofengshan town; Dong and Xi Wangping villages in Wangping town; and the southern part of Datai subdistrict. Low-risk areas are concentrated in villages with ongoing construction activities.

From a spatial distribution perspective, the comprehensive disaster risk closely mirrors the spatial pattern of flood risk, highlighting that flood disasters are a critical factor affecting the stability of the natural environment and socio-economic development. This also corroborates the complex interplay between various disasters in the Mentougou district, where floods caused by heavy rains can trigger subsidence, landslides, and debris flows. Additionally, most high-risk disaster zones are located along the Yongding River, underscoring the importance of maintaining the ecological security of the Yongding River basin for disaster prevention and relief in the Mentougou district.

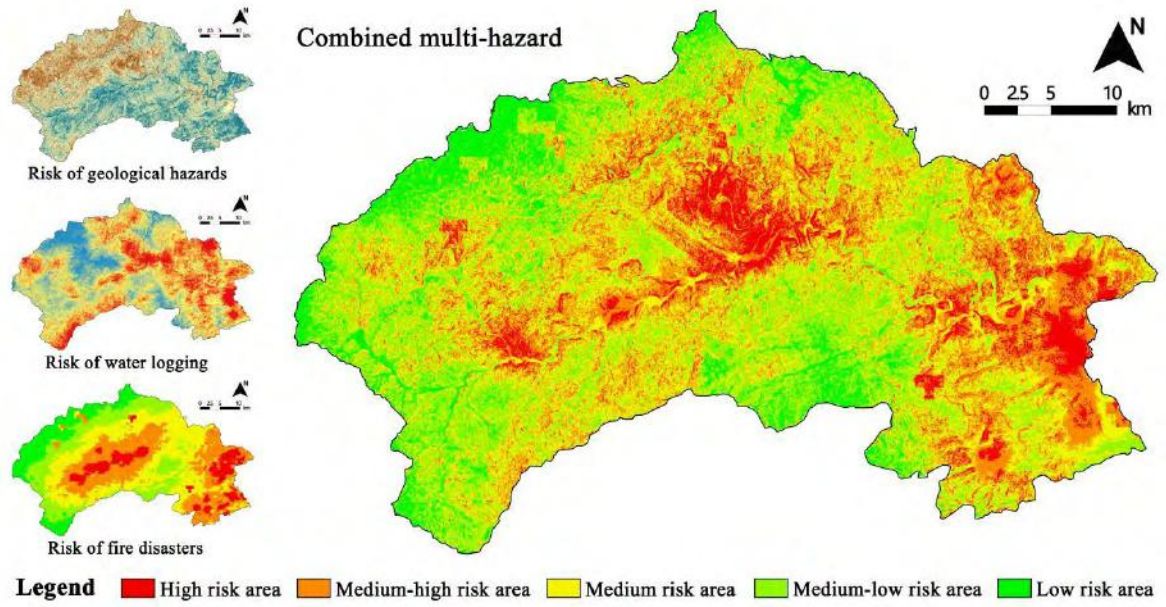


Figure 5. Mentougou district multi-hazard comprehensive risk.

3.2. Development level of urban resilience in Mentougou district

3.2.1. Resilience level of the infrastructure system in the Mentougou district

As shown in Figure 6, the resilience level of the infrastructure system in Mentougou district is centered around Mentougou new city area, Fujiatai village in Yanchi town, and Junxiang village, with a gradient decline from the center toward the periphery. Notably, high-resilience infrastructure areas in the

Mentougou district are fragmented and scattered around town centers, and have yet to form an interconnected and cohesive coverage system..

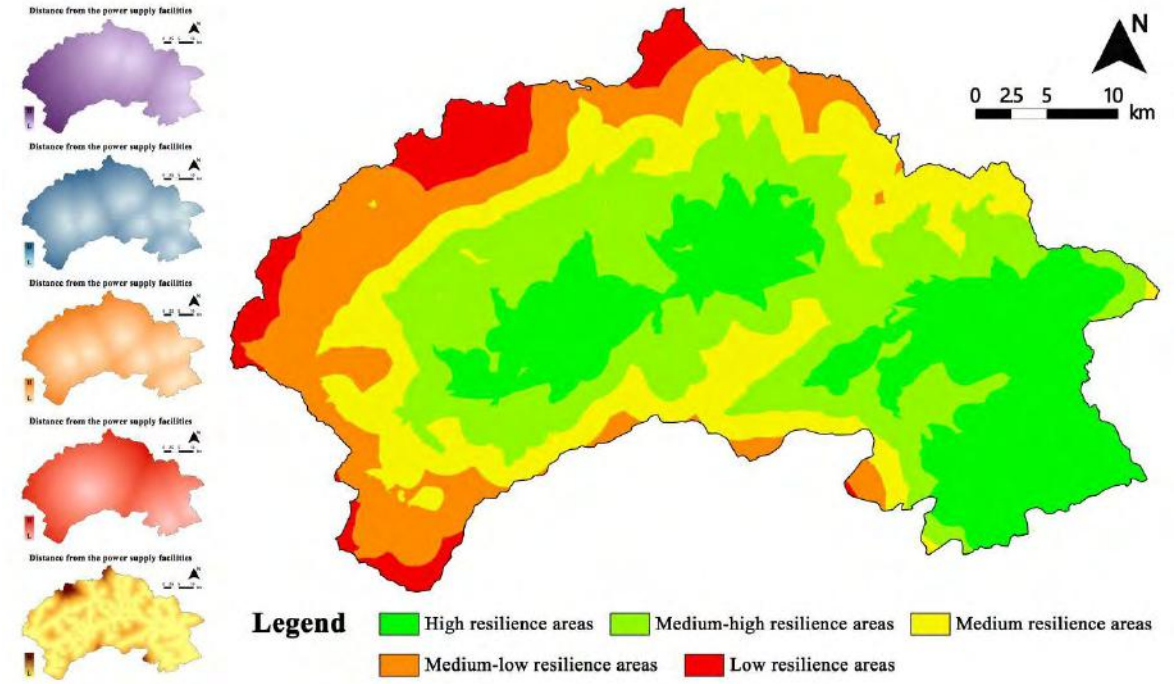


Figure 6. Evaluation results of the resilience level of the infrastructure system.

3.2.2. Resilience level of the urban ecosystem in the Mentougou district

The ecosystem resistance (P) in the Mentougou district is relatively weak, with an average value of only 0.37. The high-resistance areas are mainly distributed along the Yongding River, including the Longkou reservoir, Sanjiadian reservoir, Luopoling reservoir, Zhuwo reservoir, Fujiatai village, and Taizimu village, while low-resistance areas are concentrated in the new city area and Junzhuang town (Figure 7-a). The ecosystem restoration (R) in Mentougou district is relatively high, with an average value of 0.86. Mountainous forest areas and the Yongding River and its tributaries have high resilience, while low-resilience areas are located in the new city area, Junzhuang town, and Tanzhesi town (Figure 7-b). The ecosystem adaptation (A) in Mentougou district is extremely low, with an average value of only 0.09. The land use structure in the district is predominantly single-type forest land, with high adaptability areas concentrated in the old and new urban areas and the construction-intensive towns in mountainous areas (Figure 7-c).

Overall, the ecosystem resilience level in the Mentougou district is relatively low, with an average value of only 0.17, although the ecological resilience of the Yongding River and its tributaries is generally higher (Figure 7-d). Spatial autocorrelation analysis of resilience levels (Figure 7-e) indicates a significant clustering of high values (Z=25.4101), with the hotspots primarily located at the boundary between Miaofengshan town and Wangping town, Dingdu peak, Zhuwuo reservoir, and Zhaitang reservoir. The coldspots are mainly distributed in the Lingshan Scenic Area, Cuandixia village, and Shenquanxia Scenic Area.

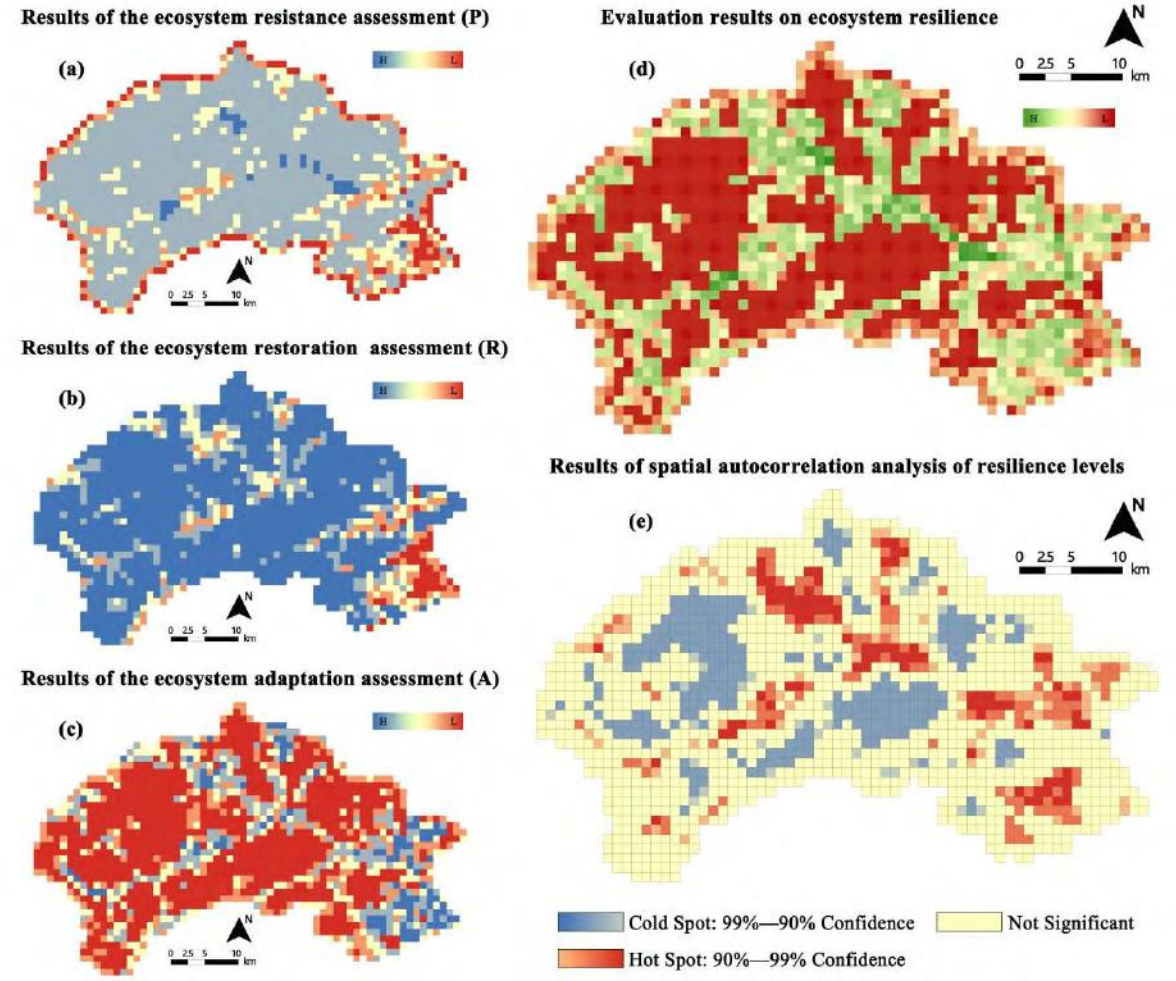


Figure 7. Evaluation results of the resilience level of the urban ecosystem.

4. Discussion

4.1. Mentougou district disaster prevention spatial layout

Mentougou district currently has 10 emergency shelters with a total evacuation area of 257,000 m2, providing approximately 0.86 square meters per capita. However, since most villages in Mentougou district are scattered across 98.5% mountainous terrain, and with rugged roads, the difficulty of emergency rescue is increased. Therefore, this study proposes a disaster prevention spatial layout tailored to local conditions. For developed towns and central urban areas, a unit-based management approach for prevention and control is recommended, with evacuation planned based on population density to ensure that the per capita effective area in fixed shelters exceeds 2 m^2. For mountainous towns, 19 additional emergency rescue points with a service radius of 3 km are proposed, including 6 in Qingshui town, 5 in Zhaitang town, 5 in Yanchi town, and 3 in Miaofengshan town (Figure 8). Each emergency rescue point will be built within village infrastructure, ensuring that the walking time from each village to the nearest rescue center is no more than 1 hour.

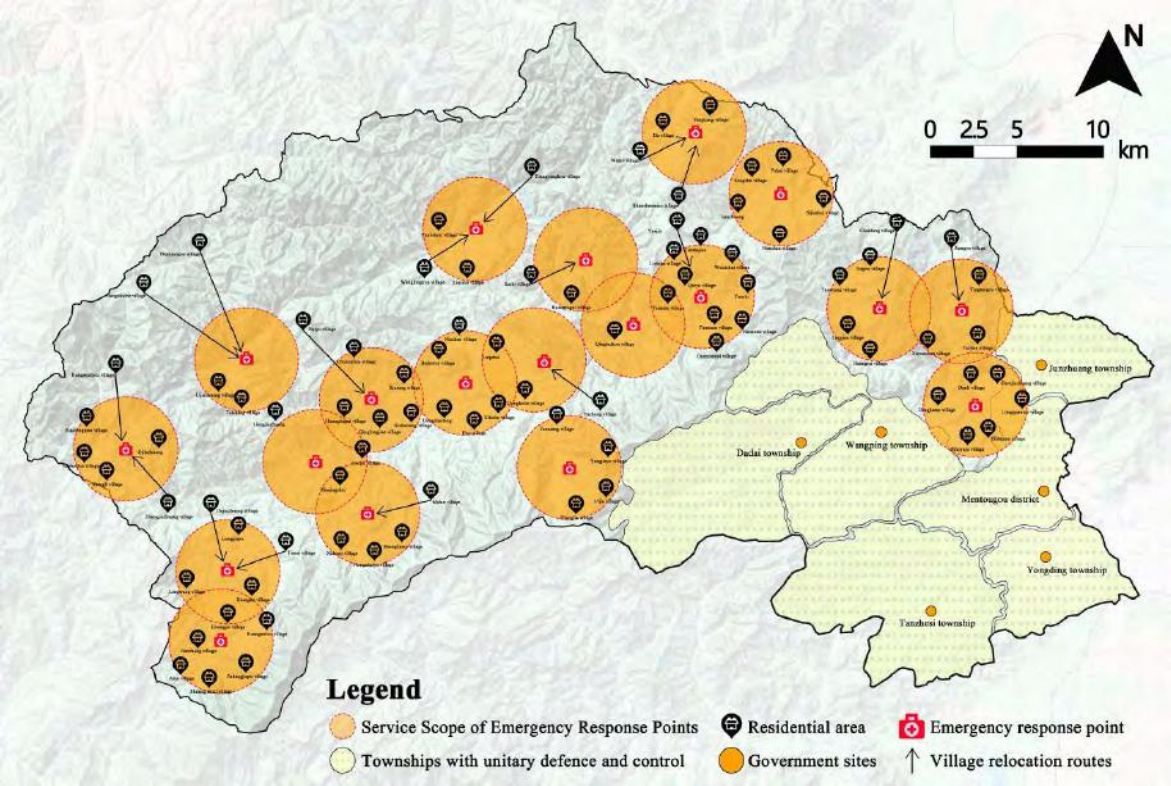


Figure 8. Mentougou district disaster prevention spatial layout planning.

4.2. Mentougou District life corridor construction

Based on the standards for urban life passageway construction and the disaster prevention spatial layout of Mentougou District, this study proposes a regional life corridor construction concept of "reliable, passable, and accessible." The study suggests dividing the corridors into three levels based on emergency support levels, which together form a "two rings and two belts" life corridor system (Figure 9). The first-level life corridor is structured as "two horizontal and one vertical," primarily responsible for ensuring basic urban traffic under major or catastrophic disasters, and for facilitating internal and external rescue transport. The second-level life corridor is structured as "two horizontal and two vertical," focusing on maintaining internal circulation for disaster relief and facilitating the transport of relief materials and personnel within the city. The third-level life corridors are dispersed and mainly connect the first and second-level corridors, extending the coverage of disaster relief and ensuring quick evacuation in the event of small to moderate disasters or pre-disaster evacuation.

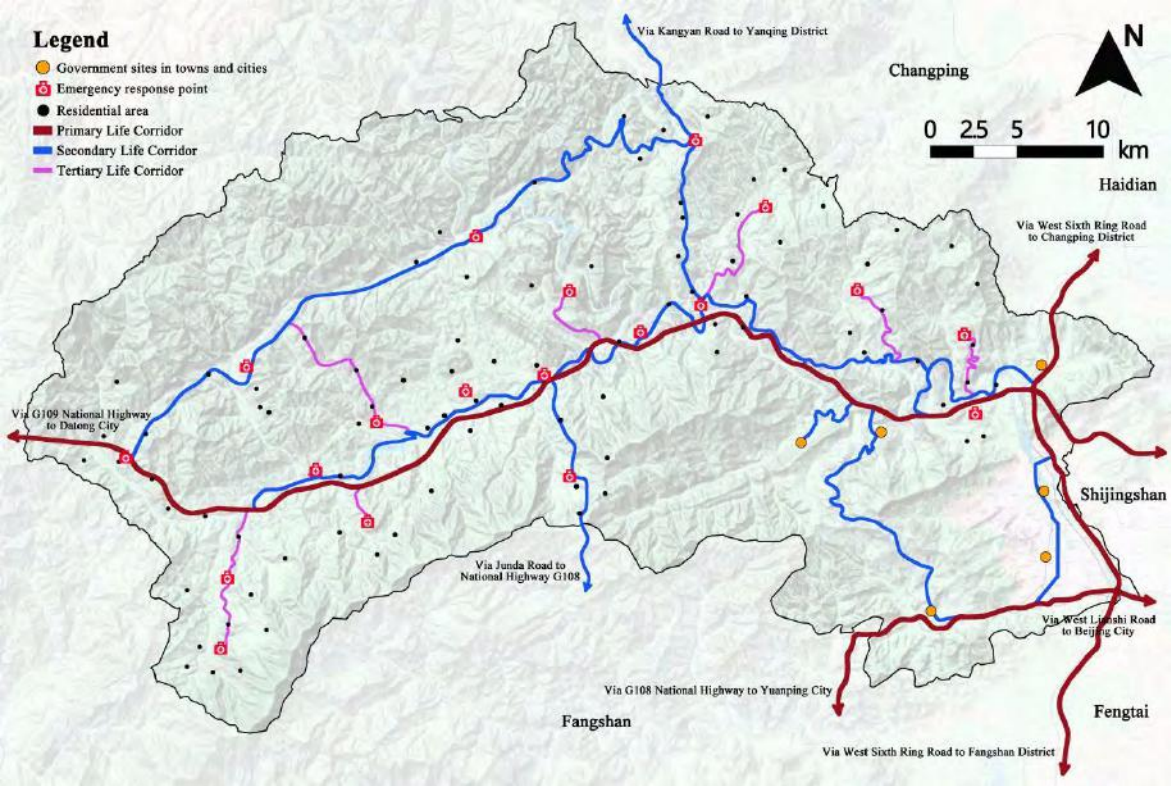


Figure 9. Mentougou district life corridor planning.

4.3. Mentougou district emergency security points identification

To meet the emergency needs of the Mentougou district during disasters, the study optimizes infrastructure coverage in four key areas: power supply, water supply, communication, and firefighting facilities. It also classifies support levels based on disaster frequency and severity, establishing a coordinated district-wide emergency support system. For power supply, the study proposes designating the Gaojing and Jingxi power plants as key support plants, with the addition of two first-level support substations and four second-level support substations (Figure 10-a). In terms of water supply, the study plans to designate the Sanjiadian reservoir, Luopoling reservoir, and Zhaitang reservoir as emergency water sources. Additionally, the study categorizes existing and planned waterwork by support level and adds one first-level waterwork (Figure 10-b). For firefighting, the study proposes to set up 9 additional fire stations to enhance the region's disaster emergency response capacity. Existing and planned fire stations are categorized by support level (Figure 10-c). For communication, the existing communication facilities are sufficient to meet regional needs, so the study categorizes them by support level and optimizes high-support equipment to ensure stable district-wide communication network coverage (Figure 10-d).

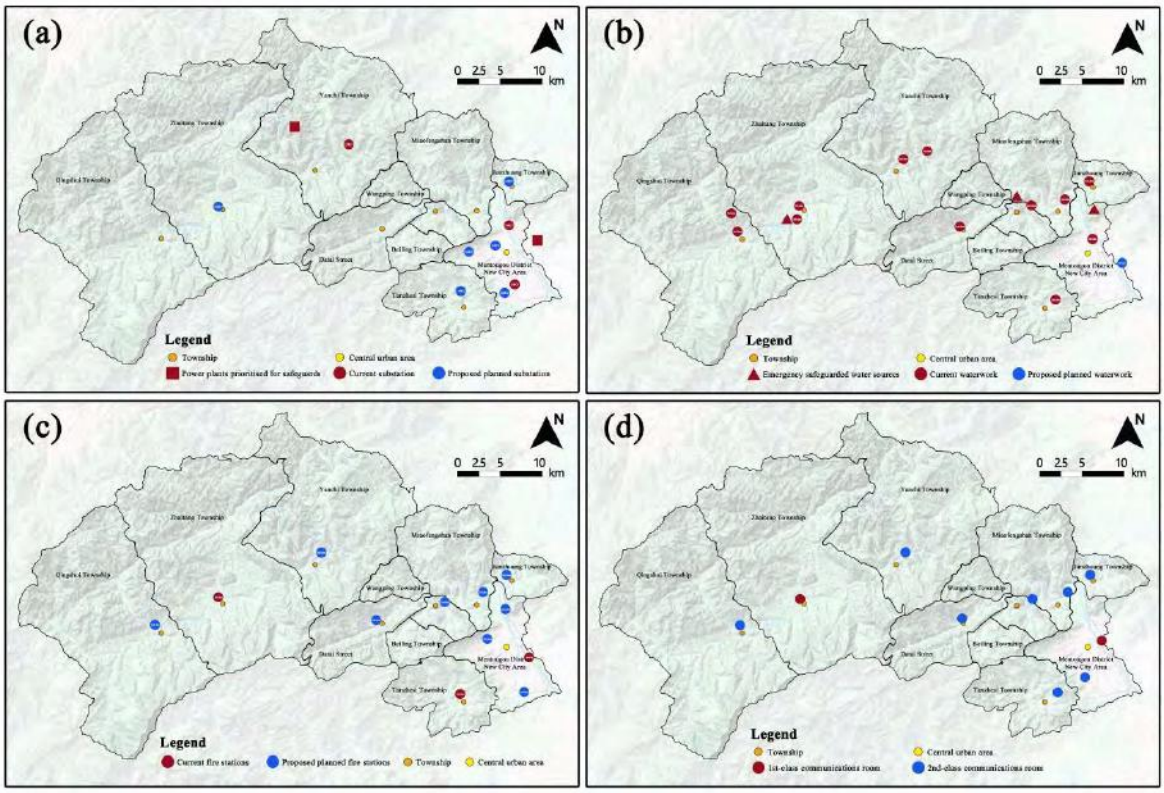


Figure 10. Mentougou district emergency security points planning.

5. Conclusion

As an important ecological barrier for Beijing, the ecological security of the Mentougou district holds significant importance for regional socio-economic development. This study, using Rs and ArcGIS platforms, assesses the comprehensive risk of multiple hazards in the Mentougou district by evaluating both hazard risk and susceptibility. By constructing a multi-factor evaluation system, the study also examines the resilience of the city ecosystems and infrastructure systems. The study proposes a disaster evaluation method from the perspective of resilient cities and establishes an integrated point-line-plane framework for urban disaster prevention and mitigation planning. Finally, the study provides strategic recommendations for disaster prevention and mitigation in the Mentougou district. The main conclusions of the research are as follows:

(1) Flooding is the type of disaster that has the highest combined risk level (Domain-wide average is 0.47) and the widest threat area (36.25% of the whole area) in Mentougou district. They primarily endanger the safety of production and construction activities in towns along the mainstream and parts of the tributaries of the Yongding River. Additionally, floods can trigger a variety of geological disasters such as subsidence and landslides, making them the key disaster type that affects the stability of the natural environment and socioeconomic development in the region.

(2) The resilience level of the infrastructure system in the Mentougou district is relatively high, with an average value of 0.71 across the region. Its spatial pattern is centered around the new city area, Fujiatai village in Yanchi town, and Junxiang village, showing a gradient decline from the center to the periphery. In contrast, the resilience level of the ecosystem in Mentougou district is generally low, with an average

value of 0.17. The spatial pattern of ecosystem resilience shows significant clustering of high values, primarily concentrated in the border area between Miaofengshan town and Wangping town, the Dingdu peak area, and the region between Zhuwo reservoir and Zhaitang reservoir.

(3) Based on the spatial patterns and temporal characteristics of various disasters in the Mentougou district, the study develops an integrated point-line-plane urban disaster prevention and mitigation system across three areas: urban planning, emergency support, and recovery enhancement. In terms of area planning, the study proposes adding 19 emergency rescue points with a service radius of 3 km, covering 83.5% of existing villages, while ensuring that the remaining villages are within 5 km of a rescue center village. For corridor planning, the study classifies corridors into three levels based on emergency support, forming a "two rings and two belts" life corridor system. After planning, the life corridors will directly connect 70.7% of villages, significantly improving the city's emergency transport capacity and ensuring the orderly execution of emergency rescue and lifesaving activities. In terms of node planning, the study optimizes infrastructure coverage in four areas—power supply, water supply, communication, and firefighting facilities—by categorizing them according to disaster frequency and severity. After optimization, the coverage of power supply, water supply, and communication facilities will increase by 126.19%, 5.59%, and 328.01%, respectively.

6. References

BAI Pengfei,TAN Xiaohu,LI Jie, et al., (2024) 'Collaborative Network Research on Urban Flood Emergency Management from a Resilience Perspective', Journal of Catastrophology, p1-9.

Shan Y F, Li W L, Zhou S S, et al., (2024) 'Ecological risk assessment of landslide hazards in the upper reaches of the Yangtze River region', Acta Ecologica Sinica (24), p1-13.

Han Lanying, Zhang Qiang, Jia Jianying, et al., (2019) 'Drought Severity, Frequency, Duration and Regional Differences in China', JOURNAL OF DESERT RESEARCH, 39(5), p1-10.

HUANG Jianping, ZHANG Guolong, YU Haipeng, et al., (2020) 'Characteristics of climate change in the Yellow River basin during recent 40 years', SHUILI XUEBAO, 51(9), p1048-1058.

Huang Z X, Wang F F, Cao W Z., et al., (2018) 'Dynamic analysis of an ecological security pattern relying on therelationship between ecosystem service supply and demand:a case studyon the Xiamen-Zhangzhou-Quanzhou city cluster', Acta Ecologica Sinica, 38(12), p4327-4340.

Li Liangang, Zhang Pingyu, Cheng Yu, et al., (2022) 'Spatio- temporal evolution and influencing factors of economic resilience in the Yellow River Basin', Scientia Geographica Sinica, 42(4), p557-567.

Li Ying, Gao Ge, Song Lianchun, (2014) 'Understanding of Disaster Risk and the Management Associated withClimate Change in IPCC AR5', PROGRESSUS INOUISITIONES DE MUTATIONE CLIMATIS, 10(4), p260-267.

Li Yuheng, Wang Shengye, Huang Huiqian, (2024) 'Rural disaster vulnerability assessment and influencing factors analysis: A case study of Xun County, Henan Province', Scientia Geographica Sinica, p1-8.

LIU He-he, SUN Meng, Temer Gaotou, et al., (2023) 'Study on Urban Resilience Assessment and Optimization Path in the Yellow River Basin', Journal of Inner Mongolia Minzu University (Social Sciences), 49(1), p74-84.

LU Xuehui, HAN Chao, ZHANG Qingyu, et al., (2024) 'Comprehensive Risk Assessment of Multiple Hazards in Chengdu Based on RS and GIS', Ecology and Environmental Monitoring of Three Gorges, 9(3), p49-61.

LUO Wei, HUANG Zhihua, CHENG Suiying, et al., (2022) 'Study on the Coordination Between Urban Resilience and Economic DevelopmentLevel in the Yellow River Basin', YELLOW RIVER, 44(7), p8-13.

PENG Jian, WANG Yang-Lin, WU Jian-Sheng, et al., (2007) 'Evaluation for regional ecosystem health:methodology and research progress', Acta Ecologica Sinica (11), p4877-4885.

REN Hai, WU Jianguo, PENG Shaolin, et al., (2000a) 'Concept of ecosystem management and its essential elements', CHINESE JOURNAL OF APPLIED ECOLOGY (3), p455-458.

REN Hai, WU Jian-guo, PENG Shao-lin, (2000b) 'EVALUATION AND MONITORING OF ECOSYSTEM HEALTH', TROPICAL GEOGRAPHY (4), p310-316.

SHEN Lulu, YANG Yanfen, WU Jing, et al., (2022) 'Spatial and Temporal Variation Characteristics of ExtremeClimate Events in the Yellow River Basin', Research of Soil and Water Conservation, 29(2), p231-242.

WANG Songmao, NIU Jinlan, (2023) 'Spatio-temporal evolution and influencing factors of urban ecological resilience in the Yellow River Basin', Acta Ecologica Sinica, 43(20), p8309-8320.

WU Zhanyun, SUN Shao, ZHANG Shuangyue, et al., (2024) 'Climate Resilience Assessment and Enhancement Countermeasures for Yellow River Basin Cities', Scientific and Technological Management of Land and Resources, 41(2), p62-74.

XIA Chuyu, DONG Zhaoyingzi, CHEN Bin, (2022) 'Spatio-temporal analysis and simulation of urban ecological resilience: A case study of Hangzhou', Acta Ecologica Sinica, 42(1), p116-126.

XIE Gao-di, ZHANG Cai-xia, ZHANG Lei-ming, et al., (2015) 'Improvement of the Evaluation Method for Ecosystem Service Value Based on Per Unit Area', JOURNAL OF NATURAL RESOURCES, 30(8), p1243-1254.

ZHANG Xiaojuan, TANG Qifeng, ZHANG Zhen, (2022) 'Spatial Differentiation Characteristics and Its Influencing Factors of Urban Resilience in the Yellow River Basin', AREAL RESEARCH AND DEVELOPMENT, 41(6), p48-54.

ZHAO Huixia, ZHUO Yingying, LIU Houfeng, (2022) 'Temporal and Spatial Variation Characteristics of Precipitation in the Yellow River Basin from 1961 to 2019', YELLOW RIVER, 44(3), p26-31.

Peng J., Liu Y., Wu J., et al., (2015) 'Linking ecosystem services and landscape patterns to assess urban ecosystem health: A case study in Shenzhen City, China', Landscape and Urban Planning, 143, p56-68.

Peterson G.D., (2002) 'Contagious Disturbance, Ecological Memory, and the Emergence of Landscape Pattern', Ecosystems, 5(4), p329-338.

Turner M.G. (1989) 'Landscape ecology: the effect of pattern on proces', Annual Review of Ecology and Systematics, 20(1): 171-197.

Research Paper

Urban Carbon Emission Prediction and Carbon Neutrality Pathways Based on Urban Spatial Elements

Yuran ZHAO, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China
Hong LENG, School of Architecture and Design, Harbin Institute of Technology, China
Yan ZHAO, School of Architecture and Design, Harbin Institute of Technology, China

Abstract

Climate change poses a significant global threat, and achieving carbon peaking and neutrality has become a key urban development strategy in China. Carbon accounting is a crucial technique for monitoring urban carbon emissions and guiding low-carbon urban development. Defining the urban built-up area as the carbon accounting boundary and integrating carbon accounting and prediction with urban spatial elements is essential for achieving the "dual carbon" targets. This study focuses on Harbin, Heilongjiang Province, China, summarizing and analyzing 15 years of energy activity and spatial usage data. The study establishes an urban carbon accounting system and develops a prediction method using urban spatial activity data. The results are compared with energy use-based carbon accounting to verify the method's accuracy. Based on this, the study analyzes how different urban elements impact carbon emissions, offering technical support for urban spatial planning to achieve the "dual carbon" targets.

Keywords

Carbon peak and carbon neutrality; urban spatial elements; carbon accounting; carbon prediction

1. Introduction

Climate change in the 21st century has significantly impacted human activities and livelihoods. Promoting low-carbon economic and social transformations to address climate change has become a global consensus (Lynn *et al.*, 2021; Dhakal, 2009). As a result, 136 countries have set clear timelines for achieving carbon neutrality. Cities, as hubs of human activity, are major centers of energy consumption and carbon emissions. Therefore, in order to achieve carbon neutrality, developing low-carbon and sustainable urban development pathways is critical (Li *et al.*, 2022).

The balance between high-density urban development and the need for low-carbon, sustainable construction is critical to the achievement of carbon neutrality (B *et al.*, 2011). Accurate methods for predicting urban carbon emissions are important for identifying carbon-neutral pathways and supporting low-carbon development decisions. However, due to the limitations of carbon accounting and forecasting techniques, studies often lack direct relevance and guidance on specific carbon reduction techniques for

urban areas.(Dhakal, 2009; D *et al.*, 2016). With the continuous development of research on spatial carbon accounting systems, new methods and perspectives for predicting urban carbon emissions have gradually emerged. The use of urban spatial data to predict carbon emission trends and the application of these findings to low-carbon development decision-making has become a key research area of great practical significance, with far-reaching implications for the realization of carbon neutrality.

Current urban carbon accounting and forecasting methods typically categorize regional emissions into four sectors: energy activities, industrial processes, agriculture and forestry, and waste treatment (Hoornweg *et al.*, 2011). Carbon emissions from each sector are calculated from energy activity data and ultimately aggregated into a total regional GHG emissions. The methodology has been widely adopted by countries around the world and is used by many cities and regions to calculate urban emissions, develop greenhouse gas emissions inventories, and project emissions changes (Li et al., 2022). Policymakers and researchers use these results to assess the impact of changes in energy use on carbon emissions and to monitor changes in the structure of urban emissions, making it the most widely used carbon accounting technique in urban planning (Steininger *et al.*, 2015). Despite the advantages of energy-based carbon accounting methods, their weak correlation with urban spatial elements leads to low correlation with spatial factors, insufficient feedback, interaction and support, and insufficient guidance for urban planning.

Strengthening the integration of carbon accounting and forecasting methods with urban spatial elements has become an important research direction. Scholars analyzed the spatial and temporal evolution and spatial distribution of urban carbon emissions using nighttime lighting data, and initially established the coupling relationship with urban spatial elements (Zhang *et al.*, 2023). An in-depth study on emission reduction mechanisms for urban and rural spatial development has established a “land use-carbon emission” framework based on categorization, inventory classification and emission reduction pathways. This framework integrates urban elements as core components of the carbon accounting method and has been applied in cities (Hu *et al.*, 2016; Huo *et al.*, 2022). Currently, urban spatial elements in research are relatively simple, mainly involving land use scale and average activity levels, while some critical activity data are challenging to obtain (Lin and Sun, 2010). Scholars have proposed a universal urban spatial carbon emission accounting and prediction method using the national greenhouse gas inventory framework, combining energy consumption data with urban land-use data to establish a research framework focused on industry, buildings, transportation, and carbon sinks (Li et al., 2022). Based on this, they developed a comprehensive carbon emission assessment framework for urban master plans, encompassing all natural resource elements and validated with Wuhan as a case study (Zhang *et al.*, 2021; Yang *et al.*, 2016; Raciti *et al.*, 2014). Significant progress has been made in developing urban spatial carbon emission accounting methods. Although these methods typically consider the entire city and account for emissions from all urban spatial elements, they are most effective in urban areas with large-scale construction and high development intensity (Bhatt *et al.*, 2023). For cities dependent on agriculture and mineral resources, the accounting results often lack accuracy and fail to reflect their development levels accurately. Additionally, these methods provide limited guidance for comprehensive spatial planning at the city center level. In summary, energy-based urban carbon emission accounting methods are widely used. However, they lack integration with spatial elements, limiting their support for spatial planning. In urban planning research, considerable effort has been devoted to improving the carbon accounting system for urban spatial elements. However, most studies are not consistent with central urban planning, leading to discrepancies in accounting and prediction results for resource-dependent cities and limited feedback on spatial changes. Therefore, developing carbon accounting and prediction methods aligned with urban planning boundaries and focused on urban spatial activity elements is crucial.

2. Method

2.1. Carbon accounting method based on space utilization activity data

Carbon accounting is a key method for assessing low-carbon urban development and monitoring the implementation of "dual carbon" targets in cities. It is primarily used for collecting foundational data during the early stages of urban planning and for monitoring and evaluation in later stages. Current urban carbon accounting research relies mainly on energy and economic activity data to calculate total carbon emissions within municipal boundaries. However, most urban carbon accounting methods cannot be directly linked to urban spatial planning data, making them difficult to apply in the planning process. To enhance the integration of urban spatial planning systems with carbon accounting methods, this study uses spatial activity metrics related to urban development as parameters to develop a carbon accounting framework integrated with urban spatial planning. To align with the existing carbon accounting system, this study adopts a production-based approach, covering direct emissions within urban boundaries and indirect emissions from energy activities like electricity distribution and regional heating. In constructing the accounting framework, this study uses the internationally recognized IPCC model, linking energy activities with spatial activities, which are then translated into urban spatial elements supporting energy consumption activities, as shown in Figure 1. Thus, by translating energy activities into spatial activities, the IPCC greenhouse gas inventory is connected to the urban spatial planning system, supporting the development of a carbon accounting method based on urban spatial elements.

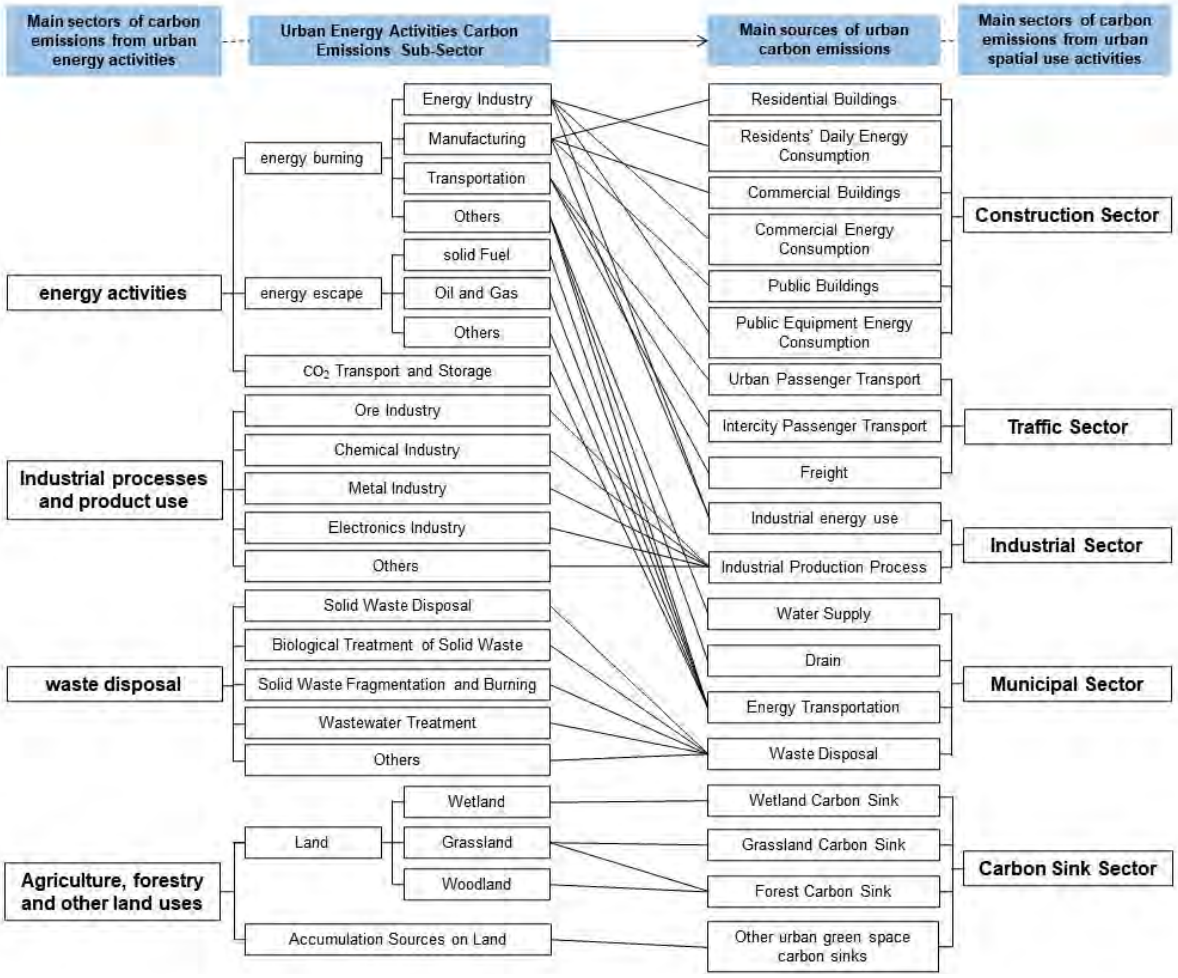


Figure 1. Carbon accounting framework for urban spatial elements. Source: Drawn by the author.

Based on the urban spatial element carbon accounting system, this study uses urban spatial activity data to account for carbon emissions from various sub-sectors and develops an accounting method for urban built-

up areas focused on spatial activity data, as shown in Table 1. In this method, most basic urban spatial and activity data can be obtained from planning drawings, documents, or statistical yearbooks, while the annual average travel distance of private vehicles must be gathered from urban transportation survey reports or questionnaires. Compared to energy-based carbon accounting methods, this approach allows the process to be independent of energy data, instead using spatial activity data, making the results more timely. The results clearly reflect the impact of urban spatial development and changes in spatial activities on carbon emissions, thus supporting low-carbon urban spatial planning.

Table 1. Carbon accounting method based on space utilization activity data. Source: Created by the author.

Sectors	Urban spatial basic data	Space utilization activity data	Calculation method
Construction Sector	residential building area, commercial service facility land area, public management and public service land area, new building area	residential vacancy rate	$C_b^c = \left(S_{residence} \times r_{vacancy\ rate} \times k_{residence}^{tce} + \sum A_i \times k_i^{tce} + S_{new} \times k_{new}^{tce}\right) \times f_{tce}$
Industrial Sector	industrial and mining storage land area	average industrial output value	$C_i^c = A_m \times p_m \times k_m^{tce} \times f_{tce}$
Municipal Sector	heating building area, water supply pipeline length	population, per capita garbage collection volume, harmless garbage treatment rate, per capita sewage discharge	$C_m^c = L_{water} \times j_{water}^{electricity} \times f_{electricity} + \left(P \times \mu_{waste} \times r_{harmless} \times k_{waste}^{tce} + P \times \mu_{sewage} \times k_{sewage}^{tce} + S_{heating} \times j_{heating}^{tce}\right) \times f_{tce}$
Traffic Sector	average annual travel distance of private cars, total freight distance, and total passenger distance	number of private cars, electrification rate of residents' travel, total freight volume, total passenger trips	$C_t^c = L_{private\ car} \times C_{private\ car} \times r_{electrical} \times j_{new\ energy}^{electricity} \times f_{electricity} + L_{private\ car} \times C_{private\ car} \times (1 - r_{electrical}) \times j_{fuel}^{tce} \times f_{tce} + \sum L_i \times T_i \times k_{turnover}^{tce} \times f_{tce}$
Carbon Sink Sector	woodland, grassland, wetland, urban green space area, water area	—	$C_s^c = \sum A_i \times c_i$

2.2. Urban carbon emission prediction model

Based on the carbon accounting method focused on urban spatial elements, this study introduces an LSTM model to develop a prediction method for carbon accounting using urban spatial elements, as shown in Figure 2. The model is initially trained on 15 years of urban carbon emission data. The process involves repeated iterations of "model building—model training" to establish the carbon emission prediction model. The final prediction is made by predicting the fourth year's carbon emissions based on data from the

preceding three years. Based on this, the model incorporates urban spatial element data to improve prediction accuracy. Key data include population, built-up area, industrial area, transport turnover, water supply pipe length, heating area, residential area, public facilities land, and urban green space. Since this model is based on a spatial element-oriented carbon accounting method, incorporating spatial data highly correlated with carbon emissions helps correct outliers, making predictions more accurate and consistent with urban development patterns.

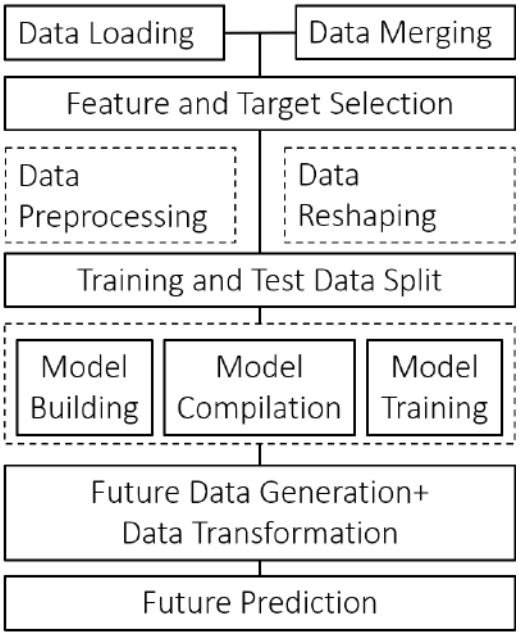


Figure 2. LSTM prediction model framework. Source: Drawn by the author.

3. Case study

3.1. Overview of the case study city

The study selects Harbin, a city in Heilongjiang Province, as the case study, collecting and organizing its energy and spatial activity data. Harbin, located in the southern part of Heilongjiang Province, China, has a temperate continental monsoon climate, with an average annual temperature of 5.2℃, long severe winters, and short cool summers. Consequently, residential energy consumption is lower in summer and higher in winter. Using statistical yearbook and remote sensing data, this study extracted Harbin's built-up area from 2017 to 2021 and identified changes, as shown in Figure 3, which presents the built-up area boundaries for representative years. The built-up area has expanded annually, with the six districts in the central urban area consistently showing expansion, particularly in the southern and northern regions. In the three peripheral districts, towns in the southwest and southeast initially contracted and then grew.

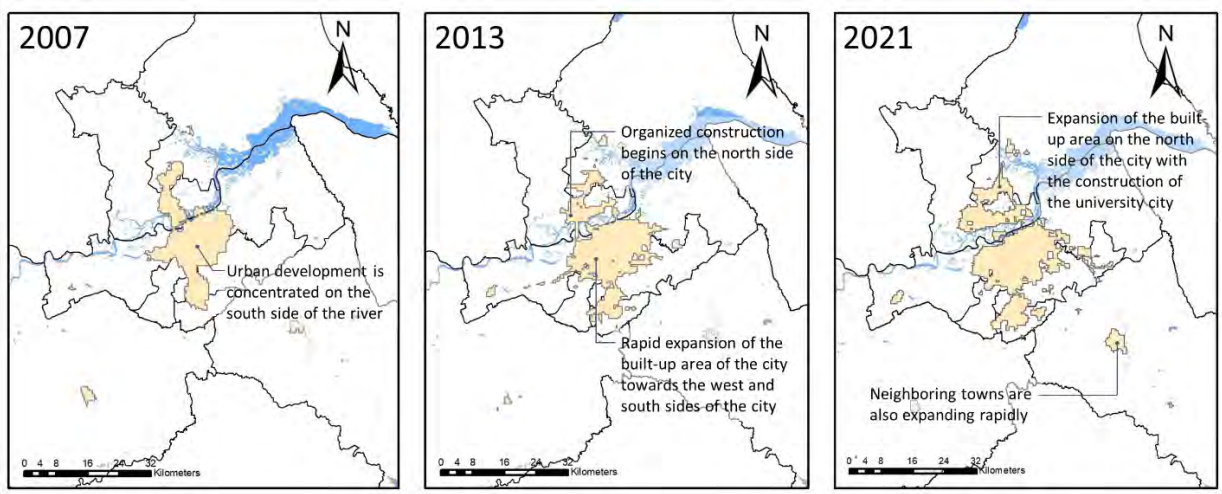


Figure 3. Spatial Changes in the Built-up Area of Harbin. Source: Drawn by the author.

3.2. Urban carbon emission accounting results

Using the spatial activity carbon accounting method, the study reviewed statistical yearbooks and transportation survey reports to obtain Harbin's spatial and activity data and conducted accounting of total and sectoral carbon emissions in the built-up area. The results were compared with those from energy-based carbon accounting, as shown in Figure 4. Overall, the accounting results were similar to those based on energy data. The building sector exhibited a similar trend over time, though with some differences in values. In the transportation sector, significant differences were observed between 2012 and 2017, mainly because data on private vehicle travel could only be estimated based on per capita travel expenditures from statistical yearbooks and questionnaires, resulting in larger errors. For other years, urban transportation survey data were available, leading to smaller discrepancies in the results.

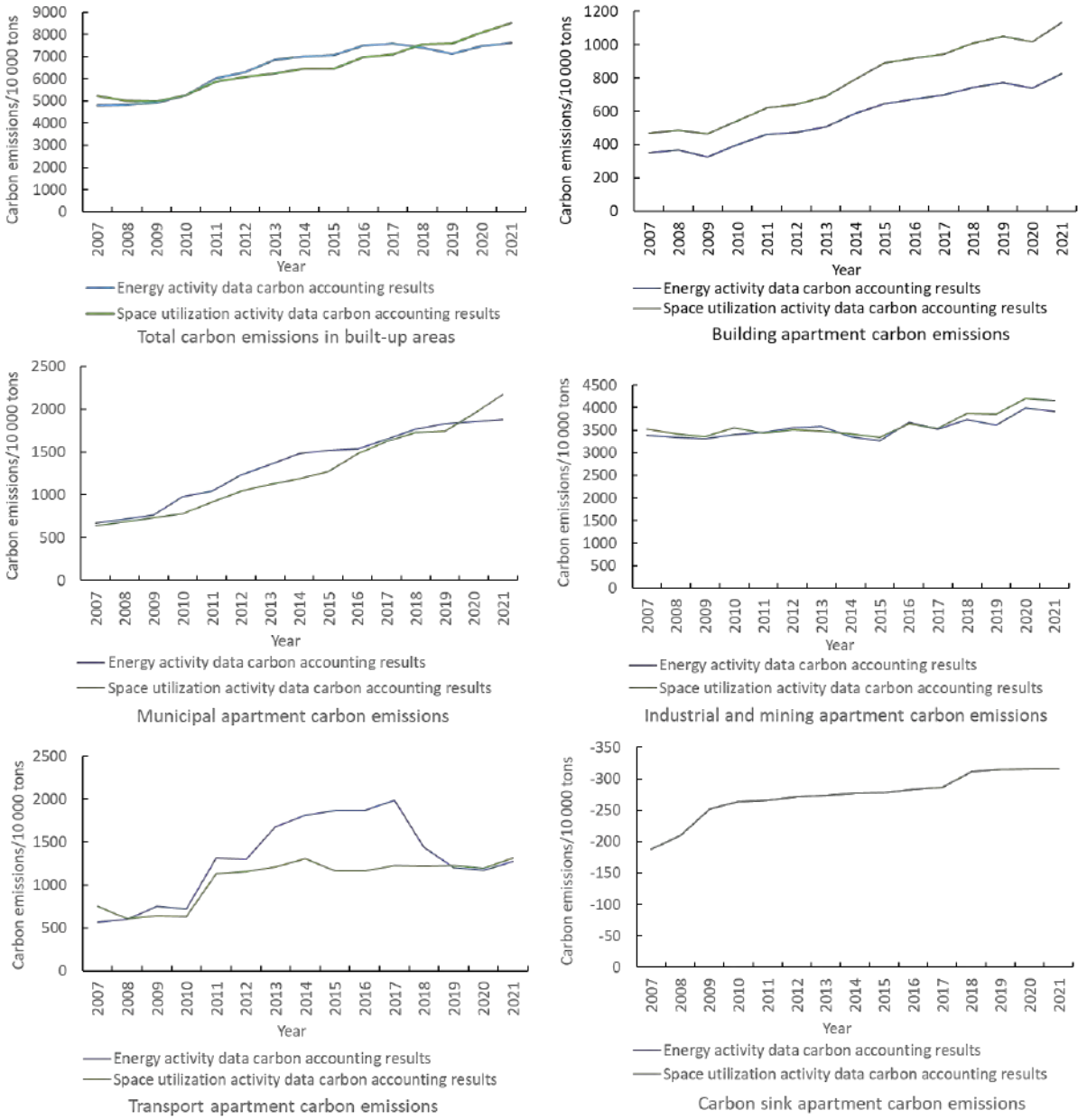


Figure 4. Comparison of carbon accounting results from both methods. Source: Drawn by the author.

Compared to the energy-based carbon accounting method, the spatial activity-based method accounts for carbon emissions within built-up areas based on urban spatial characteristics. In the building sector, the accuracy of results is significantly influenced by the vacancy rate and energy consumption per unit area; accurate data ensure that spatial activity-based accounting results closely match those of energy accounting. In the transportation sector, data on private vehicle travel significantly impact accounting precision. However, these data are rarely reported in statistical yearbooks and must be collected through transportation surveys or questionnaires, potentially introducing errors. In other sectors, relevant data can be obtained from statistical yearbooks and greenhouse gas inventories, leading to high accuracy in results. Overall, results from the spatial activity-based method are numerically similar to those from the energy-based method, while being easier to obtain and more widely applicable. Furthermore, due to its strong association with urban spatial elements, this method can adjust results in real time according to changes in the built-up area, reducing dependence on energy data and providing greater flexibility and scalability.

In summary, developing a carbon accounting method for urban built-up areas based on spatial activity data is a crucial tool to support dual carbon targets and assist urban spatial planning in establishing low-carbon cities.

3.3. Urban carbon emission prediction results

Using the carbon accounting results of the case study city, the study imported 15 years of Harbin's carbon emission data into the prediction model and obtained predictions based on a logic of predicting one year from every three years of data, as shown in Figure 5. The carbon emission forecast for 2023 to 2050 shows an initial increase in urban emissions followed by a decrease. Emissions are projected to peak around 2030 and then gradually decline. However, due to the limited initial sample size, the input data for the prediction model are relatively small and mainly consist of homogeneous carbon emission data, leading to some errors in predictions.

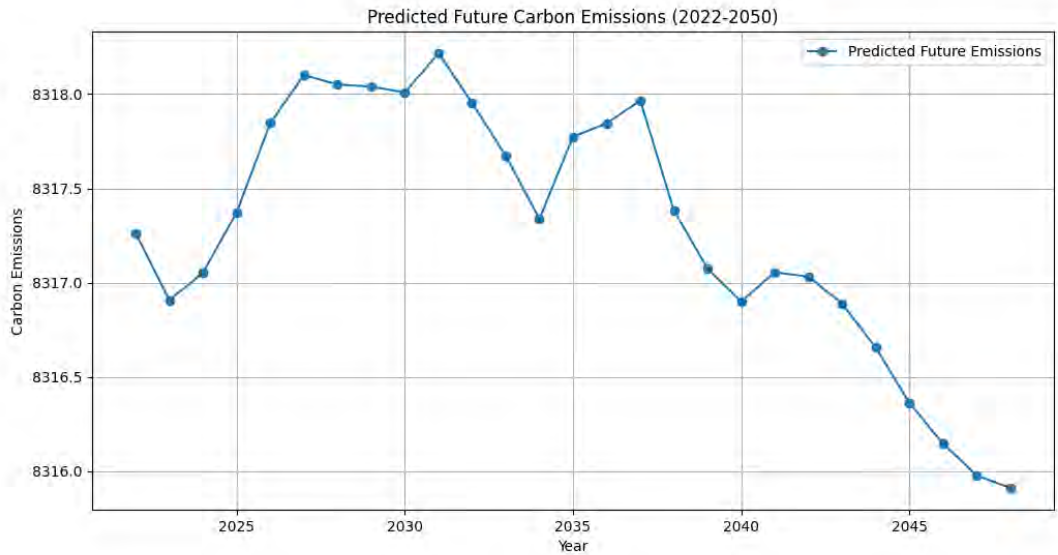


Figure 5. Urban carbon emission prediction results. Source: Drawn by the author.

To improve prediction accuracy, the study introduced a multi-scenario prediction technique. By defining multiple potential future urban development scenarios and inputting scenario-specific data into the prediction model, the volume of baseline sample data was increased, improving prediction accuracy. In this process, three future development scenarios were defined: the Baseline Scenario, Low-Carbon Scenario, and High-Carbon Scenario, with their main characteristics shown in Figure 6. The Baseline Scenario assumes no major changes in policies or technology, with urban development continuing along its current trajectory. The Low-Carbon Scenario assumes strong policy measures and rapid technological advancements, leading to a significant reduction in carbon intensity. The High-Carbon Scenario prioritizes urban growth over environmental concerns, resulting in increased carbon emissions.

Baseline Scenario

Basic Information:

- The Baseline Scenario assumes that future development trends will continue as they have in the past few years, with **no major policy changes or technological breakthroughs**.
- This is **a "business-as-usual" scenario**, assuming that economic and social development will proceed smoothly along the current trajectory.

Assumptions:

- Indicators such as **urban population growth, industrial development, and building area expansion** maintain the average growth rate of the past.
- The **city's energy structure, transportation modes, and carbon emission intensity** remain consistent with historical data.
- No new major policies are introduced; **environmental protection and carbon reduction measures** continue at current levels.

High-Carbon Scenario

Basic Information:

- Future urban development will **prioritize economic growth**.
- Economic and social development will **proceed smoothly along the current trajectory**.

Assumptions:

- **Faster urban expansion**, accelerated industrialization, and urbanization, with a rapid increase in building area and industrial land.
- The energy structure remains **dominated by fossil fuels**, with slow development of renewable energy and increased carbon intensity in transportation and buildings.
- **Weakening of environmental protection policies**, lacking carbon taxes and emission restrictions.

Low-Carbon Scenario

Basic Information:

- There will be **proactive policy interventions and technological innovations** in the future.
- This scenario reflects an optimal emission reduction path, with **strong policy measures, rapid social transformation, and a significant decline in carbon intensity**.

Assumptions:

- Promote **new energy technologies**, reduce dependence on fossil fuels, and increase the share of renewable energy in the energy mix.
- Implement stricter urban planning and energy-saving policies to **reduce energy consumption in buildings and carbon emissions from transportation**.

Figure 6. Details of urban development scenarios. Source: Drawn by the author.

By introducing the multi-scenario prediction technique, the study incorporated three potential urban development scenarios into the model, resulting in carbon emission forecasts for each scenario, as shown in Figure 7. According to the results, if urban development is left unchecked, carbon emissions will fluctuate but overall levels will remain relatively stable. If urban development focuses only on economic growth and expansion and ignores sustainability, carbon emissions could increase rapidly. Conversely, if urban development prioritizes low-carbon and sustainability goals, carbon emissions will gradually decline.

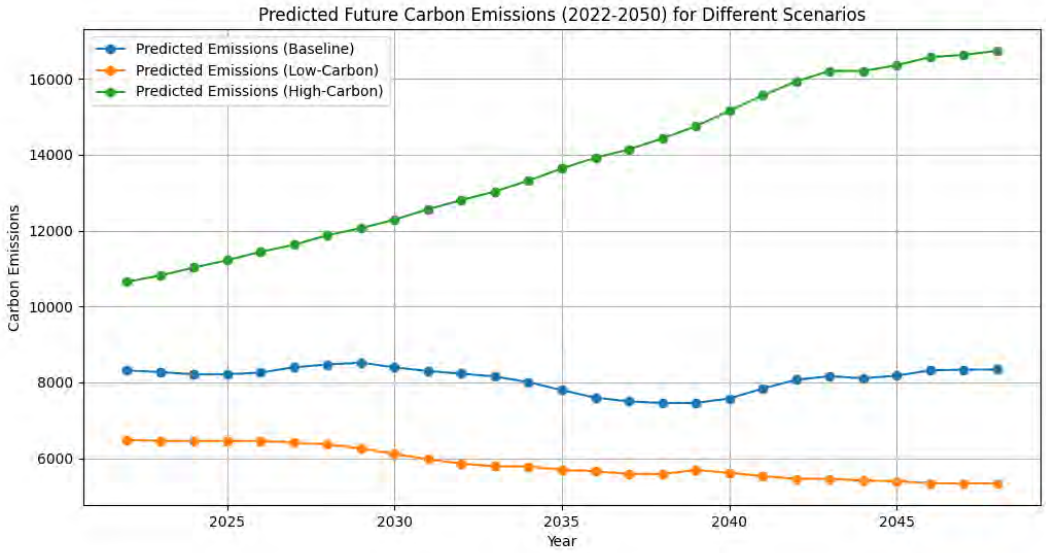


Figure 7. Multi-Scenario carbon emission prediction results. Source: Drawn by the author.

4. Conclusions

The study shows that the carbon accounting method based on urban spatial elements can accurately and efficiently assess carbon emissions, providing valuable guidance for the development of targeted low-carbon city optimization strategies. The introduction of carbon emission prediction modeling further enhances the ability to predict future urban emissions, helping policy makers to formulate effective strategies for sustainable urban development. In addition, the multi-scenario simulation reveals the significant impact of different spatial planning approaches on urban carbon emissions, providing important insights for improving the sustainability of urban development planning. To better illustrate the effects of changes in urban spatial elements on carbon emissions, this study explores the effects of multiple factors through regression analysis, as shown in Figure 8. On the left side of the figure are positive influencing factors, the increase of which leads to an increase in carbon emissions; on the right side are negative influencing factors, the increase of which reduces carbon emissions, indicating a positive effect on the environment. By further analyzing the spatial elements, the impact of spatial changes on carbon emissions can be assessed, so that more targeted spatial renewal strategies can be developed in urban planning. By inhibiting the growth of positive factors and promoting the development of negative factors, the construction of low-carbon cities can be effectively promoted and sustainable urban development can be realized.

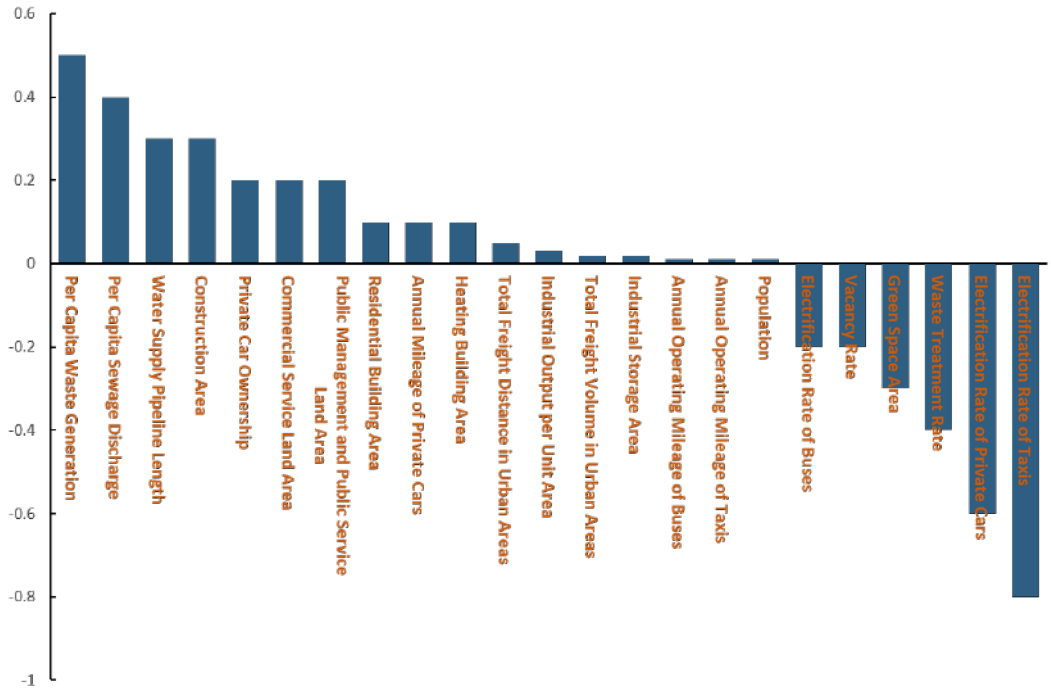


Figure 8. Impact of urban spatial elements on carbon emissions. Source: Drawn by the author.

5. References

B, H. D. A., C, J. G., C, G. M., D, A. M. S., E, X. W. & C, Y. W. (2011) 'CO2 emissions embodied in China–US trade: Input–output analysis based on the emergy/dollar ratio - ScienceDirect', *Energy Policy,* Vol. 39 No. 10, pp. 5980-5987.

Bhatt, H., Davawala, M., Joshi, T., Shah, M. & Unnarkat, A. (2023) 'Forecasting and mitigation of global environmental carbon dioxide emission using machine learning techniques', *Cleaner Chemical Engineering,* Vol. 5100095.

D, R. W. A., B, Y. G., C, H. D., C, T. F. & D, X. T. A. (2016) 'Changes of CO 2 emissions embodied in China–Japan trade: drivers and implications', *Journal of Cleaner Production,* Vol. 1124151-4158.

Dhakal, S. (2009) 'Urban energy use and carbon emissions from cities in China and policy implications', *Energy Policy,* Vol. 37 No. 11, pp. 4208-4219.

Hoornweg, D., Sugar, L. & Gomez, C. L. (2011) 'Cities and greenhouse gas emissions: moving forward', *Environment & Urbanization,* Vol. 23 No. 1, pp. 207-227.

Hu, Y., Lin, J., Cui, S. & Khanna, N. Z. (2016) 'Measuring Urban Carbon Footprint from Carbon Flows in the Global Supply Chain', *Environmental Science & Technology,* Vol. 50 No. 12, pp. 6154.

Huo, T., Ma, Y., Xu, L., Feng, W. & Cai, W. (2022) 'Carbon emissions in China's urban residential building sector through 2060: A dynamic scenario simulation', *Energy,* Vol. 254124395.

Li, Z., Wang, F., Kang, T., Wang, C., Chen, X., Miao, Z., Zhang, L., Ye, Y. & Zhang, H. (2022) 'Exploring differentiated impacts of socioeconomic factors and urban forms on city-level CO2 emissions in China: Spatial heterogeneity and varying importance levels', *Sustainable Cities and Society,* Vol. 84104028.

Lin, B. & Sun, C. (2010) 'Evaluating carbon dioxide emissions in international trade of China', *Energy Policy,* Vol. 38 No. 1, pp. 613-621.

Lynn, J., Peeva, N., Oppenheimer, M. & Yohe, G. (2021) 'Communications in the IPCC's Sixth Assessment Report cycle'.

Raciti, S. M., Hutyra, L. R. & Newell, J. D. (2014) 'Mapping carbon storage in urban trees with multi-source remote sensing data: Relationships between biomass, land use, and demographics in Boston neighborhoods', *Science of The Total Environment,* Vol. 500-50172-83.

Steininger, K. W., Lininger, C., Meyer, L. H., Mu Oz, P. & Schinko, T. (2015) 'Multiple carbon accounting to support just and effective climate policies', *Nature Climate Change,*.

Yang, Z., Wei, T., Moore, J. C., Chou, J., Dong, W., Dai, R., Yang, S. & Ban, J. (2016) 'A new consumption-based

accounting model for greenhouse gases from 1948 to 2012', *Journal of Cleaner Production,* Vol. 133 No. oct.1, pp. 368-377.

Zhang, X., Cai, Z., Song, W. & Yang, D. (2023) 'Mapping the spatial-temporal changes in energy consumption-related carbon emissions in the Beijing-Tianjin-Hebei region via nighttime light data', *Sustainable Cities and Society,* Vol. 94104476.

Zhang, X., Yan, F., Liu, H. & Qiao, Z. (2021) 'Towards low carbon cities: A machine learning method for predicting urban blocks carbon emissions (UBCE) based on built environment factors (BEF) in Changxing City, China', *Sustainable Cities and Society,* Vol. 69102875.

Research Paper

Multi-Scale Analysis of Urban Density and Carbon Emission Dynamics

A Case Study of Harbin, China (2007-2021)

Yan ZHAO, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Qing YUAN, School of Architecture and Design, Harbin Institute of Technology, China

Yuran ZHAO, School of Architecture and Design, Harbin Institute of Technology, China

Abstract

Global urbanization accelerates economic development but also poses significant environmental challenges. As urban expansion continues, the coexistence of high-density central areas and low-density fringes raises a critical issue in urban planning: balancing density distribution with environmental sustainability. This study examines Harbin, a typical expanding city in Northeast China, to analyze the dynamic changes in spatial structure and carbon emissions during urban expansion. By exploring the complex relationship between urban density and carbon emissions at different spatial scales, it provides insights for sustainable development with reduced environmental impact. This study uses multi-source data, combining statistical analysis and nighttime light imagery, to investigate urban density and carbon emissions in Harbin. The results show that: From 2007 to 2021, Harbin's total carbon emissions significantly increased, especially in central and fringe areas, indicating a spatial clustering effect. Compact urban development promotes low-carbon urbanization. The detailed block-scale analysis revealed that the effect of increasing density on reducing carbon emissions diminishes beyond a certain threshold. These findings underscore the critical role of density in sustainable urban development. The study also provides guidance on density management strategies to support sustainable urban planning.

Keywords

Sustainable urban density, Carbon emission dynamics, Urban Expansion, Multi-Scale analysis

1. Introduction

With the acceleration of global urbanization, spatial and population growth have driven economic development but also increased risks to urban society and the environment. Approximately 80% of global greenhouse gas emissions are estimated to originate from cities, which are centers of human activity, industrial production, transportation, and construction, characterized by high energy consumption and carbon emissions (Liu and Qin, 2016; Dhakal, 2009). Against the backdrop of rapid economic development in China, urban expansion has introduced new pressures on sustainable urban development. Issues such as dispersed land use, inadequate supporting services, and ecological pollution have emerged during urban expansion(Schuster-Olbrich et al., 2024), contributing significantly to urban carbon emissions. Sustainable urban development is a critical issue for cities globally.

Rapid urban expansion has led cities into a phase of high-density development, increasing resource and environmental constraints. The coexistence of high-density central areas and low-density urban fringes presents a pressing challenge to balance urban density distribution with environmental sustainability.

It has been shown that urban density is one of the key factors influencing carbon emissions (Hong et al., 2022). Dense cities are generally considered to be more resource-efficient and sustainable than sparse cities (Kumar and Sen, 2025). Previous have examined various drivers of carbon emissions, such as urban economic development, land use, industrial structure, and urban form (Wang et al., 2016; Martínez-Zarzoso et al., 2011). Existing studies on urban density and carbon emissions usually adopt two perspectives: one is a macro-scale study on cities or urban agglomerations that explores the relationship between population density and carbon emissions (Gudipudi et al., 2016; Hong et al., 2022), and the other is a micro-scale study on spatial density in the built environment, which mostly focuses on residential areas (Du et al., 2024). These two types of studies have their own focus, but due to the differences in research areas, research scope, and research methods, it is more difficult to form a systematic research conclusion. The combination of multi-scale research, from macro to micro, top-down systematic analysis, can make up for these shortcomings, and more effectively put forward research conclusions with guiding significance (Luo et al., 2024).

A systematic analysis of the impact of urban density on carbon emissions requires a macro to micro estimation of carbon emissions. Nighttime light data show greater potential for this type of study (Shi et al., 2016). Previous estimation methods based solely on statistical data could only achieve provincial-scale estimates, making it difficult to achieve comparisons of spatial differences between regions. The advent and application of nighttime light hassolved this problem. Nighttime light can better reflect the intensity of social and economic activities in cities. It is often used to conduct research related to urban sprawl patterns and spatial distribution of carbon emissions, and is now accepted as a representative feature of urban carbon emissions (Shi et al., 2016). This method is able to simulate the relationship between the value of nighttime light and total carbon emissions through a linear regression model, which simulates the spatial distribution of carbon emissions in different areas of the city based on the intensity of nighttime light in the city (Wu et al., 2024). Therefore, the method plays an important role in solving the estimation of carbon emissions from macro to micro level, and can systematically reveal the evolutionary trend of the spatial distribution of urban carbon emissions.

This study uses a typical sprawling city in northeastern China, Harbin, as a case study to explore the relationship between density and carbon emissions in this type of city. Using nighttime light data, we analyzed urban spatial and carbon emission changes in Harbin, systematically analyzing and discussing the complex relationship between urban density and carbon emissions from the macro-urban level to the micro-block level. The results of the study provide insights into how to achieve sustainable development

while minimizing the impact on the environment, and provide guidelines for density control in the urban planning process to promote low-carbon city building and sustainable development.

2. Study area and research methods

2.1. General situation and study area

Harbin, located in Heilongjiang Province in northeastern China, serves as the economic center of the region. Harbin represents cold-region cities in China, characterized by a temperate continental climate with low average temperatures, long winters, and short summers. Consequently, winter heating energy consumption in Harbin is high. As a resource-based city, Harbin's carbon emissions are moderate compared to other Chinese cities, creating pressure to achieve energy conservation and emission reductions.

As of 2023, Harbin's total urban area covers 53,076.4 km^2. As a typical city in northeastern China, Harbin has experienced significant spatial expansion in recent years. The construction of large-scale, low-density new urban areas has posed new challenges for managing urban density. Due to historical and cultural factors, Harbin's central area contains extensive Russian-style historical zones and large industrial legacy areas. These areas, developed many years ago with high density, contrast sharply with newly constructed areas. Currently, urban renewal in old districts and new area development are underway. Balancing density management in these areas to achieve low-carbon and emission reduction goals is a pressing challenge for Harbin.

This study focuses on Harbin's built-up area, using a 15-year longitudinal analysis from 2007 to 2021, considering data availability and spatial transformation characteristics. This period captures Harbin's major urban expansion and subsequent stabilization, allowing effective examination of changes in urban spatial structure and carbon emissions. Figure 1 shows the location of Harbin.

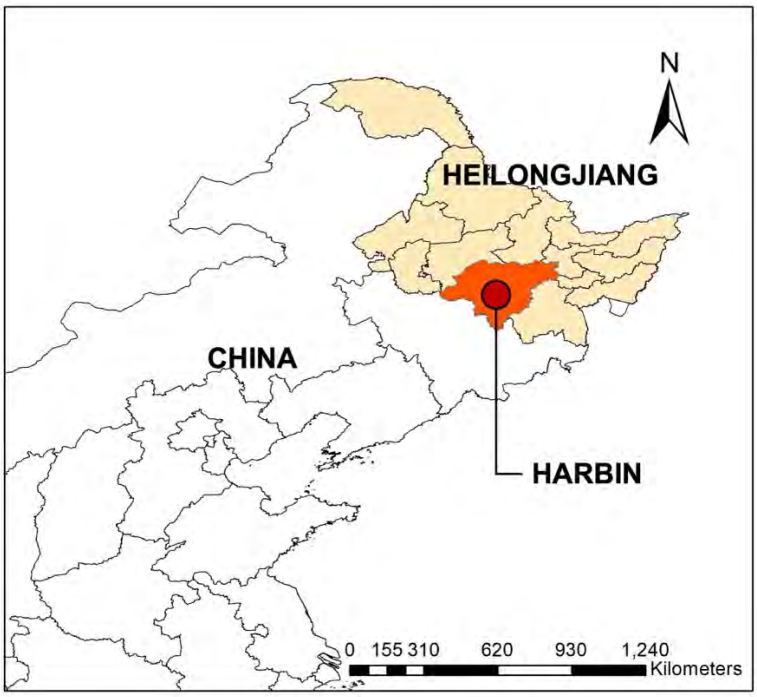


Figure 1. The location of Harbin.

2.2. Carbon emissions estimation

Harbin's carbon emissions were calculated using its energy consumption statistics. We determined carbon emission factors for various energy sources (coal, natural gas, oil, electricity, etc.) based on IPCC Guidelines for National Greenhouse Gas Inventories (2006) (Zhang et al., 2023). We calculated carbon emissions from five key sectors: buildings, transportation, industry and mining, municipalities, and carbon sinks. These are the sectors that previous studies have shown to be significant contributors to the city's overall carbon emissions and energy consumption. We aggregated the energy use of each sector within the built-up area and applied the relevant carbon emission factors to estimate the carbon emissions of the sector.

Total carbon emissions are calculated by adding up the emissions from these sectors for the year, for a total of 15 years of data from 2007-2021. This 15-year study period covers the rapid expansion of the city and the subsequent stabilization of the city's development, enabling a comprehensive assessment of the time-varying characteristics of Harbin's carbon emissions as a result of the city's development.

2.3. Nighttime light analysis

Nighttime light imagery analysis is widely used as a spatial method for estimating carbon emissions (Chen et al., 2021). Nighttime light images can visualize the distribution of artificial light sources in the city and can effectively represent human activities (Fang et al., 2022). There has been extensive research demonstrating the ability of nighttime light imagery to assess GDP, energy use, or population density. The initial nighttime light images were from the Defense Meteorological Satellite Program's Operational linescan system (DMSP-OLS). Since 2011, a new generation of night-time light data, NPP/VIIRS, sensed by the Visible Infrared Imaging Radiometer Suite (VIIRS) carried by the Suomi National Polar-Orbiting Partnership (Suomi NPP) satellites, which has higher radiometric and spatial resolution, has been operational.

This study requires continuous annual nighttime light imagery data from 2007-2021. Therefore, we use a long time series nighttime light data obtained by synthesizing DMSP-OLS and NPP/VIIRS after oversaturation correction and timing correction, which solves the problem that these two sets of nighttime light data can not be used at the same time (Chen et al., 2021). This dataset has parameter attributes consistent with the NPP-VIIRS nighttime light data and has similar data quality. The accuracy of this data is 500-meter resolution.

In order to systematically simulate the spatial distribution of carbon emissions and the process of change using nighttime light images, we developed a linear regression model for the total digital number value of nighttime light and carbon emissions. Linear regression is a widely adopted approach in similar studies. This model estimated carbon emissions based on nighttime light intensity, simulating emissions across different spatial locations within Harbin's built-up area. Using this method, we obtained the spatial distribution and temporal variation of carbon emissions in Harbin from 2007 to 2021.

2.4. Multi-Scale Density analysis

Density has long been a crucial factor in urban sustainability studies. Many studies have confirmed a relationship between density and carbon emissions. However, the mechanisms and extent of density's influence on carbon emissions vary across different spatial scales. Therefore, this study uses a multi-scale analysis to explore the complex relationship between density and carbon emissions at both city and block levels.

At the city level, we conducted spatial structure analysis to examine the impact of density on carbon emissions from a macro perspective. We used ArcGIS to analyze urban expansion and spatial trends in

carbon emissions in Harbin's built-up area from 2007 to 2021. We also calculated changes in urban density during expansion and assessed their effect on total carbon emissions. Urban density was measured using two indicators: population density and urban spatial compactness, with their formulas provided below.

At the block level, we selected 20 representative blocks in Harbin as study samples. Our focus at this scale was to analyze the density differences across different types of blocks and how these differences influence carbon emissions at a more localized scale. Building density and floor area ratio were used as indicators to assess block density. These indicators are commonly used in block-scale studies and are suitable for discussing density differences in greater detail.

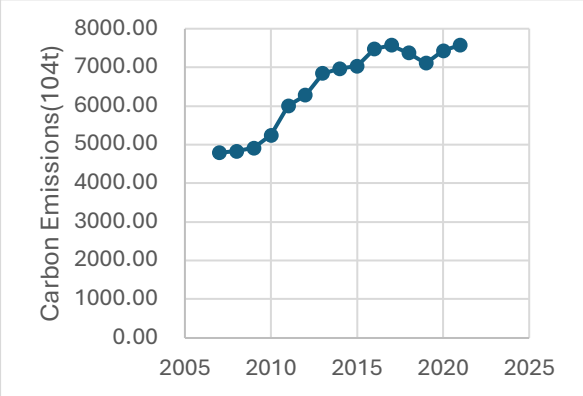
3. Results

3.1. Carbon emissions estimation results

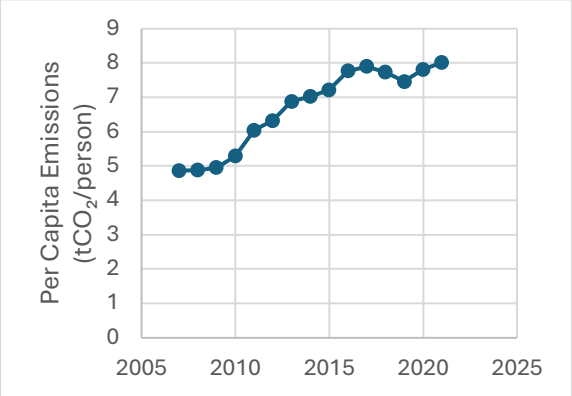
Using energy usage statistics for Harbin's built-up area, we estimated carbon emissions from 2007 to 2021 and conducted a preliminary analysis. We analyzed the temporal trends in carbon emission intensity from three perspectives: total carbon emissions, per capita carbon emissions, and carbon emissions per unit of GDP. We then examined the characteristics and changes in carbon emissions across various sectors in Harbin over the 15-year period.

As shown in Figure 2a, total carbon emissions showed an overall increasing trend, with significant growth observed before 2018, reaching a peak in that year. After 2018, total carbon emissions stabilized. Per capita carbon emissions also showed an upward trend, with a particularly rapid increase from 2010 to 2015 (Figure 2b). In contrast, as shown in Figure 2c, carbon emissions per unit of GDP declined significantly over the 15-year period, with the most pronounced decrease between 2007 and 2012, indicating more carbon-efficient economic growth over time. Between 2012 and 2018, emissions per unit of GDP remained relatively stable with minimal change.

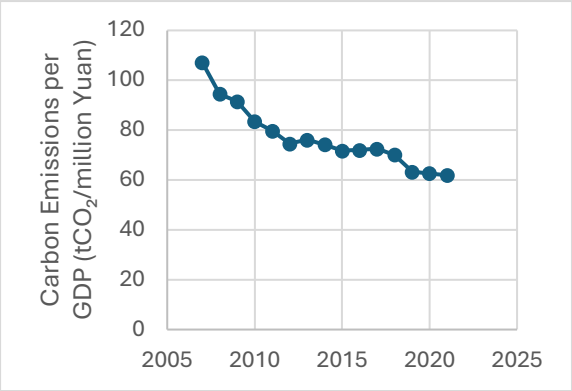
Finally, Figure 2d shows the four main sectors contributing to emissions: buildings, transportation, industry, and municipal services. The results indicate that industrial carbon emissions consistently accounted for the largest share. Transportation emissions also represented a substantial proportion, especially between 2011 and 2017. Overall, while industrial emissions remained stable, other sectors showed fluctuations.

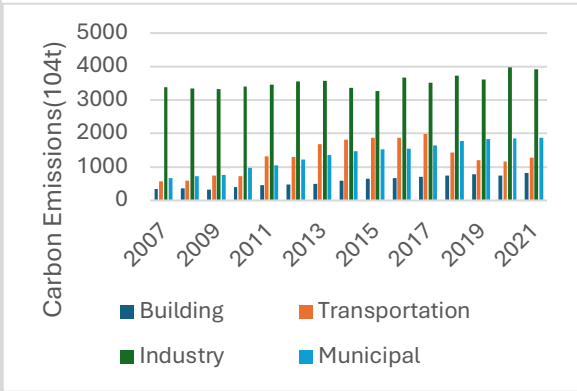


(a) Annual Total Carbon Emissions



(b) Per Capita Carbon Emissions





(c) Carbon Emissions per Unit of GDP

(d) Carbon Emissions by Sectors

Figure 2. Carbon Emission Analysis of Harbin.

3.2. Nighttime light analysis results

Nighttime light imagery analysis reveals the spatial distribution of carbon emissions in Harbin. Compared to simple time series analysis, this approach provides insights into the dynamic spatial evolution of carbon emissions within the built-up area of Harbin. To facilitate observing changes in carbon emissions, we categorized emissions into four levels: High-CE, Mid-high-CE, Mid-low-CE, and Low-CE. Figure 3 shows the spatial distribution changes of carbon emissions in Harbin's built-up area from 2007 to 2021.

The results indicate that in 2007, high carbon emission areas were concentrated in the central urban area. With urban development, High-CE areas expanded and transformed from a single large cluster into multiple dispersed clusters, indicating a shift in Harbin's urban structure from monocentric to polycentric development. Mid-high-CE areas expanded slightly as the city developed but remained stable after 2013. Mid-low-CE areas accounted for the largest proportion of Harbin's built-up area, mainly expanding at the urban fringe. Low-CE areas were mainly concentrated at the urban periphery, showing edge expansion. This pattern reflects Harbin's urban expansion, where construction at the urban fringe led to the emergence and growth of Mid-low and Low-CE areas. Since the urban fringe is in early development, characterized by low construction and population densities, energy consumption and carbon emissions are relatively lower compared to the city center. This does not necessarily mean these areas are genuinely low-carbon.

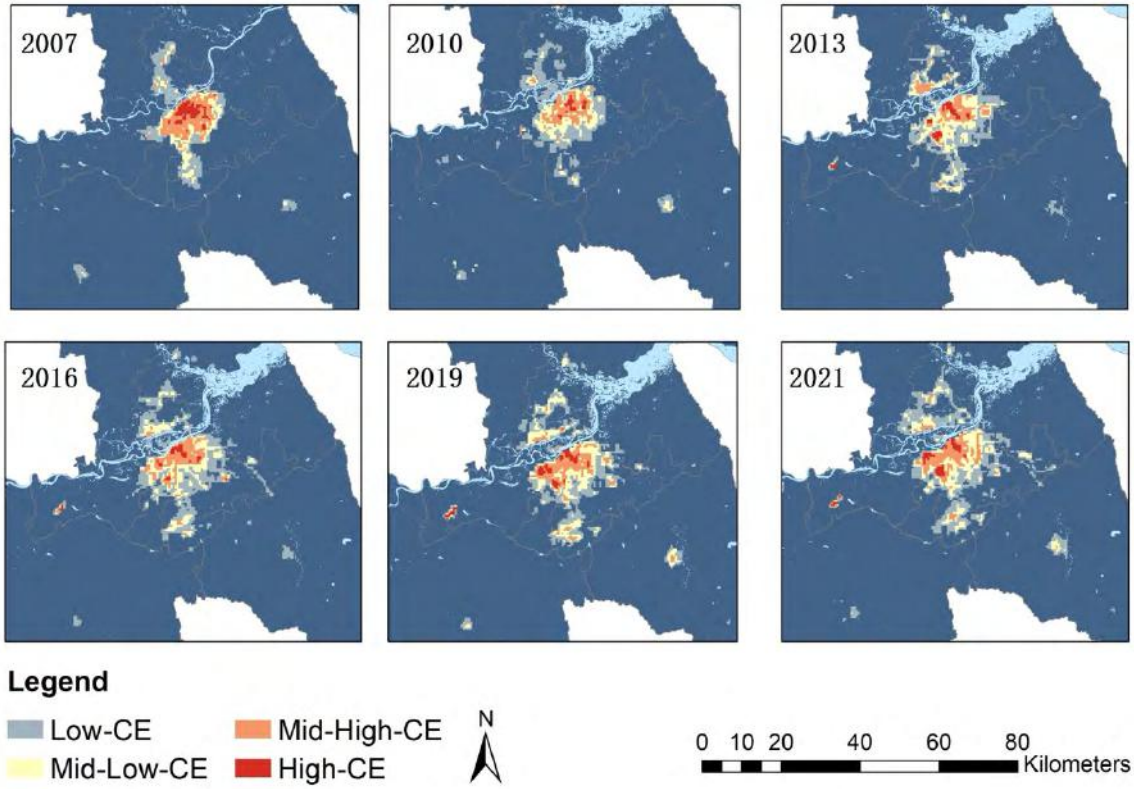


Figure 3. Changes in the spatial distribution of carbon emissions in Harbin.

3.3. City-level spatial structure analysis results

The spatial structure analysis at the city scale focuses on the urban expansion trends in Harbin and the impact of changes in urban form on carbon emissions during the expansion process. Figure 3 also shows that, over the 15 years, the urban fringes of Harbin experienced significant outward expansion. This expansion was most pronounced between 2007 and 2013, with the largest expansion area and fastest growth rate during this period.

As mentioned earlier, this study uses population density and urban spatial compactness to measure urban density changes. Figure 4 shows the trends of these two indicators over the 15-year period. Harbin's population density showed an overall decline, with significant fluctuations before 2012. Urban spatial compactness followed a similar trend, with more pronounced fluctuations, especially before 2013. This confirms that Harbin experienced rapid, unplanned urban expansion from 2007 to 2013, resulting in inefficient land use.

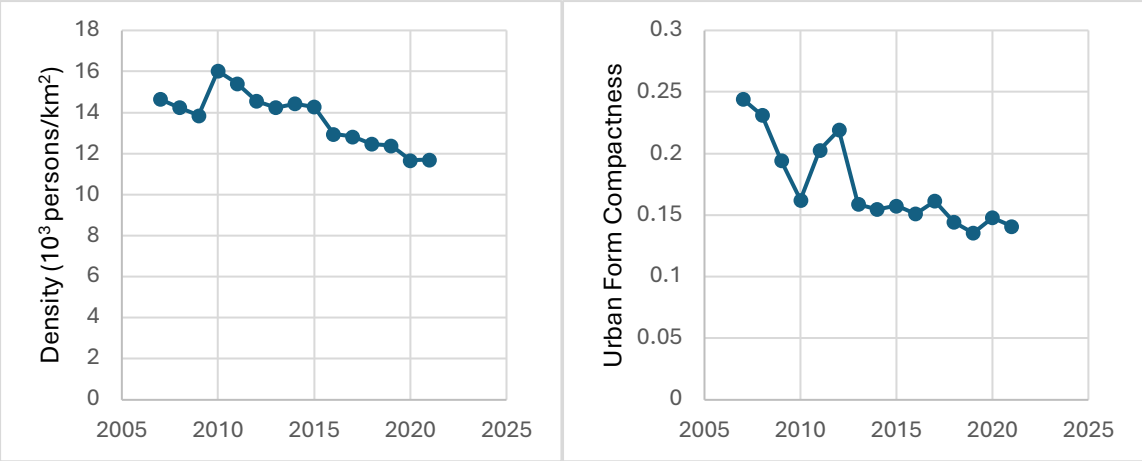


Figure 4. Harbin's density and urban form compactness change trends (2007-2021).

We conducted regression analyses of population density and urban spatial compactness against total carbon emissions to further explore the impact of density on carbon emissions. The results indicate that both population density and urban form compactness exhibit a negative nonlinear relationship with carbon emissions (Figure 5). At the city level, higher population density and greater urban compactness were associated with lower total carbon emissions. This confirms that high-density, compact development is beneficial for low-carbon outcomes at a macro urban scale. This effect may be attributed to increased efficiency in energy and infrastructure use in a compact urban form, and reduced energy costs for transportation, thereby lowering overall carbon emissions.

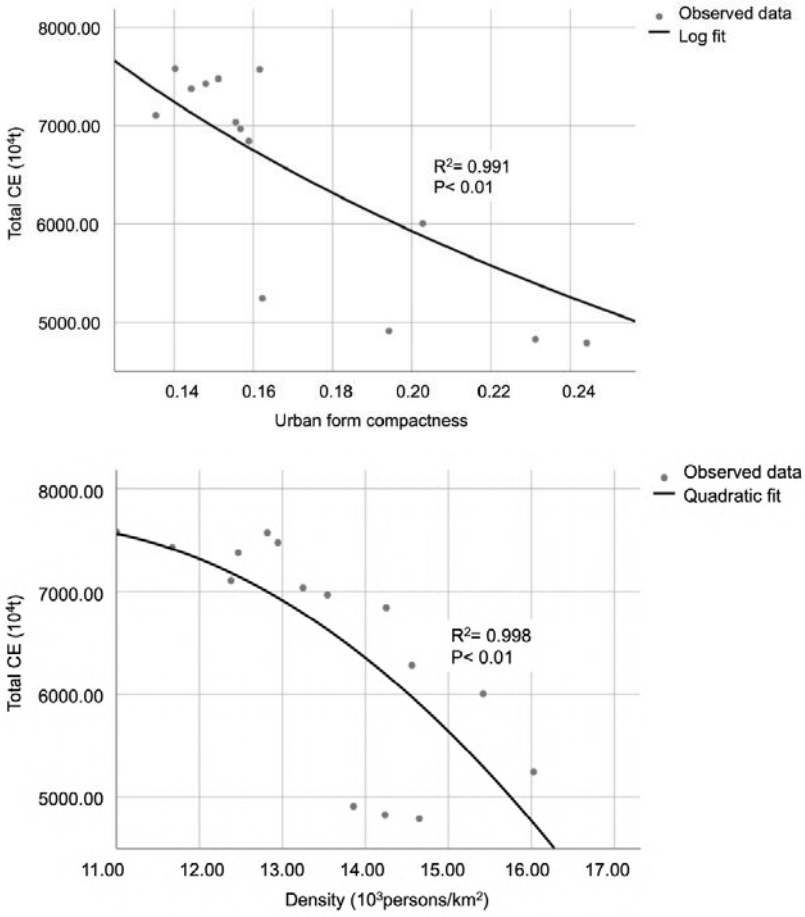
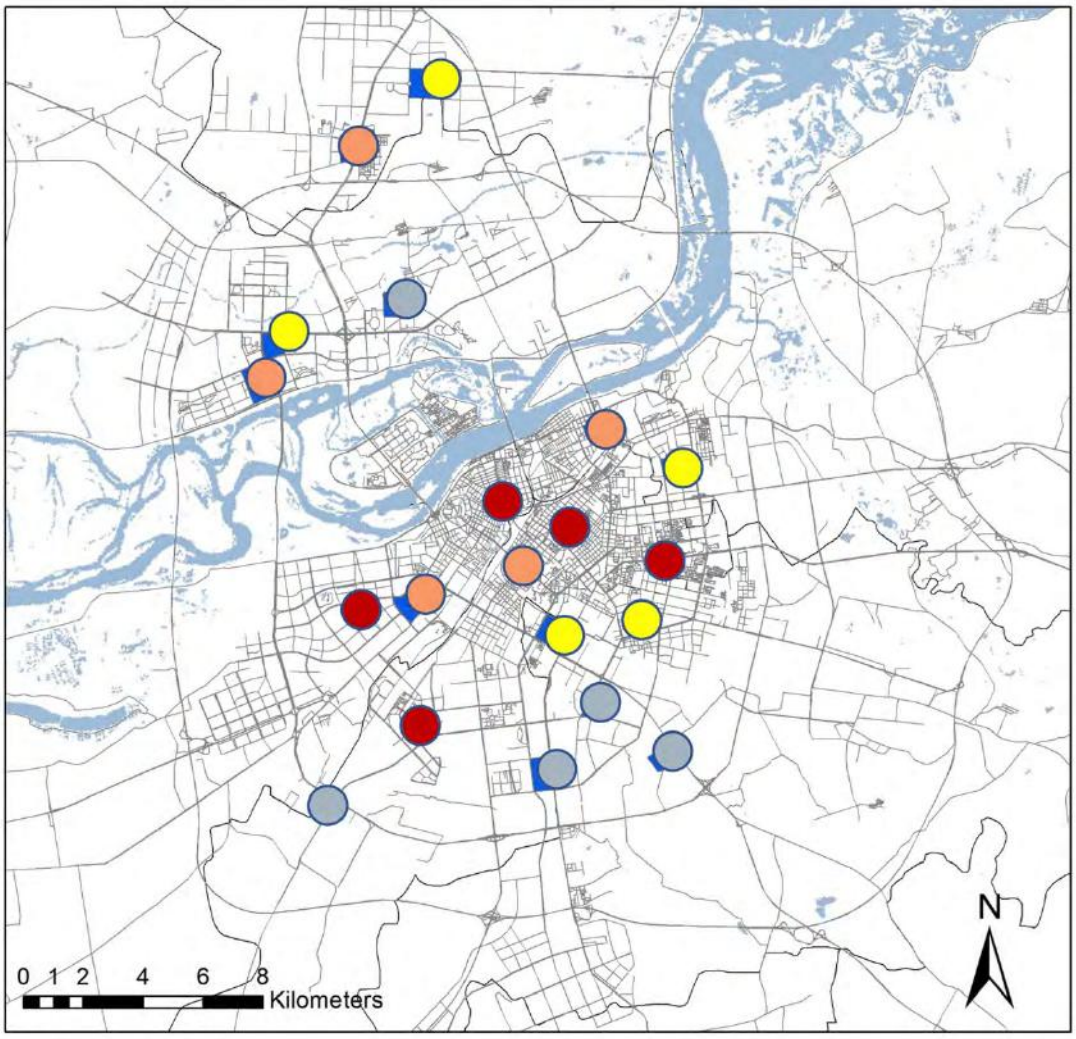


Figure 5. Relationships Between Total Carbon Emissions and Urban Density Metrics (Urban Form Compactness and Population Density).

3.4. Block-level density analysis results

In this study, we selected 20 blocks for block-level density analysis (Figure 6). Based on the carbon emission distribution in Harbin, we randomly selected five blocks from each of the four emission levels: High-CE, Mid-high-CE, Mid-low-CE, and Low-CE. As shown in Figure 6, these blocks are evenly distributed across the main urban area of Harbin, representing different parts of the city. Additionally, these blocks encompass various construction periods and urban form characteristics, making them representative for this study.



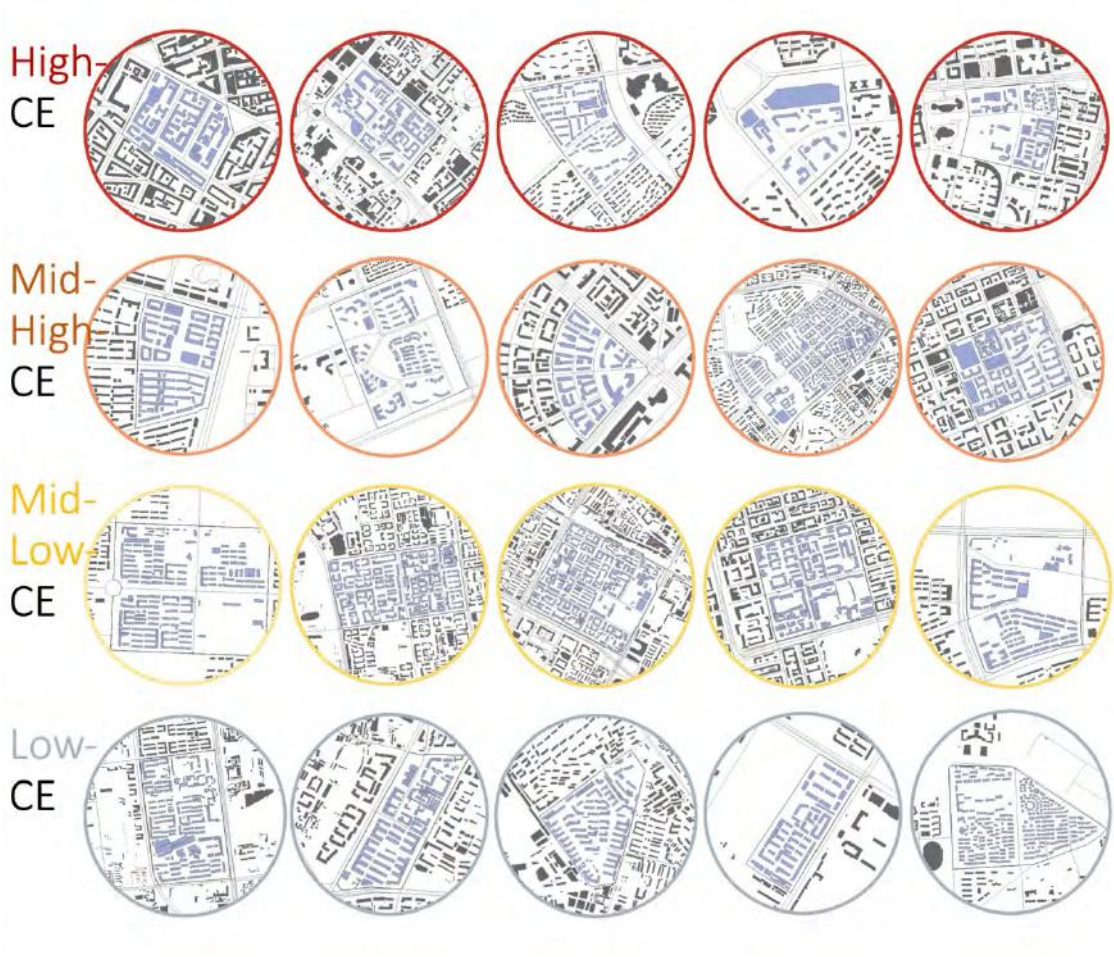


Figure 6. 20 block samples.

At the block scale, we used building density and floor area ratio (FAR) to measure density differences. The preliminary analysis of the block samples revealed large differences in density and urban form between new and older blocks in Harbin, as well as large differences between blocks in different parts of the city. Harbin's older blocks are generally located in the central areas of the city. They tend to have smaller block sizes, higher building densities and higher Floor Area Ratios. In contrast, newer blocks are usually found in the outskirts of the city or in newer areas of the city. These blocks are usually larger in scale, with lower building densities and relatively lower Floor Area Ratios.

In order to analyze the impact of these density differences on carbon emissions in more detail, we also conducted a regression analysis of block-scale density metrics with total block carbon emissions. The results showed that building density and floor area ratio were negatively correlated with total carbon emissions in a nonlinear relationship (Figure 7). Increased building density and floor area ratio were associated with reduced total carbon emissions. This may be because higher building density and floor area ratio indicate a more compact building layout. Compact layouts lead to more efficient land use and improved public transport accessibility, reducing total carbon emissions at the block level.

However, analysis of both building density and floor area ratio revealed a similar trend. When building density and floor area ratio reached a certain threshold, the reduction in carbon emissions began to slow. This may be because extremely high-density areas, beyond a certain point, create new environmental challenges that increase energy consumption and demand. For example, high-density environments lead

to poor ventilation, increased cooling demand, and reduced green spaces, all contributing to additional energy consumption.

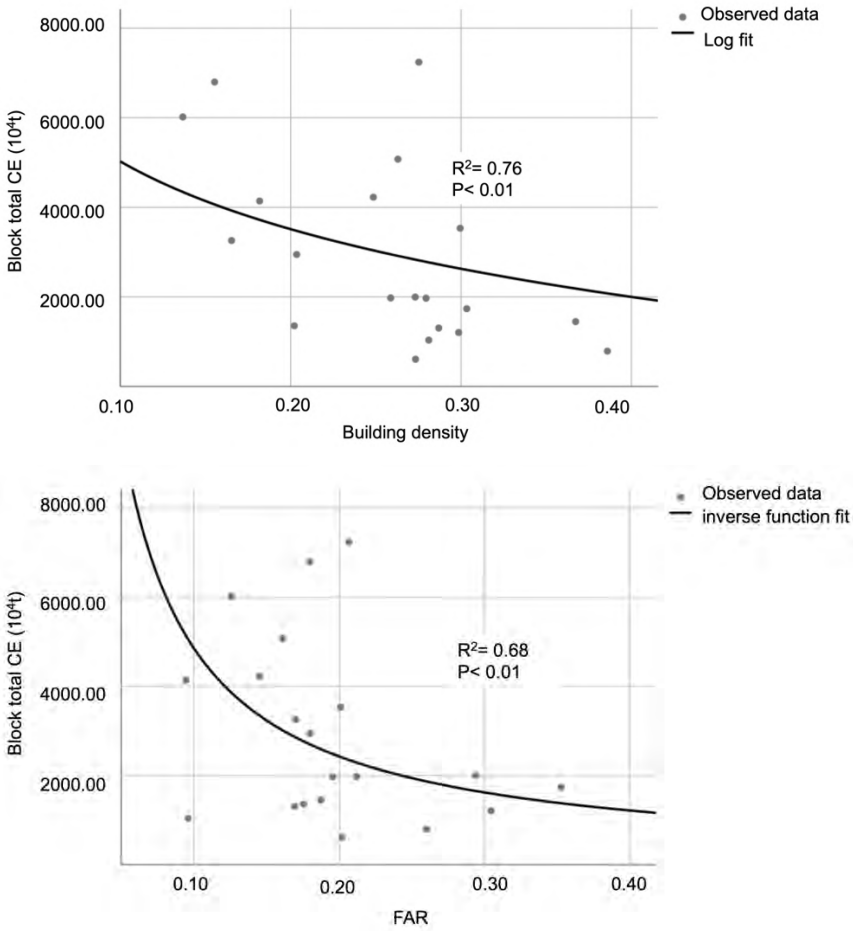


Figure 7. Relationships Between Total Carbon Emissions and Block Density Metrics (Building Density and Floor Area Ratio).

4. Conclusion

To systematically analyze the relationship between density and carbon emissions, this study used a multi-scale approach to examine the impact of density on carbon emissions from macro to micro perspectives. High-density, compact development helps reduce urban carbon emissions. However, at finer spatial scales, the effect of density on carbon emissions becomes more complex. Once density reaches a certain threshold, its impact on reducing emissions begins to diminish. This study emphasizes the role of density management in promoting sustainable urban development and provides strategic insights for urban density control.

We recommend delineating high-density, mid-density, and low-density control zones based on land use at the city level. Density management should be implemented at both the macro city and micro block scales, with targeted control measures for different functional zones. The concept of high-density, compact development should be consistently applied in urban planning, particularly in newly developed areas. For already developed areas, it is not feasible to apply the same density control measures as during initial construction. In these areas, emphasis should be placed on improving energy and resource efficiency, enhancing public transportation accessibility, and reducing carbon emissions while maintaining high density. Increasing green space and planting high-carbon sequestration vegetation in developed areas can

create a better living environment while enhancing urban carbon sinks. Intelligent monitoring technologies should be used in urban management to monitor density distribution and carbon emissions in real-time, ensuring urban development aligns with sustainable principles.

Due to data limitations, this study has constraints in deeply exploring the impact of density distribution on carbon emissions. Additionally, many factors beyond density influence carbon emissions. Factors such as land use, road networks, and residents' behaviors are also important contributors to carbon emissions. In future research, we plan to incorporate these factors to develop more effective strategies for guiding urban planning to reduce carbon emissions and promote sustainable urban development.

5. References

Gudipudi, R., Fluschnik, T., Ros, Anselmo García Cantú, Walther, C. and Kropp, Jürgen P. (2016), 'City density and CO2 efficiency', *Energy Policy*, Vol. 91352-361.

Martínez-Zarzoso, Inmaculada and Maruotti, A. (2011), 'The impact of urbanization on CO2 emissions: Evidence from developing countries', *Ecological Economics*, Vol. 70 No. 7, pp. 1344-1353.

Chen, Z., Yu, B., Yang, C., Zhou, Y., Yao, S., Qian, X., Wang, C., Wu, B. and Wu, J. (2021), 'An extended time series (2000–2018) of global NPP-VIIRS-like nighttime light data from a cross-sensor calibration', *Earth Syst. Sci. Data*, Vol. 13 No. 3, pp. 889-906.

Dhakal, S. (2009), 'Urban energy use and carbon emissions from cities in China and policy implications', *Energy Policy*, Vol. 37 No. 11, pp. 4208-4219.

Du, S., Zhang, Y., Sun, W. and Liu, B. (2024), 'Quantifying heterogeneous impacts of 2D/3D built environment on carbon emissions across urban functional zones: A case study in Beijing, China', *Energy and Buildings*, Vol. 319114513.

Fang, G., Gao, Z., Tian, L. and Fu, M. (2022), 'What drives urban carbon emission efficiency? – Spatial analysis based on nighttime light data', *Applied Energy*, Vol. 312118772.

Hong, S., Hui, E. C. M. and Lin, Y. (2022), 'Relationships between carbon emissions and urban population size and density, based on geo-urban scaling analysis: A multi62carbon source empirical study', *Urban Climate*, Vol. 46101337.

Kumar, S. and Sen, R. (2025), 'Are larger or denser cities more emission efficient? Exploring the nexus between urban household carbon emission, population size and density', *Applied Energy*, Vol. 377124500.

Liu, W. and Qin, B. (2016), 'Low-carbon city initiatives in China: A review from the policy paradigm perspective', *Cities*, Vol. 51131-138.

Luo, H., Wang, C., Li, C., Meng, X., Yang, X. and Tan, Q. (2024), 'Multi-scale carbon emission characterization and prediction based on land use and interpretable machine learning model: A case study of the Yangtze River Delta Region, China', *Applied Energy*, Vol. 360122819.

Schuster-Olbrich, J. P., Marquet, O., Miralles-Guasch, C. and Fuentes Arce, L. (2024), 'Spatial patterns and drivers of urban expansion: An exploratory spatial analysis of the Metropolitan Region of Santiago, Chile, from 1997 to 2013', *Cities*, Vol. 153105305.

Shi, K., Chen, Y., Yu, B., Xu, T., Chen, Z., Liu, R., Li, L. and Wu, J. (2016), 'Modeling spatiotemporal CO2 (carbon dioxide) emission dynamics in China from DMSP-OLS nighttime stable light data using panel data analysis', *Applied Energy*, Vol. 168523-533.

Wang, Y., Chen, L. and Kubota, J. (2016), 'The relationship between urbanization, energy use and carbon emissions: evidence from a panel of Association of Southeast Asian Nations (ASEAN) countries', *Journal of Cleaner Production*, Vol. 1121368-1374.

Wu, H., Yang, Y. and Li, W. (2024), 'Dynamic spatiotemporal evolution and spatial effect of carbon emissions in urban agglomerations based on nighttime light data', *Sustainable Cities and Society*, Vol. 113105712.

Zhang, X., Cai, Z., Song, W. and Yang, D. (2023), 'Mapping the spatial-temporal changes in energy consumption-related carbon emissions in the Beijing-Tianjin-Hebei region via nighttime light data', *Sustainable Cities and Society*, Vol. 94104476.

Case Study Report

Climate neighbourhoods in Flanders:

Initiating a broad transition process towards a sustainable urban environment

Anneloes VAN NOORDT, Department of Environment & Spatial Development, Flanders

Abstract

The Climate Neighbourhoods trajectory starts with the hypothesis that it offers several advantages to link different challenges in the areas of energy, climate and space, to tackle the transformation at the scale of the neighbourhood, and to focus on a more collective, place-based and integrated approach. Three concrete neighbourhoods in Kortrijk, Leuven and Mechelen in Flanders, Belgium, were chosen for a learning by doing approach to be supported in their sustainability transition. Testing the hypothesis of climate neighbourhoods resulted in a number of new questions that policy, research and practice will have to deal with. It also resulted in 7 tracks of change and a plea to further develop the climate neighbourhood approach beyond pilot projects towards a Climate Neighbourhood Program.

Keywords

Spatial Development; Energy Transition; Climate Change; Mitigation; District level

1. Introduction

In the last 10 years the Department of Environment and Spatial Development (DOMG), part of the Flemish Government, has worked on extending its knowledge base on the link between the energy and climate transition and spatial challenges and development (Posad *et al.*, 2016; Architecture Workroom Brussels, Boeijenga and Vereniging Deltametropool, 2017; Wauters *et al.*, 2017; Declerck, Peeters and Alderweireldt, 2019; Van Den Driessche *et al.*, 2019). The results of each of these research projects shows us that the energy and climate transition will have a profound effect on our direct living environment and will result in an extensive spatial transformation (van Noordt, 2018, 2019, 2022).

In order to link two long-term ambitions of the Flemish government of (1) the energy transition and (2) high-quality densification of existing built up areas and test the possibilities within concrete projects, the DOMG together with Team Flemish Government Architect and the Flemish Climate and Energy Agency launched the project call 'Climate Neighbourhoods' in 2020. The aim was to realize renovation projects at building block or neighbourhood level. The projects link various renovation and climate measures. For the purpose of this call we defined ‘climate neighbourhoods’ as districts initiating a broad-based transition process that transforms the urban fabric to become more sustainable.

By introducing a "learning by doing" process concrete reconversion projects on a neighbourhood scale are supported in their sustainability transition. The projects integrate various renovation, climate and sustainability measures. Three cities (Kortrijk, Mechelen and Leuven) were chosen from the applications for the call for projects. For each of the three districts, a multidisciplinary research team was appointed with expertise in the field of design, energy, participation, real estate, financing and legal knowledge.

2. Climate Neighbourhoods: an integrated, place-based and collective approach

When we want to tackle the energy transition we need to become aware that this challenge is more complex and broader then merely renovating our houses. If we want to evolve towards a more sustainable urban environment an integrated, place-based and collective approach is needed (Vervloesem *et al.*, 2024). The research trajectory of Climate Neighbourhoods in Flanders started with the hypothesis that linking different challenges on the scale level of neighbourhoods would have several advantages. Transition challenges like energy, mobility, circularity, health, green-blue infrastructures, social cohesion, housing, and so on all come together in space. Moreover, the neighbourhood level is the place where abstract policy objectives descend and can be addressed hands-on, in close cooperation between citizens, market parties and government institutions. It is therefore the place where the policy set out can be given a tangible and readable form, where challenges become very concrete and manageable (Van Den Driessche *et al.*, 2019).

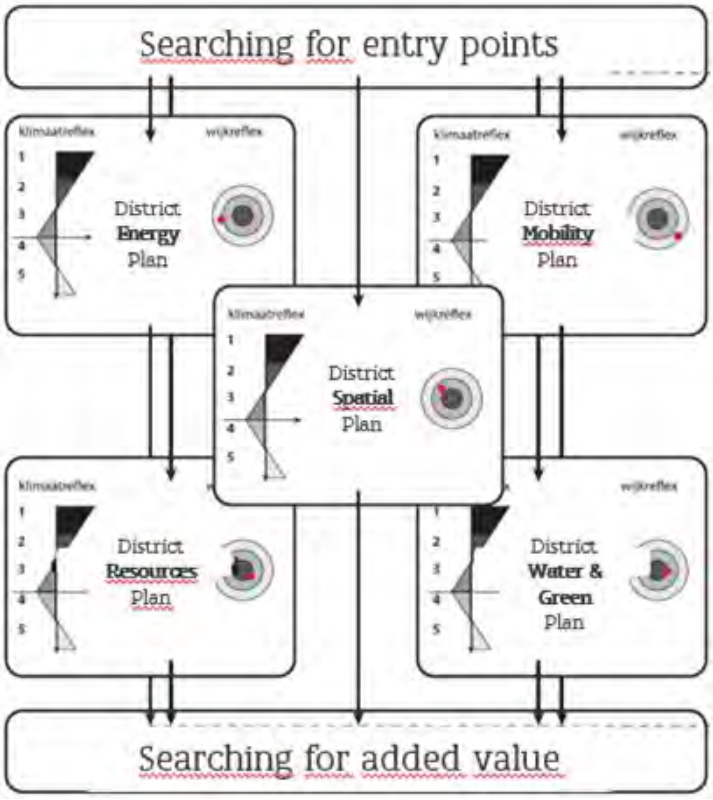


Figure 1: Searching for synergies and linkages between transition challenges. © UGent - LABO A, Blaf Architecten, Bureau Bouwtechniek (Van Den Driessche *et al.*, 2019).

With a research by design approach the interlinkages could be imagined and possible solutions tested. The neighbourhood level allows to simplify the very complex and abstract transition challenges and makes it comprehensible for residents in the area to get involved and create a sense of ownership for the needed transformation. The neighbourhood level is therefore regarded as a crucial link in the intended transition process. This focus on the neighbourhood level is not new, European projects like the ones within the DUT Partnership[1] focussing on Positive Energy Districts or PEDs are also zooming in on the district level.

3. Cases: Learning by doing

In order to test the hypothesis of climate neighbourhoods, a learning by doing experiment was initiated, selecting three cases to test new and inspiring solutions. By working with real neighbourhoods and involving real actors new insights on how climate neighbourhoods could actually be developed are created. Opportunities can be seized and current barriers inventoried and possible solutions proposed.

3.1 Case Mechelen: The ring road as backbone for the energy transition

The case of Mechelen focusses on three scale levels, linking energy planning with sustainable spatial policy (De Nijs *et al.*, 2022). The first level is the ring road around the city centre. The city administration already has plans to transform this car dominated infrastructure to a green space, with place for recreation and more emphasis on cycling and walking instead of car use. The research team investigated the possibility of developing a back bone of a heat network to supply heat to the whole city centre. In tandem, the collective renovation of the apartment buildings next to the ring road was investigated. To connect these two scale levels a development plan at the neighbourhood level, further specifying the heating zoning plans for the city, was to be developed.

During the project a research by design approach was used. Using spatial scenarios allows to visualise the future in a concrete way, asses impacts and evaluate the positive and negative effects. Several scenarios, visual illustrations and 'building blocks' were designed and tested. The building block approach put forward in the Mechelen case was based on a previous project on the concept of climate neighbourhoods (Van Den Driessche *et al.*, 2019). This previous research identified 5 coherent themes which all need to be addressed within a climate neighbourhood (see also figure 1). The project in Mechelen further operationalised this concept. When a neighbourhood is being (re)developed, these building blocks can be combined to imagine a more sustainable future.

In order to speed up the rate of collective renovations for apartment buildings several recommendations are formulated. First of all it is important to focus on the no regret measures that are easily executed. Examples include insulating roofs and large facades. Secondly, it is good to keep in mind that renovation is not only a technical challenge, but also a communication challenge. It is therefor very important to support the association of co-owners in these complex decision processes. The city administration could play a vital role in this. Thirdly and most importantly, renovation master planning is needed, this will prevent ad hoc decisions with in the end higher costs and potential lock-ins.

[1] https://dutpartnership.eu/

At the neighbourhood level, as a smaller part of the whole city centre, 4 different design scenarios were developed to test how the previous mentioned 'building blocks' could be used to not only see in what way a neighbourhood could be connected to a city wide heat network, but also to see how linkages could be made to other spatial transformations, like greening, sustainable mobility, water safety, etc.

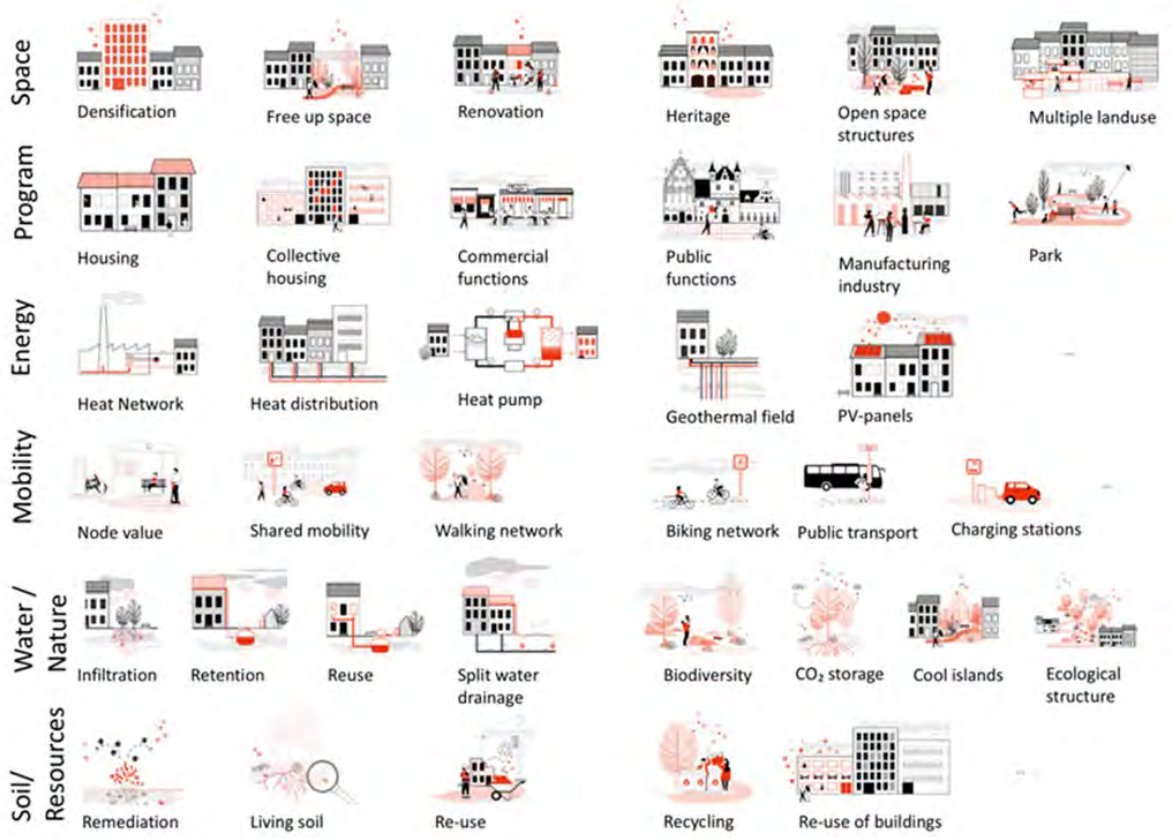


Figure 2: Building blocks towards an integrated spatial project. © Ingenium, Atelier Horizon, Bureau Bouwtechniek & Levuur (De Nijs *et al.*, 2022)

As a last part, the potential of a city wide heat network was explored. The challenge in Mechelen is however that there is no big heat source available on a short distance, several smaller heat sources therefor needed to be combined and connected which also increased the costs. Again several different scenarios were tested in detail and costs were calculated. In the end the concept of 'heat islands' was proposed as most promising. In this concept smaller heat islands are developed step-by-step, cutting the big challenge of supplying the whole city centre of Mechelen with renewable heat into smaller parts. Subsequently, these heat-islands can be connected to each other and to a larger heat backbone, creating a robust citywide network.

3.2 Case Leuven: From Garden City Neighbourhood to Climate Neighbourhood

The neighbourhood in Leuven, Ter Elst, is a garden city, developed in the 1950's. This heritage neighbourhood is slowly being renovated by new owners moving into the neighbourhood. These individual interventions however compromise the collective value a garden city has. The challenge therefor focusses on how the transition towards a more sustainable neighbourhood could happen

without losing the specific heritage identity. A collective approach involving the whole neighbourhood makes sense, also within the historical context. But the split up ownership, which is very typical for Flemish neighbourhoods, makes a collective approach difficult.

The research (Augusteyns *et al.*, 2022) focused on seven intertwined transition questions: (1) What is the heritage value? (2) How do we evolve towards a climate robust living environment? (3) How can we initiate a modal shift? (4) How do we insulate our buildings? (5) How do we use renewable energy? (6) How can we afford this transitions? (7) How do we organise ourselves?

Figure 3: Climate Neighbourhood Ter Elst, Leuven. © Michiel De Cleene

To safeguard the heritage character of the neighbourhood, the researchers proposed a set of 38 rules which applied to both the houses themselves, but also to the private and public open spaces. The rules are put together in a renovation guide specifically designed for this neighbourhood. It focusses on incentives rather then pure restrictions, to boost the renovation rate while at the same time safeguarding the specific identity. When searching for alternative, sustainable heating options, return on investment should not be the only driver to invest in the energy transition. Environmental and life cycle considerations should be part of a cost and benefits analysis to decide what are the best options on the long term for society as a whole.

The challenges regarding a climate robust design and the need for a modal shift are very much intertwined. By moving away from individual car ownership and towards softer forms of mobility, like cycling or using public transport, space, formally used to park cars, is freed up to develop green areas. These green areas have several advantages: they can retain water, lower the urban heat island effect, improve social cohesion and health. The research team proposed a step wise approach to transform both the public and the private open spaces. Lastly, the research shows that in general in Flanders almost half of the people are not able to afford a complete renovation of their houses and the other half might not

be willing to invest large sums into renovation. A three tier strategy is proposed to first of all incite those who can afford to renovate by offering group purchases and specific loans. Secondly, to offer financial guarantees by the government and thirdly to subsidies those that cannot afford the transition.

To organise the physical transition, the cooperation between neighbours and financing of actions, a neighbourhood cooperation is put forward. More detailed research is however needed to further operationalise this concept.

Figure 4: Vision Ter Elst, Leuven by 2050. © OMGEVING landscape architecture - urbanism, RE-ST, Sweco Energy, SuMa consulting en Transition Heroes (Augusteyns *et al.*, 2022)

3.3 Case Kortrijk: Transforming a recalcitrant district

The case of Kortrijk evolves around a typical neighbourhood in Flanders: the building block Walle. It consists of both industry in the core and detached and terraced housing and a school at the fringes. The redevelopment of the industry in the core was the trigger to see how this whole building block, including the housing, could be transformed into a carbon neutral, autarkic neighbourhood. Trying to merge these two processes, of the very concrete redevelopment of the industrial site with the pragmatic reality of developers and the more ambitious and holistic research by design process of becoming a climate neighbourhood proved to be very challenging and in the end not possible.

But despite these difficulties, the project did give some interesting results (Huygh *et al.*, 2023). By focusing on further developing the details of what was needed for each transition theme, it further proved the way these transitions are intertwined, like also indicated in figure 1. The mobility transition for instance is a very important lever. Rethinking oversized roads and parking spaces and developing public transport and soft connections is vital in an energy strategy. Moreover, it also revealed the importance of working on different scale levels. The climate and energy transition cannot be solved at

the neighbourhood level alone, especially mobility issues need to be tackled at a city-region level to be able to achieve a modal shift. Concrete actions to reduce heat islands, loss of biodiversity, water stress and sealed soil are on the other hand better tackled on the neighbourhood scale. A cascade of scale levels needs to be intertwined to reach the best results. Another recommendation was the concept of a 'neighbourhood deal'. This deal would consist of a framework to tackle several societal challenges in a neighbourhood, like energy transition, mobility, etc. in an integrated way and in cooperation with both governments, civil society and companies. A deal would provide clarity in government priorities and decisions and offer investment security and an increased realization grade. The deal itself would be signed by the Flemish and the local government and would include a facilitating and supporting framework offered by the Flemish region. The concept of a neighbourhood deal is promising, but needs further operationalisation.

4. Key Findings: Proposing 7 tracks for change

Testing the hypothesis of climate neighbourhoods resulted in a number of new questions that policy, research and practice will have to deal with. The level of the neighbourhood is not the be-all and end-all, it has advantages but sometimes also disadvantages and the coherence with other scale levels is important. Based on what we learned in this limited number of three neighbourhoods, and from the discussions with other cities and municipalities that are working on similar tasks, we remember that it is certainly worthwhile to continue working on this area-oriented and integrated approach, and that the Flemish government has a role to play in this. Based on the three cases we put forward 7 tracks of change (Vervloesem *et al.*, 2024). These tracks of change are specified to the Flemish (policy) context and aimed at both the regional and the local policymakers. However, the findings can also be generalized and used in other countries with other specificities.

The first track focusses on the need of a **collective approach** that complements individual measures. The transition to collective systems can be more efficient and effective in technical and economic terms, compared to a building-by-building approach. Moreover, a collective vision and approach for energy and other facilities also offers unmissable opportunities to make linkages.

Secondly, we need to go from one-size-fits all to **customization and a place-based approach**. Every neighbourhood is different, customization makes it possible to respond to specific, local needs and urgencies and forms a crucial complement to generic, 'one size fits all' measures. In addition, customization offers opportunities to steer towards desired reinforcement of cores and densification.

Thirdly, to make the transformation of our built-up environment sustainable and robust, we need to **go from working in silos to linking opportunities**. In this way, in addition to achieving climate objectives, other related challenges, such as affordable housing, sustainable mobility, quality public space, accessible care, socio-economic inequality, etc., are tackled at the same time.

Fourthly, traditional financing logics should give way to **new partnerships**, new collective forms of commissioning, and corresponding organizational and financing models. Ownership of an integrated approach at neighborhood level does not sit with one party, but requires coordinated cooperation, and this in terms of vision development, implementation, legal certainty, and financing

Fifth, citizens should no longer be seen as passive consumers: their agency should be actively used through innovative and far-reaching forms of **collective citizen participation**, such as establishing public-

civil partnerships, setting up co-creation processes in which citizens take an active role, and making commitments that translate into ownership.

Sixth, the energy transition is exposing socio-economic inequalities. It is often the most vulnerable groups in society that are hit first and hardest by the burdens of climate and energy crises. By using flanking measures, the potentially exclusionary effects of sustainability investments can be countered as much as possible to strive for a **just energy transition.**

Last but not least: a **mission-oriented Flemish government** could act as a booster and facilitator to achieve the necessary breakthroughs in making the built environment climate-neutral. Local governments should be seen as equal partners.

5. Conclusion

The insights gathered within the three pilot projects lead towards an argumentation to further develop the climate neighbourhood approach beyond pilot projects towards a Climate Neighbourhood Program. It should connect the local level with the Flemish level and have a mission to link several transition challenges. Such cross-policy programming will offer the opportunity to streamline several initiatives working with the climate and energy transition within the built-up environment. Moreover, a program would offer the opportunity of more in-depth cooperation and co-creation between the Flemish and local level. Furthermore, it is essential that resources and capacity is made available to be able to realize the set climate and energy targets. Local governments should take the lead developing a place-based approach using their knowledge of the local context and challenges.

References

Architecture Workroom Brussels, Boeijenga, J. and Vereniging Deltametropool (2017) *De Lage Landen 2020-2100. Een toekomstverkenning.* Brussel.

Augusteyns, S. *et al.* (2022) 'Klimaatwijk Leuven'.

De Nijs, A. *et al.* (2022) 'Klimaatwijk Mechelen'.

Declerck, J., Peeters, M. and Alderweireldt, J. (2019) 'Ruimte voor de energietransitie'.

Huygh, J. *et al.* (2023) 'Klimaatwijk Kortrijk'.

van Noordt, A. (2018) 'The role of spatial development in the energy and climate transition'. *54th ISOCARP Congress 2018*, Bodo.

van Noordt, A. (2019) 'The spatial dimension of the Flemish Covenant of Mayors: A comparative spatial analysis on the transition towards climate friendly municipalities'. *AESOP anual congress Planning for Transition*, Venice.

van Noordt, A. (2022) 'Regional Territorial Energy Strategies. A roadmap to transform abstract climate goals into concrete spatial actions', in. *ISOCARP Congress 2022*, Brussels.

Posad *et al.* (2016) *Energielandschappen*.

Van Den Driessche, M. *et al.* (2019) *Strategische verkenningsfase energie- en klimaatwijken*.

Vervloesem, E. *et al.* (2024) 'Klimaatwijken'.

Wauters, E. *et al.* (2017) *De rol van ruimtelijke ordening in de energie- en klimaattransitie*.

Research Paper

How the urban morphology impact thermal environment in high-density areas

A city-block-scale study in Harbin, China

Qi AN, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Yu DONG, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Wei DONG, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

A large number of studies have been conducted to explore the relationship between land surface temperature (LST) and urban morphology. However, few have analysed the diurnal variation of LST and their drivers at the block scale, especially in densely populated urban environments within cold cities. To fill the gaps, this study classified urban blocks into nine types based on building density and height. Using ECOSTRESS LST data, we analysed diurnal differences in LST and assess the influence of block type on LST. Correlation analyses and stepwise regression models were employed to identify key indicators of green space patterns that significantly affect LST intensity. The results indicate that: (1) The spatial distribution of LST varies significantly between day and night. (2) There is a diurnal difference in the effect of urban block classification on LST. During the daytime, building density is the main factor dominating the magnitude of LST intensity. Nighttime, on the other hand, may be related to building height. (3) The results of the correlation analysis and stepwise regression modelling indicate that urban green space patterns is closely related to LST within each type of urban blocks. The results provide new perspectives on urban thermal environment mitigation.

Keywords

Urban heat island, urban block morphology, green space, ECOSTRESS, cold city

1. Introduction

1.1. Urban heat island effects and climate change

As global warming and extreme weather events become more frequent, populations in urban areas will become more sensitive to the combined effects of the urban heat island (UHI) phenomenon and increased heat due to climate change. The urban heat island phenomenon has now been observed in more than 1,100 cities worldwide (Peng et al., 2018). In these cities, the heat island intensity can reach 4 to 5°C and even exceed 10°C in extreme cases (Santamouris, 2020). The UHI effect not only causes negative impacts such as increased energy consumption and deterioration of air quality, but also jeopardizes human health and well-being.The UHI effect is linked to a range of negative outcomes, including elevated energy

consumption, deteriorated air quality, and adverse impacts on human health and well-being. Therefore, it is crucial to understand the spatial distribution of urban heat and to analyse its associated influences.

1.2. Thermal management challenges in cold cities

More than 600 million people worldwide live in regions with cold climates. Under the pressure of rapid urbanization, these regions are warming twice as fast as the global average (Welegedara et al., 2023). Therefore, even in colder climates, rapid increases in urban temperatures can expose residents to greater risks. Thermal risk management in cold regions is becoming increasingly urgent. However, a great deal of UHI research is currently focused on warmer cities, with less research on cold areas like Harbin.

1.3. Block-level mitigation of thermal environment in high-density urban areas

Numerous studies have shown that rational urban planning strategies can significantly mitigate UHI. At the same time, remote sensing products such as MODIS, Landsat, and ECOSTRESS provide long time-series and wide-area data coverage, making LST data more easily accessible. However, there are still relatively few studies related to the diurnal variation of LST in densely populated cities. Therefore, we chose the densely populated cold city of Harbin as the study area. Firstly, we obtained the diurnal spatial distribution of LST using ECOSTRESS data. Secondly, blocks were extracted as the basic unit of study, and urban blocks were classified into nine types based on building density and height. We further extracted the landscape characteristics of urban green spaces within each type of block. Subsequently, we calculated distribution indices to assess the effect of block type on LST. Finally, the key factors affecting LST were identified using Pearson correlation analysis and stepwise regression methods, respectively.

2. Methodology

2.1. Study area

Harbin (125°42′–130°10′ E, 44°04′–46°40′ N) is the capital of Heilongjiang Province in Northeast China (Figure 1). The city has a total area of 53,136.94km^2 and 9.395 million residents by the end of 2022. Harbin has a mid-temperate continental monsoon climate, and the temperatures here have consistently increased over the past decade. Our study focuses on the core urban area of Harbin within the fourth ring road. This part of the region covers an area of 4,068.04km^2, has the highest building density, a variety of urban functions and a high population density.

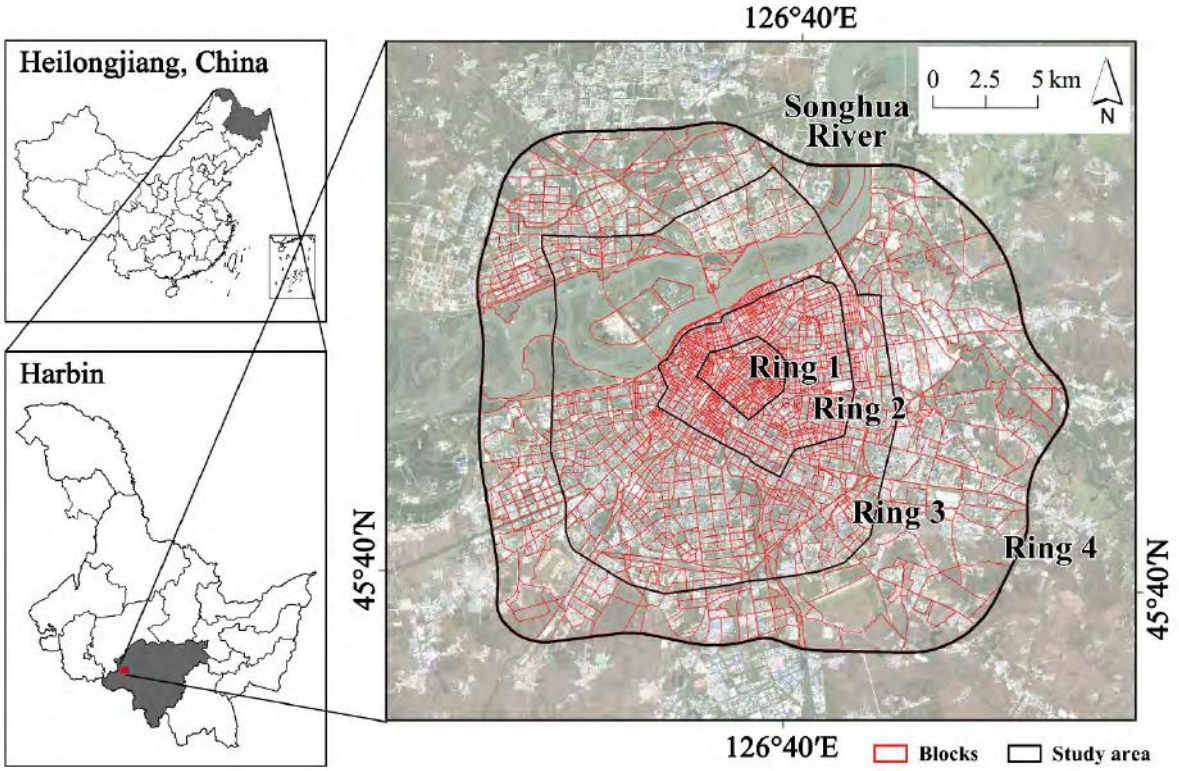


Figure 1. Geographical location map of the study area and blocks. Source: By the authors.

2.2. LST data collection

ECOSTRESS LST products were sourced from the the NASA Land Processes Distributed Active Archive Center (https://lpdaac.usgs.gov/) (Chang et al., 2021). ECOSTRESS instruments operate on the International Space Station orbit. This approach provides diurnal surface temperature at a spatial resolution of 70 meters and a temporal resolution of 3-5 days (Hulley et al., 2019). Previous studies shows strong consistency between ECOSTRESS surface temperature data and other thermal infrared instruments (Hook et al., 2020; Silvestri et al., 2020).

In this study, we used the ECOSTRESS Atmospherically Corrected Surface Temperature and Emissivity Level 2 product (ECO2LSTE) (https://lpdaac.usgs.gov/products/eco2lstev001/). This dataset applies a physically-based Temperature Emissivity Separation (TES) method to derive LST. Our analysis focused on summer, with data from July 2022 to August 2023. We downloaded the ECOSTRESS LST scenes from the AppEEARS tool (https://lpdaac.usgs.gov/tools/appeears/). Two high-quality scenes were aquired at different Beijing time (UTC+8): 10:17 on August 10, 2022, and 19:07 on July 30, 2023 (Table 1). We also verified the LST accuracy using hourly geostationary satellite data from Copernicus Global Land Service (Chang et al., 2021). In ArcGIS, we selected 100 radom sampling points to compare the two datasets. Their Pearson correlation coefficients were 0.843 and 0.773, which indicates a strong linear correlation relationship.

Table 1. Specific information of Landsat imagery and atmospheric correction parameters of LST.

Date acquisition data and time	Maximum value of data /℃	Minimum value of data /℃	Mean value of data /℃	Standard deviation of data	The temperature at the last full hour /℃	Wind speed at the last full	Average daily temperature /℃

						hour /(m·s^{-1})	
2022/08/10 UTC 02:17 UTC+8 10:17	48.8	23.8	33.0	3.9	24.9	3.8	21.9
2023/07/30 UTC 11:07 UTC+8 19:07	27.6	14.0	21.5	1.4	29.3	4	25.3

2.3. Mapping urban blocks

We followed previous studies (Hu et al., 2022; Yao et al., 2023; Zhou et al., 2022) to define block categories. These categories rely on building density (BD) and building height (BH). Stewart and Oke's classification criteria guided this approach (Stewart and Oke, 2012). We divided blocks into three density levels: low (BD＜0.15), medium (0.15≤BD＜0.25), and high (BD≥0.25). We also divided blocks into three hight levels: low-rise (BH＜9m), mid-rise (9m≤BH＜21m), and high-rise (BH≥21 m). These divisions produce nine block categories.

We used building vector data from Baidu map in June 2019 (https://lbsyun.baidu.com/). This dataset includes spatial locations, vertical projection boundaries, and floor counts. Chen et al. (2023) showed that this data can effectively help to study the influence of building form on the SUHI effect. We estimated building height by multiplying the number of floors by three (Sun et al., 2020). And we calculated building density as the ratio of each block's building basal area to its total area. To ensure accuracy, we also used Sentinel-2 imagery from May 10, 2022 to fill any missing data.

2.4. Extraction of urban green space morphological characteristics

In urban areas with dense construction, green spaces offer effective and economical strategies for mitigating thermal environments. We used Fragstats to measure the morphological factors of urban green spaces. These factors include Total Class Area (CA), Percentage of Landscape (PLAND), Patch Density (PD), Landscape Shape Index (LSI), and Aggregation Index (AI) (Table 2). We sourced the urban green space data from the fine-grained urban green space map (UGS-1m) (https://doi.org/10.57760/sciencedb.07049) developed by Shi et al. (2023). This dataset has a spatial resolution of approximately 1.1 m, with an overall accuracy of 87.56% and an F1 score of 74.86%.

Table 2. Description and calculation of urban green space morphological characteristics.

Metrics	Abbreviation	Description	Calculation
Total Class Area	CA	The sum of the area of urban green space in a block	$CA = \sum_{j=1}^{n} a_{ij} \times \frac{1}{10000}$
Percentage of Landscape	PLAND	Proportion of the landscape occupied by urban green space in a block	$PLAND = \frac{\sum_{j=1}^{n} a_{ij}}{A} \times 100$

Patch Density	PD	Patch density of urban green space in a block	$PD = \frac{n_i}{A} \times 10000 \times 100$
Landscape Shape Index	LSI	Irregular degree of urban green space shape in a block	$LSI = \frac{0.25\sum_{k=1}^{m} e_{ik}^{*}}{\sqrt{A}}$
Aggregation Index	AI	Aggregation degree of urban green space shape in a block	$AI = \left[\frac{g_{ii}}{\max \rightarrow g_{ii}}\right] \times 100$

Notes：The relevant calculation method comes from https://www.fragstats.org/.

2.5. Influence of urban block categories on LST

In this study, we used the distribution index (DI) to measure the impact of different urban block categories (Yao et al., 2022). The formula is shown as follows:

$$DI = \frac{S_{hi}}{S_i} \Big/ \frac{S_h}{S}$$

We defined high temperature center (HTC) using the temperature threshold method (Zhao et al., 2024). Where S_{hi} and S_i represent the areas of HTC in the ith urban blocks and the entire study area respectively. S_h and S indicate the total area of HTC and the total area of all urban block categories. If the DI of a certain urban block is greater than 1, then the HTC in that block is its main distribution region (Huang and Wang, 2019).

2.6. Main driving factors affecting the LST in urban blocks

We used a Pearson correlation analysis to analyze the relationship between LST and five green space morphological indicators. After that, the factors that are significantly correlated with LST are identified as relevant influences (Yao et al., 2023). Finally, LST and all relevant influences were entered into the stepwise regression model. The main drivers were identified based on the results of the model. The above statistical analysis were completed using SPSS (v20).

3. Results

3.1. Diurnal distribution characteristics of LST

The spatial distribution of LST at different observation times is shown in Figure 2. Fig. 2a shows the LST during the day (10:17 local time). Fig. 2b shows the LST at night (19:07 local time). The daytime LST in the study area is 23.77°C to 48.75°C, with an average of 33.02°C. The LST at night is 14.05°C to 27.61°C, with an average of 21.51°C. These values show that the distribution of LST has obvious diurnal differences. Figure 3 shows the spatial distribution of urban green space and related land use. The study area is densely populated, with important infrastructure such as Harbin Railway Station and large shopping mail. Nearby industrial facilities, including Harbin Boiler Factory and Harbin Pharmaceutical Group, may also cause the increase of LST. The LST of water body and forest is low during the day. This discovery also supports the previous research results that blue-green space is conducive to cooling down. At night, the LST of Songhua River and nearby middle and high-rise buildings is higher. This may be due to the high specific heat capacity of water body and the slow release of heat. High-rise buildings will also retain heat until night. Therefore, even if there is no direct sunlight at night, these areas will maintain a high LST.

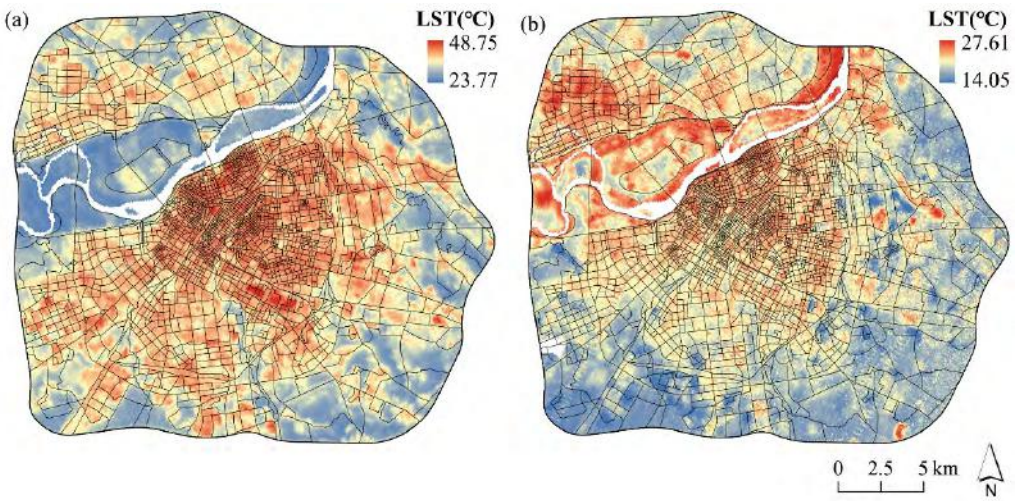


Figure 2. Spatial distribution of LST at different observation times. (a) 10:17; (b) 19:07. The white area in the map has been removed because it was covered by clouds. Source: By the authors.

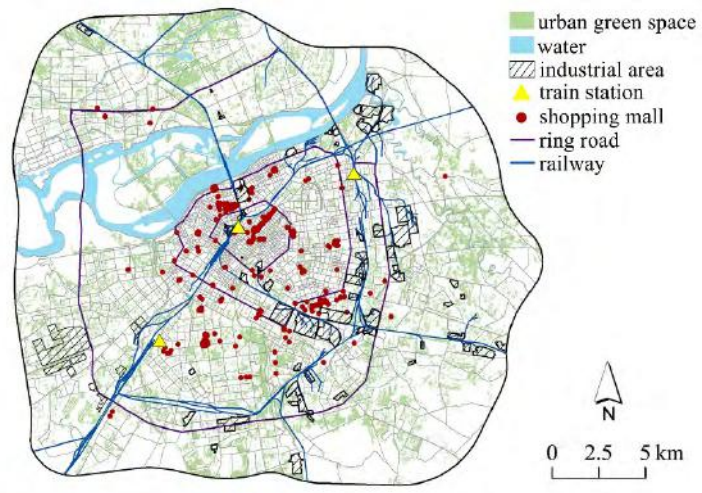


Figure 3. Spatial distribution of urban green space and related land use. Source: By the authors.

3.2. Effect of urban block categories on LST

The average value of LST in each block type shows that the influence of urban block types on LST is also different day and night (Figure 4). During the day, the average LST of high-rise and high-density blocks is the highest, and that of low-rise and low-density blocks is the lowest. Urban blocks with high building density, including HRHD, HRMD, MRHD, MRMD and LRHD, have high LST. This shows that building density is the key factor affecting the intensity of LST during the day. At night, the highest and lowest block types of LST are still HRHD and LRLD respectively. Blocks with the height of middle and high-rise buildings also show relatively high LST at night. This shows that the building height is related to LST at night.

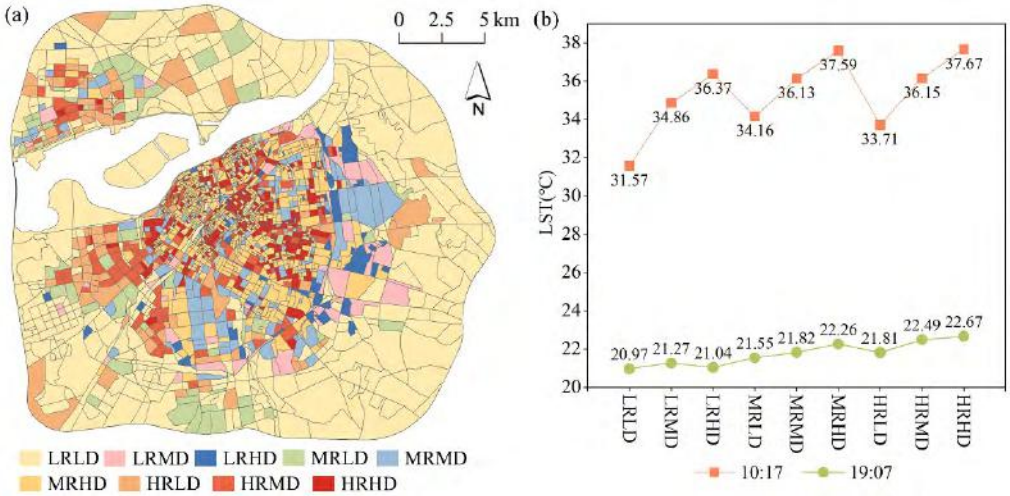


Figure 4. (a) Spatial distribution of urban block categories. The white area in the map has been removed because it was covered by water. (b) Average LST in each urban block category. Source: By the authors.

The calculation results of distribution index (DI) show that HRHD block has the highest distribution index value, which indicates that this kind of block contributes a lot to LST strength (Table 3). The DI values of MRHD and MRMD blocks in both periods exceeded 1. This shows that these two types of blocks are also important heat sources in the study area. In addition, the blocks of HRMD, HRLD, MRLD and LRHD also have a significant impact on the LST intensity at night.

Table 3. The distribution index (DI) of urban block categories at the observation times.

Urban block category	DI value at 10:17	DI value at 19:07
LRLD	0.02	0.08
LRMD	0.04	0.51
LRHD	0.89	1.74
MRLD	0.05	1.29
MRMD	0.99	1.69
MRHD	5.95	2.96
HRLD	0.12	1.41
HRMD	0.62	2.48
HRHD	7.82	5.47

3.3. Influence of urban green space morphological characteristics on LST

Table 4 lists the correlation coefficient between urban green space landscape pattern index and LST. The calculation results show that there is a significant correlation between all indexes and LST. Among them, CA, PLAND, LSI and AI are negatively correlated with LST, while PD is positively correlated with LST. In view of the difference between day and night, LSI and LST in all block categories are negatively correlated during the day. PLAND is negatively correlated with LST in all blocks except LRLD and MRLD. This may indicate that larger area, higher proportion and more dispersed green patches will help to reduce the LST during the day. At night, the relationship between CA, PLAND, LSI and LST is weakened, but it is still significant. This shows that the small cold islands formed by scattered green spaces effectively reduce the LST at night.

Additionally, AI values negatively correlate with LST in LRLD, LRMD, and MRMD blocks during the day, while positively correlating in LRHD blocks at night. This suggests that aggregated green space patches provide cooling during the day but may contribute to warming at night, possibly due to water vapor from vegetation acting as a greenhouse gas, enhancing nighttime thermal insulation. Regarding PD, LRLD, MRLD, and high-rise low-density (HRLD) blocks exhibit significant positive correlations with LST during the day, with LRLD maintaining this correlation at night. This commonality of low building density suggests that increasing the number of green space patches in low-density urban blocks may not effectively enhance cooling.

Table 4. Correlation between LST and urban green space morphological characteristics in different block categories.

Urban block category	CA	PLAND	LSI	AI	PD
10:17-Daytime					
All	-0.495**	-0.366**	-0.512**	-0.223**	0.215**
LRLD	-0.357**	0.047	-0.345**	-0.115**	0.378**
LRMD	-0.494**	-0.456**	-0.423**	-0.356**	0.113
LRHD	-0.423**	-0.318**	-0.231*	-0.133	-0.055
MRLD	-0.427**	0.159	-0.419**	-0.049	0.344**
MRMD	-0.418**	-0.388**	-0.449**	-0.205**	0.095
MRHD	-0.246**	-0.310**	-0.250**	-0.067	-0.122*
HRLD	-0.613**	-0.197*	-0.517**	-0.157	0.303**
HRMD	-0.383**	-0.277**	-0.391**	-0.159*	0.072
HRHD	-0.371**	-0.201**	-0.275*	-0.101	-0.123*
19:07-Nighttime					
All	-0.350**	-0.220**	-0.460**	-0.157**	0.147**
LRLD	-0.226**	-0.115**	-0.357**	-0.066	0.203**
LRMD	-0.139	-0.092	-0.146	0.121	0.027
LRHD	-0.184	0.140	-0.315**	0.295**	0.210
MRLD	-0.410**	0.019	-0.366**	-0.107	0.100
MRMD	-0.370**	-0.239**	-0.367**	-0.099	0.079
MRHD	-0.272**	-0.255**	-0.334**	-0.095*	-0.086*
HRLD	-0.300**	-0.197*	-0.383**	-0.088	0.093
HRMD	-0.063	-0.055	-0.120	-0.046	0.097
HRHD	-0.317**	-0.201**	-0.275**	-0.101	-0.061

Notes : * and ** denote P＜0.05 and P＜0.01 (2-tailed), respectively.

3.4. Main driving factors of LST

All statistically significant urban green space morphological characteristics were entered into stepwise regression models. Separate models were created for all blocks and 9 block categories (Table 5). Considering all blocks, urban green space morphological drivers explained 36.8% of the daytime LST variation and 23.4% of the nighttime LST variation. Specifically, CA was a significant driver of LST during the

day for most block categories (except MRMD and HRMD). For LRLD, LRHD, MRHD, HRLD, and HRHD at night, the significant driver became LSI.PLAND and PD were stronger drivers of LST during the day than at night.AI had a weak or irrelevant driving influence on LST in most block categories. Overall, our results suggest to some extent that increasing the area and proportion of green space is an effective measure to reduce LST during the daytime, while increasing the discrete degree of green space patches is an effective way to reduce LST at night.

Table 5. Standardized regression coefficients between urban green space morphological characteristics and LST for different block categories.

Urban block category	CA	PLAND	LSI	AI	PD	R^2
10:17-Daytime						
All	-0.154**	-0.259**	-0.322**	×	0.155**	0.368
LRLD	-0.194**	×	-0.131*	×	0.303**	0.225
LRMD	-0.385**	-0.327**	×	×	×	0.316
LRHD	-0.423**	×	×	×	×	0.168
MRLD	-0.416**	0.244*	×	×	0.228*	0.267
MRMD	×	-0.313**	-0.389**	×	×	0.289
MRHD	-0.157**	-0.255**	×	×	×	0.115
HRLD	-0.445**	×	-0.230**	×	0.147*	0.423
HRMD	×	×	-0.393**	-0.166*	×	0.171
HRHD	-0.317**	×	×	×	×	0.098
19:07-Nighttime						
All	×	-0.135**	-0.416**	×	0.095**	0.234
LRLD	×	×	-0.327**	×	0.124**	0.138
LRMD	×	×	×	×	×	×
LRHD	×	×	-0.274**	0.322**	0.270*	0.208
MRLD	-0.410	×	×	×	×	0.158
MRMD	-0.370**	×	×	×	×	0.133
MRHD	×	-0.130**	-0.274**	×	×	0.122
HRLD	×	×	-0.383**	×	×	0.140
HRMD	×	×	×	×	×	×
HRHD	×	×	-0.168**	×	×	0.025

Notes :* and ** denote P＜0.05 and P＜0.01, respectively. × indicates that the metrics were not considered in the final model.

4. Discussion

4.1. Implications for urban planning

The results of this study suggest that focusing on the daytime thermal environment alone is not sufficient to develop strategies to mitigate the effects of SUHI, and that the nighttime thermal environment should

also be considered. The effects of urban green space form indicators on surface temperature (LST) in different block types differed between day and night. Specifically (1) the spatial distribution of LST varies significantly between day and night. Higher daytime LST indicates that urban landscapes (e.g., buildings, water bodies, and woodlands) strongly influence the spatial pattern of LST under strong solar radiation; regions of high intensity of nighttime LST are characterized by water bodies and areas of medium- to high-rise buildings. (2) The effect of urban block class on LST varies with diurnal and nocturnal heat differences. During daytime, building density dominates the magnitude of LST intensity, while at night it may be related to building height. The DI differences in urban block categories during day and night show that high-rise, high-density blocks contribute significantly to LST intensity during both day and night. (3) The results of correlation analysis and stepwise regression modeling suggest that increasing the area and proportion of green space is an effective measure to reduce LST during the daytime, while increasing the discrete degree of green space patches is an effective way to reduce LST at night.

4.2. Limitations and prospects

This study highlights the value of ECOSTRESS-derived LST data for understanding diurnal thermal differences in urban blocks, providing new insights into thermal environment mitigation in high-density areas. However, due to the lack of long time series of continuous LST observations, ECOSTRESS LST using only 2 observation times, especially the LST data excluding the hottest moments, may not be able to fully characterize the diurnal variation of LST. The availability of longer ECOSTRESS records in the future will help to more accurately reveal the diurnal variability of LST at finer scales. Second, although this study identified different effects of urban block type and green space morphological features on daytime and nighttime LST, it did not propose a joint strategy to mitigate the effects on both LSTs simultaneously. In future studies, it would be beneficial to determine the optimal range of daytime and nighttime LST reductions by incorporating a more comprehensive set of urban form factors and considering the variation in the marginal effects of urban form characteristics on daytime and nighttime LST. Third, although the stepwise regression analysis carried out effectively identified the main drivers, it is essentially a linear regression-based approach that may not reveal the nonlinear relationship between the explanatory variables and LST. Therefore, in the future, machine learning-based nonlinear models can be used to jointly explore the quantitative relationship between urban characteristics and LST.

5. References

Chang, Y. *et al.* (2021) 'Exploring diurnal thermal variations in urban local climate zones with ECOSTRESS land surface temperature data', *Remote Sensing of Environment*, 263, p. 112544. Available at: https://doi.org/10.1016/J.RSE.2021.112544.

Chen, K. *et al.* (2023) 'Evaluating the seasonal effects of building form and street view indicators on street-level land surface temperature using random forest regression', *Building and Environment*, 245, p. 110884. Available at: https://doi.org/10.1016/J.BUILDENV.2023.110884.

Hook, S.J. *et al.* (2020) 'In-Flight Validation of the ECOSTRESS, Landsats 7 and 8 Thermal Infrared Spectral Channels Using the Lake Tahoe CA/NV and Salton Sea CA Automated Validation Sites', *IEEE Transactions on Geoscience and Remote Sensing*, 58(2), pp. 1294–1302. Available at: https://doi.org/10.1109/TGRS.2019.2945701.

Hu, D. *et al.* (2022) 'How do urban morphological blocks shape spatial patterns of land surface temperature over different seasons? A multifactorial driving analysis of Beijing, China', *International Journal of Applied Earth Observation and Geoinformation*, 106, p. 102648. Available at: https://doi.org/10.1016/J.JAG.2021.102648.

Huang, X. and Wang, Y. (2019) 'Investigating the effects of 3D urban morphology on the surface urban heat island effect in urban functional zones by using high-resolution remote sensing data: A case study

of Wuhan, Central China', *ISPRS Journal of Photogrammetry and Remote Sensing*, 152, pp. 119–131. Available at: https://doi.org/10.1016/J.ISPRSJPRS.2019.04.010.

Hulley, G. *et al.* (2019) 'New ECOSTRESS and MODIS Land Surface Temperature Data Reveal Fine-Scale Heat Vulnerability in Cities: A Case Study for Los Angeles County, California', *Remote Sensing*, 11(18), p. 2136. Available at: https://doi.org/10.3390/RS11182136.

Peng, J. *et al.* (2024), 'Response of urban green space cooling effect to urbanization in the Three Ring Road area of Changsha City', *Sustainable Cities and Society*, 109, p. 105534. Available at: https://doi.org/10.1016/J.SCS.2024.105534.

Peng, J. *et al.* (2018) 'Spatial-temporal change of land surface temperature across 285 cities in China: An urban-rural contrast perspective', *Science of The Total Environment*, 635, pp. 487–497. Available at: https://doi.org/10.1016/J.SCITOTENV.2018.04.105.

Santamouris, M. (2020) 'Recent progress on urban overheating and heat island research. Integrated assessment of the energy, environmental, vulnerability and health impact. Synergies with the global climate change', *Energy and Buildings*, 207, p. 109482. Available at: https://doi.org/10.1016/J.ENBUILD.2019.109482.

Shi, Q. *et al.* (2023) 'UGS-1m: fine-grained urban green space mapping of 31 major cities in China based on the deep learning framework', *Earth System Science Data*, 15(2), pp. 555–577. Available at: https://doi.org/10.5194/ESSD-15-555-2023.

Silvestri, M. *et al.* (2020) 'First Comparisons of Surface Temperature Estimations between ECOSTRESS, ASTER and Landsat 8 over Italian Volcanic and Geothermal Areas', *Remote Sensing*, 12(1), p. 184. Available at: https://doi.org/10.3390/RS12010184.

Stewart, I.D. and Oke, T.R. (2012) 'Local Climate Zones for Urban Temperature Studies', *Bulletin of the American Meteorological Society*, 93(12), pp. 1879–1900. Available at: https://doi.org/10.1175/BAMS-D-11-00019.1.

Sun, F. *et al.* (2020) 'The effects of 3D architectural patterns on the urban surface temperature at a neighborhood scale: Relative contributions and marginal effects', *Journal of Cleaner Production*, 258, p. 120706. Available at: https://doi.org/10.1016/J.JCLEPRO.2020.120706.

Welegedara, N.P.Y., Agrawal, S.K. and Lotfi, G. (2023) 'Exploring spatiotemporal changes of the urban heat Island effect in high-latitude cities at a neighbourhood level: A case of Edmonton, Canada', *Sustainable Cities and Society*, 90, p. 104403. Available at: https://doi.org/10.1016/J.SCS.2023.104403.

Yao, X. *et al.* (2023) 'Exploring the diurnal variations of the driving factors affecting block-based LST in a "Furnace city" using ECOSTRESS thermal imaging', *Sustainable Cities and Society*, 98, p. 104841. Available at: https://doi.org/10.1016/J.SCS.2023.104841.

Yao, X. *et al.* (2022) 'Investigating the effects of urban morphological factors on seasonal land surface temperature in a "Furnace city" from a block perspective', *Sustainable Cities and Society*, 86, p. 104165. Available at: https://doi.org/10.1016/J.SCS.2022.104165.

Zhao, H., Fang, Y. and Xu, X. (2024) 'Quantifying morphology evolutions of urban heat islands and assessing their heat exposure in a metropolis', *Sustainable Cities and Society*, 102, p. 105244. Available at: https://doi.org/10.1016/J.SCS.2024.105244.

Zhou, Y. *et al.* (2022) 'Exploring surface urban heat island (SUHI) intensity and its implications based on urban 3D neighborhood metrics: An investigation of 57 Chinese cities', *Science of The Total Environment*, 847, p. 157662. Available at: https://doi.org/10.1016/J.SCITOTENV.2022.157662.

Research Paper

Critical Success Criteria for sustainable and affordable housing delivery in high-density urban areas

A case study of Indian megacities

Debanjali SAHA, Department of Architecture and Regional Planning, Indian Institute of Technology, Kharagpur, West Bengal, India

Haimanti BANERJI, Department of Architecture and Regional Planning, Indian Institute of Technology, Kharagpur, West Bengal, India

Umesh KUMAR, Department of Architecture and Regional Planning, Indian Institute of Technology, Kharagpur, West Bengal, India

Abstract

Housing is a critical determinant of citizens' quality of life, especially in rapidly urbanizing nations like India. Despite various housing policies, considerable debate remains about which factors are essential for achieving sustainable and affordable housing (SAH) in high-density urban areas. This paper reviews the CSCs of SAH delivery in Indian megacities based on an in-depth analysis of experts' opinions. It was undertaken through a questionnaire survey among 100 housing experts and factor analysis to derivate six significant elements: Housing Operational Cost, Land Use Planning, Housing Quality and Safety, Project Management and Governance, Social and Community aspects, and Environmental Quality and Sustainability. While cost-related criteria maintained primary importance (explaining 17.897% variance), with ranking and normalization analysis identifying the top three CSCs as housing price versus income (mean=4.55), lifecycle cost reduction (mean=4.53), and rental price versus income (mean=4.52), the findings reveal significant correlations between various CSCs, highlighting their interconnected nature. This study contributes to the literature on affordable housing and develops a validated framework for high-density urban environments. This research concludes that SAH needs to be implemented through an integrative holistic approach covering multiple sustainability dimensions, not just economic ones, and offers insight into comprehensive housing strategies.

Keywords

Critical success criteria, Affordable, Sustainable, Housing, India

1. Introduction

Housing is one of the most fundamental human needs, essential for improving the quality of life and providing social cohesion and sustainable development (Saha et al., 2024; Winston and Pareja Eastaway, 2008). However, rapid urbanization has put immense pressure on housing infrastructure, particularly in developing countries where urban population growth is accelerating at unprecedented rates (Roy, 2020). By 2050, an estimated 90% of the additional 2.5 billion urban dwellers will come from developing nations. The burden will be predominantly in Asia as well. According to UN-Habitat (2005), India faces a severe

housing crisis. Around 80% of this crisis is attributed to inadequate and overcrowded living conditions (Abhay and Sharma, 2023; Surjan and Shaw, 2009). Approximately 35% of urban residents live in substandard housing, which could rise to 38% by 2030 if adequate measures are not implemented. Furthermore, only about 8% of the housing supply is affordable and sustainable for middle-class urban residents (Tiwari and Rao, 2011). The situation is even more dire for marginalized communities, low-income groups (LIG), and other disadvantaged sections of society, who account for 96% of India's housing deficit of 18.78 million units (Agarwal et al., 2021). These statistics indicate the need for affordable housing strategies to efficiently address growing needs while promoting equitable and sustainable urban development.

This study explores the challenges of affordable and sustainable housing for densely populated urban areas in Indian megacities. Indeed, though numerous government-sponsored initiatives have been undertaken to reduce housing shortages, the effectiveness of these interventions remains debatable, particularly for LIGs (Chan and Adabre, 2019; Saha et al., 2024). Traditionally, price affordability has been the focal point, while other essential factors like environmental sustainability, accessibility, and social integration have been omitted from consideration (Mulliner et al., 2013). Such a narrow view has resulted in problems such as housing underutilization and abandonment of affordable housing schemes. For instance, Greater Mumbai has more than 15% of its residential stock lying vacant while facing an acute shortage of housing (Gandhi et al., 2022). Similar trends noticed in Indian megacities have strengthened this argument. This paper will enhance the comprehension of SAH provision by scrutinizing economic and non-economic indicators.

The necessity of this research is rooted in addressing several significant challenges and gaps in current research and policy instruments. Despite the overwhelming body of literature, housing sustainability and affordability have been regarded as two distinct areas. The gap observed so far in terms of a lack of integrating frameworks capable of addressing the needs of the densely populated urban regions lies here. The contemporary literature often cannot consider the interplay of complexity between environmental issues, social equity, and economic pressures in fast-growing cities like India's megacities (Adabre and Chan, 2019b; Yan et al., 2019). Moreover, no uniform criteria for evaluating housing policy effectiveness are present; thus, its implementation is fragmented with limited long-term impact. These inadequacies must be addressed to develop realistic strategies that integrate the diversified interests of all stakeholders and promote effective policy implementation. From the mentioned gaps, therefore, this research can significantly improve the development and implementation of housing policy. Additionally, it will contribute to the theoretical debates and support practical applications in urban development.

Despite growing recognition of the importance of SAH, limited empirical work has been carried out to identify and validate the Critical Success Criteria (CSCs) required for delivering SAH in high-density urban contexts. CSCs represent the specific and measurable outcomes that define the project's success in relation to achieving the project's objectives (Adabre and Chan, 2019a; Ahadzie et al., 2008; Chan and Adabre, 2019; Yan et al., 2019). For policymakers, planners, and developers, this lacks standardized criteria as it is essential to implement integrative approaches relevant to specific issues in urban megacities of India. Therefore, filling this gap is necessary to study critical success criteria pertinent to SAH provision in the Indian megacity settings. The research objectives (RO) are mentioned below:

RO1: To identify, validate, and prioritize CSCs for SAH delivery in high-density Indian megacities.
RO2: Develop an integrated policy framework incorporating stakeholder perspectives to implement SAH solutions based on identified CSCs.

The outcomes of this research are critical to policymakers, urban planners, and developers of Indian megacities and other high-density cities in developing nations. It bridges the current theory-practice gap in

housing policy and urban planning by identifying CSCs in the context of context-specific interventions and developing an integrated framework. It contributes to the broader discourse concerning sustainable urban development and provides a robust foundation for designing more effective SAH initiatives. Besides, the study's expected outcomes will better align the interests of various stakeholders so that the solution provided will be equitable, sustainable, and scalable in housing in rapidly urbanizing regions.

The paper is divided into the following sections: Section Two is a comprehensive literature review that describes the research methodology for identifying and validating potential CSCs for SAH. Section Three elaborates on the analysis and findings of the empirical study and the associated prioritization of identified CSCs. Section Four elaborates on the implications of results and relevance to the broader fields in SAH. Finally, Section Five summarizes the main conclusions and gives further recommendations for practitioners, policymakers, and future research directions in SAH.

2. Research methodology

2.1 Identification of potential CSC for SAH

A literature review was conducted in multiple databases, including Web of Science, Scopus, and Google Scholar. The review scope included peer-reviewed articles, book chapters, policy documents, and reports published between 2014 and 2024. Sources were selected to identify the CSCs contributing to SAH, mainly in high-density urban areas in developing countries. In the preliminary stage, 39 CSCs were identified. The validation procedure consisted of two distinct phases. Initially, the criteria were assessed by academic professionals for their thoroughness, pertinence, and lucidity. This panel comprised two senior professors with expertise in sustainable urban development, a postdoctoral researcher concentrating on affordable housing policies, and a doctoral candidate specializing in urban sustainability metrics. Following their recommendations, three supplementary criteria—"Reduced Social Segregation," "Access to Healthcare Facilities," and "Disaster Resilience Measures"—were integrated to fill the gaps recognized during the literature validation and for the consensus among experts.

During the second phase, six experts working in affordable housing in Indian megacities—including architects, town planners, and housing development authorities—checked the feasibility of the indicators for practical implementation. Their responses brought out refinements that dealt with the interdependencies and specific conditions of the urban contexts in India. This resulted in a finalized set of 36 CSCs through an iterative process that assured academic rigor and practical relevance. Table 1 shows all the final CSCs with supporting references, which shall be further used for analysis and discussion.

Table 1. List of potential CSC for sustainable and affordable housing projects

CSC Code	CSC for Sustainable & Affordable Housing	References
CSC1	Spatial functionality of unit space	(Al-Tmeemy et al., 2011)
CSC2	Integrating renewable and sustainable strategies	(Moghayedi et al., 2021)
CSC3	Adequate incentives by the Government	(Hamidi et al., 2016)
CSC4	Low presence of environmental problems	(M.A. Adabre and Chan, 2019b)
CSC5	Rental Price V/S Income	(Albert P.C. Chan and Adabre, 2019; Saha et al., 2024)
CSC6	Reduced Social segregation	*Pilot Survey*
CSC7	Access to local commercial areas	(Gan et al., 2019)
CSC8	Public support or acceptance	(Agarwal et al., 2022)
CSC9	Pollution control initiatives	(Adabre and Chan, 2021)
CSC10	Availability of open green space	(Adabre et al., 2020)

CSC11	Quality of housing	(M.A. Adabre and Chan, 2019b)
CSC12	Environmental performance of housing facility	(Chan & Hou, 2015)
CSC13	Allowing flexibility in zoning and development standards	(Adel et al., 2022)
CSC14	Reduce the life cycle cost of Housing	(Ezennia and Hoskara, 2021)
CSC15	Timely completion of Project	(Liang and Jia, 2018)
CSC16	Good location for residential accommodation	(M.A. Adabre and Chan, 2019)
CSC 17	Cultural sensitivity in design	(Wang and Ajovalasit, 2020)
CSC 18	Disaster resilience features	(Moghayedi et al., 2021)
CSC19	Maintenance of existing houses	(Valença, 2015)
CSC20	Available waste management facilities	(Winston, 2010)
CSC21	Number of dwelling units based on Household size	(Abastante et al., 2018)
CSC22	Marketability of housing facility	(Chan & Adabre, 2019)
CSC23	Effective coordination with government bodies	(Adel et al., 2022)
CSC24	Efficient land management policies for housing supply	(Adabre et al., 2020)
CSC25	Safety and Security measures	(Chan & Adabre, 2019)
CSC26	Project completed within the allocated budget	(Gan et al., 2019)
CSC27	Appropriate risk allocation and risk sharing	(Amora and Juanzon, 2022)
CSC 28	Technology transfer	(Chan & Adabre, 2019)
CSC29	Reduced commuting cost/distance	(Adabre and Chan, 2021)
CSC30	Adequate physical infrastructure supply	(Saha et al., 2024)
CSC31	Comfortable and healthy indoor environment	(Maqbool et al., 2020)
CSC 32	Reducing various approval cost	(Chan & Hou, 2015)
CSC33	Community participation	(Ezennia, 2022)
CSC34	Housing Price V/S Income	(Lamprou and Vagiona, 2022)
CSC35	Access to employment opportunities	*Pilot Survey*
CSC36	Access to health care services	*Pilot Survey*

2.2 Data collection and survey designs

A questionnaire survey was developed to elicit experts' opinions on the importance of the identified CSCs within the SAH delivery. It comprised questions for each CSC about the relevance and importance of various dimensions of SAH delivery. Respondents were chosen based on two key selection criteria: (1) substantial contribution to research or practical knowledge in urban planning, as evident from academic writings or professional qualifications, and (2) in-depth knowledge about affordable housing schemes. The survey targeted researchers, project managers, urban planners, developers, and consultants chosen from articles in peer-reviewed journals and professional housing databases like Liases Foras and CREDAI (The Confederation of Real Estate Developers Associations of India). A snowball sampling technique was also used where primary respondents shared the questionnaire with other qualified experts within their professional network. This ensures greater generalizability and access to specialists whose niches are often left out in traditional sampling strategies (Saha et al., 2024). The questionnaire was then sent to 178 experts via email using Google Forms. For each CSF, the experts indicated the relative importance using a five-point Likert scale (1 = "not significant"; 5 = "significant"). Of the responses received, 109 were analyzed, but nine were excluded due to missing data or outliers detected. The outlier exclusions were based on statistical anomalies. Hence, 100 valid responses remain, which gives a response rate of 56%.

Respondent profiles provided a balanced representation, with 38% from academia and 62% from industry sectors such as architects, engineers, urban planners, project/construction managers, and developers. Most respondents presented considerable professional experience in affordable housing: 67% mentioned 5–10 years, 22% 11–20 years, and 11% reported more than 20 years of involvement in affordable housing

projects. Housing project experience spanned across social housing (43%), cooperative housing (25%), public housing (22%), and other specialized categories of public-private partnership developments, corporate housing, and community-led initiatives (10%). This allows for professional and sectoral heterogeneity, ensuring a holistic range of opinions and expertise over the findings. Figure 1 illustrates the methodological structure adopted in the investigation in terms of sequential phases, research methodologies, and procedures adopted. This framework presents a guide to understanding how each stage of the method applied assists in the identification and validation of CSCs.

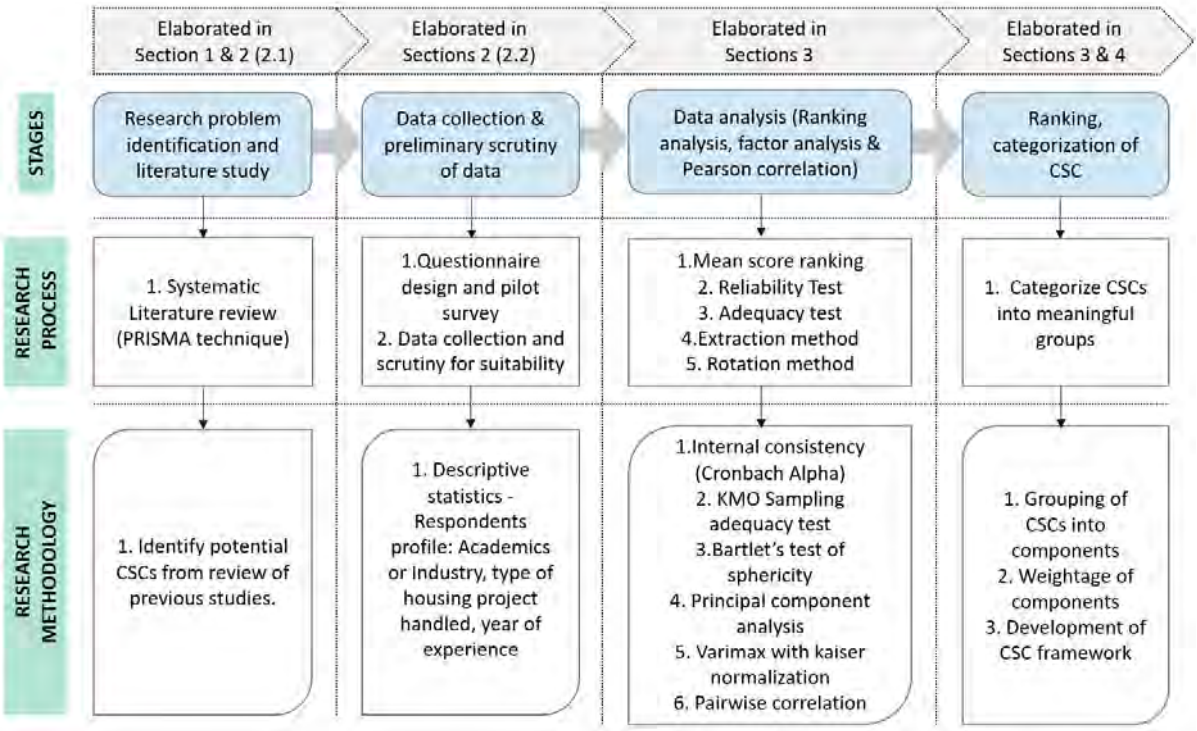


Figure 1. Research framework for the study. Source: Author.

3. Data analysis and results

Data analysis was performed using the Statistical Package for Social Science (SPSS) version 29. SPSS was chosen due to its advanced statistical modeling features and its suitability for academic research. The analytical process was divided into three main methods: (1) descriptive statistics to rank the CSCs in terms of mean value and standard deviations, (2) Pearson correlation analysis to establish relationships among the individual CSCs, and (3) factor analysis for further grouping of the 36 CSCs to components that reflect similar constructs (Ahadzie et al., 2008).

3.1. Ranking analysis of the CSCs

CSCs were ranked according to their mean values, with lower standard deviations used as a tiebreaker for identical means. Table 3 summarizes the rankings, highlighting the five highest-ranked criteria as house price versus income (CSC34, mean=4.55), lifecycle cost reduction (CSC14, mean=4.53), rental price versus income (CSC5, mean=4.52), housing quality (CSC11, mean=4.47), and residential location suitability (CSC16, mean=4.43). These results are consistent with the findings of Gan et al. (2017), where affordability metrics were similarly prioritized across stakeholders. This underscores a key challenge: while other sustainability features are essential, improvements that increase the overall costs may face resistance as they would reduce affordability for housing. Chan et al. (2018) similarly identified increases in cost as a hindering factor

in the adoption of energy-efficient technologies but stressed the use of cost-effective measures to continue the sustainability agenda without losing affordability. On the other side, the five highest-ranked criteria were cultural sensitivity in design (CSC17), approval cost reduction (CSC32), technology transfer (CSC28), disaster resilience features (CSC18), and zoning flexibility (CSC13). These criteria obtained a score of below 3.77, which marked a lower degree of perceived importance or viability in SAH scenarios. For instance, the overall low score on technology transfer corroborates with Ahadzie et al. (2008), who argue that there are inherent difficulties in integrating advanced technologies within existing frameworks.

Table 2. Ranking of CSC. Source: Author.

Code	Mean	Standard Deviation (S.D)	Normalization score	Rank
CSC1	4.42	0.622	0.930	6
CSC2	4.25	0.821	0.838	18
CSC3	4.37	0.691	0.903	12
CSC4	4.38	0.736	0.908	11
CSC5	4.52	0.703	0.984	3
CSC6	4.39	0.764	0.914	9
CSC7	4.15	0.845	0.784	25
CSC8	4.26	0.505	0.843	17
CSC9	4.37	0.734	0.903	12
CSC10	4.34	0.536	0.886	14
CSC11	4.47	0.703	0.957	4
CSC12	4.41	0.552	0.924	7
CSC13	3.77	0.863	0.578	32
CSC14	4.53	0.611	0.989	2
CSC15	4.15	0.796	0.784	25
CSC16	4.43	0.640	0.935	5
CSC17	2.7	0.870	0.000*	36
CSC18	3.28	0.889	0.314*	33
CSC19	4.13	0.812	0.773	31
CSC20	4.16	0.813	0.789	23
CSC21	4.4	0.696	0.919	8
CSC22	4.16	0.615	0.789	23
CSC23	4.17	0.711	0.795	21
CSC24	4.39	0.650	0.914	9
CSC25	4.31	0.861	0.870	16
CSC26	4.17	0.865	0.795	21
CSC27	4.24	0.605	0.832	19
CSC28	2.94	0.983	0.130*	34
CSC29	4.14	0.779	0.778	29
CSC30	4.32	0.898	0.876	15
CSC31	4.22	0.848	0.822	20
CSC32	2.74	1.031	0.022*	35
CSC33	4.15	0.821	0.784	25
CSC34	4.55	0.657	1.000	1
CSC35	4.15	0.796	0.784	25
CSC36	4.14	0.921	0.778	29

Note: Normalization Value = (Mean - Minimum Mean)/ (Maximum Mean - Minimum Mean).

*The normalization value <= 0.50 indicates that the indicator (CSC) was not critical.

Normalization analysis excluded four CSCs with values below the 0.50 criticality threshold: approval cost reduction (CSC32, normalized value=0.022), cultural sensitivity in design (CSC17, normalized value=0.000), disaster resilience features (CSC18, normalized value=0.314), and technology transfer (CSC28, normalized value=0.130). This refinement reduced the total number of CSCs from 36 to 32, which ensures that subsequent analysis focused only on criteria that substantially impact SAH outcomes.

3.2. Factor analysis

The goal of factor analysis was to find relationship patterns between the CSCs. This would allow related factors to be organized in a way that would make understanding SAH criteria easier. For the 32 CSCs to be considered reliable, they have to be validated using Cronbach's Alpha, and, in this case, α=0.706, which is greater than the acceptable level of 0.70. Two tests evaluated the adequacy of the sample for factor analysis. The value of the Kaiser-Meyer-Olkin (KMO) index of sampling adequacy was 0.669, which is higher than the established level of 0.50. Bartlett's test of sphericity (χ^2=1423.151, p<0.001) was statistically significant, which means that variables are dependent on each other (Field, 2013).

The retention parameter is based on Principal Component Analysis (PCA), which calculated 26 substantial variables using eigenvalues greater than 1.0. This ensures that the retained components capture a reasonable amount of data variance. Six components emerged from the Varimax rotation, collectively accounting for 55.46% of the total variance in this study. Such components relate to CSCs' dimensions, comprehensively explained in Table 5.

Table 3. Correlation matrix of Critical Success Criteria (CSC). Source: Author.

Code	Perason Correlation	CSC1	CSC2	CSC3	CSC4	CSC5	CSC6	CSC7	CSC8	CSC9	CSC10	CSC11	CSC12	CSC13	CSC14	CSC15	CSC16	CSC19	CSC20	CSC21	CSC22	CSC23	CSC24	CSC25	CSC26	CSC27	CSC29	CSC30	CSC31	CSC33	CSC34	CSC35	CSC36
CSC1	r	1.00																															
CSC2	r	0.01	1.00																														
CSC3	r	-0.26	0.01	1.00																													
CSC4	r	0.05	0.19	-0.07	1.00																												
CSC5	r	-0.02	-0.29	-0.01	0.08	1.00																											
CSC6	r	0.10	-0.13	-0.24	0.16	0.12	1.00																										
CSC7	r	-0.02	-0.09	0.01	0.08	0.12	0.37	1.00																									
CSC8	r	0.00	-0.05	0.05	-0.01	0.01	0.11	0.22	1.00																								
CSC9	r	0.00	0.11	0.00	0.34	-0.08	0.06	-0.09	-0.06	1.00																							
CSC10	r	-0.12	-0.10	0.02	-0.17	-0.08	-0.20	-0.08	0.05	-0.15	1.00																						
CSC11	r	-0.08	0.06	0.00	0.04	-0.06	0.16	-0.13	-0.07	0.14	-0.20	1.00																					
CSC12	r	0.06	-0.17	0.13	-0.19	-0.08	-0.17	0.03	0.12	0.00	0.57	-0.24	1.00																				
CSC13	r	0.18	0.09	-0.11	0.26	0.03	0.12	0.08	-0.07	0.00	-0.20	0.11	-0.25	1.00																			
CSC14	r	-0.02	-0.29	-0.13	0.02	0.68	0.04	0.06	-0.16	-0.07	-0.12	0.09	-0.11	0.05	1.00																		
CSC15	r	-0.02	-0.14	-0.20	-0.03	0.06	0.19	-0.03	-0.11	0.16	-0.11	0.19	0.02	0.24	0.09	1.00																	
CSC16	r	0.18	-0.12	-0.06	0.07	0.23	0.17	0.19	0.14	-0.18	-0.19	0.07	-0.08	0.44	0.20	0.12	1.00																
CSC19	r	-0.06	0.15	0.01	0.04	-0.06	0.05	0.06	-0.12	0.22	-0.17	0.59	-0.20	0.14	0.06	0.25	0.07	1.00															
CSC20	r	0.00	-0.10	-0.12	-0.06	0.10	-0.05	-0.16	-0.12	0.03	-0.04	0.13	-0.05	0.16	0.10	0.28	0.04	0.15	1.00														
CSC21	r	-0.29	0.13	0.16	-0.23	-0.16	-0.07	0.06	-0.05	-0.13	0.05	0.29	-0.02	-0.21	-0.04	-0.07	-0.24	0.36	-0.10	1.00													
CSC22	r	-0.16	-0.11	-0.13	0.12	0.43	0.23	0.03	-0.24	0.10	-0.21	0.39	-0.25	0.23	0.52	0.36	0.19	0.32	0.19	0.01	1.00												
CSC23	r	-0.06	-0.01	-0.17	0.24	0.15	0.29	0.06	0.08	0.13	-0.31	0.30	-0.26	0.21	0.21	0.39	0.13	0.41	0.13	-0.13	0.40	1.00											
CSC24	r	-0.03	-0.01	-0.13	0.19	0.05	0.15	-0.02	-0.04	0.01	-0.26	0.23	-0.24	0.32	0.17	0.40	0.18	0.28	0.16	-0.14	0.43	0.57	1.00										
CSC25	r	-0.23	0.05	0.07	-0.12	-0.19	-0.12	-0.28	-0.12	0.02	0.10	0.45	0.09	-0.13	-0.10	0.00	-0.34	0.29	-0.09	0.58	0.04	0.00	-0.07	1.00									
CSC26	r	-0.22	-0.16	0.05	0.12	0.46	0.10	-0.05	-0.18	0.19	-0.10	0.43	-0.24	0.16	0.56	0.20	0.22	0.36	0.13	0.04	0.72	0.29	0.34	0.07	1.00								
CSC27	r	-0.17	-0.05	-0.16	0.15	0.08	0.33	0.06	-0.03	0.04	-0.23	0.13	-0.14	0.13	0.06	0.27	0.08	0.23	-0.02	0.03	0.14	0.63	0.30	0.13	0.11	1.00							
CSC29	r	0.06	-0.05	0.03	0.17	0.09	0.22	0.21	0.05	-0.12	-0.38	0.18	-0.27	0.26	0.12	0.09	0.36	0.18	-0.02	-0.15	0.38	0.34	0.56	-0.28	0.32	0.14	1.00						
CSC30	r	-0.09	0.04	0.01	0.19	0.17	0.23	0.26	0.27	-0.08	-0.07	0.07	-0.05	0.13	0.10	0.04	0.43	0.05	-0.02	-0.17	0.21	0.11	0.34	-0.30	0.23	-0.10	0.41	1.00					
CSC31	r	0.04	0.12	-0.08	0.12	-0.05	0.21	-0.07	-0.05	0.20	-0.23	0.74	-0.31	0.14	0.09	0.24	0.09	0.63	0.15	0.18	0.37	0.30	0.42	0.31	0.41	0.24	0.30	0.09	1.00				
CSC33	r	-0.01	0.04	-0.04	0.02	0.17	-0.07	-0.08	-0.08	0.06	-0.22	0.24	-0.23	0.21	0.19	0.18	0.09	0.23	0.42	-0.13	0.33	0.28	0.19	-0.11	0.35	-0.04	0.26	0.05	0.27	1.00			
CSC34	r	-0.01	-0.30	0.10	-0.01	0.64	0.12	0.19	-0.07	-0.03	-0.12	0.10	-0.12	0.02	0.66	0.03	0.24	0.04	-0.03	0.00	0.41	0.08	0.07	-0.03	0.45	0.03	0.04	0.12	0.06	0.07	1.00		
CSC35	r	0.08	-0.10	-0.06	0.24	0.20	0.55	0.32	0.11	-0.07	-0.12	-0.05	-0.01	-0.12	0.10	-0.03	0.07	-0.12	-0.10	-0.01	-0.01	0.07	-0.08	0.03	-0.07	0.06	0.02	0.16	-0.02	-0.20	0.16	1.00	
CSC36	r	-0.06	0.03	0.02	0.23	0.02	0.53	0.44	0.35	0.11	-0.23	0.03	-0.07	0.02	-0.07	-0.03	0.27	0.00	-0.21	-0.15	0.08	0.21	0.13	-0.26	0.03	0.07	0.33	0.51	0.11	-0.05	-0.01	0.48	1.00

Strong positive correlation (0.5 to 1.0)
Moderate positive correlation (0.3 to 0.49)
Weak positive correlation (0.1 to 0.29)
Weak Negative correlation (-0.29 to -0.1)
Moderate to strong negative correlation (-0.5 to -0.3)

Table 4. Results of the factor analysis (rotated component matrix). Source: Author.

Component name	CSC Code	Components Loading					
		1	2	3	4	5	6
Component 1: Housing Operational cost-related CSC	CSC14	0.864	-	-	-	-	-
	CSC34	0.829	-	-	-	-	-
	CSC26	0.655	-	-	-	-	-
	CSC22	0.611	-	-	-	-	-
Component 2: Land use planning-related CSC	CSC30	-	0.729	-	-	-	-
	CSC29	-	0.724	-	-	-	-
	CSC16	-	0.637	-	-	-	-
	CSC24	-	0.508	-	-	-	-
	CSC11	-	-	0.721	-	-	-

Component 3: Housing Quality and Safety-related CSC	CSC21	-	-	0.707	-	-	-
	CSC25	-	-	0.681	-	-	-
	CSC19	-	-	0.672	-	-	-
Component 4: Project Management and governance-related CSC	CSC15	-	-	-	0.698	-	-
	CSC23	-	-	-	0.682	-	-
	CSC27	-	-	-	0.643	-	-
	CSC3	-	-	-	-0.523	-	-
Component 5: Social and Community-related CSC	CSC35	-	-	-	-	0.740	-
	CSC36	-	-	-	-	0.700	-
	CSC6	-	-	-	-	0.650	-
	CSC7	-	-	-	-	0.585	-
Component 6: Environmental Quality & sustainability-related CSC	CSC12	-	-	-	-	-	-0.659
	CSC10	-	-	-	-	-	-0.630
	CSC4	-	-	-	-	-	0.613
▪ **Eigenvalue**		5.727	3.517	2.823	2.332	1.778	1.569
▪ **Variance (%)**		17.897	10.992	8.823	7.288	5.556	4.903
▪ **Cumulative Variance (%)**		17.897	28.889	37.712	44.999	50.555	55.457

Extraction method: Principal Component Analysis.
Rotation method: Varimax with Kaiser Normalization

4. Discussion of the results

4.1. Component 1: Housing Operational Cost-related CSC

The first component addresses household operational costs and includes five significant criteria: reducing the lifecycle cost of housing, rental price versus income, housing price versus income, project completion within the allocated budget, and marketability of the housing facility. These criteria demonstrated strong factor loadings, ranging from 86.4% (lifecycle cost reduction) to 61.1% (housing marketability). This component contributed the highest variance among all six components, explaining 17.897% of the total variance (Table 5). A significant correlation between rental and housing price-to-income ratios (r=0.659, p=0.01) informed the choice of the housing price-to-income ratio as the primary affordability metric, as it offers broader insights into overall housing affordability.

Lifecycle cost reduction emerged as the most significant criterion, reflecting the cumulative costs incurred throughout a housing unit's lifespan. These include maintenance, repairs, utilities, and regular upkeep expenses (Ruparathna et al., 2016). Minimizing lifecycle costs is crucial for enhancing long-term affordability in sustainable and affordable housing. These operational considerations directly influence rental and purchase affordability metrics, affecting housing facility take-up rates (Chan & Adabre, 2019). The housing price-to-income ratio is a key indicator of homeownership feasibility. High housing costs relative to household income can negatively affect take-up rates and prolong waiting periods for potential residents (Ahadzie et al., 2008; Teck-Hong, 2012). Compliance with project budgets is critical for maintaining affordability metrics. Efficient resource utilization during construction helps prevent cost escalations, ensuring affordability for end-users (Adabre and Chan, 2019a; Agarwal et al., 2021). Adhering to financial discipline directly influences market viability by ensuring that housing developments remain operationally efficient and appealing to potential buyers or tenants. The effective integration of lifecycle cost reduction, affordability metrics, budget compliance, and marketability ensures financial sustainability and broad market acceptance, mitigating risks of low occupancy rates and prolonged allocation periods (Al-Tmeemy et al., 2011).

4.2. Component 2: Land use planning-related CSC

The land use planning component explains 10.992% of total variance (Table 5), encompassing four critical success components: adequate physical infrastructure supply (72.9%), reduced commuting costs and distances (72.4%), strategic residential location (63.7%), and efficient land management policies (50.8%).

Land use planning optimizes land utilization through agglomeration economies and public infrastructure development (Crook, 1996). While infrastructure enhancement increases land value through communal benefits, it reduces available land for housing development. Planning authorities address this through value capture mechanisms, implementing developer taxes and levies on infrastructure-derived capital gains. These revenues support affordable housing initiatives, establishing a crucial link between land-use planning systems and housing finance (Whitehead, 2007). Strategic residential locations for low-income households are better served through mixed-land-use developments, enhancing economic and social sustainability (Adabre and Chan, 2019b). This integrated approach combines residential, commercial, and office spaces, reducing commuting costs and fostering walkable neighborhoods. The agglomeration economies facilitate better service access, reduced energy consumption, and efficient resource distribution, benefiting low-income residents through improved accessibility to essential services and employment opportunities (Koster and Rouwendal, 2012).

4.3. Component 3: Housing Quality and Safety related CSC

This component accounts for 8.823% of the total variance, encompassing critical criteria with significant factor loadings: quality of housing (72.1%), dwelling units based on household size (70.7%), safety and security measures (68.1%), maintenance of existing houses (67.2%), and comfortable indoor environment (62.6%). The analysis reveals a robust correlation between comfortable indoor environments and overall housing quality ($r=0.740$, $p=0.01$), manifesting in both “quality in fact” (technical specifications, material standards, and construction processes) and “quality in perception” (resident satisfaction and lived experience). Neglecting perceived quality can lead to housing abandonment (Arditi and Gunaydin, 1997). Housing quality optimization requires functional interior layouts with adequately sized living spaces, strategic room arrangements, and sufficient storage areas (Ren & Folmer, 2017). Privacy considerations through appropriate bedroom numbers and sizes and adequate bathroom facilities are particularly significant for low-income households, with living space emerging as the most reliable quality indicator (Opoku and Abdul-Muhmin, 2010). Living space has emerged as the most reliable quality indicator among these design features.

Safety and security elements encompass well-lit public areas, secure parking facilities, protected indoor spaces, and child-safe public areas. Security features, including neighborhood crime rates and gated community status, significantly influence residential satisfaction and home ownership decisions, particularly among first-time buyers (Teck-Hong, 2012). Combining secure environments with quality leisure facilities enhances residential satisfaction (Ren and Folmer, 2017). Regular needs assessments before and during project implementation ensure that technical standards and resident expectations are consistently met throughout the project lifecycle (Adabre and Chan, 2019a).

4.4. Component 4: Project Management and governance-related CSC

The fourth component, explaining 7.288% of the total variance, includes timely completion of the project (69.8%), effective coordination with government bodies (68.2%), appropriate risk allocation and risk sharing (64.3%), and adequate incentives by the government (-52.3%).

Timely project delivery is crucial for reducing low-income earners' waiting time and preventing construction disputes that could arise from delays (Sambasivan and Soon, 2007). This requires effective coordination with government bodies throughout the project lifecycle, particularly in navigating regulatory requirements and securing necessary approvals. The success of such coordination is enhanced through appropriate risk allocation, where private developers manage development-related risks (design, building, operation, and maintenance), while governments handle non-commercial risks and regulatory oversight (Abdul-Aziz and Jahn Kassim, 2011). Government incentives are crucial in ensuring project viability through various mechanisms: land allocation, low-interest financing, design flexibility, density bonuses, and fee concessions. For instance, the United Kingdom implements mandatory policies through section 106 (S106), while Australia and New Zealand provide low-interest finances for inclusionary affordable housing projects. Singapore's land allotment system, supported by strong public ownership, has proven effective in affordable housing delivery (Adabre and Chan, 2019b). These incentives and streamlined approval processes through effective government coordination contribute to economic sustainability and price affordability while maintaining project timelines.

4.5. Component 5: Social and Community-related CSC

The fifth component, explaining 5.556% of the total variance, contains four CSCs: access to employment opportunities (74%), access to health care services (70%), reduced social segregation (65%), and access to local commercial areas (58.5%). This component accounted for 5.556% of the total variance (Table 5).

Access to employment opportunities emerges as the most significant factor within this component, as housing locations facilitating easy access to work directly impact household economic stability and long-term affordability. Research indicates that proximity to employment centers reduces transportation costs and commuting time, effectively increasing disposable income for housing expenses (Agarwal et al., 2021; Ballous and Bashir, 2022). Healthcare accessibility plays a crucial role in sustainable housing development, with proximity to medical facilities particularly vital for low-income households facing mobility constraints. The correlation between healthcare access and housing success extends beyond physical proximity, including the affordability and quality of available medical services.

Reducing social segregation through mixed-income developments fosters community integration and social sustainability. When affordable housing projects are strategically integrated within existing neighborhoods rather than isolated in peripheral locations, they promote social cohesion and reduce the stigmatization of low-income residents (Agarwal et al., 2021; Moghayedi et al., 2021). This integration is further enhanced by access to local commercial areas, which provide essential services and create opportunities for local employment and community interaction. The presence of diverse commercial facilities within walking distance contributes to neighborhood vitality and reduces transportation expenses for daily necessities (Chan & Adabre, 2019).

4.6. Component 6: Environmental Quality and Sustainability-related CSC

The sixth component, explaining 4.903% of the total variance, comprises three environmental criteria: environmental performance of housing facility (65.9%), availability of open green space (63%), and low presence of environmental problems (61.3%).

The environmental performance of housing facilities is a critical determinant of long-term sustainability, encompassing energy efficiency, water conservation, and resource optimization. Efficient environmental performance reduces operational costs for low-income residents through lower utility bills and enhances the overall quality of life through improved indoor environmental quality(Adabre & Chan, 2019a; Chan & Adabre, 2019). The availability of open green spaces contributes dual benefits: providing recreational areas

that enhance community well-being while simultaneously serving environmental functions such as natural ventilation, reduced urban heat island effects, and improved air quality. Studies indicate that access to green spaces correlates positively with residential satisfaction and community engagement in affordable housing developments (Agarwal et al., 2022, 2021).

Minimizing environmental problems, including air pollution, noise levels, and waste management issues, directly impacts housing success through improved health outcomes and reduced maintenance costs. Low-income communities often face disproportionate exposure to environmental hazards, making this criterion particularly significant for SAH initiatives. Integrating these environmental considerations into housing design and planning ensures both immediate livability and long-term sustainability, contributing to the overall success of affordable housing projects through reduced operational costs and enhanced resident well-being Chan and Adabre, 2019; Lamprou and Vagiona, 2022).

4.7 Relevance and Integration of CSC Components for SAH

The empirical analysis reveals six distinct but interconnected components essential for SAH delivery: Housing Operational Cost, Land Use Planning, Housing Quality and Safety, Project Management and Governance, Social and Community aspects, and Environmental Quality and Sustainability. These components demonstrate strong interdependencies across economic, social, and environmental dimensions of sustainability. Housing Operational Cost (Component 1), explaining the highest variance (17.897%), fundamentally influences economic and social sustainability. The strong correlation between lifecycle costs and housing affordability metrics ($r=0.659$, $p=0.01$) demonstrates how operational efficiency directly impacts housing accessibility for low-income residents. This component's integration with Land Use Planning (Component 2, 10.992% variance) is evident through the relationship between infrastructure development and housing costs, where strategic location choices influence initial and long-term affordability.

Housing Quality and Safety (Component 3, 8.823% variance) bridges social and economic sustainability through its significant correlation between indoor environment quality and overall housing satisfaction ($r=0.740$, $p=0.01$). This component's success criteria directly influence residential take-up rates and long-term occupancy, demonstrating its crucial role in project viability. Project Management and Governance (Component 4, 7.288% variance) facilitates the implementation of these quality standards through effective coordination and risk management, ensuring that sustainability goals align with practical delivery constraints. The Social and Community component (Component 5, 5.556% variance) enhances social and economic sustainability by strategically integrating housing with essential services and employment opportunities. This integration is reinforced by Environmental Quality and Sustainability measures (Component 6, 4.903% variance), where green spaces and environmental performance contribute to both community well-being and operational efficiency.

The interdependencies between these components highlight that successful SAH requires a holistic approach. For instance, environmental performance improvements (Component 6) can reduce operational costs (Component 1), while strategic land use planning (Component 2) enhances both social integration (Component 5) and project viability (Component 4). This integrated framework demonstrates that sustainability in affordable housing is achieved not through isolated interventions but through carefully balancing and optimizing all six components (Figure 2).

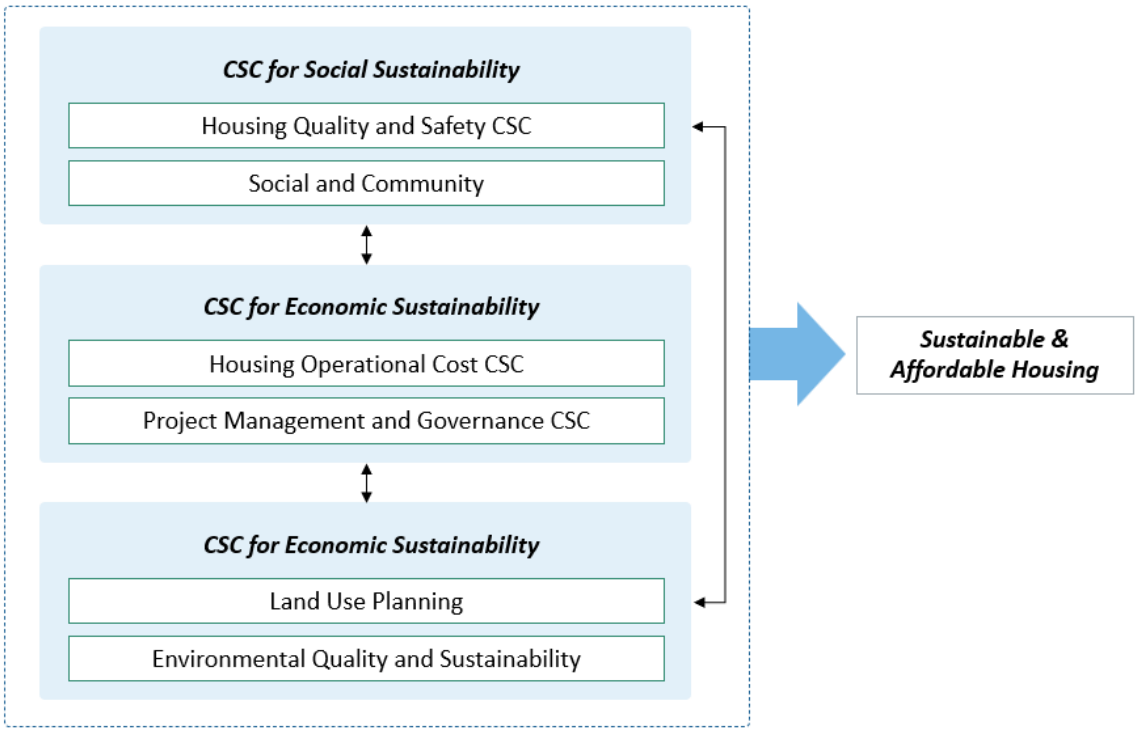


Figure 2. A framework for sustainable affordable housing. Source: Author.

5. Conclusions

This study investigated the CSCs for SAH delivery in high-density urban areas, mainly focusing on Indian megacities. Through comprehensive analysis of 100 expert responses and subsequent factor analysis, six distinct components emerged as fundamental to SAH's success: Housing operational cost, land use planning, housing quality and safety, project management and governance, social and community aspects, and environmental quality and sustainability. The findings reveal that while cost-related criteria maintain primary importance (explaining 17.897% variance), successful SAH delivery requires a more holistic approach integrating multiple sustainability dimensions. The analysis demonstrated significant correlations between various CSCs, such as the relationship between indoor environment quality and overall housing satisfaction ($r=0.740$, $p=0.01$), highlighting the interconnected nature of these success criteria.

Several critical theoretical and practical implications emerge from this research. It contributes to the affordable housing literature by providing an empirically validated framework of CSCs specifically contextualized for high-density urban environments while bridging the gap between sustainability and affordability by identifying and prioritizing criteria that serve both objectives. The findings suggest that successful SAH implementation requires careful consideration of all six components rather than focusing solely on economic metrics. For practitioners and policymakers, this research offers actionable insights: development authorities can utilize these CSCs for more effective resource allocation and project planning; urban planners can better integrate sustainability considerations with affordability objectives; housing developers can enhance project success by addressing all identified components systematically; and policymakers can develop more comprehensive housing policies that balance economic, social, and environmental factors.

The study has limitations, as the analysis focused primarily on expert opinions from academia and industry, potentially excluding valuable insights from housing residents. Additionally, while the response rate was

adequate (56%), a larger sample size could enable more detailed statistical analysis across different stakeholder groups. Future research could incorporate resident/household perspectives on SAH success criteria, conduct comparative analyses across different megacities, develop specific implementation frameworks for each component, and investigate the economic implications of implementing comprehensive sustainability measures in affordable housing. Despite these limitations, this research provides a robust foundation for understanding and implementing successful SAH projects in high-density urban environments. The findings underscore that while affordability remains crucial, long-term success requires careful consideration of all identified components, suggesting the need for integrated housing policy and development approaches.

6. References

Abastante, F., Corrente, S., Greco, S., Ishizaka, A., Lami, I.M., 2018. Choice architecture for architecture choices: Evaluating social housing initiatives putting together a parsimonious AHP methodology and the Choquet integral. Land use policy, 78, 748–762. https://doi.org/10.1016/J.LANDUSEPOL.2018.07.037

Abdul-Aziz, A.R., Jahn Kassim, P.S., 2011. Objectives, success and failure factors of housing public–private partnerships in Malaysia. Habitatat International, 35, 150–157. https://doi.org/10.1016/J.HABITATINT.2010.06.005

Abhay, R.K., Sharma, M., 2023. Housing shortage in a mega city: a spatio-temporal analysis of NCT-Delhi, 2001–2011. GeoJournal, 88, 261–278. https://doi.org/10.1007/S10708-022-10597-5

Adabre, M.A., Chan, A.P.C., 2021. Modeling the Impact of Barriers on Sustainable Housing in Developing Countries. J Urban Plan Dev 147. https://doi.org/10.1061/(ASCE)UP.1943-5444.0000639

Adabre, M.A., Chan, A.P.C., 2019a. Critical success factors (CSFs) for sustainable affordable housing. Building and Environment, 156, 203–214. https://doi.org/10.1016/j.buildenv.2019.04.030

Adabre, M.A., Chan, A.P.C., 2019b. The ends required to justify the means for sustainable affordable housing: A review on critical success criteria. Sustainable Development 27, 781–794. https://doi.org/10.1002/sd.1919

Adabre, M.A., Chan, A.P.C., Darko, A., Osei-Kyei, R., Abidoye, R., Adjei-Kumi, T., 2020. Critical barriers to sustainability attainment in affordable housing: International construction professionals' perspective. Journal of Cleaner Production, 253, 119995. https://doi.org/10.1016/j.jclepro.2020.119995

Adel, R., Kamel, B., Amin, A., El-Feki, S., Nasreldin, R., 2022. Middle-income residential compounds towards resilience through risk management: Experts' point of view. Ain Shams Engineering Journal 13, 101797. https://doi.org/10.1016/J.ASEJ.2022.101797

Agarwal, S., Mandal, S., Bajaj, D., Agarwal, A.S., Singh, T.P., 2021. Affordable Housing and its Sustainability A review of Critical Success Factors (CSFs). 2021 9th International Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), 1-6. https://doi.org/10.1109/ICRITO51393.2021.9596156

Agarwal, S., Singh, T.P., Bajaj, D., Pant, V., 2022. Affordable housing in urban India: a review of critical success factors (CSFs) addressing housing adequacy with affordability for the urban poor. Housing, Care and Support 25 (1), 61–79. https://doi.org/10.1108/HCS-08-2021-0022

Ahadzie, D.K., Proverbs, D.G., Olomolaiye, P.O., 2008. Critical success criteria for mass house building projects in developing countries. International Journal of Project Management 26, 675–687. https://doi.org/10.1016/j.ijproman.2007.09.006

Al-Tmeemy, S.M.H.M., Abdul-Rahman, H., Harun, Z., 2011. Future criteria for success of building projects in Malaysia. International Journal of Project Management 29, 337–348. https://doi.org/10.1016/j.ijproman.2010.03.003

Amora, V.C.M., Juanzon, J.B.P., 2022. A Framework of Critical Success Factors and Success Criteria for Structural Works of a Mixed-Use Building Construction Project. Civil Engineering and Architecture 10, 267–279. https://doi.org/10.13189/cea.2022.100123

Arditi, D., Gunaydin, H.M., 1997. Total quality management in the construction process. International Journal of Project Management 15, 235–243. https://doi.org/10.1016/S0263-7863(96)00076-2

Ballous, M., Bashir, H., 2022. Analysis of Interactions among Project Success Criteria and Factors Using a Network-Path Approach. 2022 Advances in Science and Engineering Technology International Conferences (ASET), 1-5. https://doi.org/10.1109/ASET53988.2022.9735109

Chan, A.P.C., Adabre, M.A., 2019. Bridging the gap between sustainable housing and affordable housing: The required critical success criteria (CSC). Building and Environment, 151, 112–125. https://doi.org/10.1016/j.buildenv.2019.01.029

Chan, A.P.C., Darko, A., Olanipekun, A.O., Ameyaw, E.E., 2018. Critical barriers to green building technologies adoption in developing countries: The case of Ghana. Journal of Cleaner Production, 172, 1067–1079. https://doi.org/10.1016/J.JCLEPRO.2017.10.235

Chan, E.H.W., Hou, J., 2015. Developing a framework to appraise the critical success factors of transfer development rights (TDRs) for built heritage conservation. Habitat International 46, 35–43. https://doi.org/10.1016/J.HABITATINT.2014.10.018

Crook, A.D.H., 1996. Affordable housing and planning gain, linkage fees and the rational nexus: Using the land use planning system in England and the USA to deliver housing subsidies. International Planning Studies 1(1), 49–71. https://doi.org/10.1080/13563479608721643

Ezennia, I.S., 2022. Insights of housing providers' on the critical barriers to sustainable affordable housing uptake in Nigeria. World Development Sustainability 1, 100023. https://doi.org/10.1016/J.WDS.2022.100023

Development Sustainability 1, 100023. Ezennia, I.S., Hoskara, S.O., 2021. Assessing the subjective perception of urban households on the criteria representing sustainable housing affordability. https://doi.org/10.1016/J.SCIAF.2021.E00847

Field, A., 2013. Discovering Statistics using IBM SPSS Statistics. Los Angeles, London, New Delhi: Sage.

Gan, X., Zuo, J., Baker, E., Chang, R., Wen, T., 2019. Exploring the determinants of residential satisfaction in public rental housing in China: a case study of Chongqing. Journal of Housing and the Built Environment 34 (3), 869–895. https://doi.org/10.1007/s10901-019-09691-x

Gan, X., Zuo, J., Wu, P., Wang, J., Chang, R., Wen, T., 2017. How affordable housing becomes more sustainable? A stakeholder study. Journal of Cleaner Production 162, 427–437. https://doi.org/10.1016/J.JCLEPRO.2017.06.048

Gandhi, S., Green, R.K., Patranabis, S., 2022. Insecure property rights and the housing market: Explaining India's housing vacancy paradox. Journal of Urban Economics, 131, 103490. https://doi.org/10.1016/j.jue.2022.103490

Hamidi, S., Ewing, R., Renne, J., 2016. How Affordable Is HUD Affordable Housing? Housing Policy Debate, 26 (3), 437–455. https://doi.org/10.1080/10511482.2015.1123753

Koster, H.R.A., Rouwendal, J., 2012. THE IMPACT OF MIXED LAND USE ON RESIDENTIAL PROPERTY VALUES. Journal of Regional Science, 52(5), 733–761. Portico. https://doi.org/10.1111/J.14679787.2012.00776.X

Lamprou, A., Vagiona, D.G., 2022. Identification and Evaluation of Success Criteria and Critical Success Factors in Project Success. Global Journal of Flexible Systems Management 23(2), 237–253. https://doi.org/10.1007/s40171-022-00302-3

Liang, Y., Jia, H., 2018. Key Success Indicators for PPP Projects: Evidence from Hong Kong. Advances in Civil Engineering, 2018, 1-10. https://doi.org/10.1155/2018/9576496

Maqbool, R., Deng, X., Rashid, Y., 2020. Stakeholders' satisfaction as a key determinant of critical success factors in renewable energy projects. Energy, Sustainability and Society, 10(1). https://doi.org/10.1186/s13705-020-00259-0

Moghayedi, A., Awuzie, B., Omotayo, T., Le Jeune, K., Massyn, M., Ekpo, C.O., Braune, M., Byron, P., 2021. A critical success factor framework for implementing sustainable innovative and affordable housing: A systematic review and bibliometric analysis. Buildings 11(8), 317. https://doi.org/10.3390/buildings11080317

Mulliner, E., Smallbone, K., Maliene, V., 2013. An assessment of sustainable housing affordability using a multiple decision making method. Omega, 41(2), 270–279. https://doi.org/10.1016/J.OMEGA.2012.05.002

Opoku, R.A., Abdul-Muhmin, A.G., 2010. Housing preferences and attribute importance among low-income consumers in Saudi Arabia. Habitat International, 34(2), 219–227 https://doi.org/10.1016/j.habitatint.2009.09.006

Ren, H., Folmer, H., 2017. Determinants of residential satisfaction in urban China: A multi-group structural equation analysis. Urban Studies 54(6), 1407–1425. https://doi.org/10.1177/0042098015627112

Roy, D., 2020. Housing demand in Indian metros: a hedonic approach. International Journal of Housing Markets and Analysis 13(1), 19–55. https://doi.org/10.1108/IJHMA-04-2017-0041

Ruparathna, R., Hewage, K., Sadiq, R., 2016. Improving the energy efficiency of the existing building stock: A critical review of commercial and institutional buildings. Renewable and Sustainable Energy Reviews 53, 1032–1045. https://doi.org/10.1016/j.rser.2015.09.084

Saha, D., Banerji, H., Kumar, U., 2024. Critical Success Barriers (CSB) to Rental Housing Policy Implementation in Urban India. Journal of Contemporary Urban Affairs, 9(1), 53–75. https://doi.org/10.25034/ijcua.2025.v9n1-4

Saha, D., Gupta, R., Banerji, H., 2024. Investigating the Housing Preferences of Slum Dwellers in Slum Relocation Projects: A Community-Based Operations Research Framework for Megacities in the Global South. Urban Planning and Design for Megacities in the Global South. Springer, Singapore, pp. 297–320. https://doi.org/10.1007/978-981-97-8370-0_13

Sambasivan, M., Soon, Y.W., 2007. Causes and effects of delays in Malaysian construction industry. International. Journal of Project Management, 25(5), 517–526. https://doi.org/10.1016/J.IJPROMAN.2006.11.00

Surjan, A., Shaw, R., 2009. Enhancing disaster resilience through local environment management: Case of Mumbai, India. Disaster Prevention and Management: An International Journal, 18(4), 418–433. https://doi.org/10.1108/09653560910984474

Teck-Hong, T., 2012. Housing satisfaction in medium- and high-cost housing: The case of Greater Kuala Lumpur, Malaysia. Habitat International 36(1), 108–116. https://doi.org/10.1016/J.HABITATINT.2011.06.003

Tiwari, P., Rao, J., 2011. ADBI Working Paper Series Housing Markets and Housing Policies in India Asian Development Bank Institute.

Valença, M.M., 2015. Social rental housing in HK and the UK: Neoliberal policy divergence or the market in the making? Habitat International, 49, 107–114. https://doi.org/10.1016/J.HABITATINT.2015.05.017

Wang, Y.-H., Ajovalasit, M., 2020. Involving Cultural Sensitivity in the Design Process: A Design Toolkit for Chinese Cultural Products. International Journal of Art & Design Education, 39(3), 565–584. https://doi.org/10.1111/JADE.12301

Whitehead, C.M.E., 2007. Planning Policies and Affordable Housing: England as a Successful Case Study? Housing Studies, 22(1), 25–44. https://doi.org/10.1080/02673030601024580

Winston, N., 2010. Regeneration for sustainable communities? Barriers to implementing sustainable housing in urban areas. Sustainable Development, 18(6), 319–330. Portico. https://doi.org/10.1002/SD.399

Winston, N., Pareja Eastaway, M., 2008. Sustainable housing in the urban context: International sustainable development indicator sets and housing. Soc Indic Res 87, 211–221. https://doi.org/10.1007/S11205-007-9165-8

Yan, H., Elzarka, H., Gao, C., Zhang, F., Tang, W., 2019. Critical Success Criteria for Programs in China: Construction Companies' Perspectives. Journal of Management in Engineering, 35(1). https://doi.org/10.1061/(asce)me.1943-5479.0000659

Research Paper

Reactivating High-Density Suburbs: From Regional to City-Wide Service

– A Case Study of Yishun and Jurong East in Singapore

Junbo XIA, National University of Singapore, Singapore

Abstract

This study explores suburban upgrading as a solution to alleviate urban stress in high-density cities, focusing on Yishun and Jurong East in Singapore. Using MRT passenger flow data from the Land Transport Authority, processed through R to create an Origin-Destination matrix, the study analyses temporal and spatial patterns of population flow. It also examines data from the Urban Redevelopment Authority, and Interviews with residents, identifying key factors behind the reactivation of suburban areas. Results show that revitalized suburbs maintain their appeal within the city, easing density in central areas. The study highlights three strategies: promoting mixed-use land development, enhancing transportation models through Transit-Oriented Development (TOD), and preserving green spaces. These findings offer valuable insights for suburban redevelopment in other high-density cities, particularly in the Global South, and demonstrate how cities can balance population growth with liveability to ensure sustainable urban development.

Keywords

Suburban reactivating, Sustainable development, High-density cities, Mixed land-use, Transit-Oriented Development, Green spaces

1. Introduction

In the 21st century, global urban development has progressed rapidly, accompanied by a significant rise in urbanization rates. The global urbanization rate reached 56.2% by 2020 (World Bank, 2024). In particular, for such fast-developing Asian countries as China, Malaysia, and Singapore, the urbanization rate has reached 61.4%, 77.2%, and 100%, respectively (World Bank, 2024). Several fast-growing Asian cities even reached full urbanization at the beginning of this century, with their built-up areas and populations expanding several-fold in a very short time (Cheng et al., 2023).

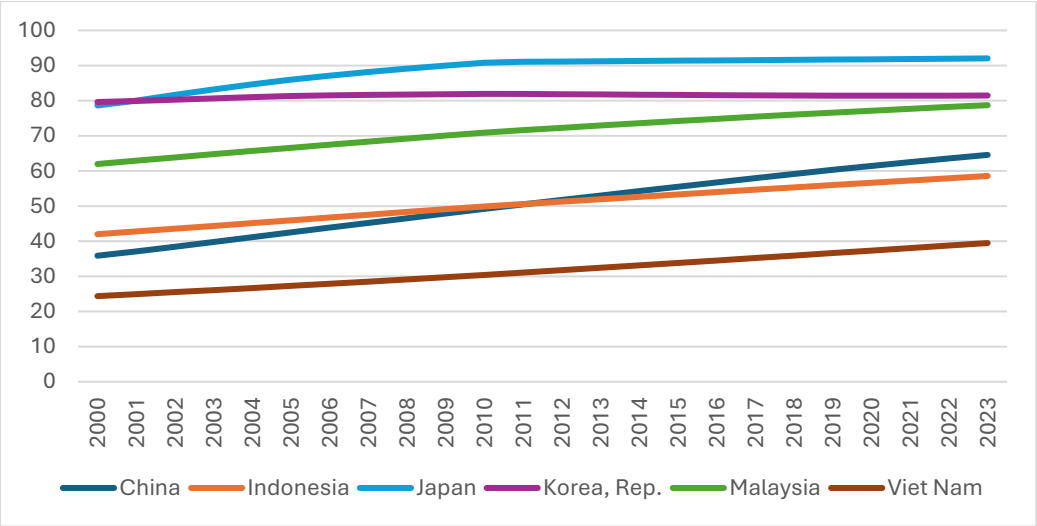


Figure 1. Changes of urbanization rate in some Asian countries in this century
Source: World Bank, 2024

This rapid urbanization often imposes significant pressure on housing, transportation, and the environment (Sumari et al., 2020; Wang et al., 2020). To alleviate these challenges, developing suburban areas and building new towns have become essential strategies for these Asian cities (Hanlon and Vicino, 2018).

The development of suburban areas exerts a positive role in terms of population redistribution and maintaining urban sustainability. Suburban growth promotes urban development while encouraging population decentralization (Ekers et al., 2012). This decentralization helps reduce traffic congestion and housing shortages in central cities. It further provides low- and middle-income groups with opportunities for affordable housing, which maintains urban vitality at the suburban area(Tong et al., 2019).

Additionally, suburban development diversifies urban economic growth, reducing reliance on the city centre and spreading economic activities outward, forming a multipolar urban economic development model that enhances economic resilience (Sadewo et al., 2023; Wood and Phelps, 2020). Moreover, suburban development contributes positively to urban ecological preservation. Natural environments and wildlife around cities can enrich suburban residents' lives (DeStefano and DeGraaf, 2003). Creating green belts and a continuous urban green space system can enhance the overall ecological attributes of cities and address environmental issues to some extent (Keil and Macdonald, 2016; Li et al., 2005).

However, with continuous suburban development, numerous new problems have emerged. Many suburban developments merely serve as geographical substitutes for urban areas, representing metropolitan construction and reconstruction at the edges (Keil, 2020). Such development lacks the demonstration of the unique ecological and geographical advantages of suburban areas, rendering them less attractive compared to city centres. Furthermore, aging suburbs from previous developments are continually losing their appeal, as noted by Keil (2020), "the suburbs have been out of style," and their attractiveness has diminished.

Currently, there are numerous issues in suburban development, which urgently need to be addressed to enhance their appeal. However, there is a noticeable lack of research on how to restore the appeal of aging suburbs and rejuvenate them. This lack of research is partly due to the late start of high-density suburban development in many cities (Brewer and Grant, 2015), where the demand for suburban renewal is not yet pressing. In early-developed cities, suburban density is relatively low (Spencer et al., 2015), and these areas still meet residents' needs, reducing the urgency for renewal. However, in high-density cities, the rapid

aging of suburban infrastructure has caused significant disruptions to residents' mobility, recreation, and daily lives (Ren, 2021). Therefore, suburban renewal in high-density cities is imperative.

Given the significant differences in economic, social, and spatial structures between suburbs and city centres (van der Veer, 1994), traditional urban renewal theories may not directly guide suburban renewal. Therefore, this paper will explore issues related to suburban renewal and propose valuable and feasible strategies for suburban revitalization.

2. Literature Review: The Decline of Suburbs

Historically, since the 1970s, many scholars have focused on the decline of inner cities and subsequent urban renewal and redevelopment (Badcock, 2001). However, it wasn't until this century that researchers gradually began to turn their attention to the decline and diminishing attractiveness of urban suburbs. In many cases, the decline in suburban appeal has been more severe and rapid than that of inner cities (Lucy and Phillips, 2000). Scholars attribute the decline in suburban attractiveness to several factors, including the aging and inadequacy of suburban infrastructure, social inequities, and the environmental degradation caused by suburban development.

2.1. Aging Infrastructure and Declining Attractiveness in Suburbs

The aging of suburban infrastructure has significantly contributed to the decline in suburban appeal. Due to lower levels of urban construction and investment in suburban areas compared to inner cities, the public resources available in suburbs—particularly infrastructure—often lag behind those in central urban areas, both in quantity and quality. As a result, suburban facilities for services, recreation, and other public amenities are often inferior (Randolph and Tice, 2014). As this already insufficient infrastructure continues to age and lacks the necessary funding for timely upgrades, the quality of life in suburban areas deteriorates, making daily life more challenging for residents (Lucy and Phillips, 2000).

In addition, a large number of suburbs were designed with a more middle-class, car-based lifestyle in mind, resulting in a lack of good public transport and pedestrian experience in these areas. The spatial separation and distance between residential and commercial areas in some suburban areas, where shopping centres are only accessible by car and parking facilities around these malls and institutions reinforce the separation between the different functions (Samarütel et al., 2010), make the daily life of car-less residents in these areas even more difficult. The negligent design of walking and cycling systems has also led to difficulties in accessing the urban landscape of the neighbourhood in everyday life, resulting in a lack of sense of belonging to the community (Larco et al., 2013).

At the same time, the neglect of the elderly in suburban design has led to a general lack of age-friendly facilities, which has also caused many inconveniences for older people living in the suburbs, directly undermining the psychological and physical health and well-being of those living in the suburbs (Campbell, 2015), and the simultaneous ageing of both the elderly and the infrastructure in the suburbs has brought to light this otherwise latent vulnerability (Hartt et al., 2023).

In addition to social infrastructure, the ageing of engineered infrastructure also makes routine maintenance in the suburbs more difficult. Spacious, large houses , which are an otherwise important source of attractiveness in suburbs, tend to have more stringent requirements for engineered infrastructure such as electricity and water supply and drainage(Wiesel et al., 2013). But as houses as well as engineered infrastructure age, these facilities tend to require more routine inspection and maintenance

(Arumsari and Rarasati, 2017), which inevitably puts more financial pressure on suburban residents, making suburbs even less attractive (Wiesel et al., 2013).

2.2. Deepening Spatial Inequality and Declining Attractiveness in Suburbs

The segregation and inequality evident in suburban areas have also contributed to their growing notoriety. As King (2004, p. 99) pointed out, "The essence of modern suburbs is physical, social, and spatial separation." This distinction between suburbs and cities has led to clear geographic divides in income and social class (Swanstrom et al., 2002). Such segregation has resulted in suburban areas being at a disadvantage in terms of social composition, service capacity, and fiscal revenue, leading to the continuous loss of well-educated, skilled workers and further weakening the professional prospects of these areas (Pham, 2024). The ongoing exodus of skilled workers and the middle class further destabilizes the social structure of suburban areas, so much so that "images of failure, insecurity, and threat have come defining features of modern suburbs" (Mack, 2023, p.659).

In immigrant nations, this segregation often manifests as racial divides, where suburbs become associated with crime and failure, which in turn becomes linked to specific racial groups, resulting in a dual stigmatization of both the suburbs and certain races. This, in turn, exacerbates racial inequality (Hess, 2021). Moreover, as previously mentioned, the inadequacy and poor quality of public facilities in suburban areas intertwine with social class and racial segregation, further intensifying suburban inequalities. In some suburban areas, the low density of public transportation infrastructure leads to poor accessibility, worsening the employment inequities faced by suburban workers (Filion and Keil, 2017). The weak educational resources in suburban areas further reduce the opportunities for residents' children to receive quality education, perpetuating these inequalities across generations (Lleras, 2008).

2.3. Deterioration of the Environment and Declining Attractiveness in Suburbs

The overdevelopment of suburban areas has, to some extent, damaged the environment and local ecosystems, diminishing the natural beauty that once defined their appeal. Studies show that while the natural environment of suburbs may still be better than that of city centres, suburban development has nonetheless negatively impacted the environment, particularly through overdevelopment, which often leads to rapid environmental deterioration (Keil, 2020). The sudden surge in traffic, industrial activity, and waste emissions in rapidly built high-density suburban areas has severely polluted suburban land (Shi et al., 2010). The air and groundwater in suburban areas have also been adversely affected (Camagni et al., 2002; Hu et al., 2024), creating what Mack (2023, p.660) describes as an "inhumane and unattractive environment."

Environmental degradation has also led to rapid ecological deterioration. High-density suburban development has quickly converted green spaces into high-intensity urban land, and the constantly changing development scope has posed serious challenges to the local ecology (Tian and Qian, 2021). Unchecked suburban construction has disrupted the ecological corridors that had naturally evolved over decades around urban areas (Peng et al., 2017), disturbing habitats for various species, including birds (Blair, 2004), thereby shattering the idyllic, pastoral vision once associated with suburban living. Furthermore, the deterioration of suburban ecology and environment has ultimately affected the physical health of suburban residents (Loh and Brieger, 2014), making suburbs even less attractive to potential inhabitants.

3. Methodology

3.1. Site Selection

This study focuses on Singapore, a mature and highly urbanized Asian city-state. By 2018, Singapore had achieved complete urbanization. Characterized by its high population density, Singapore is home to 5.92 million people living on just 735.6 square kilometres of land, making it a quintessential high-density city (Singapore Department of Statistics, 2024). To alleviate urban pressures, particularly those related to housing, the Singapore government established the Housing Development Board (HDB) in 1960 and initiated the construction of new towns (Eng, 1996), becoming one of the earliest adopters of suburban development in Asia.

However, this also means that Singapore's earliest new towns, now over 50 years old, have become outdated. The infrastructure is aging, the service capacity fails to meet current community needs, and they lack attractiveness, thus providing limited assistance to ongoing population growth. In recent years, the Urban Redevelopment Authority (URA) has proposed the rejuvenation of old towns through suburban revitalization plans, aiming to restore the attractiveness of these suburban "new towns" by updating their infrastructure. Given this context, Singapore, as an early-developed nation, offers valuable insights and reference points for other countries.

Specifically, the study will focus on Yishun and Jurong East, two new towns located in the northeastern and southwestern parts of Singapore, respectively. These areas are significant high-density residential zones and are key regions in the suburban revitalization plans for rejuvenating old towns, which is a typical case of suburban renewal in Singapore. Therefore, selecting these two areas will effectively demonstrate how suburbs can be reactivated and how they can maintain their attractiveness to both local and external populations.

Figure 2. The site of Yishun and Jurong East and Singapore's location
Source: By Author

3.2. Research Method

This study employs a mixed-methods approach to collect and analyse data. The research is divided into two distinct phases. The first phase involves a quantitative analysis of the attractiveness of Singapore's suburban new towns using relevant traffic and population movement data. The second phase focuses on qualitative data collection and analysis through the gathering of materials and reports related to the redevelopment of specific suburban new towns and conducting interviews with local residents. Choosing this explanatory sequential research design is due to the fact that subsequent qualitative data will help explain the initial quantitative results, providing deeper insights into the research questions.

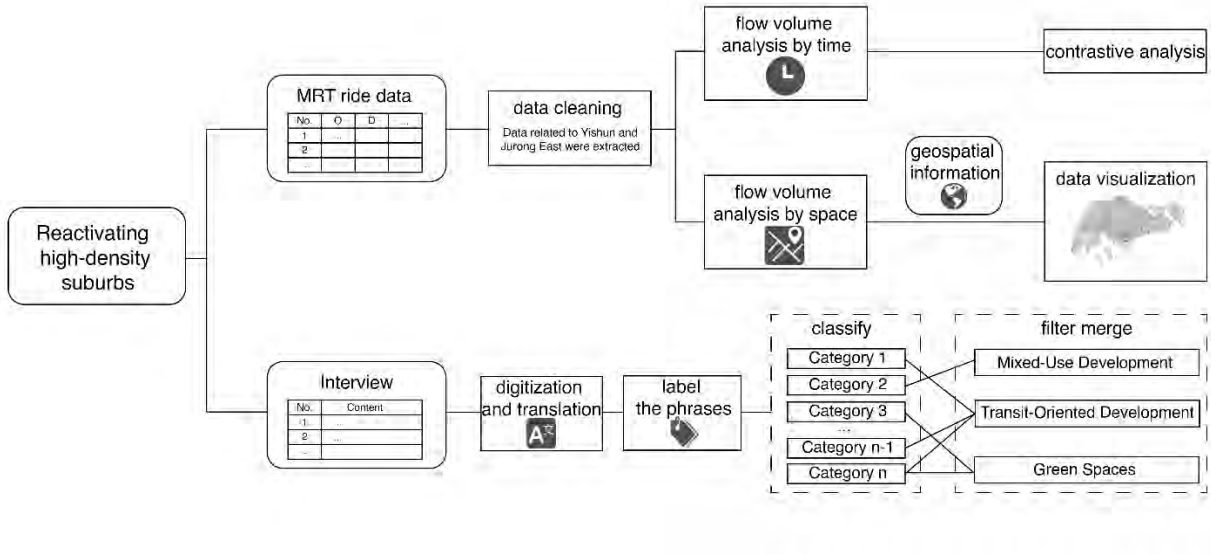


Figure 3. Research Flow
Source: By Author

3.2.1. Traffic Data Comparative Analysis

In the first phase, the study obtained Singapore-wide MRT passenger flow OD data from LTA from 2020 to 2024. This dataset mainly consists of variables such as the origin and destination station numbers of MRT rides, the specific year and month of the ride, the type of time (weekday or rest day), and the passenger flow statistics under the specific variables. Factors such as the intensity of passenger traffic in this dataset help to reflect the strength of the attractiveness of the new suburban city. Since only the first half of the year 2024 was available, data for that year was excluded. In the end, a total of 2.12 million MRT rides with different times and starting and ending points were obtained for the period from 2020 to 2023, with 134 million passenger trips.

Meanwhile, the study utilises the spatial dataset from OpenStreetMap to spatially correspond MRT stations by serial numbers for easy visualisation.

In addition, the study utilised the Master Plan 2019 land properties as well as zoning boundaries dataset from URA to define the boundaries and land use of the new city.

After collecting the above receipts, the study used R to count and integrate the relevant OD data to calculate the hourly outbound passenger flow at a given station using the following formula:

$$F_{d,h} = \sum_{\substack{d=1 \\ d \neq o}}^{n-1} x_{o-d,h} \tag{1}$$

Where:

o - the origin station,

d - the destination station,

n - the total number of MRT stations,

h - the hour (measured in hours),

$x_{o-d,h}$ - the number of trips from origin o to destination d during a specific hour

$F_{d,h}$ - the passenger flow alighting at station d during hour h.

Next, the study used the following formula to calculate the average hourly outbound passenger flow across multiple stations:

$$\bar{F}_h = \frac{1}{n} \sum_{o=1}^{n} \sum_{\substack{d=1 \\ d \neq o}}^{n-1} x_{o-d,h} \tag{2}$$

The specific station information in the OD dataset was then integrated with spatial data from OpenStreetMap. This provided spatial information for each station. Notably, the study found that some stations had changed locations or were closed. To accurately reflect changes in passenger flow within the OD dataset, these stations were retained based on their status during the relevant year. Using the following formula, the study generated a daily average passenger flow OD matrix:

$$F_{o-d} = \sum_{h=5}^{24} x_{o-d,h} \tag{3}$$

Finally, the OD matrix was visualized in QGIS by integrating it with spatial information (Tu et al., 2021). The analysis is also further enriched by combining it with land boundaries and other contextual information.

3.2.2. Semi-structure Interview

In the second phase, the study conducted interviews with residents of two key suburban new towns: Jurong East and Yishun. The research used semi-structured interviews. To explore the topic in depth, a set of open-ended questions was employed. Respondents were also encouraged to share additional relevant information. This approach provided a more comprehensive understanding of residents' perceptions of local urban renewal and attractiveness.

A total of 28 participants, including residents and visitors, were interviewed in Jurong East and Yishun. Some interviews were cut short due to language barriers or scheduling conflicts. However, 23 interviews were successfully completed. Each completed interview lasted over 20 minutes, ensuring data saturation (Marshall et al., 2013). The median age of participants was 51.6 years. Most respondents (66.7%) were local residents.

During this stage of data analysis, the study used coding analysis to identify the themes in it and processed the text using the analytical approach proposed by Braun & Clarke (2006). After completing the digitisation

of the relevant interview transcripts, the study categorised and labelled the phrases in the manuscripts and represented them with different codes, and further reviewed the codes to categorise them under different subjects and validated the subjects using deductive methods. Eventually, the study screened and merged the subjects to form three main themes, which were categorised and named.

4. Results and discussion

4.1. Attractiveness Analysis Results

Analysing the dataset by extracting data specific to weekends and holidays provides a better reflection of people's travel intentions and, consequently, a more accurate representation of the attractiveness of the respective areas. Using Formula 1, the hourly passenger outflow for Yishun and Jurong East was calculated. Formula 2 was then applied to compute the average hourly passenger flow for suburban MRT stations outside the Central Region.

The analysis revealed that the average hourly passenger flows for Yishun and Jurong East were 16,770.75 and 33,890.1, respectively, representing 2.7 to 5.4 times the average for suburban MRT stations. Figure 4 visualizes the relationship between passenger flow and time, showing that Jurong East MRT station exhibited two distinct peaks at 12:00 and 17:00. These patterns differ significantly from the average suburban MRT station and align with common dining and entertainment times (Jones and Clarke, 1988), indicating the high recreational appeal of the Jurong East area. Similarly, Yishun consistently recorded higher hourly passenger flows compared to the average, with a pronounced peak at 17:00.

Additionally, over 75% of Yishun's passenger flow occurred between 9:00 and 20:00, contrasting with the typical non-working day return travel pattern concentrated between 20:00 and 8:00 the next day (Jiang et al., 2012). This suggests that Yishun attracts a significant number of non-local residents for various activities during the day.

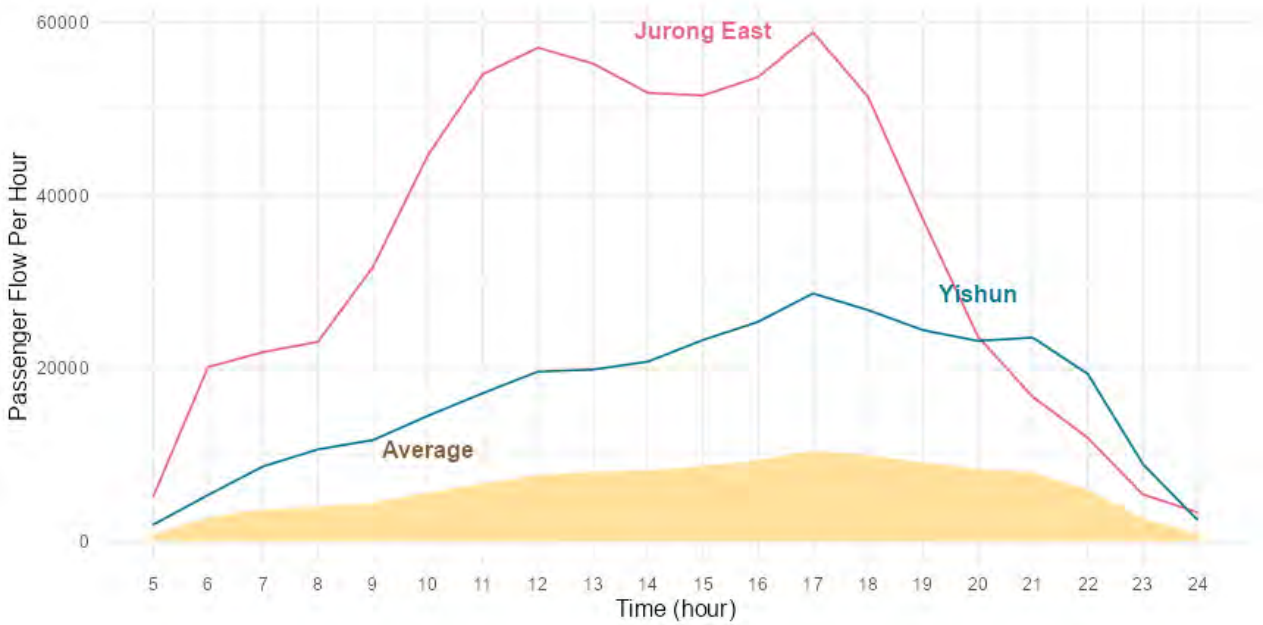


Figure 4. Hourly passengers flow of suburban MRT stations
Source: By Author

The daily average passenger flow analysis further supports that Jurong East and Yishun are the two most populated suburban areas outside the Central Region (Figure 5). Jurong East stands out as one of the busiest non-working day transit areas in western Singapore, with passenger volumes comparable to some central areas. Yishun, on the other hand, is a major hub for MRT traffic in northeastern Singapore, second only to Punggol, a developing new town in eastern Singapore (HDB, 2024). Studies indicate that daily MRT passenger flow effectively reflects the overall population activity intensity in an area (Kim et al., 2022). Therefore, it can be inferred that Jurong East and Yishun experience significantly higher population activity intensity on non-working days compared to other suburban areas, demonstrating vibrant urban vitality. Furthermore, MRT passenger flow is correlated with economic, particularly commercial, activity levels (Yu et al., 2022), suggesting that Jurong East and Yishun serve as crucial commercial activity centres in the western and eastern suburbs, respectively.

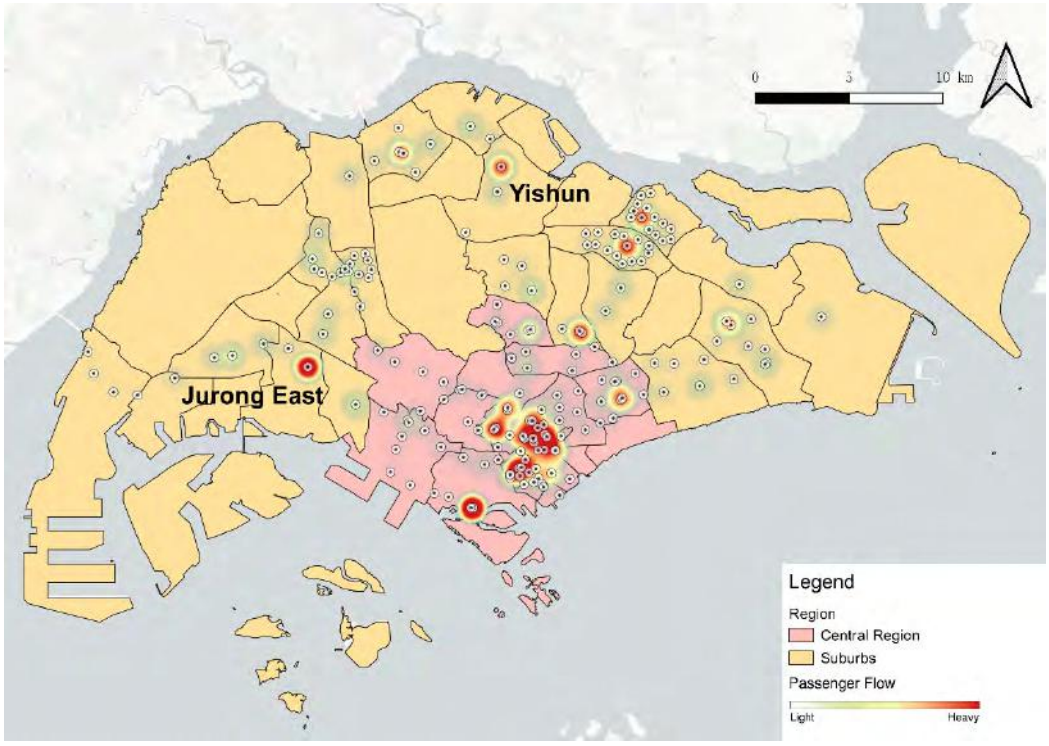


Figure 5. Average daily passengers flow by MRT station
Source: By Author

Using Equation 3, an OD matrix was calculated with Jurong East and Yishun as destination points (Figure 6 and Figure 7). The results show that Jurong East attracts a large number of visitors from the eastern region on non-working days, with a daily average of over 70,000 visitors from several neighbouring stations. Additionally, Jurong East maintains considerable attraction across much of the northern region, with 72.7% of MRT stations in the north sending more than 6,000 passengers daily to Jurong East. The furthest station with significant passenger flow to Jurong East is Tampines MRT station, located approximately 22.88 km away in the western region, from which Jurong East attracts 7,946 passengers daily on non-working days, demonstrating its strong comprehensive appeal across considerable distances (Ni et al., 2018). Similarly, Yishun exerts a strong pull on surrounding areas, with 42.98% of non-working day passenger flow to Yishun originating from the city centre, indicating Yishun's substantial impact on the central area and its effective role in bridging the urban-suburban living service zones (Zhang et al., 2016).

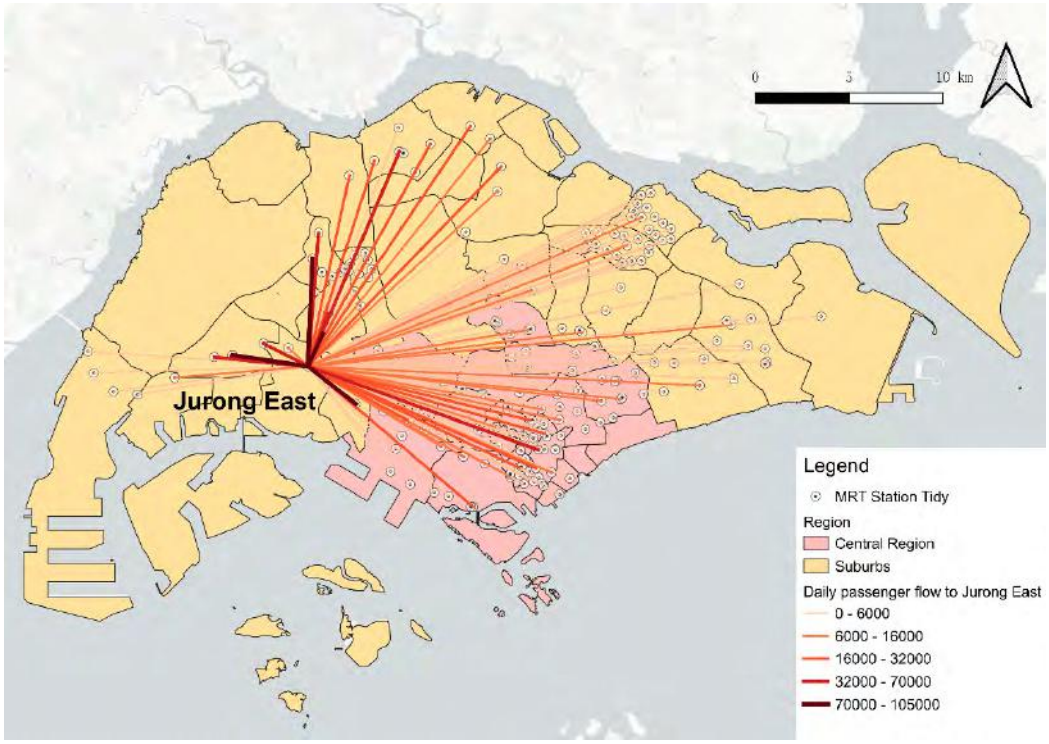


Figure 6. Passenger traffic terminating at Jurong East
Source: By Author

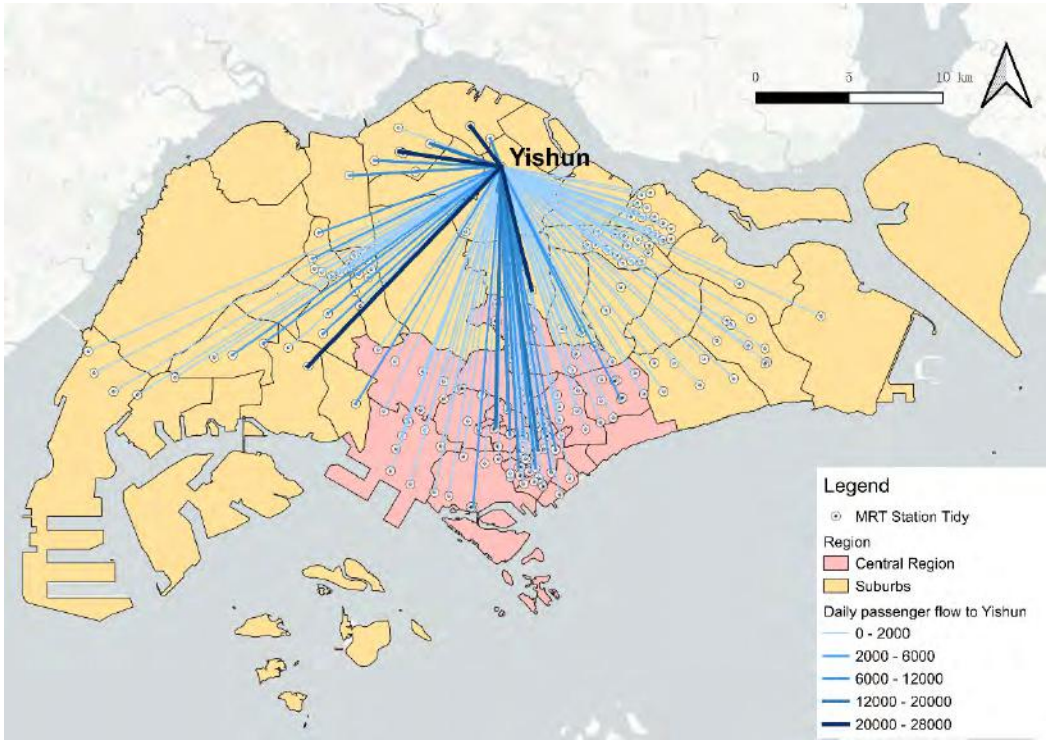


Figure 7. Passenger traffic terminating at Yishun
Source: By Author

4.2. The Role of Mixed-Use Development in Suburban Revitalization

Typically, mixed-use development is more common in urban centres, where it arises as a passive response to high-density and scarce land use (Shi and Yang, 2015). However, interviews with residents reveal that mixed-use development in suburban areas can also quickly revitalize these spaces. Specifically, the integration of commercial and residential projects effectively ensures a steady flow of people in suburban malls. By offering convenience and reducing the travel costs of nearby residents, mixed-use commercial developments help avoid the waste and pollution associated with traditional transportation, thereby promoting the overall sustainability of the community (Ewing and Cervero, 2001). Additionally, these commercial projects leverage the so-called "proximity effects" (Yang et al., 2016) to attract nearby residents, addressing the challenge of insufficient population that often leads to operational difficulties in suburban malls (Ooi and Loo-Lee, 2007). This also provides convenience for residents, as one talked:

> *"We live right above (the mall), so it's very convenient... I used to not want to go to the mall, but now it's indeed very convenient." （54-year-old Interviewee, Local）*

Moreover, mixed-use commercial complexes can effectively utilize residents' social networks to attract more customers, further enhancing the vibrancy of the area:

> *"Some friends used to come over, and we'd have coffee or dine together here... They all love coming here..." (65-year-old Interviewee, Local)*
>
> *"My son brings my grandson to visit me on weekends, and we often choose to dine here; there's a great variety—Chinese food, Thai food, Malay food, all sorts... very good... It's close and convenient..." （75-year-old Interviewee, Local）*

Such commercial complexes, with a solid customer base, are more capable of sustaining their size and thriving atmosphere, thereby attracting even more foot traffic, leading to a positive feedback loop (Ooi and Loo-Lee, 2007).

Additionally, the joint arrangement of infrastructure, particularly service-oriented infrastructure, and commercial complexes can effectively enhance service levels and increase infrastructure utilization. This, in turn, brings more foot traffic to the commercial complexes, fostering a mutually beneficial situation:

> *"There's a government activity centre here. I bring my son over for activities on weekends... Sometimes we just browse nearby, and since it's indoors, we don't have to worry about the rain... Sometimes, after the activity, we can grab a bite to eat nearby..." (37-year-old Interviewee, Visitor)*
>
> *"The library moved here (into the commercial complex), and now the lighting and everything is more comfortable than before... not to mention, the air conditioning is much better than before." (61-year-old Interviewee, Local)*

However, the flourishing development of such mixed-use complexes often leads to an increase in land value (Yang et al., 2016), which, in turn, causes a rise in prices within the complex, potentially affecting the daily lives of nearby residents:

> *"The prices at this food court are very high, and they keep going up... If they keep increasing, I'll have to go to Johor Bahru (t city on the border between Singapore and Malaysia) to eat." (65-year-old Interviewee, Local)*

Some scholars argue that this reasonable increase in prices, especially rising rental costs, to some extent, reflects the improved overall quality of the area (Sakashita, 1993; Song and Knaap, 2004). For suburban areas, this indirectly proves the increasing attractiveness of the region.

However, mixed-use development may also bring about noise and space occupation issues for local residents, referred to as "disamenity effects," which can reduce the benefits that proximity effects bring to the community (Yang et al., 2016). Yet, in terms of attractiveness, this diversified and vibrant atmosphere also helps to foster stronger community ties (Song and Knaap, 2004).

4.3. The Role of Transit-Oriented Development (TOD) in Suburban Revitalization

As numerous studies have revealed, transit-oriented development (TOD) effectively integrates urban transportation, planning, and design, offering comprehensive and sustainable urban development solutions for regions (Ibraeva et al., 2020). In suburban areas, this integrated urban development model brings core urban elements while avoiding the busyness, chaos, and congestion typical of city centres, maintaining vibrancy and robust functionality (Hall and Tewdwr-Jones, 2010; Howard, 1951). In interviews conducted for this study, respondents emphasized that under Singapore's strict regulations on private vehicle usage (Olszewski, 2007), TOD not only made their daily commutes more convenient but also made locations near transit stations popular choices for their daily activities:

> *"We don't live in Yishun; I came with my child from Sembawang... Didn't get rained on at all; in Yishun, it's very obvious—once you exit the MRT station, you're right at Northpoint City (mall); everyone likes coming here." (37-year-old Interviewee, Visitor)*
>
> *"After work, I just grab a bite near the MRT station; it's very close." (40-year-old Interviewee, Local)*

The combination of robust functionality and convenient transportation not only brings convenience to nearby residents but also significantly enhances the attractiveness of the area, effectively alleviating pressure on city centres. In some cities, this pressure shift occurs as businesses relocate part of their operations or even headquarters to the suburbs due to lower land prices and better transportation conditions (Knowles, 2012). Although many businesses in Singapore remain concentrated in the city centre and Changi Business Park (Muzaini et al., 2013), the pressure on the city centre is relieved through two additional mechanisms. First, the comprehensive service offerings at TOD stations and their surrounding areas attract residents from other regions. Second, the improved facilities allow suburban residents to enjoy services similar to those in the city centre, reducing the need to travel into the city:

> *"It's convenient to come to Jurong East—just takes a little over ten minutes... And you can buy everything here; it's no different from Orchard Road... I usually come here (to Jurong East), and rarely go to Orchard Road—it's too far." (48-year-old Interviewee, Visitor)*

Furthermore, the mixed-use TODs, connected through atrium and elevated systems, link stations to open and dynamic urban interfaces. This networked system enhances urban mobility and further increases the attractiveness of the area (Yang et al., 2019), a structure that has been well-received by residents. In the development of Jurong East, such elevated systems integrate the entire urban area's malls, hospitals, offices, and other functions, connecting them with the elevated MRT station, ground-level bus terminal, and taxi stands to form an integrated urban system known as J-Walk. This system is activated daily by food courts and cafes and further attracts people through special activities on holidays. Although this model has been criticized for issues such as the privatization of public urban space and the reinforcement of gentrification (Cuthbert and McKinnell, 2001), it successfully attracts both daily commuters and visiting tourists, efficiently directing them to their respective destinations through a well-developed, integrated urban system (Xue et al., 2012):

> *"Sometimes while walking nearby, I feel like checking out the mall since everything's connected... Especially when it rains, you're completely sheltered (between facilities), no need to worry about getting wet... If I get tired, I can quickly head home." (57-year-old Interviewee, Local)*

4.4. The Role of Green Spaces in Suburban Revitalization

Green spaces are often considered one of the most crucial components of urban infrastructure (Tian and Jim, 2012). They serve physical functions such as mitigating urban heat island effects, absorbing pollutants, and reducing noise (Knowles, 2012), while also providing psychological benefits by alleviating stress among residents (Grahn and Stigsdotter, 2010). Some scholars argue that urban green space planning essentially involves introducing natural and semi-natural suburban spaces into the highly developed urban core (Ozyavuz, 2012). Consequently, suburban areas naturally hold an advantage when it comes to green spaces. With their large, intact green areas, suburbs can significantly attract residents from city centres, who often have access only to small, fragmented, and low-quality green spaces (Jim and Chen, 2006; Žlender and Ward Thompson, 2017). Research also shows that even when urban parks are well-maintained, people tend to prefer spending their leisure time in woodlands, suburban parks, and edge forests (Grahn and Stigsdotter, 2010). This preference draws many city-centre residents to suburban areas rich in semi-natural spaces:

> *"My grandson loves coming here, and his parents are happy too... It's great to relax and enjoy some greenery... You can't find parks this nice over in Toa Payoh." (75-year-old Interviewee, Local)*

In addition, green spaces can effectively unite communities, enhancing residents' attachment to their neighbourhoods and fostering a sense of cohesion. This, in turn, makes communities more attractive and encourages residents to stay (Arnberger and Eder, 2012). While some studies suggest that green spaces in suburban areas are less appealing to urban residents compared to those in city centres (Arnberger and Eder, 2012; Kim and Kaplan, 2004), these studies generally focus on low-density suburban areas characterized by "private lawns," "family gardens," and "fields and meadows." Singapore, as a high-density city, does not feature these idyllic rural landscapes (Anwar et al., 2020). In the context of such high-density urban development, green spaces become even more valuable, and the well-maintained green spaces in suburban areas become a source of pride for local communities. Moreover, green spaces that have been preserved in strategic locations within urban planning frameworks do not result in wasted space. Due to their high accessibility and the comprehensive infrastructure surrounding them, these green spaces attract and retain a significant number of local residents on both weekdays and weekends:

> *"You can't find a park as nice as this one near Toa Payoh." (75-year-old Interviewee, Local)*
>
> *"The park next to Northpoint City... We go there often on weekends; there are plenty of restaurants and cafes nearby, so we can easily rest when we get tired." (46-year-old Interviewee, Local)*
>
> *"When I have free time, I love walking around Yishun Pond and that park (Yishun Park)... I just walk for about one or two hours... That's my way of relaxing." (71-year-old Interviewee, Local)*
>
> *"This area is full of green spaces. Besides the Central Catchment Area, we probably have the most greenery around here. Whatever type of park you want, we've got it; just take a bus to the end of the line, and it's all green..." (53-year-old Interviewee, Local)*

5. Summary

This study demonstrates that revitalizing suburban areas in Singapore has had a positive impact on both local and surrounding communities, as well as the whole city. By analysing the attractiveness of suburban areas and conducting interviews with residents from two districts—Yishun and Jurong East—this research highlights the significant role suburban regeneration plays in promoting sustainable urban development. Data from the Mass Rapid Transit (MRT) system indicate that successfully revitalized suburban areas in Singapore maintain both local and citywide attractiveness, reducing the density burden on the urban core and providing a solid foundation for sustainable growth in high-density urban environments.

Furthermore, the research identifies several key strategies for achieving sustainable suburban revitalization in high-density cities. First, proactive promotion of mixed-use land development in suburban areas is essential. Traditionally, mixed-use developments in city centres are reactive responses to land scarcity pressures. However, this study's cases show that actively pursuing mixed-use development in suburban areas can successfully rejuvenate these regions, attract a larger population, and alleviate pressure on urban centres.

Second, updating suburban transportation patterns through Transit-Oriented Development (TOD) systems and improving public transport accessibility can enhance the appeal of suburbs to both local residents and people from other areas. This can, in turn, reduce traffic congestion in city centres. The integration of more spaces with structures such as elevated walkways can further amplify the impact of TOD, creating sustainable urban densities.

Third, emphasizing green features is a critical factor in revitalizing suburban ecological spaces. In some instances of suburban redevelopment, neglecting the preservation of natural environments has led to environmental degradation. However, the appeal of green spaces is a major draw for residents and visitors alike. Thus, maintaining green attributes through green building initiatives and urban parks is vital for enhancing the overall attractiveness of suburban areas.

In conclusion, the example of Singapore illustrates that upgrading suburban areas can reinvigorate and expand their attractiveness, offering valuable insights for suburban renewal strategies in other high-density cities, particularly in the Global South. Additionally, this study explains how cities can balance population growth with liveable environments, guiding high-density urban areas toward sustainable development.

6. References

Anwar, A., Younis, M. and Ullah, I. (2020) 'Impact of Urbanization and Economic Growth on CO2 Emission: A Case of Far East Asian Countries', *International Journal of Environmental Research and Public Health*, 17(7), p. 2531. Available at: https://doi.org/10.3390/ijerph17072531.

Arnberger, A. and Eder, R. (2012) 'The influence of green space on community attachment of urban and suburban residents', *Urban Forestry & Urban Greening*, 11(1), pp. 41–49. Available at: https://doi.org/10.1016/j.ufug.2011.11.003.

Arumsari, P. and Rarasati, A.D. (2017) 'Maintenance strategy for public-rented residential building: a case study in Jakarta, Indonesia', *Built Environment Project and Asset Management*, 7(1), pp. 99–110. Available at: https://doi.org/10.1108/BEPAM-11-2015-0067.

Badcock, B. (2001) 'Thirty Years On: Gentrification and Class Changeover in Adelaide's Inner Suburbs, 1966-96', *Urban Studies*, 38(9), pp. 1559–1572. Available at: https://doi.org/10.1080/00420980120080441.

Blair, R. (2004) 'The Effects of Urban Sprawl on Birds at Multiple Levels of Biological Organization', *Ecology and Society*, 9(5). Available at: https://www.jstor.org.libproxy1.nus.edu.sg/stable/26267695 (Accessed: 3 August 2024).

Braun, V. and Clarke, V. (2006) 'Using thematic analysis in psychology', *Qualitative Research in Psychology*, 3(2), pp. 77–101. Available at: https://doi.org/10.1191/1478088706qp063oa.

Brewer, K. and Grant, J.L. (2015) 'Seeking density and mix in the suburbs: challenges for mid-sized cities', *Planning Theory & Practice*, 16(2), pp. 151–168. Available at: https://doi.org/10.1080/14649357.2015.1011216.

Camagni, R., Gibelli, M.C. and Rigamonti, P. (2002) 'Urban mobility and urban form: the social and environmental costs of different patterns of urban expansion', *Ecological Economics*, 40(2), pp. 199–216. Available at: https://doi.org/10.1016/S0921-8009(01)00254-3.

Campbell, N.M. (2015) 'Third place characteristics in planned retirement community social spaces', *Journal of architectural and planning research*, pp. 55–67.

Cheng, J., Chen, M. and Tang, S. (2023) 'Shenzhen – A typical benchmark of Chinese rapid urbanization miracle', *Cities*, 140, p. 104421. Available at: https://doi.org/10.1016/j.cities.2023.104421.

Cuthbert, A.R. and McKinnell, K.G. (2001) 'Public Domain, Private Interest — Social Space in Hong Kong', in P. Miao (ed.) *Public Places in Asia Pacific Cities: Current Issues and Strategies*. Dordrecht: Springer Netherlands, pp. 191–211. Available at: https://doi.org/10.1007/978-94-017-2815-7_10.

DeStefano, S. and DeGraaf, R.M. (2003) 'Exploring the ecology of suburban wildlife', *Frontiers in Ecology and the Environment*, 1(2), pp. 95–101. Available at: https://doi.org/10.1890/1540-9295(2003)001[0095:ETEOSW]2.0.CO;2.

Ekers, M., Hamel, P. and Keil, R. (2012) 'Governing Suburbia: Modalities and Mechanisms of Suburban Governance', *Regional Studies*, 46(3), pp. 405–422. Available at: https://doi.org/10.1080/00343404.2012.658036.

Eng, T.S. (1996) 'Character and identity in Singapore new towns: Planner and resident perspectives', *Habitat International*, 20(2), pp. 279–294. Available at: https://doi.org/10.1016/0197-3975(95)00063-1.

Ewing, R. and Cervero, R. (2001) 'Travel and the Built Environment: A Synthesis', *Transportation Research Record*, 1780(1), pp. 87–114. Available at: https://doi.org/10.3141/1780-10.

Filion, P. and Keil, R. (2017) 'Contested Infrastructures: Tension, Inequity and Innovation in the Global Suburb', *Urban Policy and Research*, 35(1), pp. 7–19. Available at: https://doi.org/10.1080/08111146.2016.1187122.

Grahn, P. and Stigsdotter, U.K. (2010) 'The relation between perceived sensory dimensions of urban green space and stress restoration', *Landscape and Urban Planning*, 94(3), pp. 264–275. Available at: https://doi.org/10.1016/j.landurbplan.2009.10.012.

Hall, P.G. and Tewdwr-Jones, M. (2010) *Urban and regional planning*. 5th edn. New York;Abingdon, Oxon, England; Routledge (Book, Whole). Available at: https://doi.org/10.4324/9780203861424.

Hanlon, B. and Vicino, T. (2018) *The Routledge Companion to the Suburbs*. Routledge.

Hartt, M., DeVerteuil, G. and Potts, R. (2023) 'Age-Unfriendly by Design: Built Environment and Social Infrastructure Deficits in Greater Melbourne', *Journal of the American Planning Association*, 89(1), pp. 31–44. Available at: https://doi.org/10.1080/01944363.2022.2035247.

HDB (2024) *HDB | Punggol*, *House and Development Board*. Available at: https://www.hdb.gov.sg/about-us/history/hdb-towns-your-home/punggol (Accessed: 9 August 2024).

Hess, C. (2021) 'Residential Segregation by Race and Ethnicity and the Changing Geography of Neighborhood Poverty', *Spatial Demography*, 9(1), pp. 57–106. Available at: https://doi.org/10.1007/s40980-020-00066-3.

Howard, E., Sir (1951) *Garden cities of to-morrow*. London: Faber (Book, Whole). Available at: https://go.exlibris.link/K7tGSf8q.

Hu, Q. *et al.* (2024) 'Does existing mixed land development promote the urban spatial composite function? Evidence from Beijing, China', *Land Use Policy*, 143, p. 107212. Available at: https://doi.org/10.1016/j.landusepol.2024.107212.

Ibraeva, A. *et al.* (2020) 'Transit-oriented development: A review of research achievements and challenges', *Transportation Research Part A: Policy and Practice*, 132, pp. 110–130. Available at: https://doi.org/10.1016/j.tra.2019.10.018.

Jiang, S., Ferreira, J. and González, M.C. (2012) 'Clustering daily patterns of human activities in the city', *Data Mining and Knowledge Discovery*, 25(3), pp. 478–510. Available at: https://doi.org/10.1007/s10618-012-0264-z.

Jim, C.Y. and Chen, W.Y. (2006) 'Recreation–amenity use and contingent valuation of urban greenspaces in Guangzhou, China', *Landscape and Urban Planning*, 75(1), pp. 81–96. Available at: https://doi.org/10.1016/j.landurbplan.2004.08.008.

Jones, P. and Clarke, M. (1988) 'The significance and measurement of variability in travel behaviour', *Transportation*, 15(1), pp. 65–87. Available at: https://doi.org/10.1007/BF00167981.

Keil, R. (2020) 'After Suburbia: research and action in the suburban century', *Urban Geography*, 41(1), pp. 1–20. Available at: https://doi.org/10.1080/02723638.2018.1548828.

Keil, R. and Macdonald, S. (2016) 'Rethinking urban political ecology from the outside in: greenbelts and boundaries in the post-suburban city', *Local Environment*, 21(12), pp. 1516–1533. Available at: https://doi.org/10.1080/13549839.2016.1145642.

Kim, J. and Kaplan, R. (2004) 'Physical and psychological factors in sense of community: New urbanist Kentlands and nearby orchard village', *Environment and Behavior*, 36(3), pp. 313–340. Available at: https://doi.org/10.1177/0013916503260236.

Kim, S.-N., Chung, J. and Lee, J. (2022) 'Exploring the Role of Transit Ridership as a Proxy for Regional Centrality in Moderating the Relationship between the 3Ds and Street-Level Pedestrian Volume: Evidence from Seoul, Korea', *Land*, 11(10), p. 1749. Available at: https://doi.org/10.3390/land11101749.

King, A. (2004) *Spaces of Global Cultures: Architecture, Urbanism, Identity*. London: Routledge. Available at: https://doi.org/10.4324/9780203483121.

Knowles, R.D. (2012) 'Transit Oriented Development in Copenhagen, Denmark: from the Finger Plan to Ørestad', *Journal of Transport Geography*, 22, pp. 251–261. Available at: https://doi.org/10.1016/j.jtrangeo.2012.01.009.

Larco, N. *et al.* (2013) 'Trips to Strips: Walking and Site Design in Suburban Multifamily Housing', *Journal of Urban Design*, 18(2), pp. 281–303. Available at: https://doi.org/10.1080/13574809.2013.772886.

Li, F. *et al.* (2005) 'Comprehensive concept planning of urban greening based on ecological principles: a case study in Beijing, China', *Landscape and Urban Planning*, 72(4), pp. 325–336. Available at: https://doi.org/10.1016/j.landurbplan.2004.04.002.

Lleras, C. (2008) 'Race, Racial Concentration, and the Dynamics of Educational Inequality Across Urban and Suburban Schools', *American Educational Research Journal*, 45(4), pp. 886–912. Available at: https://doi.org/10.3102/0002831208316323.

Loh, L.C. and Brieger, W.B. (2014) 'Suburban Sprawl in the Developing World: Duplicating Past Mistakes? The Case of Kuala Lumpur, Malaysia', *International Quarterly of Community Health Education*, 34(2), pp. 199–211. Available at: https://doi.org/10.2190/IQ.34.2.g.

Lucy, W.H. and Phillips, D.L. (2000) *Confronting Suburban Decline: Strategic Planning for Metropolitan Renewal*. Island Press.

Mack, J. (2023) 'Modernism in the present tense: "Dangerous" Scandinavian suburbs and their hereafters', *Environment and Planning D: Society and Space*, 41(4), pp. 656–682. Available at: https://doi.org/10.1177/02637758231182147.

Marshall, B. *et al.* (2013) 'Does Sample Size Matter in Qualitative Research?: A Review of Qualitative Interviews in is Research', *Journal of Computer Information Systems*, 54(1), pp. 11–22. Available at: https://doi.org/10.1080/08874417.2013.11645667.

Muzaini, H. *et al.* (2013) *Changing Landscapes of Singapore: Old Tensions, New Discoveries*. NUS Press.

Ni, L., Wang, X. (Cara) and Chen, X. (Michael) (2018) 'A spatial econometric model for travel flow analysis and real-world applications with massive mobile phone data', *Transportation Research Part C: Emerging Technologies*, 86, pp. 510–526. Available at: https://doi.org/10.1016/j.trc.2017.12.002.

Olszewski, P.S. (2007) 'Singapore motorisation restraint and its implications on travel behaviour and urban sustainability', *Transportation*, 34(3), pp. 319–335. Available at: https://doi.org/10.1007/s11116-007-9115-y.

Ooi, J.T.L. and Loo-Lee, S. (2007) 'The magnetism of suburban shopping centers: do size and Cineplex matter?', *Journal of Property Investment & Finance*, 25(2), pp. 111–135. Available at: https://doi.org/10.1108/14635780710733816.

Ozyavuz, M. (2012) *Landscape Planning*. BoD – Books on Demand.

Peng, J., Zhao, H. and Liu, Y. (2017) 'Urban ecological corridors construction: A review', *Acta Ecologica Sinica*, 37(1), pp. 23–30. Available at: https://doi.org/10.1016/j.chnaes.2016.12.002.

Pham, S. (2024) 'Places left behind? Declining inner suburbs in the Toronto Census Metropolitan Area, 1980–2015', *Cities*, 146, p. 104726. Available at: https://doi.org/10.1016/j.cities.2023.104726.

Randolph, B. and Tice, A. (2014) 'Suburbanizing Disadvantage in Australian Cities: Sociospatial Change in an Era of Neoliberalism', *Journal of Urban Affairs*, 36(sup1), pp. 384–399. Available at: https://doi.org/10.1111/juaf.12108.

Ren, X. (2021) 'Suburbs and Urban Peripheries in a Global Perspective', *City & Community*, 20(1), pp. 38–47. Available at: https://doi.org/10.1111/cico.12505.

Sadewo, E. *et al.* (2023) 'The role of urban transformation on inter-suburban commuting: evidence from Jakarta metropolitan area, Indonesia', *Urban Geography*, 44(8), pp. 1628–1653. Available at: https://doi.org/10.1080/02723638.2022.2125649.

Sakashita, N. (1993) 'Land Price Increase and Structure of Regional Income: Recent Experience in Japan', in H. Kohno and P. Nijkamp (eds) *Potentials and Bottlenecks in Spatial Development: Festschrift in Honor of Yasuhiko Oishi*. Berlin, Heidelberg: Springer, pp. 70–86. Available at: https://doi.org/10.1007/978-3-642-87901-2_5.

Samarüütel, A., Steen Selvig, S. and Holt-Jensen, A. (2010) 'Urban sprawl and suburban development around Pärnu and Tallinn, Estonia', *Norsk Geografisk Tidsskrift - Norwegian Journal of Geography*, 64(3), pp. 152–161. Available at: https://doi.org/10.1080/00291951.2010.502653.

Shi, B. and Yang, J. (2015) 'Scale, distribution, and pattern of mixed land use in central districts: A case study of Nanjing, China', *Habitat International*, 46, pp. 166–177. Available at: https://doi.org/10.1016/j.habitatint.2014.11.008.

Shi, G. *et al.* (2010) 'Comprehensive assessment of toxic metals in urban and suburban street deposited sediments (SDSs) in the biggest metropolitan area of China', *Environmental Pollution*, 158(3), pp. 694–703. Available at: https://doi.org/10.1016/j.envpol.2009.10.020.

Singapore Department of Statistics (2024) *Singstat Website - Environment*, *Singapore Department of Statistics*. Available at: http://www.singstat.gov.sg/publications/reference/ebook/society/environment (Accessed: 23 August 2024).

Song, Y. and Knaap, G.-J. (2004) 'Measuring the effects of mixed land uses on housing values', *Regional Science and Urban Economics*, 34(6), pp. 663–680. Available at: https://doi.org/10.1016/j.regsciurbeco.2004.02.003.

Spencer, A., Gill, J. and Schmahmann, L. (2015) *Urban or suburban? Examining the density of Australian cities in a global context.*

Sumari, N.S. *et al.* (2020) 'On the absurdity of rapid urbanization: Spatio-temporal analysis of land-use changes in Morogoro, Tanzania', *Cities*, 107, p. 102876. Available at: https://doi.org/10.1016/j.cities.2020.102876.

Swanstrom, T., Dreier, P. and Mollenkopf, J. (2002) 'Economic Inequality and Public Policy: The Power of Place', *City & Community*, 1(4), pp. 349–372. Available at: https://doi.org/10.1111/1540-6040.00030.

Tian, Y. and Jim, C.Y. (2012) 'Development potential of sky gardens in the compact city of Hong Kong', *Urban Forestry & Urban Greening*, 11(3), pp. 223–233. Available at: https://doi.org/10.1016/j.ufug.2012.03.003.

Tian, Y. and Qian, J. (2021) 'Suburban identification based on multi-source data and landscape analysis of its construction land: A case study of Jiangsu Province, China', *Habitat International*, 118, p. 102459. Available at: https://doi.org/10.1016/j.habitatint.2021.102459.

Tong, L., Hu, S. and Frazier, A.E. (2019) 'Hierarchically measuring urban expansion in fast urbanizing regions using multi-dimensional metrics: A case of Wuhan metropolis, China', *Habitat International*, 94, p. 102070. Available at: https://doi.org/10.1016/j.habitatint.2019.102070.

Tu, L., Chen, B. and Zhou, Z. (2021) 'A Survey on OD Data Visualization', *Journal of Computer-Aided Design & Computer Graphics*, 33(8), pp. 1160–1171. Available at: https://doi.org/10.3724/SP.J.1089.2021.18679.

van der Veer, J. (1994) 'Metropolitan Government and City-Suburban Cleavages: Differences between Old and Young Metropolitan Areas', *Urban Studies*, 31(7), pp. 1057–1079. Available at: https://doi.org/10.1080/00420989420080951.

Wang, Y. *et al.* (2020) 'Effects of rapid urbanization on ecological functional vulnerability of the land system in Wuhan, China: A flow and stock perspective', *Journal of Cleaner Production*, 248, p. 119284. Available at: https://doi.org/10.1016/j.jclepro.2019.119284.

Wiesel, I., Freestone, R. and Randolph, B. (2013) 'Owner-Driven Suburban Renewal: Motivations, Risks and Strategies in "Knockdown and Rebuild" Processes in Sydney, Australia', *Housing Studies*, 28(5), pp. 701–719. Available at: https://doi.org/10.1080/02673037.2013.758243.

Wood, A.M. and Phelps, N.A. (2020) 'Mediating Local Economic Development: The Place of Site Selection Consultants in Industrial Recruitment', *Economic Development Quarterly*, 34(1), pp. 78–84. Available at: https://doi.org/10.1177/0891242419897128.

World Bank (2024) 'World Development Indicators'. Available at: https://databank.worldbank.org/source/world-development-indicators#selectedDimension_DBList.

Xue, C.Q.L., Ma, L. and Hui, K.C. (2012) 'Indoor "Public" Space: A study of atria in mass transit railway (MTR) complexes of Hong Kong', *URBAN DESIGN International*, 17(2), pp. 87–105. Available at: https://doi.org/10.1057/udi.2012.6.

Yang, H.J., Song, J. and Choi, M.J. (2016) 'Measuring the Externality Effects of Commercial Land Use on Residential Land Value: A Case Study of Seoul', *Sustainability*, 8(5), p. 432. Available at: https://doi.org/10.3390/su8050432.

Yang, L. *et al.* (2019) 'Integrated design of transport infrastructure and public spaces considering human behavior: A review of state-of-the-art methods and tools', *Frontiers of Architectural Research*, 8(4), pp. 429–453. Available at: https://doi.org/10.1016/j.foar.2019.08.003.

Yu, D. *et al.* (2022) 'Spatio-temporal convolutional residual network for regional commercial vitality prediction', *Multimedia Tools and Applications*, 81(19), pp. 27923–27948. Available at: https://doi.org/10.1007/s11042-022-12845-9.

Zhang, X. *et al.* (2016) 'Analysis of spatial and temporal patterns of daily activities of suburban residents based on GPS data: A case study of the Shangdi-Qinghe area of Beijing', *International Review for Spatial Planning and Sustainable Development*, 4(1), pp. 4–16. Available at: https://doi.org/10.14246/irspsd.4.1_4.

Žlender, V. and Ward Thompson, C. (2017) 'Accessibility and use of peri-urban green space for inner-city dwellers: A comparative study', *Landscape and Urban Planning*, 165, pp. 193–205. Available at: https://doi.org/10.1016/j.landurbplan.2016.06.011.

Research Paper

The Factors and Indicators System That Influences Sustainable Density

Xin Zhao, South China University of Technology, Country

Abstract

In the urban planning, the evolution and prospects of density research indicate that density serves not only as a measure of urban physical form but also as a crucial tool for addressing urban challenges, managing urban morphology, and regulating the relationship between humans and their environment. With the rapid global population growth, achieving high quality and sustainable development in high-density urban settings has emerged as a significant issue in urban planning theory and practice. This paper introduces the elements of sustainability and the definition of density, categorizing streets based on their functions into commercial spaces, office spaces, residential spaces, and public spaces. Building on this functional classification, it investigate key density indicators relevant to each category. Ultimately, a model is established to illustrate the relationships among various density concepts, thereby creating a density framework. This framework can facilitate changes in urban density, promoting sustainability and enabling urban transformation.

Keywords

sustainability, density, floor area ratio, residential, commercial, office, public space

1. Introduction

The study of urban sustainable density primarily requires an examination of two aspects: urban sustainability and urban density. Urban density encompasses a variety of definitions; however, a comprehensive model that illustrates the interconnections of urban density has yet to emerge. This paper aims to construct a model at the neighborhood scale that elucidates these relationships, based on a clarification of several definitions of urban density. Initially, the paper categorizes urban functions at the neighborhood level into residential, commercial, office, public space, and other functions, and investigates the density relationships among these functional zones. Building upon this foundation, population density is incorporated to jointly establish a model that represents both urban density and population density. Finally, recommendations for the development of the urban density model are presented.

2. Definition

2.1. The definition of sustainability

Different scholars have varying definitions of sustainable development, a concept that can be traced back to the early 1970s when various studies warned of the need to impose limits on Western development models. Subsequently, the concept emphasized that sustainability is a normative concept that indicates how humanity should interact with nature and how we should be accountable to one another and future generations (Baumgärtner and Quaas, 2010)(Baumgärtner, 2010). The concept highlighted that the essence of sustainable development lies in meeting fundamental human needs while safeguarding the Earth's life-support systems. The concept of sustainable development has become a reference for scientific research on the environment and has acquired a paradigm character for development(Alvarado-Herrera et al., 2017). The concept also been used in issues related to agricultural production (Gouda et al., 2018; Lathuillièreetal., 2018) business(Amranet al., 2015; Dangelico and Pontrandolfo, 2015), industry (Lambert and Boons, 2002), circular economy (Suárez-Eiroaetal., 2019) and has become the conceptual foundation of theoretical approaches like green economy (Bina, 2013). As Mitlin(Mitlin, 1992) noted, the legacy that associates the concept of sustainable development with economic growth has sparked debates over its contradictory interpretations. This is because various scholars hold divergent views on the relationship. Some contend that development, when equated with economic growth, is at odds with sustainability, given that an infinite growth trajectory on a finite planet is inherently unfeasible (Beckerman, 1992).

Several key indicators of sustainable cities include: Sustainable Transportation: "Reflects the comprehensive social and environmental costs of the transportation services provided; respects carrying capacity; and balances mobility and safety demands with accessibility, environmental quality, and community livability needs." Density is defined as the ratio of residential units or people to a designated land area, a crucial element in the discourse on sustainable urban form. Mixed Land Use: Planners and scholars widely agree that Mixed land use is essential for promoting sustainable urban development(Daly, 2006; Spangenberg, 2002). Diversity: The diversity of activities is a key factor in achieving urban sustainability and fostering other desirable urban characteristics (Folke, 2006). Greening: Also known as green urbanism, greening has emerged as an important design concept for sustainable urban form since the 1990s (Luke, 2005).

2.2. The definition of density

The earliest definition of density originates from physics, indicating the mass per unit volume. Subsequently, the concept of density has been expanded into various fields, resulting in a multitude of definitions (Fig.1). For instance, spatial density, social density, and perceptual density, among others. In urban planning, density serves as a crucial metric for assessing urban density, primarily encompassing density indicators that influence the built environment, including Floor Area Ratio (FAR), plot density, street density, total residential density, overall site density, residential density, neighborhood density, and total living area density. Additionally, it includes density indicators beyond the built environment, such as population density. The Floor Area Ratio (FAR) is a key metric in urban planning used to evaluate building density and land use, representing the ratio of total building area to the area of land occupied by the building. Population density (POP) refers to the number of residents living within a unit area, which is a critical factor in the evaluation of residential density. However, the limitations of the population density metric lie in its inability to inform us whether each individual has adequate (or comfortable) living space, whether the size of residential units is reasonable, the condition of public spaces, and how many individuals reside within each living unit.

The comprehensive definitions of sustainability and density highlight that the essence of sustainable density lies in achieving an appropriate balance that fosters community vitality while enhancing the accessibility of services and facilities, without leading to excessive congestion, deteriorating living conditions, or adversely affecting the urban microclimate. For instance, excessively high density may result in increased stress for residents and a decline in the quality of the living environment, whereas excessively low density can lead to urban sprawl and inefficient resource utilization. Sustainable density, influenced by both population density and building density, refers to the average number of residents, buildings, or housing units per unit of land area within an urban area or specific zone, provided that the quality of life for residents and the sustainability of the urban environment are maintained. In urban planning, sustainable density plays a crucial role as it is directly linked to the goals of sustainable urban development. Therefore, relevant indicators concerning population density and building density, as mentioned in the EU SDG Indicator set 2020 from the 2019 SDG Index and Dashboards Report for European Cities (prototype version), can be utilized to establish a sustainable model of urban density. This model can serve as a framework for small-scale sustainable urban density, while also allowing for the exploration of additional factors influencing sustainable density at a larger scale to develop a comprehensive urban density model.

3. Methodology

Based on the identification of sustainable development factors, a comprehensive understanding of the diversity of urban density at the street level is established, encompassing building volume, floor area, housing, population, employment, as well as measured and perceived density. This approach seeks to explore the interconnections between various density measurement indicators within the context of sustainable development. For instance, it examines the relationships among indicators such as urban building density, super-tall building density, and regional development intensity within the framework of building density. Furthermore, it incorporates sustainable indicators mentioned in the 2019 SDG Index and Dashboards Report for European Cities (prototype version) EU SDG Indicator set 2020 classification. These include metrics related to population density, such as the coverage rate of housing security services for the resident population (%), and resident population density; as well as metrics concerning public space density, including satisfaction with cultural facilities (%), the number of sights and landmarks (per 100,000), museum coverage (per 100,000), and concert and show coverage (per 100,000). This leads to the establishment of a sustainable indicator model built upon traditional indicator frameworks. Consequently, it integrates measurement models of buildings, population, and other factors, linking them to issues of scale and urban intensity. Thus, a comprehensive approach is proposed, connecting key concepts within a defined theoretical framework.

4. Classification of indicators

Cities are composed of various streets, and studying urban density can be approached through the lens of street units. This is due to the diverse nature of street density, which encompasses residential, commercial, office, public spaces, and a variety of other uses.

The indicators of residential spaces within urban streets primarily encompass apartments, detached villas, semi-detached villas, townhouses, low-rise multi-family residences, and affordable housing's floor area ratio, along with the building heights specific to the designated study area. These indicators are regulated by both the floor area ratio and building height. This relationship, however, has exceptions, as not all built areas are above ground, nor do all structures possess clearly defined footprints and vertical walls. Nonetheless, this correlation is prevalent in a significant proportion of buildings across most cities. Structures that are inclined or span over ground spaces still adhere to the same general principles. The diagram illustrates that density is regulated by building height, but it does not originate from it; building

height is not a reliable predictor of total built area, as it is contingent upon the footprint and floor area ratio.

The indicators of commercial spaces within the streets primarily include the land use mix on both sides of the street, storefront density, transparency, the percentage of gray space, and signage density. Specifically, (1) the land use mix on both sides of the street refers to the fact that commercial mixed-use streets with urban traffic functions typically do not consist solely of commercial functions; they often include mixed residential and commercial land uses, as well as mixed office and commercial uses. Therefore, the foot traffic attracted to these commercial mixed-use areas includes not only local residents but also visitors and office workers; (2) storefront density is defined as the number of commercial unit entrances per 100 meters along each street segment, calculated using the formula: storefront density = total number of storefronts / length of the street segment × 100%. This includes: ① fully open storefronts, where the interior layout is directly visible; ② storefronts with transparent glass windows allowing visibility into the interior; ③ storefronts with advertising-style glass windows showcasing product displays; ④ storefronts obscured by opaque walls or flat advertisements. The formula for transparency is as follows: transparency = (length of type ① interfaces × 1.25 + length of type ② interfaces + length of type ③ interfaces × 0.75) / total length of the building interface along the street segment. The percentage of gray space refers to the ratio of the area of building overhangs or second floors extending over the street to the total street area per 100 meters of each segment. The formula is: gray space percentage = area of overhead buildings within the segment / total area of the segment × 100%. (3) Signage density reflects the volume of advertisements from businesses along the street, indicating the extent to which businesses provide information about their products to pedestrians. The density of street signage is defined as the ratio of the number of signs per 100 meters to the length of the street.

The metrics for office spaces within urban environments can be categorized into various types, including business office spaces, open-plan offices, semi-open offices, and unit offices. The indicators for office spaces are analogous to those for residential spaces, primarily relying on the floor area ratio and the height requirements of the office area for regulation. However, it is important to note that office buildings often consist predominantly of business-oriented structures, which are composed of one or more types of office spaces.

The indicators for public spaces within streets primarily include the open space ratio, which refers to the proportion of total open space to total built area, without distinguishing between private and public spaces. In addition to the open space ratio, public space indicators also encompass metrics such as the satisfaction rate of cultural facilities as outlined in the 2019 SDG Index and Dashboards Report for European Cities (prototype version) and the EU SDG Indicator set 2020. These metrics include the ratio of landmarks, surface area, museums, concerts, exhibitions, historical preservation buildings, and the coverage of accessible facilities in public spaces. In the context of public space indicators, The populations of "visitors," "residents," and "workers" cannot be aggregated for determining the overall population, as several local visitors serve as substitutes for residents and workers who would otherwise occupy various areas. This is shaped by the urban dynamics of production, consumption, entertainment, leisure, and mobility. The assessment of "visitors" merely indicates the distinction between local and global movements. The ratio of visitors will fluctuate according to functional makeup, employment rates, and industry categories; for instance, in dormitory suburbs, industrial districts, and tourist locales, the visitor count may be less than or beyond the number of absent residents and employees. As a result, we establish a definitive statistic termed street life density.

5. The process and content of model development

First, taking mixed-use streets as an example, I will analyze the components that contribute to street density, which include residential areas, commercial spaces, office spaces, and public spaces. Public spaces can take various forms, such as landmarks, historical buildings, museums, concert venues, and exhibition halls. Each type of building corresponds to specific sustainability indicators, such as the cultural facility satisfaction ratio and landmark ratio found in the 2019 SDG Index and Dashboards Report for European Cities (prototype version) and the EU SDG Indicator set 2020. Additionally, commercial spaces are characterized by the land-use mix on both sides of the street, storefront density, transparency, percentage of gray space, and signage density. By integrating aspects of residential, commercial, office, and public spaces, I will collaboratively establish a density model. Furthermore, I will incorporate human density, as the density of people and buildings is inherently interconnected. Building upon this, I will create a model that combines street density and population density to effectively illustrate urban density.

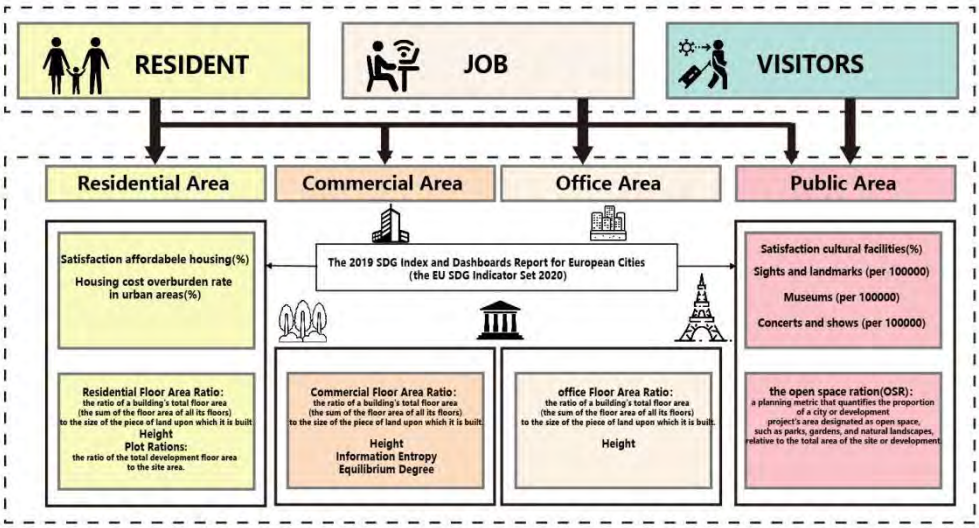


Fig. 1. Graphical representation of sustainable index model. Self-Illustrated by the Author.

This article establishes a framework for rethinking urban density. If density can be measured and interrelated in this manner, then urban density can be reinterpreted, allowing for transformations in cities through urban design and planning. Urban density plays a crucial role in urban sustainability for several reasons: efficient land use, reduced infrastructure costs, energy efficiency, the viability of public transportation, economic vitality, affordability, resource conservation, resilience, and equity.

In practice, various density control mechanisms have been developed based on these concepts, such as floor area ratio, building envelope, coverage ratio, and open space ratio. Despite the existence of such research and practice, creating a model that can capture the interactions between these diverse concepts and measurements has proven to be challenging. Urban density is not merely an attribute of buildings or individuals, but rather the spatial relationships between them; between buildings, between people, and between people and buildings. This paper presents a comprehensive approach to conceptualizing urban density, aimed at clarifying and connecting key concepts within a broader combinatorial theoretical framework. The model integrates residential space indicators, commercial space indicators, office space indicators, and public space indicators within the streets, collectively forming a comprehensive mixed-use indicator model. In the future, this model can be widely applied to enhance the sustainability of urban density by demonstrating the relationships between densities and exploring the connections between sustainability indicators.

The indicators of residential spaces within urban streets primarily encompass apartments, detached villas, semi-detached villas, townhouses, low-rise multi-family residences, and affordable housing's floor area ratio, along with the building heights specific to the designated study area. These indicators are regulated by both the floor area ratio and building height. This relationship, however, has exceptions, as not all built areas are above ground, nor do all structures possess clearly defined footprints and vertical walls. Nonetheless, this correlation is prevalent in a significant proportion of buildings across most cities.

6. References

Alvarado-Herrera, A., Bigne, E., Aldas-Manzano, J., and Curras-Perez, R. (2017) 'A scale for measuring consumer perceptions of corporate social responsibility following the sustainable development paradigm', J. Bus. Ethics, 140, pp. 243–262. https://doi.org/10.1007/s10551-015-2654-9

Amran, A., Ooi, S.K., Mydin, R.T., and Devi, S.S. (2015) 'The impact of business strategies on online sustainability disclosures', *Bus. Strategy Environ*, 24, pp. 551–564. https://doi.org/10.1002/bse.1837

Baumgärtner, S., Quaas, M. (2010) 'Sustainability economics—general versus specific, and conceptual versus practical', *Ecol. Econ*, Special Section - Payments for Ecosystem Services: From Local to Global, 69, pp. 2056–2059. https://doi.org/10.1016/j.ecolecon.2010.06.018

Beckerman, W. (1992) 'Economic growth and the environment: Whose growth? whose environment?', *World Dev*, 20, pp. 481–496. https://doi.org/10.1016/0305-750X(92)90038-W

Bina, O. (2013) 'The green economy and sustainable development: An uneasy balance?', *Environ. Plan. C Gov. Policy*, 31, pp. 1023–1047. https://doi.org/10.1068/c1310j

Daly, H.E. (2006) 'Sustainable development—definitions, principles, policies', in Keiner, M. (ed.) *The Future of Sustainability*. Dordrecht: Springer Netherlands, pp. 39–53. https://doi.org/10.1007/1-4020-4908-0_2

Dangelico, R.M., and Pontrandolfo, P. (2015) 'Being "green and competitive": The impact of environmental actions and collaborations on firm performance', *Bus. Strategy Environ*, 24, pp. 413–430. https://doi.org/10.1002/bse.1828

Folke, C. (2006) 'Resilience: The emergence of a perspective for social–ecological systems analyses', *Glob. Environ*, Change, Resilience, Vulnerability, and Adaptation: A Cross-Cutting Theme of the International Human Dimensions Programme on Global Environmental Change, 16, pp. 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Gouda, S., Kerry, R.G., Das, G., Paramithiotis, S., Shin, H.-S., and Patra, J.K. (2018) 'Revitalization of plant growth promoting rhizobacteria for sustainable development in agriculture', *Microbiol. Res*, 206, pp. 131–140. https://doi.org/10.1016/j.micres.2017.08.016

Lambert, A.J.D., and Boons, F.A. (2002) 'Eco-industrial parks: Stimulating sustainable development in mixed industrial parks', *Technovation*, 22, pp. 471–484. https://doi.org/10.1016/S0166-4972(01)00040-2

Lathuillière, M., Coe, M., Castanho, A., Graesser, J., and Johnson, M. (2018) 'Evaluating water use for agricultural intensification in southern Amazonia using the water footprint sustainability assessment', *Water*, 10, pp. 349. https://doi.org/10.3390/w10040349

Luke, T.W. (2005) 'Neither sustainable nor development: Reconsidering sustainability in development', *Sustain. Dev*, 13, pp. 228–238. https://doi.org/10.1002/sd.284

Mitlin, D. (1992) 'Sustainable development: A guide to the literature', *Environ. Urban*, 4, pp. 111–124. https://doi.org/10.1177/095624789200400112

Spangenberg, J.H. (2002) 'Environmental space and the prism of sustainability: Frameworks for indicators measuring sustainable development', *Ecol. Indic*, 2, pp. 295–309. https://doi.org/10.1016/S1470-160X(02)00065-1

Suárez-Eiroa, B., Fernández, E., Méndez-Martínez, G., and Soto-Oñate, D. (2019) 'Operational principles of circular economy for sustainable development: Linking theory and practice', *J. Clean. Prod*, 214, pp. 952–961. https://doi.org/10.1016/j.jclepro.2018.12.271

Research Paper

Study on the Evolutionary Characteristics of County Town Shrinkage and Planning Response Strategies under Multi-Dimensional Framework：Taking the Three Northeastern Provinces of China as an Example

Cheng SHI, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology Ministry of Industry and Information Technology, China

Xiaoxiang, YI, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology Ministry of Industry and Information Technology, China

Yibo LIU, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology Ministry of Industry and Information Technology, China

Abstract

With intensifying regional disparities, the number of shrinking cities in China has risen, particularly in areas facing not only population loss but also economic recession, structural challenges, and fiscal deficits. This threatens China's strategy to promote county towns as hubs of urbanization. This study analysed contraction patterns in northeastern county towns through a four-step framework: (1) constructing a multi-dimensional measurement system with an entropy-weighted index; (2) using correlation and grey relational analysis to examine inter-dimensional relationships; (3) developing a model of multi-dimensional shrinkage interactions; and (4) proposing targeted planning strategies. Key findings include: (1) Over 90% of the 178 county towns in the northeast have experienced population shrinkage, about 50% show economic contraction, and less than 10% exhibit social contraction; (2) Between 2006 and 2020, most counties faced ongoing population shrinkage, with equal parts experiencing deepening and stabilizing trends. Economic shrinkage progressed from initial growth to continuous contraction, with towns increasingly polarizing into "persistent shrinkage" or "persistent growth"; (3) Shrinkage remains largely single-dimensional, with two-dimensional shrinkage (mainly "population-economic") affecting about 20% of towns, while comprehensive shrinkage is rare; (4) There is a significant correlation between shrinkage dimensions in the early stages, which weakens over time. This study's multi-dimensional analysis of shrinkage in northeastern county towns offers insights into contraction patterns and proposes planning and policy recommendations.

Keywords

Shrinking city, Measurement, Evolutionary Characteristics, Response Strategies, County towns of China

1. Introduction

Urban shrinkage is a new challenge in China's push for urbanization. With growing regional disparities, shrinking cities in China have become more numerous, multidimensional, and severe in recent years(Guan, He and Hu, 2021; Zhang *et al.*, 2024). County-level towns, in particular, face greater shrinkage pressures due to their larger base numbers and weaker attraction for population inflows, leading to more diverse forms of urban decline. Population shrinkage in these areas is often accompanied by socio-economic recession, creating a "downward spiral" and "structural decay" that makes reversing the trend especially difficult(Lee, Won and Kim, 2016; Liu, 2022). In 2022, the country proposed a new deployment for county-level urbanization construction, clarifying that county towns will be the main body of future urbanization development. However, the phenomenon of urban shrinkage in county towns hinders the smooth progress of this deployment. Therefore, it is necessary to investigate and analyze the urban shrinkage situation in county towns, grasp the laws of county town shrinkage, and take targeted measures to respond(Tong *et al.*, 2022)..

The identification and measurement of urban shrinkage can be mainly divided into four methods: socio-economic indicators, spatial statistics, geographic landscape detection, and new data analysis (Jiang *et al.*, 2020; Lang, Deng and Li, 2020; Tan *et al.*, 2023). Most studies focus on national, regional, or prefecture-level scales, with limited research on county-level shrinkage. While some foundational research has examined multi-dimensional shrinkage—covering economic, social, and spatial aspects, while studies on the interrelations between these dimensions remain scarce(Lee, Hye-Jin and Jae-Su, 2018; Li and Mykhnenko, 2018; He *et al.*, 2023; Zhang *et al.*, 2024).

In light of this gap, this study focuses on the three northeastern provinces of China, which face the most severe urban shrinkage. Taking county-level towns in these provinces as the study subject, we aim to address the following questions: (1) What are the primary characteristics of urban shrinkage in population, economic, and social dimensions across the northeastern provinces? (2) What are the spatiotemporal evolution patterns of multi-dimensional shrinkage in these county towns? (3) What interrelationships exist among the different dimensions of shrinkage in these areas? (4) What policy recommendations can be made to improve governance in shrinking cities based on these findings?

To address these questions, this study develops a multi-dimensional measurement system for shrinkage, using correlation analysis and grey relational analysis to explore the patterns of interrelated shrinkage dimensions. Based on these findings, we propose practical strategies for urban governance.

2. Study Area and Research Methods

2.1. Study Area

The three provinces of Northeast China (TPNC) are collectively known as Heilongjiang Province, Jilin Province, and Liaoning Province, with a total of 34 prefecture level cities under their jurisdiction, including 141 municipal districts, 54 county-level cities, and 92 counties, totaling 287 county-level administrative units (as shown in the picture). They are important industrial bases, grain production bases, and foreign trade gateways in China, and also have abundant resources such as timber and minerals.

2.2. Measurement Methods and Data Collection

This study addresses the complexity of urban shrinkage by adopting a multidimensional framework that considers population, economic, and social dimensions. Following principles of scientific rigor and

systematic analysis, and drawing on existing literature and county-level data, an 8-indicator measurement system was developed(Schetke and Haase, 2008; Wang *et al.*, 2021; Chen *et al.*, 2024).

For the population dimension, shrinkage is measured through population size and change rate. Population size reflects the total resident count and serves as the primary indicator of urban shrinkage, while the rate of population change captures the intensity of population fluctuations, indicating the speed and severity of shrinkage—key for assessing the depth and trajectory of urban decline(Turok and Mykhnenko, 2007, 2007).

In the economic dimension, shrinkage is reflected in low economic development (especially low per capita GDP), slowing growth, and an imbalanced economic structure. Indicators include per capita GDP and fiscal revenue (reflecting economic strength), GDP growth rate (indicating growth trends), and the proportion of secondary and tertiary industries in GDP, which suggests industrial and service sector vitality(Fleschurz and Pallagst, 2016).

The social dimension focuses on fiscal imbalances and the quality of public services. Indicators include hospital beds per 10,000 people (measuring public service quality) and local general budget expenditures (measuring social investment). Together, these indicators assess the capacity of social infrastructure to support urban development(Glaeser and Gottlieb, 2006; Cheshire and Magrini, 2009).

Based on this analysis, a multi-dimensional measurement system for urban shrinkage is constructed, as shown in Table 1.

Table 1. Multi-Dimensional Measurement System for Shrinkage in County-Level Town. Source: Self Drawing.

Goal Level	Criterion Level	Indicator Level	Formula	Unit
Population Dimension	Population Size	Total Population	Year-end population (permanent residents)	10,000 people
	Change Rate	Population Change Rate	(Population at end of period - Population at start of period) / Population at start of period * 100%	%
Economic Dimension	Economic Level	Per Capita GDP	GDP per capita	Yuan
		Per Capita Fiscal Revenue	Local fiscal budget revenue / Total population	Yuan
	Economic Growth	GDP Growth Rate	GDP growth rate	%
	Economic Structure	Industrial Structure Index	(Value added by tertiary sector + Value added by secondary sector) / GDP	%
Social Dimension	Social Services	Public Services	Hospital beds per 10,000 people	Beds
	Social Investment	Fiscal Expenditure	Local general budget expenditure	Yuan

This study takes a macro-level approach, primarily using government statistics or open data. Ultimately, the study covers 178 county-level or district-level units. The data spans from 2000 to 2020, sourced mainly from the China County Statistical Yearbook, Heilongjiang Statistical Yearbook, Liaoning Statistical Yearbook, Jilin Statistical Yearbook, China City Statistical Yearbook, and economic and social development statistical bulletins of various counties and cities.

2.3. Analytical Framework

The analysis of urban shrinkage evolution is divided into three main aspects: spatial evolution patterns, temporal evolution patterns, and multi-dimensional shrinkage correlations(Guo *et al.*, 2021; Song, He and Zeng, 2023; Zhang *et al.*, 2023).

(1) Spatial Evolution Analysis of Shrinking Towns

The study of spatial evolution focuses on two areas: spatial distribution and spatial pattern. The spatial distribution analysis identifies the changing spatial characteristics of shrinking towns across dimensions over time. Spatial pattern analysis, on the other hand, examines the shifting centers of shrinkage and clustering characteristics of shrinking towns.

(2) Temporal Evolution Analysis of Shrinking Towns

Temporal evolution is analyzed in terms of shrinkage intensity and shrinkage dimension patterns. Shrinkage intensity analysis categorizes towns based on the temporal patterns of their multi-dimensional shrinkage, capturing overall trends in urban shrinkage. Shrinkage dimension analysis examines the changes in the combinations of shrinkage dimensions, tracking the increase or decrease in shrinkage across dimensions to capture the general trends in multi-dimensional shrinkage.

(3) Multi-Dimensional Shrinkage Correlation Analysis

The multi-dimensional correlation analysis includes two parts: correlation testing and interaction analysis. The correlation test applies Spearman correlation to assess the relationships and trends among different shrinkage dimensions. The interaction analysis breaks down shrinkage indicators by dimension and uses grey relational analysis to examine the influence of each dimension on others, constructing a theoretical framework for understanding the interrelationships in multi-dimensional shrinkage.

2.4. Analytical Framework

(1) Measurement Calculation Method

First, the range method is used to normalize the indicators to eliminate units. Given n years and m indicators, X_{ij} represents the j-th indicator in year i (i= 1,2⋯,n; j= 1,2,⋯,m). Since all indicators are positive in this study, the normalization formula is as follows:

$$X_{ij}{}' = \frac{X_{ij} - minX_j}{maxX_j - minX_j} \tag{1}$$

Second, indicator weights are determined using the entropy method to ensure objectivity and accuracy. The steps are as follows:

Proportion of the j-th indicator in year i:

$$P_{ij} = \frac{X_{ij}{}'}{\sum_{i=1}^{n} X_{ij}{}'} \tag{2}$$

Entropy value of the j-th indicator:

$$E_j = -\frac{X_{ij}{}'}{\ln(n)} \sum_{i=1}^{n} P_{ij} \ln(P_{ij}) \tag{3}$$

Redundancy of the j-th indicator:

$$d_j = 1 - E_j \tag{4}$$

Weight of each indicator W_j:

$$W_j = \frac{1 - E_j}{\sum_{j=1}^{m}(1 - E_j)} \tag{5}$$

Finally, each dimension's development index and shrinkage index for each year are calculated.

Development Index Z_i for year i:

$$Z_i = \sum_{j=1}^{m}(W_j X_{ij}') \tag{6}$$

Shrinkage Index SK_i for year i, comparing with the previous year:

$$SK_i = (Z_i - Z_{i-1}) \times 100\% \tag{7}$$

A smaller SK_i indicates a greater level of shrinkage compared to the previous year, and vice versa. Equation (7) can also be applied to calculate shrinkage over longer time spans by comparing development indices over those periods.

(2) Classification of Shrinkage Levels

Using ArcGIS 10.5, the Natural Breaks (Jenks) method is applied to classify shrinkage levels for each dimension into six categories: high, moderate, and mild shrinkage, as well as mild, moderate, and high growth (Table 2). This classification allows for a comprehensive understanding of the shrinkage level, dimensional characteristics, and regional disparities across counties and towns in the three northeastern provinces of China.

Table 2. Thresholds for Shrinkage Levels in County-Level Towns. Source: Self Drawing.

Dimension	Thresholds					
	High shrinkage	Moderate shrinkage	Mild shrinkage	Mild growth	Moderate growth	High growth
Population	R≤-7.4%	-7.4%<R≤-3.2%	-3.2%<R≤0%	0% < R≤3.3%	3.3% < R≤9.7%	9.7% < R
Economic	R≤-17.1%	-17.1% < R≤-7.8%	-7.8% < R≤0%	0% < R≤7.1%	7.1% < R≤14.8%	14.8% < R
Social	R≤-6.6%	-6.6% < R≤-2.7%	-2.7% < R≤0%	0% < R≤6.1%	6.1% < R≤13.9%	13.9% < R

(3) Weighted Mean Center Calculation

Since higher negative values in the shrinkage index indicate greater shrinkage, and positive values indicate growth, the shrinkage index is inverted for use as a weight. The weight w_i for element i representing its shrinkage level is calculated as:

$$w_i = -SK_i \tag{11}$$

The weighted mean center coordinates $(\overline{x}, \overline{y})$ are then calculated as:

$$\overline{x} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} \quad , \quad \overline{y} = \frac{\sum_{i=1}^{n} w_i y_i}{\sum_{i=1}^{n} w_i} \tag{12}$$

(4) Directional Distribution

Directional distribution (standard deviation ellipse) is used to observe clustering direction and degree. The standard deviation ellipse is centered on the weighted mean center, with calculations as follows:

$$\tan\theta = \frac{A+B}{C}$$
$$A = \sum_{i=1}^{n}(x_i-\overline{x})^2 - \sum_{i=1}^{n}(y_i-\overline{y})^2$$
$$B = \sqrt{\left(\sum_{i=1}^{n}(x_i-\overline{x})^2 - \sum_{i=1}^{n}(y_i-\overline{y})^2\right)^2 + 4\left(\sum_{i=1}^{n}(x_i-\overline{x})(y_i-\overline{y})\right)^2} \tag{13}$$
$$C = 2\sum_{i=1}^{n}(x_i-\overline{x})(y_i-\overline{y})$$
$$\sigma_x = \sqrt{2}\sqrt{\frac{\sum_{i=1}^{n}((x_i-\overline{x})\cos\theta-(y_i-\overline{y})\sin\theta)^2}{n}}$$
$$\sigma_y = \sqrt{2}\sqrt{\frac{\sum_{i=1}^{n}((x_i-\overline{x})\sin\theta+(y_i-\overline{y})\cos\theta)^2}{n}}$$

In the above formula, $x_i$and y_i,represent the coordinates of element i,while $(\overline{x},\overline{y})$ denotes the coordinates of the mean center. θ represents the angle between the major axis and true north, σ_x is the length of themajor axis, σ_y is the length of the minor axis, and n is the total number of elements.

(5) Spearman Correlation Coefficient

The Spearman correlation coefficient is used to examine the relationship between two variables, x and y. Its formula is:

$$p = \frac{\sum_{i=1}^{n}(x_i-\overline{x})(y_i-\overline{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\overline{x})^2\sum_{i=1}^{n}(y_i-\overline{y})^2}} \tag{14}$$

Where x_i and y_i are values for each object *i*, and $\overline{x}$ and $\overline{y}$ are the mean values of x and y, respectively.

(6) Grey Relational Analysis

Grey Relational Analysis (GRA) measures the similarity in geometric patterns between a reference data series and characteristic data series to assess correlation strength, often used for examining nonlinear relationships.

Step 1: Define reference and characteristic sequences and normalize data (e.g., using initial or mean values):

$$[X_1' \quad X_2' \quad \dots \quad X_n'] = \begin{bmatrix} x_1'(1) & x_2'(1) & \cdots & x_n'(1) \\ x_1'(2) & x_2'(2) & \cdots & x_n'(2) \\ \vdots & \vdots & & \vdots \\ x_1'(m) & x_2'(m) & \cdots & x_n'(m) \end{bmatrix} \tag{15}$$
$$X_0' = (x_0'(1), x_0'(2), \dots, x_0'(m))^T$$

In the above formula, X_0' represents the reference sequence (also called the parent sequence), and $x_0'(m)$ denotes the value of the parent sequence at point m. $[X_1' \quad X_2' \quad \dots \quad X_n']$ represents the n-th characteristic sequence.

Step 2: Calculate the grey relational coefficient between each element of the comparison series and the reference series:

$$\gamma_{0i}(k) = \frac{\Delta min + \rho \Delta max}{\Delta_{ik} + \rho \Delta max}$$
$$\Delta min = \min_i \min_k |x_0(k) - x_i(k)| \quad (16)$$
$$\Delta max = \max_i \max_k |x_0(k) - x_i(k)|$$
$$\Delta_{ik} = |x_0(k) - x_i(k)|$$

In the above formula, $x_i(k)$ represents the grey relational coefficient for the k-th sample of the i-th characteristic sequence. ρ is the distinguishing coefficient, with a range of (0, 1); a smaller ρ value enhances the differentiation of relational degrees between different indicators.Typically, ρ is set to 0.5, and this study adopts the same value.

Step 3: Calculate the overall relational degree as the weighted average of the grey relational coefficients:

$$r_{0i} = \frac{1}{m} \sum_{k=1}^{m} \gamma_{0i}(k) \quad (17)$$

This analysis helps determine the interdependencies among shrinkage dimensions, useful for identifying influencing factors in urban shrinkage dynamics.

3. Study Area and Research Methods

3.1 Spatial Evolution Analysis of Multi-Dimensional Shrinkage

(1) Spatial Distribution Patterns

To examine the spatial distribution patterns of multi-dimensional shrinkage in county-level towns across the three northeastern provinces of China, this study analyzes the distribution of shrinking towns in each dimension over four time periods: 2001–2005, 2006–2010, 2011–2015, and 2016–2020 (as shown in Figure 1&2&3).

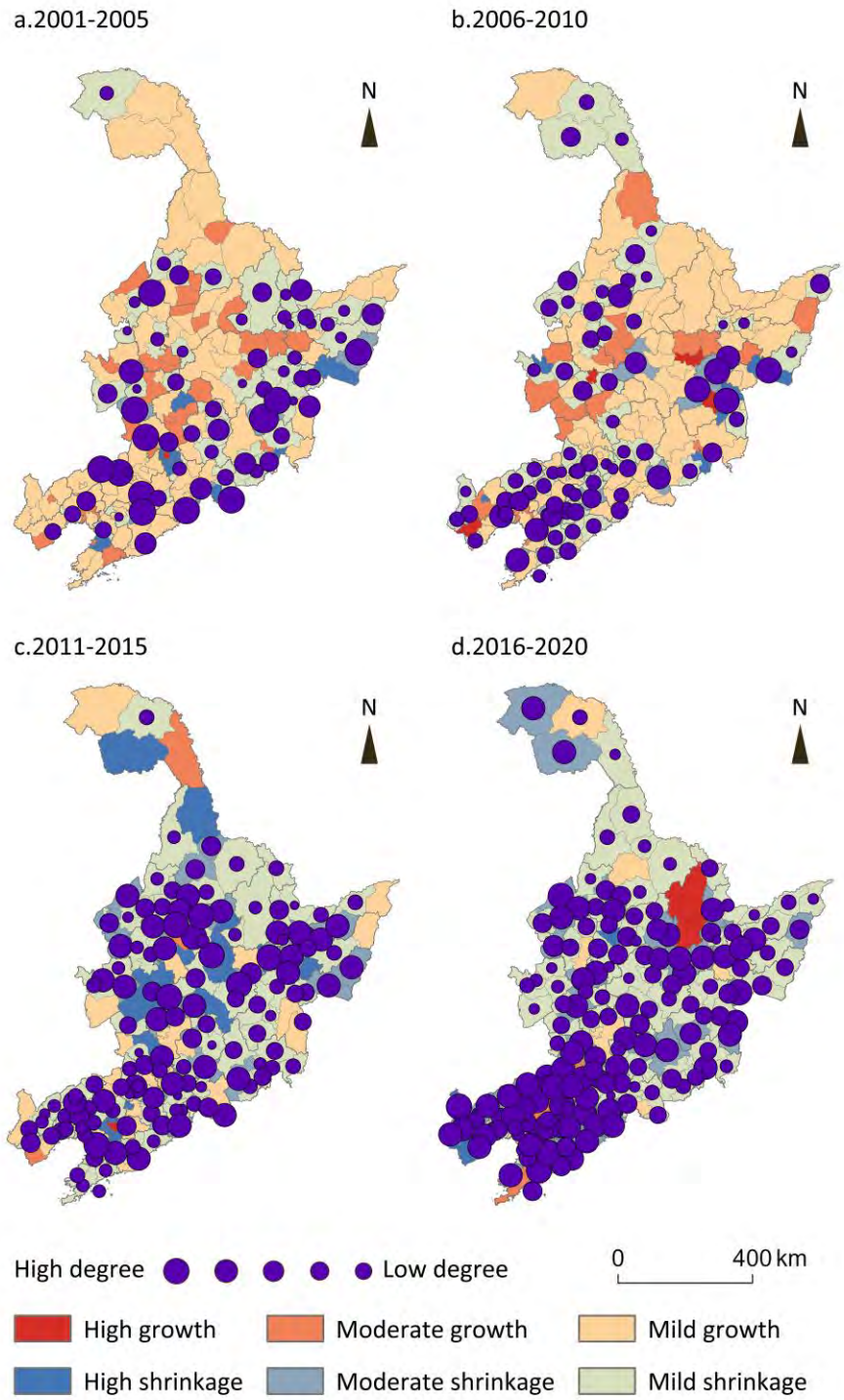


Figure 1. Analysis on the evolution of spatial distribution of towns in shrinking county. Source: Self Drawing

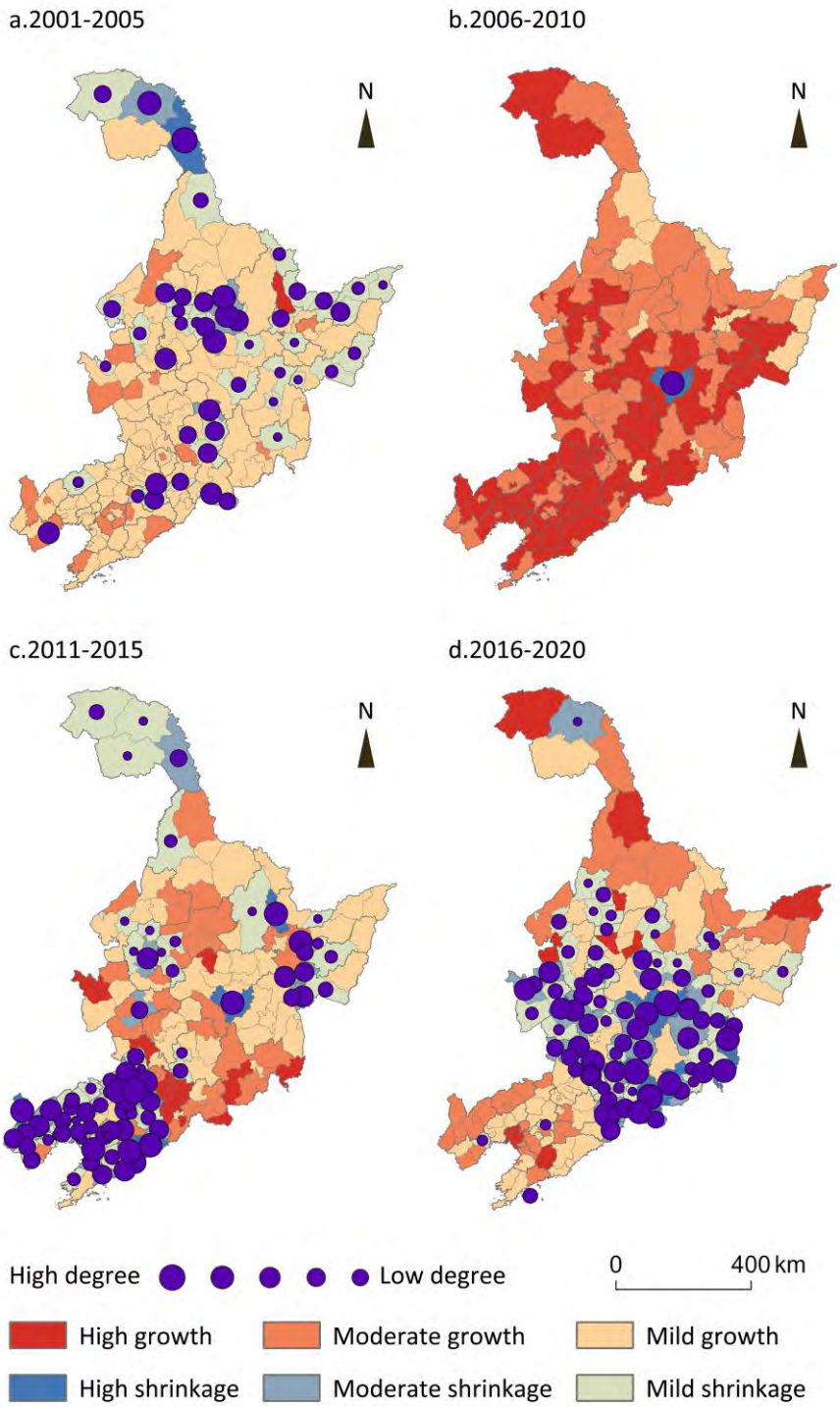


Figure 2. Analysis on the evolution of spatial distribution of cities and towns in counties with economic shrinking. Source: Self Drawing

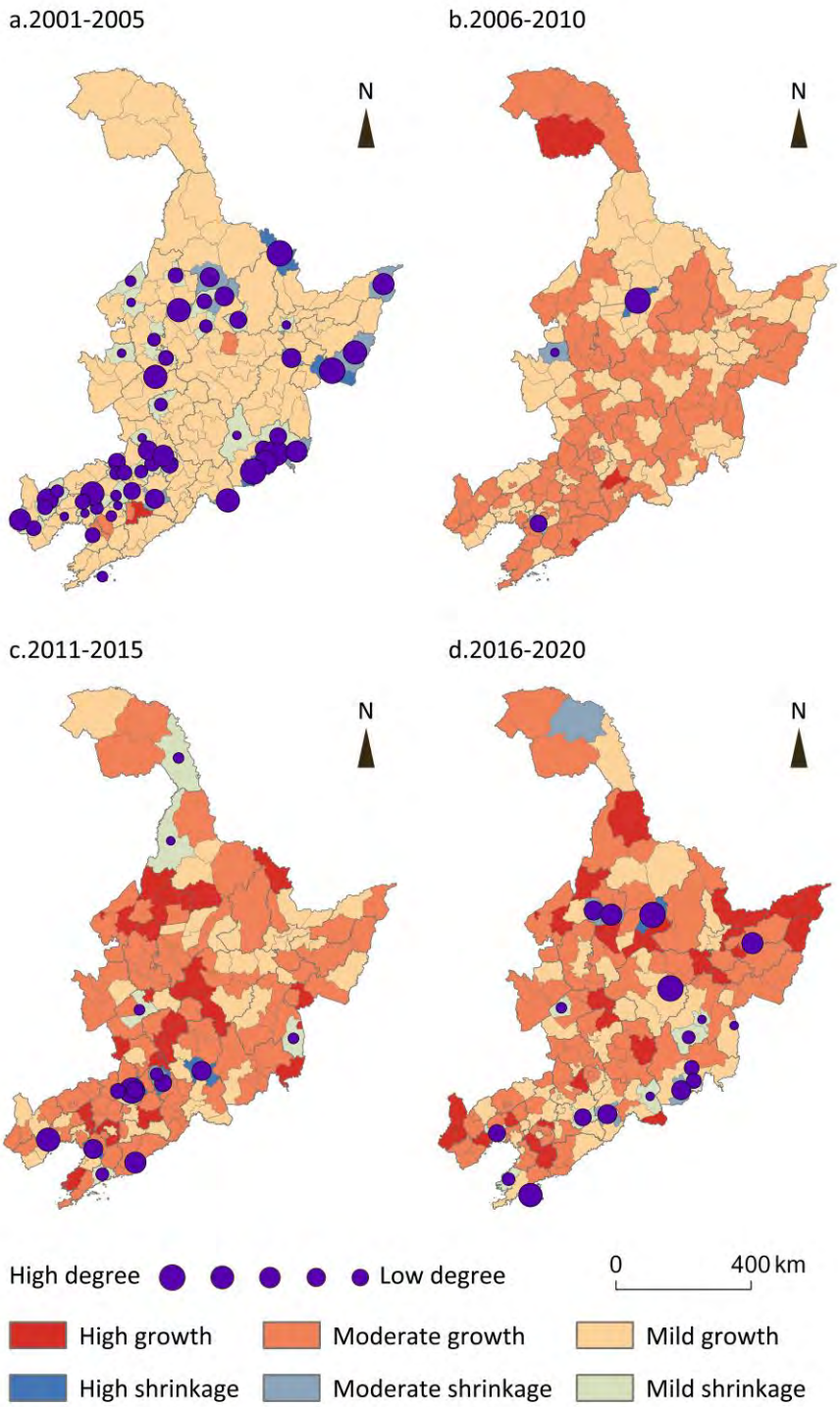


Figure 3. Analysis on the evolution of spatial distribution of towns in counties with social shrinking. Source: Self Drawing

In the population dimension, from 2001–2005, shrinkage was scattered across different regions of the three provinces, with no significant clustering of high-shrinkage towns. By 2006–2010, shrinkage became more concentrated in southeastern and western Heilongjiang and much of Liaoning, showing some spatial clustering. During 2011–2015, while shrinkage spread more widely, the northern and eastern borders of Heilongjiang experienced a slightly lower degree of shrinkage, and clustering remained weak. By 2016–

2020, most towns had fallen into shrinkage, especially in the southern regions, with high-shrinkage areas still concentrated mainly in Liaoning. Overall, the spatial distribution of population shrinkage evolved from a scattered pattern to partial clustering and eventually to widespread shrinkage, though clustering was generally weak.

In the economic dimension, economically shrinking towns initially appeared sporadically in the northern and eastern border areas of Heilongjiang from 2001–2005. However, from 2006–2010, most towns across the three provinces experienced economic growth, leaving only Shangzhi City in economic decline. During 2011–2015, shrinking towns were primarily concentrated in most of Liaoning and parts of Heilongjiang, showing significant clustering. By 2016–2020, economically shrinking towns were centered in the three provinces' central areas, particularly southern Jilin and southern Heilongjiang, while northern border areas showed strong growth. Economic shrinkage demonstrated consistent clustering, with shifting regional centers, indicating volatility in economic conditions.

In the social dimension, socially shrinking towns were evenly scattered across all four periods, with no significant clustering or distinct spatial distribution patterns.

In summary, population shrinkage in northeastern county-level towns evolved from scattered to widespread distribution, with weak clustering overall. Economic shrinkage showed clearer clustering across periods but with shifting centers, reflecting its volatility. Social shrinkage remained uniformly scattered, with no prominent clustering throughout the study period.

(2) Spatial Pattern Evolution

The spatial distribution analysis above shows that the 2011–2015 and 2016–2020 periods had the most significant shrinkage in population and economic dimensions. This section explores the evolution of spatial patterns for towns experiencing shrinkage in these two dimensions, by analyzing the average center of shrinkage and using the shrinkage degree as a weight to plot standard deviation ellipses for 2011–2015 and 2016–2020. The results are shown in Figures 4, while the coordinates of the average centers and the parameters of the standard deviation ellipses are listed in Table 3 and Table 4.

Table 3 . Average center and standard deviation ellipse for population shrinkage in county-level towns. Source: Self Drawing

Period	Center Longitude	Center Latitude	Short Axis Length	Long Axis Length	Orientation Angle
2011–2015	126.162034	44.832756	2.915568	4.817849	50.702558
2016–2020	125.179684	43.768928	2.904518	5.335846	53.804972

Table 4. Average center and standard deviation ellipse for economic shrinkage in county-level towns. Source: Self Drawing

Period	Center Longitude	Center Latitude	Short Axis Length	Long Axis Length	Orientation Angle
2011–2015	126.732861	44.703729	2.436813	5.468996	55.283068
2016–2020	126.753215	44.054627	2.571538	3.186308	104.770424

In terms of population, from 2011-2015 to 2016-2020, the center of population contraction shifted towards the southwest, indicating that the population outflow in the southwest direction was more severe than in the northeast direction. Geographically, this is consistent with the location of the inland border, and the closer the cities are to the inland area, the more severe the population outflow becomes. According to the distribution ellipse of the standard deviation of population shrinkage, the length of the short axis in 2016-2020 is slightly less than that in 2011-2015, while the length of the long axis is greater than that in 2011-2015. This indicates that the centripetal distribution of population shrinkage towns in the short axis

direction is more obvious, and the spatial distribution clustering has been improved. However, the directional distribution of population shrinkage towns in the long axis direction is more obvious. In other words, the distribution range and dispersion degree of population shrinkage towns in the southwest and northeast directions are expanding, and overall, the ellipticity has decreased, and the distribution of shrinkage towns is more scattered. However, the direction of the major axis of the ellipse did not change significantly during the two time periods, so the concentrated axial distribution of shrinking towns did not change much, roughly fitting a straight line passing through the centers of Harbin, Changchun, and Shenyang.

In summary, with the development of time, the population shrinkage of counties and cities in the three provinces of Northeast China has become increasingly severe from the border to the inland. The overall distribution shows a clustering of the northeast and southwest axes, and the degree of dispersion is gradually increasing. The population shrinkage is becoming more uniform.

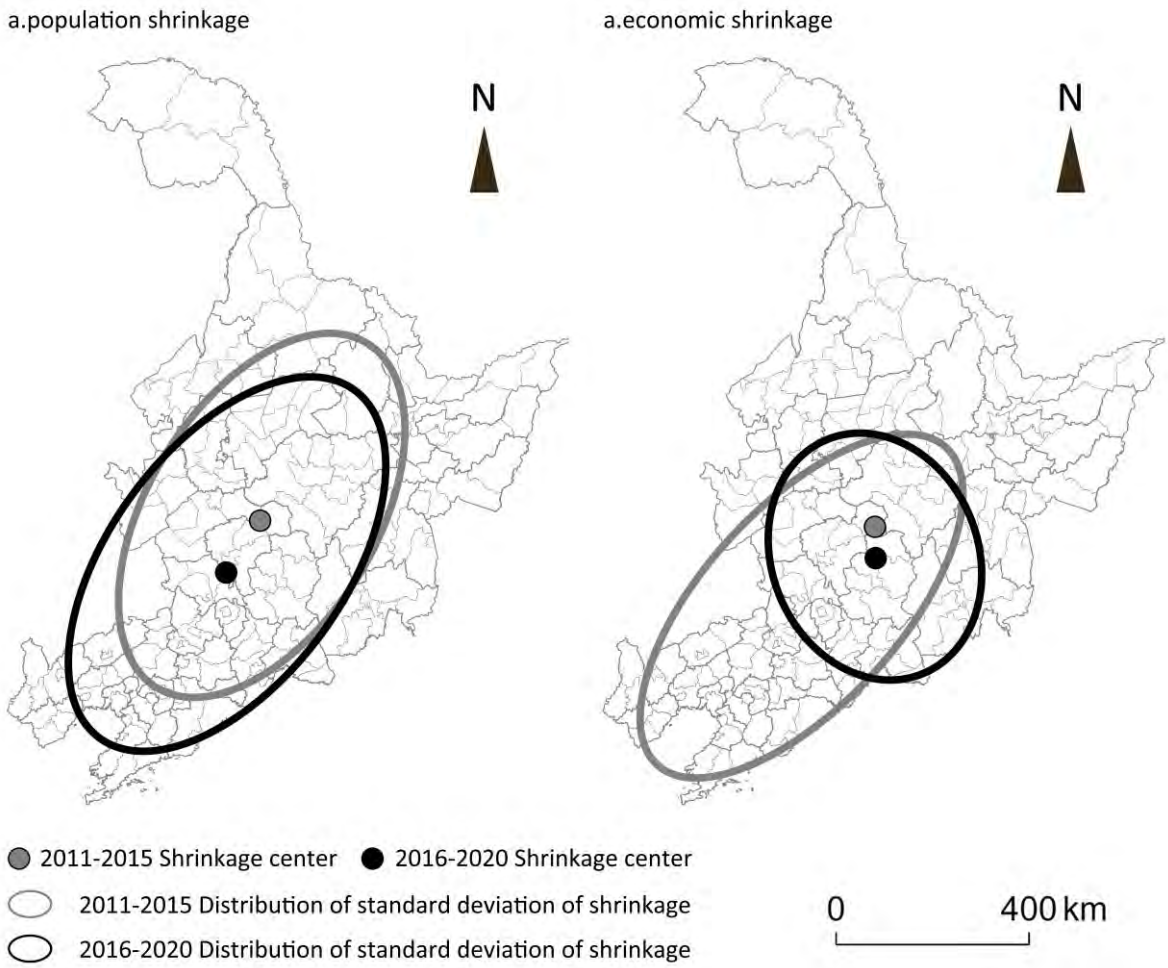


Figure 4. Analysis of the spatial pattern evolution of population shrinkage and economic shrinkage in county-level towns. Source: Self Drawing

In the economic dimension, from 2011-2015 to 2016-2020, the center of economic contraction shifted towards the southeast direction, indicating a stronger trend of economic recession intensification in the southeast direction. According to the distribution ellipse of the standard deviation of economic contraction, the length of the short axis in 2016-2020 is slightly greater than that in 2011-2015, while the length of the long axis is much smaller than that in 2011-2015. This indicates that the directional distribution of population shrinking towns in the short axis direction is more obvious, and the spatial distribution dispersion has improved. However, the clustering of population shrinking towns in the long axis direction is more obvious. That is to say, the distribution range of shrinking towns in the northwest and southeast directions is shrinking, and the degree of clustering is increasing. Overall, the ellipticity has increased, and the distribution of shrinking towns is more clustered. The direction of the major axis of the ellipse changed dramatically during the two periods, shifting from southwest and northeast to northwest and southeast, indicating that the economically contracted towns in the northwest and southeast directions were more concentrated and distributed. In summary, with the development of time, the main clustering direction of economically contracted towns in the counties of the three northeastern provinces has shifted from the northeast and southwest axes to the northwest and southeast axes, and the degree of clustering is gradually increasing. Economically contracted towns tend to appear more concentrated.

3.2 Spatial Evolution Analysis of Multi-Dimensional Shrinkage

(1) Analysis of Shrinkage Intensity Evolution

In order to further study the temporal evolution of shrinkage intensity in different dimensions of county-level towns in the three provinces of Northeast China, this section examines the changes in shrinkage intensity from 2006 to 2010, 2011 to 2015, and 2016 to 2020. The analysis focuses on the evolution of shrinkage intensity between consecutive periods and the relationships between these changes. The primary method involves plotting scatter diagrams with shrinkage intensity from the previous period on the horizontal axis and shrinkage intensity from the following period on the vertical axis. These scatter diagrams are divided into eight zones, representing eight types of shrinkage evolution. The classification criteria for each type of evolution pattern between periods i and j are shown in Table 5, and the zoning method is illustrated in Figure 5.

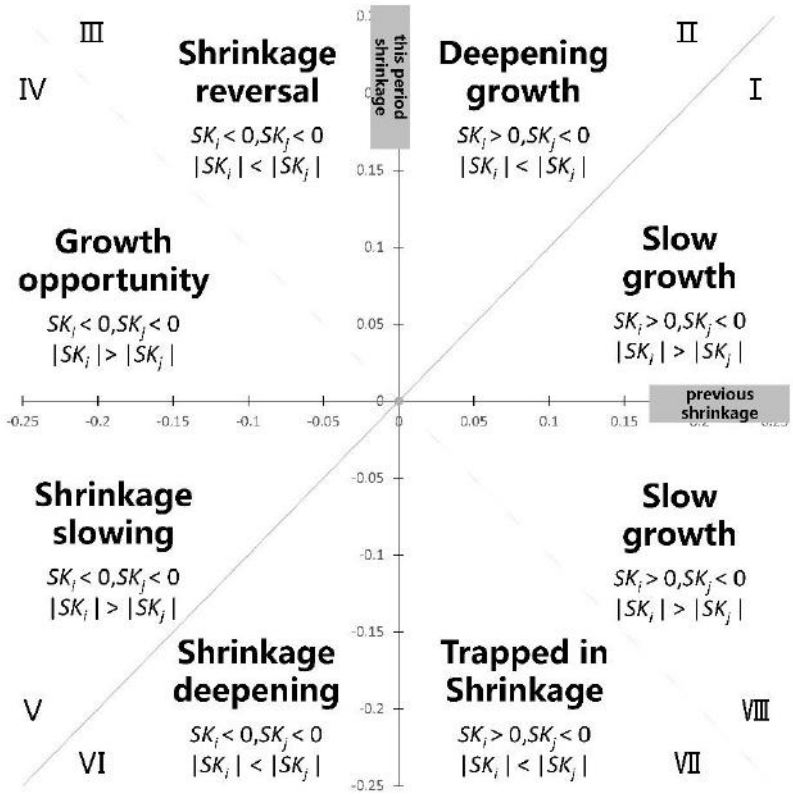
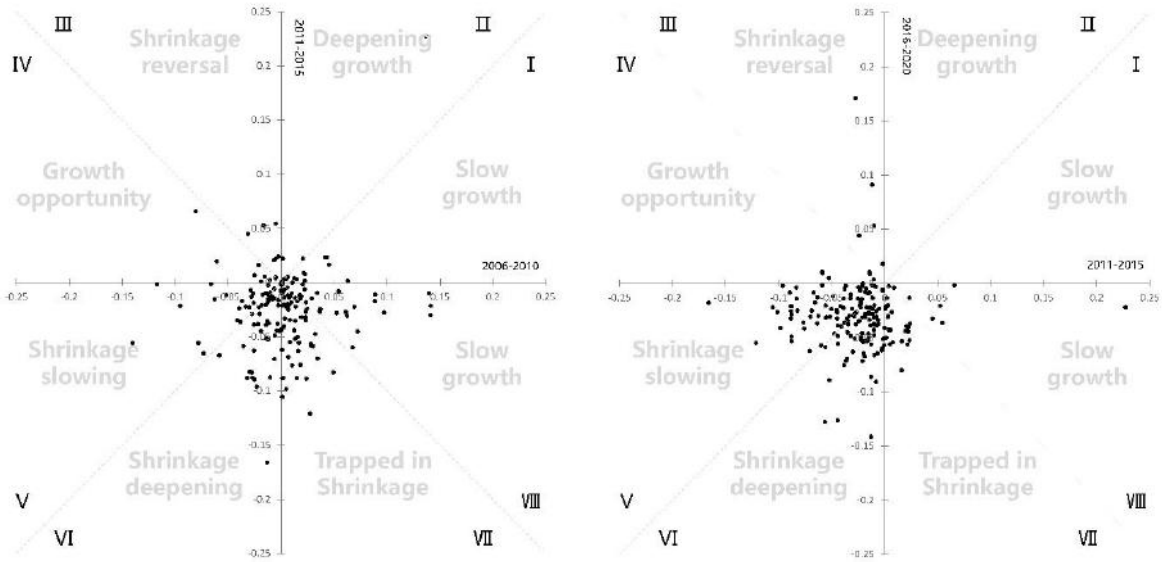


Figure 5. Schematic diagram of classification standard of shrinking evolution mode. Source: Self Drawing

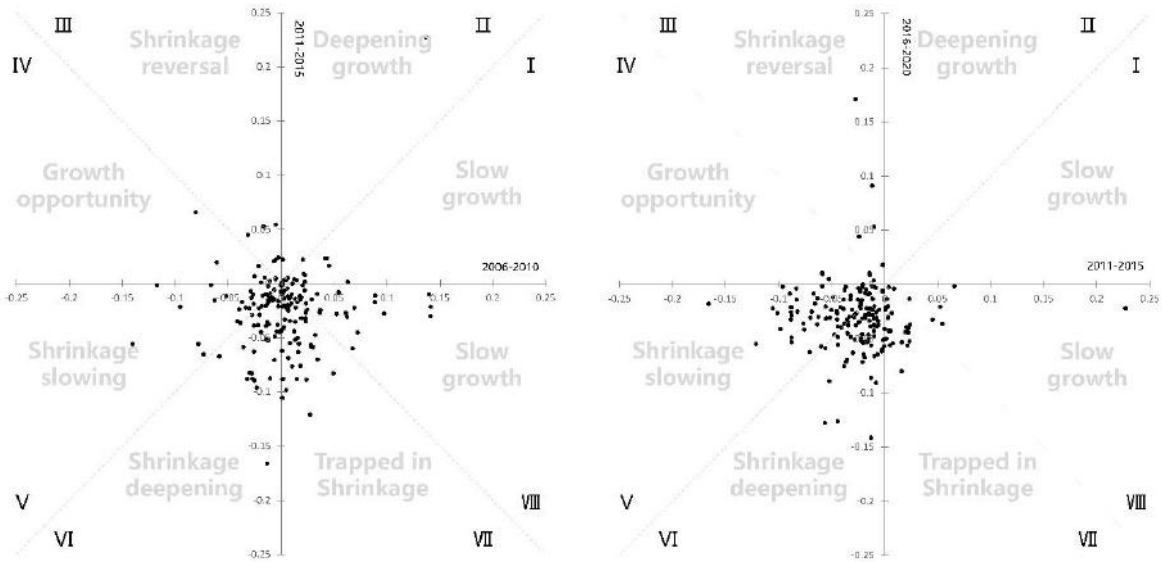
Table 5. Classification Criteria for Shrinkage Evolution Patterns. Source: Self Drawing.

Major categories	Subclass	Partition principle
Continuous growth	Deepening growth	Both periods growth, and the growth rate in the later period is higher
	Slow growth	Both periods growth, and the growth rate in the later period is lower
Continuous shrinking	Shrinkage deepening	Both periods shrinking, and the growth rate in the later period is higher
	Shrinkage slowing	Both periods shrinking, and the growth rate in the later period is lower
First increase and the n decrease	Trapped in Shrinkage	Growth followed by shrinking, and the degree of shrinking is higher
	Shrinkage risk	Growth followed by shrinking, and the degree of shrinking is lower
Shrink first and then e nlarge	Shrinkage reversal tr ansformation	Shrinking followed by growth, and the degree of shrinking is higher
	Growth opportunity	Shrinking followed by growth, and the degree of shrinking is lower



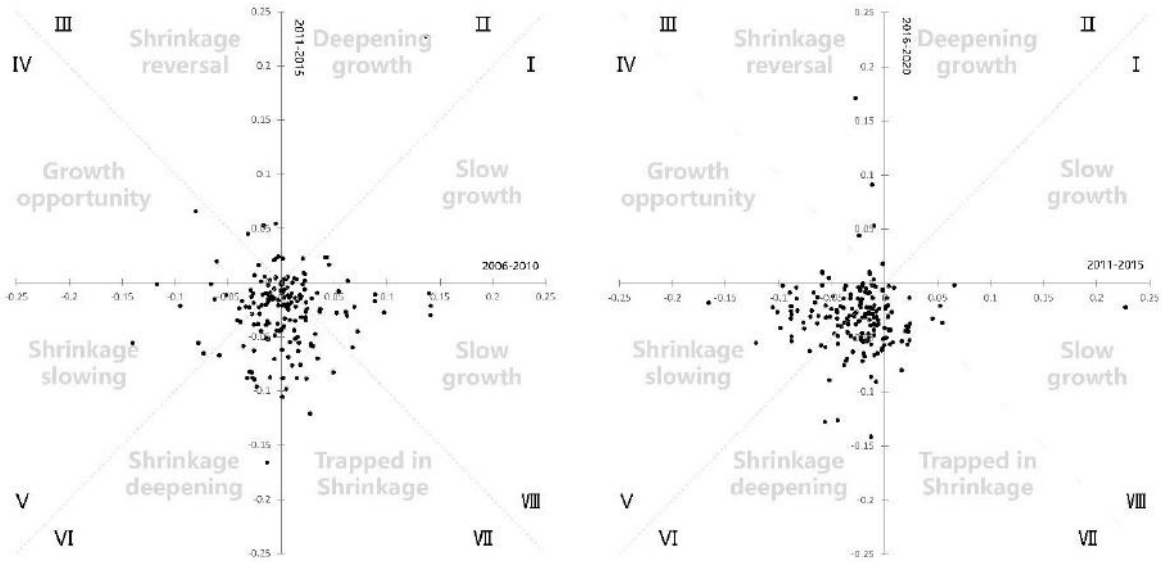
a. From 2006-2010 to 2011-2015 b. From 2011-2015 to 2016-2020

Figure 6. Analysis on the evolution of shrinking degree: population dimension



a. From 2006-2010 to 2011-2015 b. From 2011-2015 to 2016-2020

Figure 7. Analysis on the evolution of shrinking degree: economic dimension



a. From 2006-2010 to 2011-2015 b. From 2011-2015 to 2016-2020

Figure 8. Analysis on the evolution of shrinking degree: social dimension

In the population dimension (Figure 6), most towns experienced shrinkage between 2011–2015, with many of the towns that had grown from 2006–2010 shifting to shrinkage. The degree of shrinkage often exceeded the previous growth levels. Towns that were already shrinking in 2006–2010 generally continued to shrink, with half showing deeper shrinkage and the other half slowing down. A few towns even displayed potential for population shrinkage reversal. From 2011–2015 to 2016–2020, shrinkage intensified; all towns that had grown in the previous period fell into shrinkage, with most experiencing more severe shrinkage than their previous growth. In summary, the most common patterns are transitions from growth to sustained shrinkage or from initial shrinkage to continued shrinkage, showing a trend toward consistent and widespread population decline.

In the economic dimension (Figure 7), most urban areas saw economic growth between 2006–2010, followed by a mixed pattern of shrinkage and continued growth from 2011–2015. Towns with sustained growth often experienced slowing growth rates, while towns with shrinkage faced relatively mild declines, indicating a risk of future shrinkage without severe downturns. From 2011–2015 to 2016–2020, a marked polarization occurred, with towns either in "sustained growth" or "sustained shrinkage" categories. Towns switching between growth and shrinkage were few, indicating a trend where economic trajectories are becoming increasingly fixed. Overall, economic development across the periods resembles a process of "peeling off" towns from growth into shrinkage, eventually leading to persistent economic decline in many areas.

In the social dimension (Figure 8), from 2006–2010 to 2011–2015, most towns continued to grow socially, with variations in growth rate; only a few towns faced mild social shrinkage, posing minimal risk. From 2011–2015 to 2016–2020, towns that experienced social shrinkage mostly returned to growth, with only two towns facing deepening shrinkage. Overall, the social dimension maintained a stable growth trend across the three periods, with most towns showing increased growth levels. Towns in zones I and II were more dispersed and farther from the origin, suggesting overall growth momentum.

In summary, population and economic shrinkage showed increasing polarization and consistency toward decline, while the social dimension remained relatively stable, continuing on a growth trajectory throughout the study period.

(2) Analysis of Shrinkage Dimension Evolution

To understand the overall patterns of shrinkage across dimensions in county-level towns of the three northeastern provinces, a statistical analysis was conducted on the combinations of shrinkage dimensions across the three time periods (2006—2010, 2011—2015, and 2016—2020). The results are shown in Table 6.

Table 6. Classification Criteria for Shrinkage Evolution Patterns. Source: Self Drawing.

Shrink dimension combination type	2006 to 2010		2011 to 2015		2016 to 2020		Total	
	Count	%	Count	%	Count	%	Count	%
Only population shrinkage	71	39.89%	78	43.82%	71	39.89%	220	41.20%
Only economic shrinkage	7	3.93%	10	5.62%	10	5.62%	27	5.06%
Only social shrinkage	3	1.69%	7	3.93%	11	6.18%	21	3.93%
Unidimensional shrinkage	81	45.51%	95	53.37%	92	51.69%	268	50.19%
Population economic shrinkage	37	20.79%	26	14.61%	32	17.98%	95	17.79%
Population social shrinkage	5	2.81%	6	3.37%	6	3.37%	17	3.18%
Economic social shrinkage	0	0.00%	2	1.12%	7	3.93%	9	1.69%
Dual dimensional shrinkage	42	23.60%	34	19.10%	45	25.28%	121	22.66%
Population economy social shrinkage	6	3.37%	7	3.93%	5	2.81%	18	3.37%

Across the three time periods, single-dimension shrinkage is the most common, accounting for over 50% of shrinking towns in the northeastern provinces. Among these, population shrinkage is the most prevalent, comprising over 40% of single-dimension cases, followed by economic shrinkage, with social shrinkage being the least frequent.

Towns with two-dimensional shrinkage represent nearly 25% of cases, with the "population and economic" combination being the most common (17.8%). The combination of population and social shrinkage is less frequent, and economic-social shrinkage is the least common. Only about 3.4% of towns experience full-dimension shrinkage (population, economic, and social), indicating that comprehensive shrinkage is rare.

Over time, from 2006–2010 to 2016–2020, the proportions of single-, two-, and three-dimension shrinkage towns have remained relatively stable. There is no significant decrease in single-dimension shrinkage or increase in multi-dimensional shrinkage, suggesting that shrinkage in one dimension does not necessarily lead to additional dimensions over time.

In summary, single-dimension shrinkage—especially population decline—is the dominant form of urban shrinkage in county-level towns in the northeastern provinces. While multi-dimensional shrinkage occurs, there is no clear trend that shrinkage expands across dimensions as it progresses.

3.3 Multi-Dimensional Shrinkage Correlation Analysis

(1) Correlation Analysis

To quantify the correlations between different dimensions of shrinkage, Spearman correlation analysis was conducted using shrinkage data from the three time periods (2006 – 2010, 2011 – 2015, and 2016 – 2020). The results are presented in Table 7.

Table 7. Classification Criteria for Shrinkage Evolution Patterns. Source: Self Drawing.

Time Period	Population-Economy	Population-Social	Economy-Social

2006–2010	-0.233 (0.001***)	-0.187 (0.011**)	0.306 (0.000***)
2011–2015	-0.182 (0.014**)	-0.127 (0.086*)	0.187 (0.011**)
2016–2020	-0.171 (0.021**)	-0.118 (0.111)	0.282 (0.000***)

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively.

Between 2006 and 2010, there was a significant correlation between population and economic shrinkage, as well as between economic and social shrinkage. Although population shrinkage also correlated with social shrinkage, the correlation coefficients for population-economy and population-society were relatively low, indicating weaker links, while the economic-social correlation was somewhat stronger.

As shrinkage progressed, the correlation between population and economic shrinkage weakened, though it remained statistically significant. By the third period, the correlation between population and social shrinkage had further declined and was no longer significant. In contrast, the correlation between economic and social shrinkage remained strong and consistently significant across all periods.

In summary, during the early stages of shrinkage, all three dimensions showed significant correlations. Over time, however, the correlations between population-economic and population-social shrinkage declined, while the economic-social correlation persisted, indicating a closer and more stable relationship between economic and social dimensions.

(2) Grey Relational Analysis

The correlation analysis above provides an understanding of the general relationships between dimensions over time, but it does not reveal the specific influence of individual factors on each dimension. To further explore the mutual influences of factors within each shrinkage dimension over time, grey relational analysis was conducted for the three time periods (2006–2010, 2011–2015, and 2016–2020). The grey relational degrees are shown in Table 8.

Table 8. Classification Criteria for Shrinkage Evolution Patterns. Source: Self Drawing.

Dimension	Factors	Correlation	Ranking
Population	Public financial expenditure	0.974	1
	Number of hospital beds	0.971	2
	GDP	0.963	3
	Revenue	0.961	4
	GDP growth rate	0.792	5
	Industrial Structure Index	0.712	6
Economic	Public financial expenditure	0.829	1
	Number of hospital beds	0.775	2
	Total population	0.745	3
	Population change rate	0.737	4
Social	Total population	0.977	1
	GDP	0.976	2
	Revenue	0.972	3
	Population change rate	0.965	4
	GDP growth rate	0.789	5
	Industrial Structure Index	0.709	6

In the population dimension, four factors have correlation coefficients above 0.9 with population shrinkage, highlighting that the key to retaining residents lies in high-quality urban infrastructure and public services, followed by economic development.

In the economic dimension, urban infrastructure is strongly linked to economic levels, while social services, population size, and population change show a slightly lower correlation with economic performance.

In the social dimension, four factors are also highly correlated (above 0.9) with population shrinkage. Population size is the primary factor affecting social shrinkage, as it determines demand for social infrastructure, followed by economic development, which influences funding for social projects, and population change rate, which impacts the pace of social development.

In summary, correlations between factors across dimensions show a hierarchical pattern, with stronger links between population and social factors. Per capita fiscal revenue, hospital beds, GDP, and fiscal revenue are significantly correlated with population shrinkage.

4. Conclusions and Recommendations

4.1 Conclusions

This study analyzes the status and evolution of urban shrinkage in counties of the China's three northeastern provinces from a multidimensional framework, explores the correlation between multidimensional shrinkage, and proposes policy recommendations for planning response. The main conclusions are as follows:

(1) Spatial Evolution: the shrinkage of population dimension has gone through a process from scattered distribution to regional aggregation, and then to comprehensive deployment, with the aggregation gradually becoming less significant; The economic dimension has shifted from a scattered distribution to a clustered distribution, and spatial clustering remains significant; Over time, the population loss of cities located closer to inland areas in the counties and cities of the three northeastern provinces has become increasingly severe;

(2) Temporal Evolution: Population shrinkage remained steady across most towns, with an even split between intensifying and slowing trends. Economic shrinkage followed a clear path from growth to decline, leading to polarized outcomes of "persistent shrinkage" or "persistent growth." Shrinkage in multiple dimensions is not inevitable; single-dimension shrinkage predominates, with around 20% of towns experiencing two-dimensional shrinkage (primarily "population-economy"), and few experiencing comprehensive three-dimensional shrinkage.

(3) Multi-Dimensional Correlation: Significant correlations exist between shrinkage dimensions in the early stages, but these weaken over time. Multi-dimensional shrinkage can lead to a vicious cycle, where shrinkage in one dimension triggers others, potentially leading to comprehensive urban decline.

4.2 Recommendations

(1) Enhance Shrinkage Assessment and Develop Specialized Response Plans

According to the research findings, there are differences in the dimensions, degree, and duration of urban shrinkage in the three provinces of Northeast China. The impact and driving factors of urban shrinkage also vary among different cities. Therefore, the most effective coping strategies for urban shrinkage should also differ among different cities. Combining the contraction response thinking of the systematic treatment of "acupuncture and moxibustion - whole therapy", exploring the key problems of urban contraction and identifying the negative impact of contraction is an important basis for accurate response to contraction. The special plan for contraction response combined by "acupuncture and moxibustion" to address the key

problems and "whole therapy" to eliminate the overall impact is an important means to achieve effective treatment of contraction. Therefore, it is necessary to have a clear understanding of the important impact of shrinkage background on urban development, strengthen the status of urban shrinkage examination work, and carry out special planning for shrinkage response.

(2) Optimize Spatial Patterns and Leverage Regional Gateway Advantages

According to the research findings, the distribution pattern of shrinking cities in the three provinces of Northeast China is significantly characterized, and some regions have significant clustering, especially in terms of economic dimension clustering and outliers. Therefore, solving the problem of shrinking from a regional perspective is crucial. Combining the coping strategy of "internal supplementation external adjustment" penetrative therapy, contraction physical examination and special planning are the urban "repair" to cope with contraction, while leveraging regional linkage advantages and building urban cooperation patterns are the regional "regulation" to cope with contraction. Only by combining the two can a new trend of regional growth be constructed. Therefore, it is important to recognize the importance of contraction in response to urban cooperation, and to construct a coordinated approach for urban contraction areas. Combining the characteristics of lighter contraction in border towns and significant growth in contraction areas, we should optimize the urban spatial pattern and leverage the advantages of regional external windows.

(3) Promote Compact Urban Development and Enhance Town Development Quality

According to research findings, the process of sustained and highly contracted urban shrinkage, as well as the trend of polarized development, tells us that irreversible shrinkage has become a certainty for some cities. Therefore, we should transform our growth mindset and develop the correct scale for these cities. Combining the coping strategy of "reducing fat and increasing muscle" strengthening treatment, intensive development, rational disposal of inefficient land and redundant facilities, restoration of vitality in the central area, and improvement of urban construction quality are the correct paths.

References

Chen, X. *et al.* (2024) 'Conceptualizing the nexus between spatiotemporal shrinkage patterns of natural cities and driving mechanisms: Insights into urban shrinkage in Northeast China', *CITIES*, 152, p. 105179. Available at: https://doi.org/10.1016/j.cities.2024.105179.

Cheshire, P. and Magrini, S. (2009) 'Urban growth drivers in a Europe of sticky people and implicit boundaries', *JOURNAL OF ECONOMIC GEOGRAPHY*, 9(1), pp. 85–115. Available at: https://doi.org/10.1093/jeg/lbn044.

Fleschurz, R. and Pallagst, K. (2016) 'Design After Decline: How America Rebuilds Shrinking Cities', *JOURNAL OF PLANNING EDUCATION AND RESEARCH*, 36(1), pp. 126–127. Available at: https://doi.org/10.1177/0739456X15616436.

Glaeser, E.L. and Gottlieb, J.D. (2006) 'Urban resurgence and the consumer city', *URBAN STUDIES*, 43(8), pp. 1275–1299. Available at: https://doi.org/10.1080/00420980600775683.

Guan, D., He, X. and Hu, X. (2021) 'Quantitative identification and evolution trend simulation of shrinking cities at the county scale, China', *SUSTAINABLE CITIES AND SOCIETY*, 65, p. 102611. Available at: https://doi.org/10.1016/j.scs.2020.102611.

Guo, F. *et al.* (2021) 'Spatiotemporal pattern evolution and influencing factors of shrinking cities: Evidence from China', *CITIES*, 119, p. 103391. Available at: https://doi.org/10.1016/j.cities.2021.103391.

He, X. *et al.* (2023) 'Quantifying spatiotemporal patterns and influencing factors of urban shrinkage in China within a multidimensional framework:A case study of the Yangtze River Economic Belt', *SUSTAINABLE CITIES AND SOCIETY*, 91, p. 104452. Available at: https://doi.org/10.1016/j.scs.2023.104452.

Jiang, Z. *et al.* (2020) 'Identifying Shrinking Cities with NPP-VIIRS Nightlight Data in China', *JOURNAL OF URBAN PLANNING AND DEVELOPMENT*, 146(4), p. 04020034. Available at: https://doi.org/10.1061/(ASCE)UP.1943-5444.0000598.

Lang, W., Deng, J. and Li, X. (2020) 'Identification of "Growth" and "Shrinkage" Pattern and Planning Strategies for Shrinking Cities Based on a Spatial Perspective of the Pearl River Delta Region', *JOURNAL OF URBAN PLANNING AND DEVELOPMENT*, 146(4), p. 05020020. Available at: https://doi.org/10.1061/(ASCE)UP.1943-5444.0000612.

Lee, J.S., Won, S. and Kim, S. (2016) 'Describing Changes in the Built Environment of Shrinking Cities: Case Study of Incheon, South Korea', *JOURNAL OF URBAN PLANNING AND DEVELOPMENT*, 142(2), p. 05015010. Available at: https://doi.org/10.1061/(ASCE)UP.1943-5444.0000305.

Lee, S., Hye-Jin, J. and Jae-Su, L. (2018) 'An Investigation into the Evaluation Criteria, Cases and Causes of Urban Shrinkage', 주택도시연구, 8(3), pp. 83–100. Available at: https://doi.org/10.26700/shuri.2018.12.8.3.83.

Li, H. and Mykhnenko, V. (2018) 'Urban shrinkage with Chinese characteristics', *GEOGRAPHICAL JOURNAL*, 184(4), pp. 398–412. Available at: https://doi.org/10.1111/geoj.12266.

Liu, R. (2022) 'Long-Term Development Perspectives in the Slow Crisis of Shrinkage: Strategies of Coping and Exiting', *SUSTAINABILITY*, 14(16), p. 10112. Available at: https://doi.org/10.3390/su141610112.

Schetke, S. and Haase, D. (2008) 'Multi-criteria assessment of socio-environmental aspects in shrinking cities. Experiences from eastern Germany', *ENVIRONMENTAL IMPACT ASSESSMENT REVIEW*, 28(7), pp. 483–503. Available at: https://doi.org/10.1016/j.eiar.2007.09.004.

Song, Y., He, W. and Zeng, J. (2023) 'Exploration of Spatio-Temporal Evolution and Threshold Effect of Shrinking Cities', *LAND*, 12(7), p. 1474. Available at: https://doi.org/10.3390/land12071474.

Tan, Z. *et al.* (2023) 'Identification and Measurement of Shrinking Cities Based on Integrated Time-Series Nighttime Light Data: An Example of the Yangtze River Economic Belt', *REMOTE SENSING*, 15(15), p. 3797. Available at: https://doi.org/10.3390/rs15153797.

Tong, Y. *et al.* (2022) 'County town shrinkage in China: Identification, spatiotemporal variations and the heterogeneity of influencing factors', *JOURNAL OF RURAL STUDIES*, 95, pp. 350–361. Available at: https://doi.org/10.1016/j.jrurstud.2022.09.029.

Turok, I. and Mykhnenko, V. (2007) 'The trajectories of European cities, 1960–2005', *Cities*, 24(3), pp. 165–182. Available at: https://doi.org/10.1016/j.cities.2007.01.007.

Wang, R. *et al.* (2021) 'A study on the spatial and temporal evolution of urban shrinkage and its influencing factors from a multidimensional perspective: A case study of resource-based cities in China', *PLoS ONE*, 16(10), p. e0258524. Available at: https://doi.org/10.1371/journal.pone.0258524.

Zhang, Xiao *et al.* (2023) 'Spatial-temporal evolution pattern of multidimensional urban shrinkage in China and its impact on urban form', *APPLIED GEOGRAPHY*, 159, p. 103062. Available at: https://doi.org/10.1016/j.apgeog.2023.103062.

Zhang, Y. *et al.* (2024) 'Research on spatiotemporal patterns and influencing factors of county-level urban shrinkage in urbanizing China', *SUSTAINABLE CITIES AND SOCIETY*, 109, p. 105544. Available at: https://doi.org/10.1016/j.scs.2024.105544.

Case Study Report

DNA analysis and research by design as a framework for quality of life

Case study Veurne, Belgium

Guy VLOEBERGH, OMGEVING cv, Belgium

Daphné ROELS, OMGEVING cv, Belgium

Abstract

The identity or DNA of a place determines its attractiveness and quality of life. Core reinforcement or sustainable urban density must respect that DNA. Various characteristic elements such as built heritage, public spaces, green and blue elements, etc. but also intangible elements need to be identified because they create preconditions for future qualitative (re)developments. In the case study of Veurne, a small town in the north of Belgium, we analysed the DNA and created a robust vision that respects it. Several guidelines were drawn up, visualized and tested in detail at different strategic locations. Research by design was the perfect tool for this. The quality-of-life plan, as we called it in Veurne, consisted of an integrated long-term vision for the city to meet future challenges. This policy plan eventually translated into different planning regulations to give the city council sufficient guidance.

Keywords

DNA analysis, research by design, quality of life, vision, planning regulation

1. Introduction / Context

1.1. Location

Veurne is a small medieval town in the region of Flanders (northern part of Belgium, situated approximately 30 km from the seacoast), characterised by a historic centre that is a UNESCO World Heritage Site thanks to its belfry. The town of 12,500 inhabitants is characterised by some remarkable structures. The historical centre is surrounded by a ring structure and the shape of the canal refers to the former VAUBAN defence structure. The city centre has many iconic buildings that form a large ensemble thanks to the yellow bricks, the (stepped) gabled roofs, special facade shapes and highly detailed towers or dormers. Outside the centre are mainly twentieth-century residential areas and some multifunctional historical access roads.

Figure 1. The city centre with iconic buildings with yellow bricks, (stepped) gabled roofs etc. Source: Marc Ryckaert.

1.2. Challenges

Just like the rest of Flanders, the town has many challenges. Veurne must provide new and qualitative housing to cope the rising number of inhabitants and changing housing needs, without cutting back on open space. These transformations need to be in harmony with the heritage values. Like other medieval cities such as Bruges, the public spaces are very paved with minimal greenery. They need to become more climate resilient. Too many cars occupy the public space which does not have a lot of residential quality. Transforming public space from just parking space to interesting meeting places goes hand in hand with a modal shift where more space for cars is replaced by more space for pedestrians and bikes.

Figure 2. Challenges for Veurne. Source: OMGEVING.

1.3. Approach

The city of Veurne wanted to tackle these challenges. Therefore, they asked design and planning office OMGEVING (www.omgeving.be) to develop some ordinance planning instruments to replace the current outdated ones. OMGEVING made the city council aware that first an integrated and long-term vision is

necessary before taking regulating action(s). For that reason, OMGEVING made a 'quality-of-life plan' for the city that consisted of five big steps:

1. analysis of historic evolution of city centre and of current (spatial and policy) situation
2. valorisation of identifying elements and coherent entities (DNA analysis)
3. vision linked to different spatial structures of the city
4. implementation with possible guidelines for valuable buildings, public spaces and coherent entities
5. research by design on strategic locations.

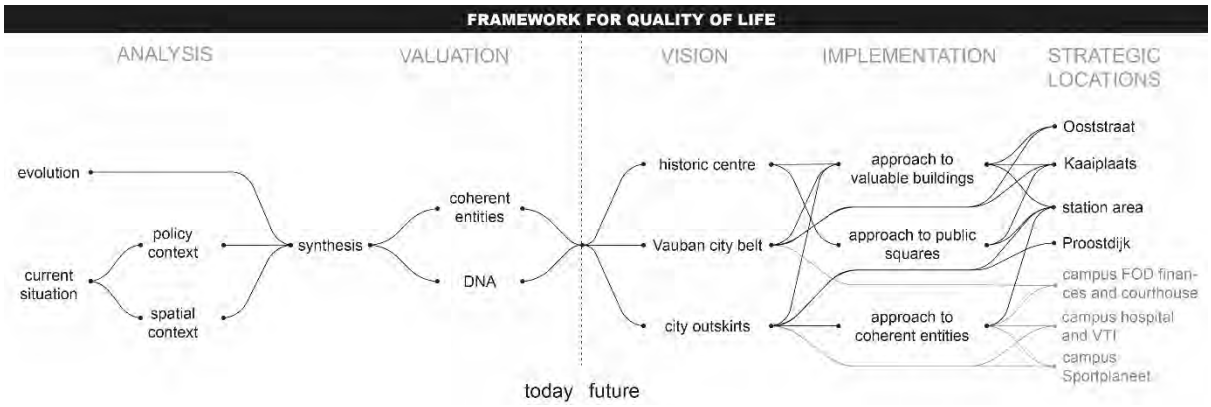


Figure 3. Project approach. Source: OMGEVING.

This plan indicated how Veurne will deal with contemporary issues such as 'core reinforcement', 'climate adaptation', 'liveability', 'preservation of open space', 'proximity and interwovenness' etc. in the coming years. The plan was developed in close collaboration with the city council, different local architects and many advisory boards such as the Municipal Planning Advisory Board ("GECORO"). However, the city council is not so keen on organising a broad participation. Therefore, a limited number of inhabitants were involved, more concrete only the ones living at some strategic locations.

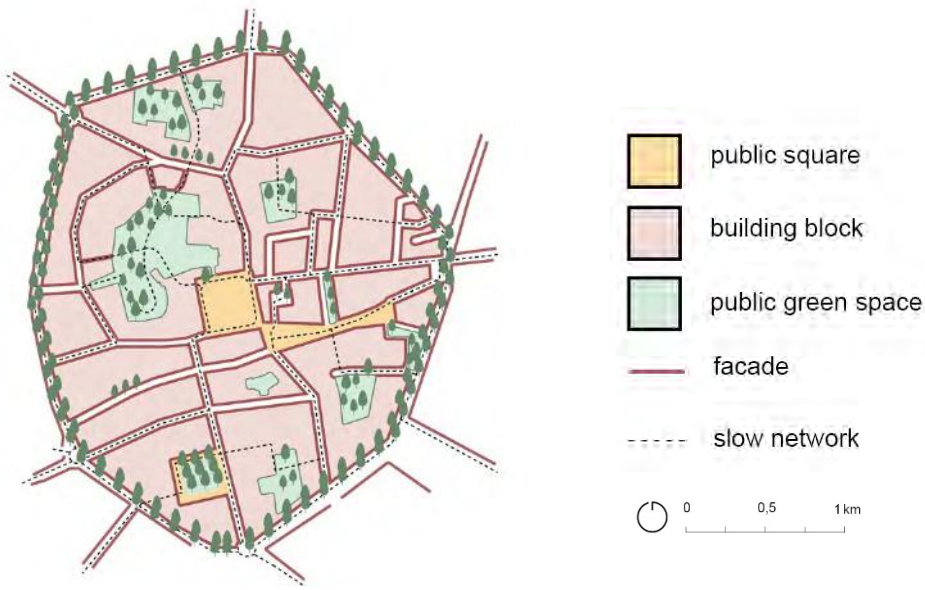


Figure 4. Vision map for the historic city centre. Source: OMGEVING.

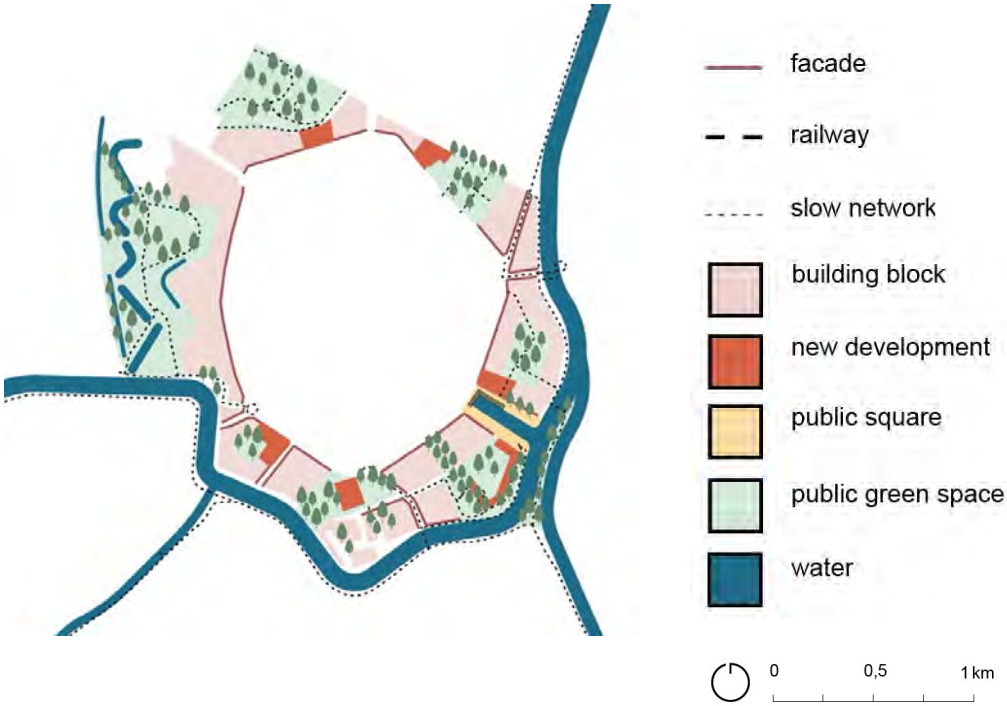


Figure 5. Vision map for the Vauban belt around the city centre. Source: OMGEVING.

Figure 6. Vision map for the city outskirts. Source: OMGEVING.

2. Results

It is not the intention of this paper to explain every step in the process of the quality-of-life plan or all the substantive results, but rather to focus on the importance of some interesting tools that are applicable in different projects of spatial planning and urbanism. Also, the meaning and status of such a quality-of-life plan in relation to legal planning instruments are explained below.

2.1. DNA analysis as a framework

The DNA analysis determines the tangible and intangible identifying elements of the city. It consists characteristic houses, landmarks, public spaces, green areas, slow roads but also traditions, stories etc. These elements must be preserved for the future. Often, preserving valuable buildings or facades, for example is not enough. The adjacent buildings and context need to be in harmony in order to not create a break in scale. If a characteristic building is dwarfed by huge apartment blocks, how high is the value then?

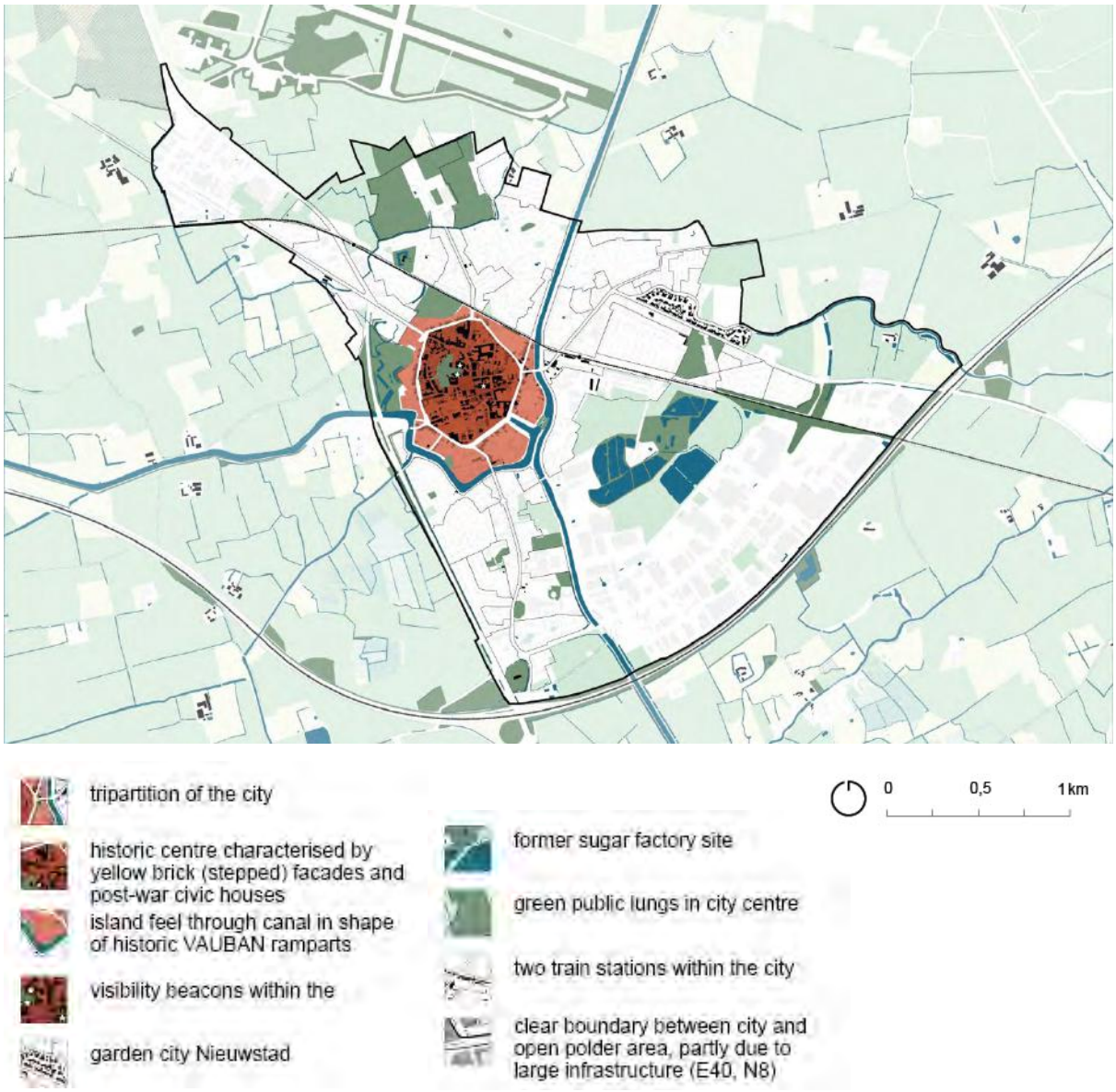


Figure 7. DNA map. Source: OMGEVING.

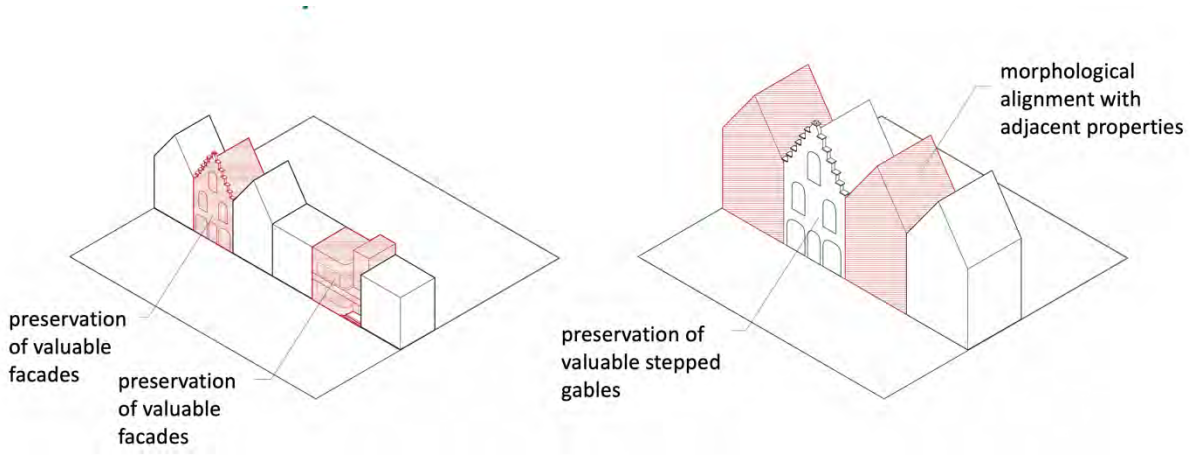


Figure 8. Conceptual axonometry to showcase various guidelines for DNA elements. Source: OMGEVING.

Besides identifying valuable elements to preserve, the DNA analysis also defined coherent entities which have the same morphology, history etc. For example, a historic city centre is different from a twentieth-century residential neighbourhood or an industrial site. In every coherent entity there are different options and opportunities to deal with the different challenges as mentioned above because they have different characteristics. For example in a recent residential area - characterised by single, detached houses with big gardens, large (oversized) infrastructure, mainly local traffic and almost no other functions except housing - the possibilities for making this entity more green, with more space for cyclists and pedestrians, and with more and/or different housing typologies, are totally different from, for example along a main access road with a lot of through traffic, a large street profile, a mix of functions, buildings of different scales etc.

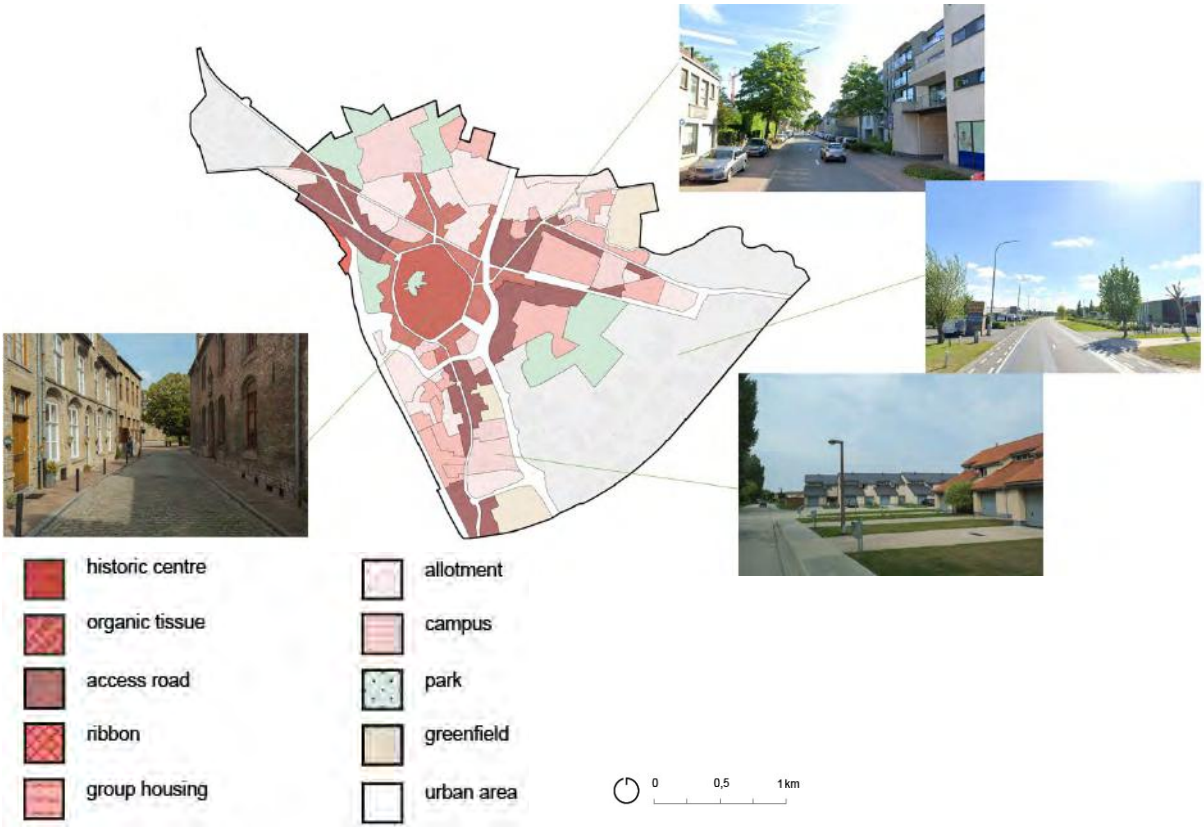


Figure 9. Map and photos of coherent entities. Source: OMGEVING.

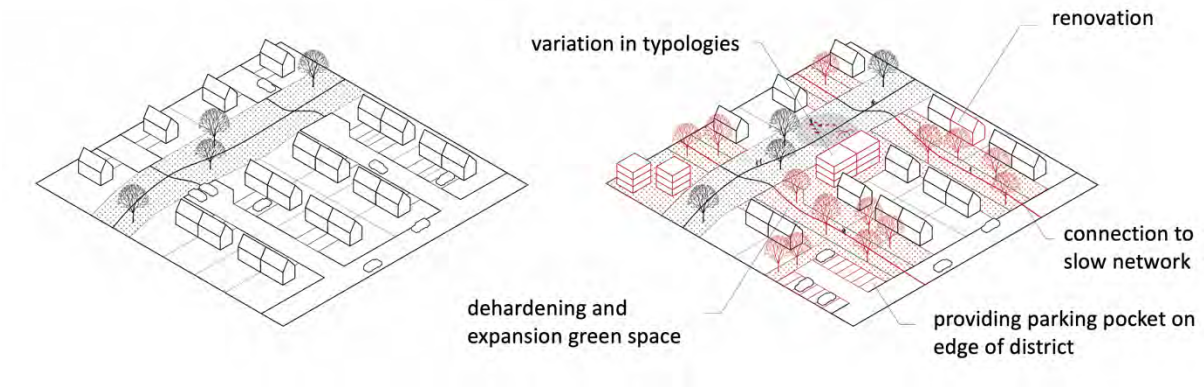


Figure 10. Conceptual axonometry to showcase various guidelines in a coherent entity 'suburban residential area'. Source: OMGEVING.

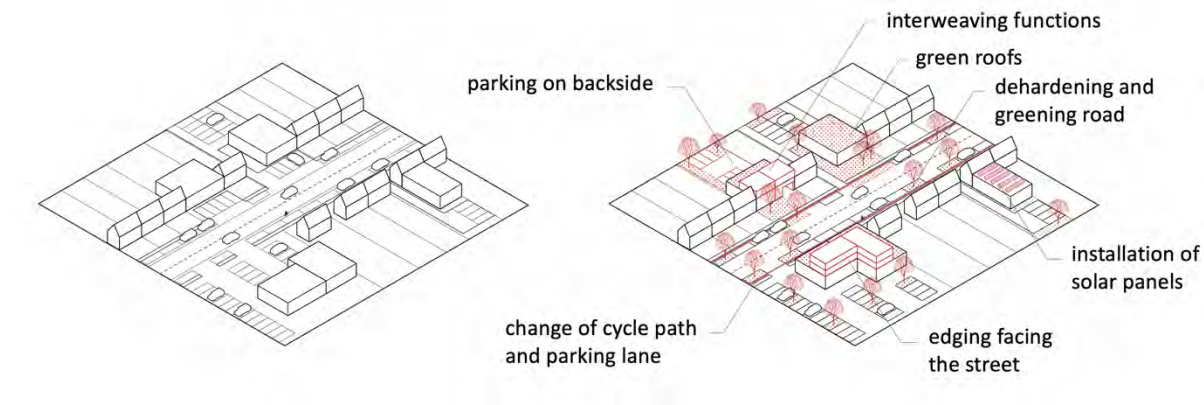


Figure 11. Conceptual axonometry to showcase various guidelines in a coherent entity 'main access road'. Source: OMGEVING.

The DNA forms with other words spatial conditions for a sustainable urban renewal. In respect with the DNA the vision for the town Veurne was designed. The vision shows how a core-strengthening policy can take shape in the city, in which a balance between renewal and preservation is crucial.

2.2. Research by design

Another important tool in this process was 'research by design'. Research by design has many forms such as scenario research and different visualisation techniques.

Related to the coherent entities as mentioned above, different conceptual axonometries were designed. They show the existing situation with the characteristic elements and a projection of possible guidelines for improving the quality of life in that entity. These axonometries help to show what exactly we mean when we talk about making the entity greener or implementing other housing typologies, for example. It gives a range of possibilities that can be applied somewhere, without focusing on a parcel level which is often too dangerous and undesirable within a policy plan.

Incidentally, research by design was carried out at some strategic locations. These are locations where different opportunities arise and where the vision deserves a concrete (rather than conceptual) deepening

because of their diverse nature and their importance for the whole city of Veurne. Research by design helped to concretise and visualize the DNA at that location, but also designed the vision and possible, let's say: the 'preferable future'. This resulted in graphically attractive vision maps and photorealistic visualisations.

Figure 12. Existing and new situation by research by design on a strategic location. Source: OMGEVING.

Figure 13. Visualisation of desirable future on a strategic location. Source: OMGEVING.

2.3. From policy plan to planning regulation

The quality-of-life plan resulted in an integrated plan that determines the spatial policy for the next twenty years. In order to give the municipality sufficient support and certainty and to make the vision concrete and not 'non-binding', we made an action plan that tells which actions and thus regulatory planning instruments are needed on short and long-term.

Shortly after the approval of the quality-of-life plan, the municipality chose to design two different spatial planning regulations: a thematic one for heritage preservation and a spatial one for the inner city that talks about building regulations, greenery, mobility etc. The task of writing these two regulations was also entrusted to design and planning office OMGEVING cv.

Figure 14. Two spatial regulation plans to translate the vision into planning instruments. Source: OMGEVING.

The results (vision, guidelines etc.) of the quality-of-life plan had to be translated into regulatory instruments. Here it was difficult to find a good balance between what we wanted to fix in strict (binding) rules in the planning regulations and what we wanted to keep in the (non-binding) policy plan where there is no guarantee that these rules will be respected. Because if it the rules are too fixed and rigid, they may not be resilient and flexible enough for future needs and evolutions. And if the rules are too open and broad-minded, the municipality may not exert enough pressure in order to deliver qualitative urban renewal projects. During the drafting of these regulations, the Municipal Planning Advisory Board was closely involved, and public information evenings were organised.

In the future it is the idea to initiate other spatial planning regulations covering the different city districts and different coherent entities to (hopefully) ensure better spatial policies.

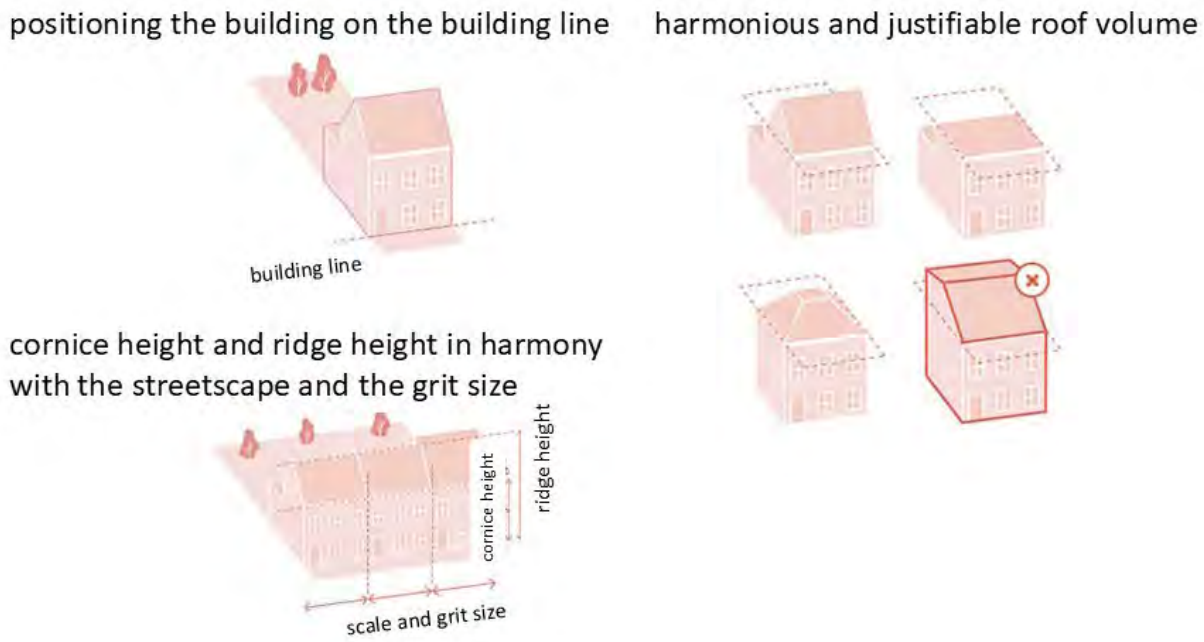


Figure 15. Examples of regulations included in the regulation plans. Source: OMGEVING.

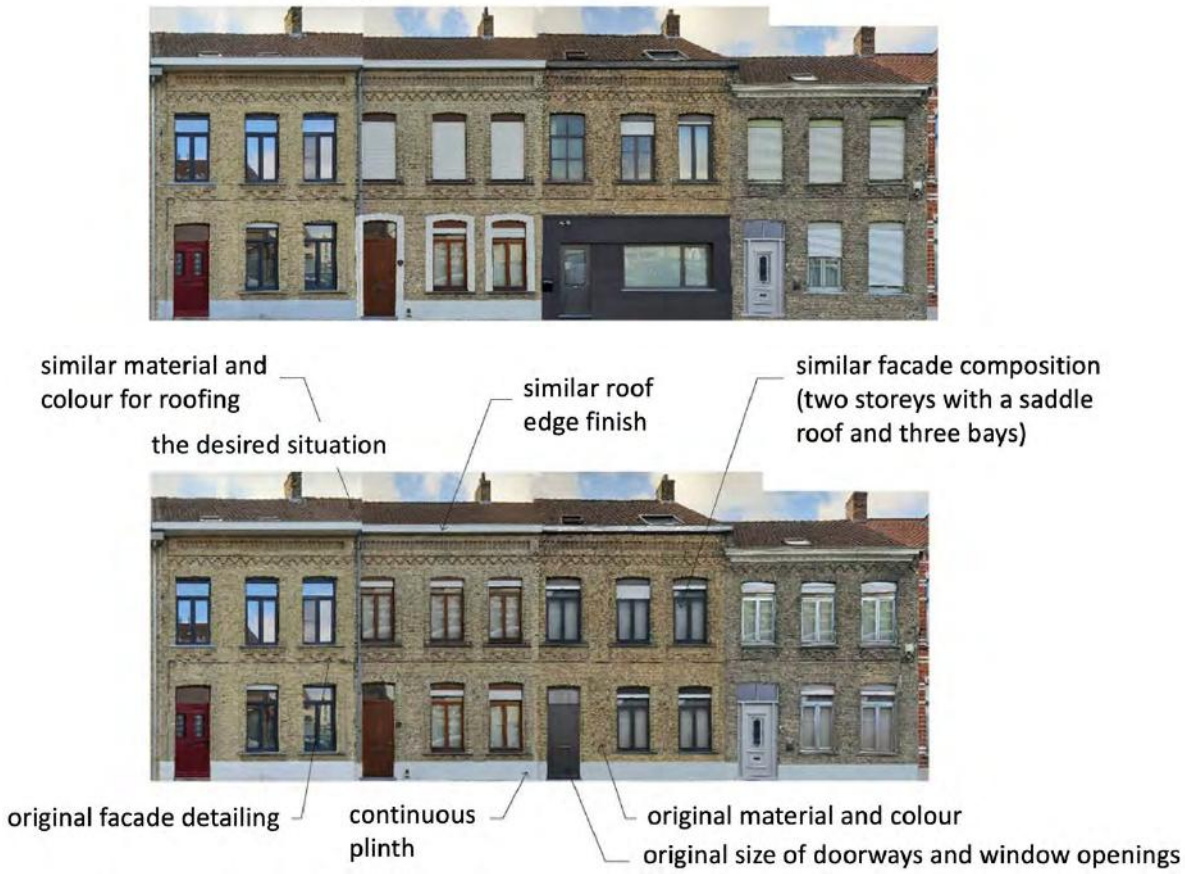


Figure 16. Example of ideal image where regulations are applied. Source: OMGEVING.

3. Conclusion

The case study in Veurne confirmed the importance of spatial planning in the shape of a strategic (long-term) vision, before taking action. Without knowing where the municipality wants to go, it is impossible to establish different rules. If there is no clear vision, ad hoc policies will persist, and unwanted and non-qualitative projects and redevelopments will continue to occur.

Additionally, spatial planning regulations are recommended to have sufficient certainty. If a municipality does not have any legal binding rules, it is very hard to keep up the 'good work' and to ensure a good spatial policy. Due to the growing legalisation in spatial planning processes and thus the many associated objections, it is not easy to continue defending the 'good spatial planning'. It takes a lot of patience and courage, and it does not always stand up.

Furthermore, it is important to define the DNA of a place. The DNA sets preconditions for future developments so that they are qualitative. If they do not take into account the identifying elements, the inhabitants lose contact with their known environment (their home) and heritage gets lost.

To conclude, research by design is an important tool in our practice, spatial planning and urbanism. It has many advantages and is therefore worthy to integrate in every project or planning process. Research by design results in visualisations that are better understandable than 2D maps, for example. They are important in communication and participation with all kinds of stakeholders. They illustrate the vision of spatial planners, which is often not so easy for a citizen to interpret. Moreover, the vision can be tested on some interesting (strategic) locations. By zooming in on certain locations and then zooming out again at a more strategic level, it is possible to adjust the vision and guidelines and test whether they are realisable.

4. References

Agentschap Digitaal Vlaanderen (february 2023) *Grootschalig Referentiebestand*.

Agentschap Onroerend Erfgoed (2023) *Aanduidingsobjecten*.

Instituut voor Natuur- en Bosonderzoek (2021) *Biologische waarderingskaart*.

Research Paper

Would Brasília be less Brasília if more people lived in the protected area?

Gabriela de Souza TENORIO, University of Brasilia, Brazil

Abstract

The capital of Brazil, Brasília, has been a UNESCO World Heritage site since 1987 due to its modernist characteristics. Although it is now the third-largest city in Brazil, only 10.87% of the population lives within its designated heritage area, which supports 40.7% of formal employment. Despite abundant open spaces and underutilized buildings, both the government and parts of the public are resistant to increasing density, resulting in sprawling, low-density expansion into natural savanna areas. One of the arguments for this resistance is that higher residential density in the protected area might compromise its core characteristics and potentially endanger its UNESCO status. This study aims to demonstrate, through simulations of four new residential areas based on existing building types and typical public/private space ratios, that densification can be achieved without compromising Brasília's modernist essence. A comparison with four gated communities – a typical model of the city's expansion – illustrates that this proposed model also promotes more efficient use of infrastructure, preserves natural landscapes, and fosters diversity and inclusivity, all aligned with sustainable urban density principles. The study believes that simulations and morphological comparisons can contribute to informing the debate and help combat the exclusionary and prejudiced rhetoric of those against densification.

Keywords

Brasilia, world heritage site, sustainable urban density

1. Introduction

Brasília, the modernist city and third capital of Brazil (Figure 1), had its design chosen through a national public competition held in 1957, which was won by Brazilian architect Lucio Costa. According to the competition guidelines, it would be located in the Federal District (DF), within a 5,761 km² rectangle in the central-west region and was intended to house a maximum of 500,000 people (IPHAN, 2018).

Men and women from all over the country came to work on the construction of the city, leading to the emergence and consolidation of additional urban centers around it, adding to the two that already existed there. Brasília was inaugurated in 1960, with a population of 141,742, including residents of the modernist core, or Pilot Plan—which in a way was born as a historic center—and the residents of the satellite cities. By 1970, its total population had already exceeded the estimated limit, reaching 546,015 inhabitants (CODEPLAN, 2022), and today it is the third-largest city in the country, with 2,817,381 inhabitants (IBGE, 2022). In 1987, Brasília earned UNESCO World Heritage status, and a protection perimeter was defined within which only 327,413 people currently live, or 11.62% of the city's population. Within this perimeter, however, 40.7% of formal jobs are concentrated (Figure 2).

Figure 1. Brasilia, Brazil. Pilot Plan (left) and the city today (right). Source: left: IPHAN, 2018; right: Nelson Kon.

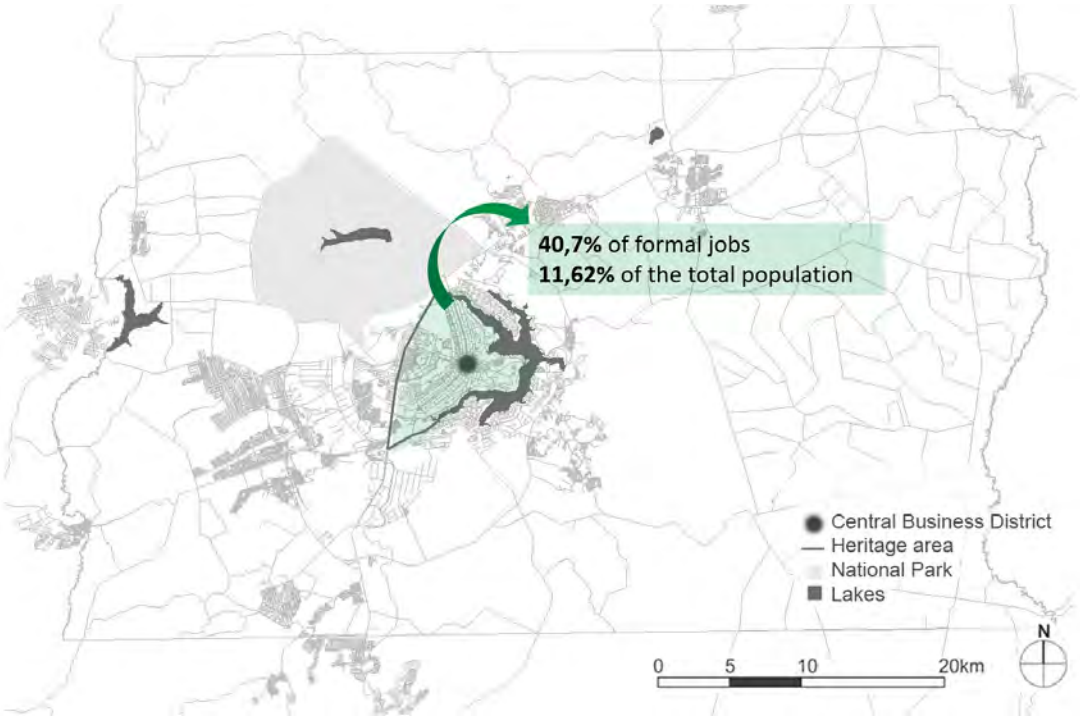


Figure 2. The Federal District and the perimeter of the protected area. Source: the author, CODEPLAN, 2022 and IBGE, 2022.

Recently, after more than 15 years of studies, drafting, and debates, the Brasília Urban Ensemble Preservation Plan (PPCUB) was approved, a document that sparked controversy for suggesting, among other things, relaxing certain zoning regulations and creating new areas for construction. Heated debates ensued, in which it was often argued that allowing certain changes would lead to Brasília losing its World Heritage status or that it would be unsustainable for the designated heritage area to accommodate more residents. Generally, these claims appear to come primarily from current residents of the heritage area, who are concerned about potential changes to their status quo. However, such claims are rarely backed by data, studies, or simulations to support or validate them.

To help inform this debate, this article records the author's contribution in November 2017 during a roundtable titled "Possibilities and Strategies for Housing Inclusion in Brasília's Urban Ensemble," held as part of the "Housing in Central Areas of the Federal District" seminar organized by the Federal District Government (GDF). One of the key motivations for this seminar was the idea of relaxing zoning regulations in central areas to allow residential use, based on findings that several properties in sectors such as the

Commercial and Banking Sectors were vacant. Here, simulations and comparisons are presented to demonstrate that increasing density in the heritage area does not necessarily disrupt the city's essential characteristics and may be far more sustainable than the current growth model.

This paper was originally written in Portuguese, and used ChatGPT (OpenAI, 2024) for the translation process.

2. Simulation

The study began by selecting four areas with distinct characteristics within the designated heritage perimeter (Figure 3). In each area, a visual simulation was created by introducing new residential buildings, and the population was estimated.

Figure 3. The simulation areas: 1) Superquadra Norte/SQN 206; 2) Avenida L3 Norte; 3) Setor de Grandes Áreas Norte 707/907 e 4) Setor Bancário Sul. Source: the author.

The visual simulation used an aerial view provided by Google Earth as a starting point, as it allows for observation of the relationships between public and private areas, which in the case of the Pilot Plan highlights the large predominance of open spaces over built-up areas. All buildings added in the simulation are copies of buildings present in the original image, created using Adobe Photoshop. This insertion respected the existing public/private space ratio, aimed to maintain the same level of greenery, and employed established building types that are deeply ingrained in the image that Brasília's residents hold of their city.

The population estimate was based on disaggregated data from the 2010 census. Census tracts with the same type of building were researched to calculate the number of inhabitants per residence for that specific type, using the corresponding attribute table (Figure 4). Since these are well-established areas with very limited potential for transformation, it is believed that the values still reflect the current reality, as the most recent data from the 2022 census remains preliminary.

Figure 4. Census tracts and attribute table. Source: Google Earth and IBGE, 2012.

2.1. Superblock SQN 206

The superblock has been present since the city's conception and was one of the two forms of housing envisioned in the original plan. There are two types of superblock: one with six-story buildings on pilotis, and one with three-story buildings on pilotis. The first type, which is more common, was chosen for the study. It consists of a square measuring 250 meters per side, surrounded by tree vegetation, and generally contains 11 buildings, which should occupy 15% of its surface, with the remaining 85% designated as public space. Ideally, these pilotis should be open, without fences or any barriers that might block pedestrian access.

The SQN 206 - the author's place of residence – was chosen, and it consists of 11 identical buildings, each with 36 apartments (Figure 5). Two additional buildings were added to the original image. For the calculation of the new population, it was assumed that each new building would house 68 apartments.

Figure 5. SQN 206 as it is (left), and with 2 more buildings (right). Source: Google Earth, with adaptations.

In summary:
+136 dwellings
+408 inhabitants
1 building type
Area occupied by the "new" buildings: 1,920 m²
Average number of residents per household: 3
Distance from the CBD: 4.5 km

2.2. North L3 Avenue

North L3 Avenue is an arterial road that, in the selected stretch, separates the residential buildings of the University of Brasília to the east from the large plots designated for schools, institutions, clinics, and temples to the west, in front of which there are extensive parking lots and setbacks. In this area, the simulation involved adding square mixed-use buildings with commercial ground floors and two additional floors of studio apartments or commercial spaces, which are found in the local commercial streets of the region, as well as two more residential buildings from the university (six stories on pilotis) (Figure 6).

The square mixed-use building type was not included in the city's original design; it was created and adapted over the course of its growth. Originally, local commercial streets were not allowed to have residences of any kind, as still prevails in Asa Sul. Their presence in Asa Norte adds significant dynamism to this neighborhood.

Figure 6. Avenida L3 Norte as it is (left), and with the simulation (right). Source: Google Earth, with adaptations.

In summary:
+850 dwellings
+1,562 inhabitants
2 building types
Area occupied by the "new" buildings: 23,400 m²
Average number of residents per household: 1.7 to 3
Distance from the CBD: 7.4 km

2.3. North Large Areas Sector 707/907

This area includes the private university UniCEUB, large plots housing institutions, temples, and schools, as well as a storage facility for vehicles seized by the Department of Traffic (Detran). Here, the simulation

involved occupying vacant areas, surface parking lots, or spaces whose use does not align with the social role of urban property. For this purpose, the urban design and various building types present in the nearby 700 blocks were adopted, namely: row single-family houses; mixed-use buildings with commercial ground floors and five residential floors; and residential buildings with pilotis and two or five stories (Figure 7).

This section was not included in the city's original design; it was added during its construction and adapted over the course of its development.

Figure 7. 707/907 North as it is (left), and with the simulation (right). Source: Google Earth, with adaptations.

In summary:
+1,955 dwellings
+4,396 inhabitants
5 building types
Area occupied by the "new" buildings: 342,000 m²
Average number of residents per household: 1.7 to 3.7
Distance from the CBD: 6 km

2.4. South Bank Sector

This is one of the central sectors of the city, where residential use is prohibited and where taller buildings are allowed. It is part of the gregarious scale of Brasília, which includes sectors such as the Bank Sector, Radio and TV Sector, Hotel Sector, and Commercial Sector. The chosen area encompasses blocks 1 and 2 of the South Bank Sector, which is a large platform with buildings that typically feature institutions and commercial offices, with generally 15 floors. The lower levels of the platform are widely used as garages (Figure 8).

Here, the speculation of the study advances the discussion of relaxing the rigid zoning imposed on central sectors, allowing for residential use in small units without garages, taking advantage of the proximity to the city's main public transportation terminals. Thus, it is proposed to utilize areas occupied by large surface parking lots to construct new mixed-use buildings. In estimating the population, only the new residences were considered, without calculating a possible conversion of existing underutilized buildings into housing on their upper floors, while retaining the ground floor for retail and service activities. The proposed buildings would have the same configuration as the existing ones.

Figure 8. South Bank Sector as it is (left), and with the simulation (right). Source: Google Earth, with adaptations.

In summary:
+1,300 dwellings
+2,600 inhabitants
1 building type
Area occupied by the "new" buildings: 6,375 m²
Average number of residents per household: 2
Distance from the CBD: 1.4 km

The proposed areas added 8,966 inhabitants through 4,241 housing units offered by 8 different building types, occupying an area of approximately 374,000 m² or 37.4 hectares. Although this may not seem like a very large number, it becomes significant when considering the potential of the heritage area to absorb more residents, especially when compared to the data that will be presented next.

The decision to consider the actual number of inhabitants per dwelling, depending on the building type, was made to provide greater accuracy in the simulation. Currently, the average in the Federal District is close to 3 residents per household (a figure used for the "pilotis plus 6 floors" type). If we had used this number, the proposed 4,241 housing units would have brought 12,723 new inhabitants to the heritage area, a figure significantly higher than the approximately 9,000 obtained.

In 2021, the housing deficit in the Federal District was 100,701 units, with 48.64% of those falling within the medium-low income range (IPEDF, 2023). Coupled with current data on household arrangements, which show that 38.6% of households are occupied by single individuals or couples without children (CODEPLAN, 2022), it makes sense to speculate about building types that provide smaller apartments, such as those proposed for central areas, or those located in mixed-use buildings, where the resident-to-dwelling ratio tends to be below 2. These building types also typically have lower sale and rental prices.

3. Comparison

For comparison purposes, the study selected 4 gated communities located to the north of the heritage area: Império dos Nobres, RK, Bianca, and Recanto Real, which together cover a total area of 2,047,000 m² or 204.7 hectares. These communities are primarily composed of single-family detached houses on 450 m² lots (Figures 9 and 10). At the entrances of these condominiums, it is common to find a small commercial street with mixed-use buildings, where up to 4 upper floors are occupied by offices or residences. For the purposes of this speculation, these commercial areas were not considered.

These gated communities are representative of a growth model widely practiced in Brasília: suburban sprawl, characterized by low height and low density occupancy in homogeneous neighborhoods (dominated by a single type of housing), which are closed off from the surrounding area and lack diversity in use.

In this case, visual simulation was not employed; rather, population figures were obtained from the census, and the area occupied was calculated.

Figure 9. The Federal District and the location of the comparison areas, 10 Km outside the protected area. Source: the author (left) and Google Earth, with adaptations (right).

Figure 10. Area occupied by 4 gated communities (left) and their typical dwelling (right). Source: Google Earth, with adaptations.

In summary:
8,846 inhabitants
1 building type
Area occupied: 2,047,000 m² or 204.7 hectares
Average number of residents per household: 3.5
Distance from the CBD: 18.5 to 20.7 km

4. Discussion

The following table compares some data obtained from the simulation with that of the comparison areas, as both accommodate approximately the same number of inhabitants.

	Simulation	Gated Communities
Inhabitants	8,966	8,846
Area occupied	374,000 m² or 37.4 ha	2,047,000 m² or 204.7 ha
Building types	8	1
Integration with the city	total	none
Average distance to CBD	4.82 km	19.25 km

From this simulation and brief comparison, several reflections can be made.

Regarding the area occupied, the buildings proposed in the simulation would occupy five times less land than the existing condominiums. The condominiums took over natural land, while the proposed buildings would occupy already anthropized and urbanized land. Furthermore, a significant portion of them would be situated in areas currently occupied by surface parking, which are already impervious.

As for the need for infrastructure implementation, the new housing could utilize the existing urban infrastructure within the heritage area (water, electricity, sewage, drainage, landscaping, public transport); benefit from already established facilities for health, education, culture, and leisure; and have nearby commerce and services. In contrast, residents of the gated communities, while having local shopping options, must travel to other regions to access all the other necessary activities for their daily lives.

Regarding the need for commuting, in addition to the points mentioned earlier, the proposed housing would be located in the area with the highest concentration of jobs in the city. This would reduce commuter traffic, congestion, time loss, greenhouse gas emissions, and perhaps even the need of owning a private vehicle. The average distance to the CBD reinforces this argument.

In terms of integration with the city, urban vitality, and enhanced security, the new housing would be situated within existing or proposed streets and blocks, featuring a roadway system that allows for the free movement of all transportation modes, promoting walking and active transport. The mixed-use buildings would offer active ground-floor facades, and both these buildings and the row houses would maintain a direct public/private relationship, with their doors opening onto the sidewalk. Although the pilotis buildings do not have a direct public/private relationship (as one must use stairs or elevators to access the residences), they would still feature permeable, open, and traversable pilotis, characteristic of the modernist city. All these features, combined with an increased population, would enhance safety in the city, providing more "eyes on the street" and greater activity on the sidewalks, as exemplified by Jane Jacobs (2017). In contrast, gated communities represent the antithesis of these qualities.

Regarding the variety of building types, certain attributes (such as the presence or absence of underground garages, pilotis, or elevators), along with specific characteristics of their neighborhood urban design, determine their accessibility to different segments of the population (Holanda, 2007 and Tenorio & Santos Júnior, 2010). Consequently, whenever there is only one type of housing – or a significant predominance of one type – in a given area, it leads to a homogeneous community, as seen in gated condominiums. This creates enclaves, undermines urbanity, and fosters distrust and intolerance among different social groups (Tenorio, 2013).

The simulation employs eight different building types, all of which are already present in the designated heritage area, aiming to maintain the same volumetric relationships and the strong presence of urban greenery that characterize it. Only one type is not currently used for housing – the one from the Southern Bank Sector – and it should be adapted while retaining its volumetry and direct relationship with the sidewalk.

5. Final considerations: limitations, further developments, and contribution

The research proposes densification in the designated heritage area, but it was not initially within its scope to conduct a thorough study on the territory's capacity to support this new population. There was no consultation with utility companies to assess the landscape of water supply, sewage treatment, urban cleaning, and energy for the new units, for example. However, the following two facts were considered: 1) the original city plan was intended to accommodate 500,000 people, according to the competition notice for the new capital, indicating that there is room for densification; and 2) Brasília continues to grow, and new housing will be constructed in the Federal District, meaning that all necessary infrastructure must be provided. Studies that relate urban form and costs show that more compact and dense cities save more on the implementation and maintenance of infrastructure than sprawling and low-density cities (Mascaró, 1989).

There is also no in-depth analysis of the calculations that relate permeable to impermeable area. The impermeabilization of soil and its detrimental effects in the designated heritage area, due to the construction of additional housing, is often cited as an argument against increased density. However, comparisons show that growth beyond the designated perimeter could lead to much greater impermeabilization, as well as other environmental risks, such as the suppression of native savana vegetation, contamination of the groundwater, and loss of aquifer recharge. If an ecosystemic and integrated approach is required, impermeabilization of 10 km from the designated perimeter should be considered just as harmful as that occurring within it.

Future research could involve: updating data based on the 2022 Census; simulating more housing throughout the entire heritage area; creating 3D simulations to allow for observer-level visualizations; calculating the areas to be impermeabilized and obtaining more precise quantifications of the infrastructure needs for this new population.

And now, addressing the question posed by this article: Would Brasília be less Brasília if more people lived in the protected area? The belief is that the answer is no. Although the study also discusses issues related to sustainable density, its initial focus was on configurational aspects. According to these aspects, the use of existing building types with the same intervolumetric and public/private relations, while maintaining the predominance of green spaces and promoting the necessary urban density, ensures the preservation of significant elements of Brasília's modernist urban landscape. This approach upholds the characteristics that led to Brasília being designated a UNESCO World Heritage site.

The study aims to engage both the general public and experts, contributing to an informed debate on the city's growth and development. It provides a visualization of a possible scenario and its positive implications, emphasizing the need for contemporary cities to recognize and value their past while preparing for a near future focused on resource and energy efficiency, more responsible use of urbanized land, and the promotion of justice, urbanity, and equity.

6. References

CODEPLAN/Companhia de Planejamento do Distrito Federal (2022). *PDAD 2021 – Pesquisa Distrital por Amostra de Domicílios 2021: Relatório Codeplan. Distrito Federal* [online]. Available at: https://www.ipe.df.gov.br/wp-content/uploads/2022/05/Relatorio_DF-2021-1.pdf (Accessed: 23 March 2025). Brasília: CODEPLAN.

Holanda, F. (2007). 'Be aware of local properties', *6th International Space Syntax Symposium: Proceedings* [online]. Istambul, 12-15 June. Available at: spacesyntaxistanbul.itu.edu.tr/papers/longpapers/082%20-%20Holanda.pdf (Accessed: 23 March 2025).

IBGE/Instituto Brasileiro de Geografia e Estatística (2012) *Censo Brasileiro de 2010* [online]. Available at: https://www.ibge.gov.br/estatisticas/sociais/populacao/9662-censo-demografico-2010.html (Accessed: 23 March 2025). Rio de Janeiro: IBGE.

IBGE/Instituto Brasileiro de Geografia e Estatística (2022) *Censo Brasileiro de 2022: Panorama* [online]. Available at: https://cidades.ibge.gov.br/brasil/df/panorama (Accessed: 23 March 2025). Rio de Janeiro: IBGE.

IPEDF/Instituto de Pesquisa e Estatística do Distrito Federal (2023). *Déficit Habitacional do Distrito Federal 2021: Sumário Executivo* [online]. Available at: https://www.ipe.df.gov.br/wp-content/uploads/2023/10/Sumario-Executivo-Deficit-Habitacional.pdf (Accessed: 23 March 2025). Brasília: IPEDF.

IPHAN/Instituto do Patrimônio Histórico e Artístico Nacional (2018). *Relatório do Plano Piloto de Brasília* [online]. Available at: https://bibliotecadigital.iphan.gov.br/items/c8257202-fde8-4f25-813a-72914687a097 (Accessed: 23 March 2025). Brasília: IPHAN.

Jacbos, J. (2011). *Morte e vida de grandes cidades*. São Paulo: Martins Fontes.

Mascaró, J.L. (1989). *Desenho urbano e custos de urbanização*. Porto Alegre: Sagra Luzzatto.

OpenAI. (2024). *ChatGPT* [online]. Available at: https://chat.openai.com (Accessed: 31 October 2024).

Tenorio, G. (2013). 'The danger of community engagement as an exclusion tool: four case studies in four different scales in Brasilia, Brazil', *49º International Society of City and Regional Planners/ISOCARP Congress: Frontiers of Planning* [online]. Brisbane, 1-4 October. Available at: https://www.isocarp.net/Data/case_studies/2338.pdf (Accessed: 23 March 2025). The Hague: ISOCARP.

Tenorio, G. & Santos Júnior, R. (2010). 'Setor Noroeste, Brasília - can an elite neighborhood be considered green?', *46º International Society of City and Regional Planners/ISOCARP Congress: Sustainable city, developing world* [online]. Kenya, 19-23 September. Available at: https://www.isocarp.net/Data/case_studies/1822.pdf (Accessed: 23 March 2025). The Hague: ISOCARP.

Research Paper

Urban Density in Portland (USA).
The experience of the Urban Growth Boundary

Guido CIMADOMO, Universidad de Malaga, Spain

Abstract

This study explores the Urban Growth Boundary (UGB) in Portland, Oregon, implemented in 1979 as a strategy to control urban sprawl and protect natural resources. While the UGB successfully restricted expansion and preserved rural lands, it has faced challenges in fostering higher-density development within its limits. Portland's metropolitan area still comprises predominantly low-density, single-family homes, which strains public services and increases car dependency. The paper examines four urban development projects, offering insights into Portland's efforts to boost urban density. Findings highlight a complex balance between policy goals, private sector involvement, and cultural factors favouring suburban lifestyles. Although the case study projects promote density, car dependency and infrastructure limitations persist as significant obstacles. To sustain higher-density living, Portland must further refine its policies and enhance public-private collaboration.

Keywords

Portland, Urban Growth Boundary, Urban Density, Urban Transformations, Borders

1. Introduction

Portland, Oregon, has been recognized for its pioneering urban planning initiatives, notably the Urban Growth Boundary (UGB) established in 1979 (Bates, 2018). The UGB was created to control urban sprawl and preserve natural resources like agricultural lands and forests. The boundary has played a critical role in preventing the unchecked suburban expansion common in many U.S. cities, and it was expected to maintain a more compact urban form. While the UGB has succeeded in protecting rural and natural areas from development, it has not always been as effective at fostering higher-density development within the boundary. Much of the metropolitan area of Portland remains dominated by low-density, single-family housing, creating challenges for public services, transportation, and sustainability goals (Adler, 2022; Gray & Shriver, 2006). This paper examines, as part of a broader research on urban density in Portland, several urban development projects with a focus on improving livability and increasing density, assessing their successes and ongoing challenges, questioning if Portland urban density model is different from that of many other American cities (Beuer, 2018).

The UGB was intended to promote efficient land use and reduce car dependency by encouraging more compact, transit-oriented development. Since its inception, Portland's UGB has been updated to accommodate population growth, with some border areas added to the boundary to ensure enough space for housing and commercial activities. The integration of the different planning figures under a single department for coordination at the state or metropolitan level allowed for the limitation of building in priority areas within defined boundaries. This was considered a necessary tool to restrict the liberal market

forces that exploited the reduced cost of peri-urban areas for real estate development, serving as a response to the uncontrolled urban sprawl typical in the country. During the 1970s the centralization of land use regulation was seen as a necessary step especially in the western states because of the convergence of interests of environmentalists, developers, activists, and state officials who pushed for its implementation (Popper, 1988). In 1999 Senate Bill 100, which created an institutional structure for statewide planning requiring every Oregon city and county to prepare a comprehensive plan in accordance with a set of general state goals, was declared a National Planning Landmark by the American Planning Association (Firmino, 2007). Despite the innovation brought about by the implementation of the UGB, the urban model around which Portland's metropolitan environment has grown continues to have a significant ecological and environmental impact, especially because of its limited urban density. Many neighborhoods within the UGB remain characterized by low-density development. Single-family homes with large yards dominate much of the residential landscape, leading to inefficient land use, increased traffic, and higher infrastructure costs. This is due on the one hand to the enormous extension that was originally included in the UGB, and on the other hand to the absence of minimum limits on the number of units allowed on each parcel together with the "Euclidean planning" (after the city of Euclid in Ohio) which configures a hierarchy of land uses, with single-family zoning being the most restrictive and commercial zoning the least restrictive. Thus, the standard allows for all types of uses and typologies, including single-family, to be located on the latter plots (Nelson & Moore, 1993). Today, the city's challenge lies in balancing growth with the need for livability, green spaces, and sustainable urban environments.

In response to these challenges, Portland has implemented several policies aimed at increasing urban density, which anyway rely on private investments. The Residential Infill Program (RIP) approved by City Council in 2020 allows for the construction of multifamily housing in areas previously zoned for single-family homes, facilitating a shift towards higher-density living. The RIP has led to a marked increase in building permits for duplexes, triplexes, and fourplexes, demonstrating market demand for this type of housing (Department of Land Conservation and Development, 2023). Other policies, such as reducing parking requirements for new developments, have been implemented to encourage higher density. By removing the mandate for a certain number of parking spaces per housing unit, Portland hopes to encourage the use of public transportation, biking, and walking.

This research uses a mixed-method approach, combining cartographic analysis through Geographic Information Systems (GIS) with case studies of urban developments in Portland. Geospatial data on the UGB, urban growth, and zoning were collected, along with interviews with key figures in the real estate sector. Three private real estate projects in Gresham and a major public project in central Portland were examined to understand the dynamics of densification and the challenges faced by both public and private sectors. AI tools (OpenAI's ChatGPT) has been used only to improve readability of some paragraphs.

2. Case Studies of Urban Densification

To better understand Portland's approach to increasing urban density within the UGB, several key projects were analyzed. These case studies represent a diverse range of urban development initiatives that reflect the city's efforts to promote more compact, sustainable living environments. Each project is an attempt to address Portland's overarching goals of reducing sprawl, encouraging public transportation use, and creating walkable neighborhoods that prioritize community and sustainability.

The case studies selected for this research provide insights into both the successes and challenges of implementing higher-density developments in different contexts across Portland's metropolitan area. They vary in scale, from large redevelopment projects aimed at revitalizing key areas of the city, to smaller, more localized developments focused on sustainable, mixed-income housing. These examples illustrate the complexities of transitioning from low-density, car-oriented suburban environments to denser, more urbanized models that align with Portland's long-term vision for sustainable growth. The selection of Alta Civic Station, Downtown Rockwood Rising, and Sunrise East Gresham as case studies was influenced by the opportunity to engage directly with Matt Brown, lead architect at YBA Architects in Portland, who worked closely on these projects. Brown not only provided valuable insights through interviews but also facilitated access to key documents and design plans, allowing for a more detailed analysis of these developments. The three interventions are located in Gresham, the second most populated city after Portland in Multnomah County, and the fourth in the state, according to the 2020 census. Other data of interest offered by the census is the urban density, which reaches 1879.6 people per square kilometer, with a growth of 6.96% in the last decade. The city, which is strengthening its own centrality to consolidate itself as a complementary center and limit dependence on Portland, continues to orbit in its gravitational sphere, justifying the selection of case studies. The city has a privileged connection to the business district via the T-Max surface light rail line, at a distance of approximately 30 minutes.

The forth case study, the Broadway Corridor, is the most relevant urban (public) project currently under development in the city of Portland, contemplating a new masterplan for the 13.7 ha located in the city center. According to public developer Prosper Portland, this project's main objective is to establish a seamless connection between Old Town/Chinatown and the Pearl District, in downtown Portland, with the purpose of maximizing benefits for the community as a whole, with special emphasis on those groups that historically have not gained significant advantages from other urban projects in the region, and also to transform the actual trend of decreasing occupancy in the sector between the nearest neighborhoods (Prosper Portland, 2020).

By examining the design, execution, and outcomes of these projects, this section highlights the multifaceted nature of urban densification. It also underscores the balance that must be struck between market demands, public policy, and community needs in creating livable, resilient urban spaces. The four case studies demonstrate the varying degrees of success in achieving Portland's density goals, offering lessons for future urban planning efforts.

2.1. Alta Civic Station

Located near a MAX light rail station in Gresham, the Alta Civic Station project (Fig. 1) is an example of transit-oriented development (TOD) designed to reduce car dependency and increase residential density. The project includes 318 residential units, as well as commercial and public spaces.

While the development has succeeded in providing higher-density housing near public transit, it still faces challenges related to parking. Nearly 50% of the site is allocated for surface parking, which detracts from the project's goal of creating a fully walkable, compact urban environment. This reflects a broader issue in Portland's suburban areas, where car dependency remains high despite efforts to promote transit use.

Figure 1. Alta Civic Station development plan. Source: YBA Architects.

2.2. Downtown Rockwood Rising

The Downtown Rockwood Rising project in Gresham (Fig. 2) aims to revitalize a struggling neighborhood through a mixed-use development that includes residential, commercial, and public spaces. The project centers around a large public plaza, designed to create a vibrant community hub and encourage pedestrian activity.

Rockwood Rising is an important case of urban renewal in a historically under-invested area. However, the project faces similar challenges to Alta Civic Station, with large portions of land still dedicated to parking. This limits the potential for creating a truly walkable, high-density neighborhood. Nonetheless, the inclusion of public spaces and the focus on integrating public transit are steps in the right direction for fostering urban density. Downtown Rockwood Rising is designed with future legislative modifications in mind, allowing for the replacement of parking lots with new blocks, which will eventually move parking in the underground levels of the new buildings, reaching a more compact, parking free neighbourhood.

Figure 2. Downtown Rockwood Rising development plan. Source: YBA Architects.

2.3. Sunrise East Gresham

Close to Downtown Rockwood Rising, the Sunrise East Gresham project (Fig. 3) is planned as a mixed-income housing development to begin at the end of 2014. Its feasibility is linked to the previous development, as its public plaza and commercial offer will attract more residents to the neighbourhood. The project includes green spaces and communal areas to prioritize walkability and community interaction, and 79 mixed-typology houses into two independent buildings, with a footprint of 24% of the total area. As in previous developments, 50% of the plot is dedicated to parking, with a 1,19 ratio compared to the total number of parking spaces required by regulations.

Though smaller in scale than the other case studies, Sunrise East Gresham exemplifies how focusing on green infrastructure and mixed-income housing, the project addresses both social and environmental sustainability goals.

Figure 3. Sunrise East Gresham development plan. Source: YBA Architects.

2.4. Broadway Corridor

The Broadway Corridor is one of the largest and most ambitious redevelopment projects in Portland's history (Fig. 4). The project, promoted by the local public agency Prosper Portland, aims to transform a 13.7-hectare area in downtown Portland, which previously housed the U.S. Postal Service, into a vibrant, high-density neighborhood. The master plan includes a mix of residential, commercial, and public spaces, designed to enhance connectivity between the Old Town/Chinatown and Pearl District neighborhoods.

The Broadway Corridor is seen as a key opportunity for increasing urban density in Portland's city center. However, the project has faced significant challenges, particularly in light of the COVID-19 pandemic. High vacancy rates in downtown office buildings and the rise of remote work have raised questions about the long-term viability of large-scale commercial developments in the area. They reflect the uncertainties of the private developers who have been charged with leading the process, which also spread to the rest of private real estate developments in the metropolitan area.

Nevertheless, the project remains a critical component of Portland's strategy to increase density and revitalize its urban core, being a relevant experience to follow up in the next years, in order to evaluate the efforts in densifying the urban tissue of the city.

Figure 4. Broadway Corridor location in downtown Portland. Source: Prosper Portland, public domain.

3. Challenges to Increasing Density

Despite the efforts shown in the case studies presented, which also if low in number are a good representation of the trends in act in the city, Portland faces several challenges in achieving its density goals. First, car dependency remains a significant barrier. Many residents still rely on private vehicles for commuting and daily activities, even in areas served by public transportation. This is reflected in the high demand for parking spaces in new developments, which limits the potential for truly walkable, high-density neighborhoods.

Second, there are infrastructure limitations. As population density increases, so does the demand for public services, such as transportation, utilities, and green spaces. However, much of Portland's infrastructure was designed for lower-density living and has not kept pace with the city's growth or RIP new developments. Upgrading infrastructure to accommodate denser populations will require significant public investment and careful planning.

Third, market hesitancy has slowed the progress of some larger-scale developments. The COVID-19 pandemic has added uncertainty to Portland's real estate market, particularly in the commercial sector. Projects like the Broadway Corridor, which rely on significant private investment, may struggle to attract tenants and buyers in a post-pandemic economy where remote work and office vacancies remain high.

Finally, cultural preferences for single-family homes continue to shape Portland's housing market. Many residents are attached to the suburban model of living, with large yards and private parking. Shifting these preferences toward more compact, multifamily housing will require not only policy changes but also public investments and a broader cultural shift.

4. Discussion and Conclusions

Portland's Urban Growth Boundary has been successful in controlling sprawl and preserving rural land, but challenges remain in fostering higher-density development within the boundary. The Residential Infill Program (RIP) has made significant progress in promoting multifamily housing, and the case studies analysed provide examples of how density could be increased in suburban areas. While there is clear momentum behind the city's densification efforts, the balance between market realities, public policy, and community needs remains delicate. Projects like Alta Civic Station and Downtown Rockwood Rising show that progress is being made in creating higher-density, mixed-use developments, but they also underscore the persistence of car-dependent infrastructure that limits the full potential of these projects, highlighting the complexities of increasing urban density. However, these projects also show the ongoing struggle to balance parking needs, car dependency, and the goal of creating walkable, high-density neighborhoods.

The Broadway Corridor represents a key opportunity for increasing density in downtown Portland, an area which is anyway more dense than the rest of the city, but its success will depend on the city's ability to address the economic uncertainties facing the commercial real estate market. Public investment in infrastructure, transportation, and public spaces will be crucial to support denser developments, especially in the face of changing work patterns and housing demand. It stands as a symbol of Portland's ambition to reshape its urban core, despite the formidable challenges it faces.

Moving forward, Portland must continue refining its policies to better incentivize sustainable, high-density development. This will require a coordinated effort between public and private sectors, as well as a cultural shift toward accepting more compact forms of urban living. While Portland remains a key example of urban growth management in the U.S., it must address crucial challenges to consolidate a truly sustainable urban model. European and Latin American urban experiences offer lessons on how to revitalize urban spaces through pedestrianization, renaturalization of spaces, and the focus on proximity models like the 15-minute city, which could serve as a guide for Portland's future transformations. If successful, Portland's approach to urban density could serve as a model for other cities seeking to balance growth, sustainability, and livability in the 21st century.

Acknowledgments

This work has been funded by the Ministry of Universities of the Kingdom of Spain, through the Spanish University System Reclassification Program. The availability and suggestions of Howard Davis, Professor at the University of Oregon, and Matt Brown of YBA Architects throughout the conduct of this research are gratefully acknowledged.

References

Adler, S. (2022) *Planning the Portland urban growth boundary: the struggle to transform trend city*. Corvallis: Oregon State University Press.

Bates, L.K. (2018) 'Growth without Displacement: A Test for Equity Planning' in Krumholz N. and Werheim K. (eds.) Hexter *Advancing Equity Planning Now.* Ithaca: Cornell University Press, pp. 21-43.

Beuer, S. (2018) 'Houston Or Portland: Which City Is Doing Urban Density Better?', *The Market Urbanist,* 25 October 2018. Available at: https://marketurbanismreport.com/blog/houston-or-portland-which-city-is-doing-urban-density-better (Accessed: 24 October 2024)

Department of Land Conservation and Development (2023) 'Residential Infill Project. Year-One Report', 26 August 2023 [online]. Available at: https://www.oregon.gov/lcd/op/pages/history.aspx (Accessed: 24 October 2024)

Firmino, R. (2007) 'Book Review: City Limits: Walking Portland's Boundary DAVID OATES, 2006 Corvallis, OR: Oregon State University Press 112 Pp. US$18.95 Paperback ISBN 0 87071 095 8 Paperback', *Urban Studies* 44(10), p.2050-52.

Gray, J. D. and Shriver K. (2006) 'Land Use Planning Information Fo

r the Citizens of Oregon' The *Oregon Community Foundation,* 2 November 2006 [online] Available at: https://oregonexplorer.info/data_files/OE_topic/landuse/documents/gray_white_paper.pdf (Accessed: 24 October 2024)

Nelson, A.C. and Moore, T. (1993) 'Assessing urban growth management: The case of Portland, Oregon, the USA's largest urban growth boundary', *Land Use Policy* 10 (4), p.293-302.

Popper, F. (1988) 'Understanding American Land Use Regulation Since 1970: A Revisionist Interpretation'. *Journal of the American Planning Association* 54 (3), p.291-301.

Prosper Portland (2020) *Putting people first* [online]. Available at: https://www.broadwaycorridorpdx.com/people-first (Accessed: 24 October 2024)

Research Paper

Landscape Character Assessment and Sustainable Development Strategies Under the Urban-Water Integration Perspective:

A Case Study of Dongting Lake Area, Hunan Province, China

Yini ZHU, College of Landscape Architecture, Beijing Forestry University, CHINA

Chi LI*, College of Landscape Architecture, Beijing Forestry University, CHINA

Abstract

Dongting Lake is an important storage lake in the Yangtze River Basin and a vital national ecological security barrier in China. The Dongting Lake area of Hunan province, centered around Dongting Lake, comprises 25 urban spaces and covers an area of 46,300 square kilometers. Influenced by the human-land relationship, this region has developed a distinctive urban-water integrated spatial pattern by the interactive adaptation of the urban spaces growth and its river and lake systems. There are a variety of natural and cultural landscape, and urban residents live according to the water.

In recent years, the total population volume and the level of urbanization in the Dongting Lake area have been rising steadily. In order to balance the synchronous development of urban and natural space and realize the overall protection and sustainable utilization of urban space in Dongting Lake area, it is necessary to seek a system to identify, describe and assess the characteristics of the basic units of the ecosystem in the region, and put forward the corresponding sustainable development strategies.

Based on the theory of Landscape Character Assessment(LCA), the research of the sustainable development of urban space in Dongting Lake area has been carried out through literature review, field research, GIS analysis, spatial clustering and other methods. The research contents are as follows: 1) Constructing a set of methods for assessing the landscape character of the area under the "urban-water" integrated spatial pattern. 2) Considering the cultural and social indicators at the urban level and the natural geographical indicators at the water level to identify, classify and describe the characteristic elements of Dongting Lake area. 3) Assessing the value of the characteristic areas through literature analysis and expert scoring method. Then, dividing them into high value characteristic area, medium value characteristic area and low value characteristic area.4) Providing regional sustainable development strategies based on the assessment, in order to build a livable and resilient town space. The research results also provide guidance for sustainable development with similar urban space.

Keywords

Urban-water integration, Landscape character assessment, Dongting lake area, Sustainable development strategy

1. Introduction

Dongting Lake is an important storage lake in China's Yangtze River basin and an important national ecological security barrier (Yu *et al.*, 2023, Yuan *et al.*, 2024). Due to the continuous urban-water interaction, the Dongting Lake area presents a special human environment (Liang *et al.*, 2021). It generates spatial heterogeneity and has high natural and humanistic multiple values. So it is a key area for landscape protection and development. In recent years, the total population and urbanization level of the Dongting Lake area have been steadily increasing (Xiong *et al.*, 2022, Zhu and He, 2021). In the existing researches, the researches for the Dongting Lake area mainly focus on ecological protection (Yuan *et al.*, 2024), water body management (Niu, Yu and Jiang, 2015, Wang *et al.*, 2018), etc., which can not provide a clear target orientation for the habitat environmental protection under the urban-water system in the Dongting Lake area. So identifying, describing and evaluating the spatial heterogeneity of the lake area and proposing corresponding sustainable development strategies are the key prerequisites for realizing the inheritance, protection and development of the town space in the Dongting Lake area.

Landscape character, defined as the pattern of unique, recognizable and consistent elements in a landscape, is one of the effective methods for identifying spatial heterogeneity, providing a methodology and research framework for the evaluation and management of spatial heterogeneity(Butler and Akerskog, 2014, Pan *et al.*, 2022). Since the first application of Landscape Character Assessment (LCA) in the UK in 1991, and the formal definition of the concept of landscape character assessment in Landscape Character Assessment Guidance for England and Scotland in 2002, LCA has been widely used in research (Butler and Akerskog, 2014, Herlin, 2016, Terkenli, Gkoltsiou and Kavroudakis, 2021). And with the multi-scale effect, many scholars have conducted landscape character assessment at different scales, such as national (Butler and Berglund, 2014), watershed (Koc and Yilmaz, 2020), natural areas (Ding *et al.*, 2020), urban areas (Lu *et al.*, 2022), village areas (Lokocz, Ryan and Sadler, 2011).

In order to achieve accurate landscape classification, with the development of technology, many spatial clustering methods have been introduced into LCA, such as bidirectional indicator species analysis (TWINSPAN), K-means, Som, two-step clustering method, etc (She, Liu and Chen, 2024, Zhao, Lu and Jiang, 2023). The limitation of TWINSPAN is that it can process up to 25,000 objects (Yang *et al.*, 2020), which makes it impossible to properly process large sample data. K-means and Som can only identify continuous variables, which also has certain limitations. Two-step clustering is widely used because it can handle large scale data and cluster categorical variables and continuous variables simultaneously.

Based on the theory of Landscape Character Assessment (LCA), this paper carried out the research on the sustainable development of the town space in Dongting Lake area through literature review, field research, GIS analysis, spatial clustering, etc. It proposed the corresponding sustainable development strategy by identifying, describing and evaluating the landscape character assessment in the area. In order to construct a livable and resilient town space in the lake area. The research results also provide guidelines for the sustainable development of town spaces with similar characteristics.

2. Method

2.1. Study area: Dongting lake area of Hunan province

Dongting Lake is an important regulation lake in the Yangtze River basin and the second largest freshwater lake in China(Deng and Lin, 2024). This paper takes Dongting Lake area as the research scope, with Dongting Lake as the center, covering three cities and one district(Yueyang, Changde and Yiyang cities, Wangcheng District). The geographical locations are 111 53 ′ to 113 05 ′ E and 28 44 ′ to 29 35 ′ N

(Figure 1). It is a typical representative of the combination of cross-administrative divisions and natural divisions(Xiong *et al.*, 2022). It covers an area of 46,300 square kilometers.

The unique habitat of the Dongting Lake area exemplifies a complex urban-water system, shaped by the interplay between urban expansion and the adaptive relationship of rivers and lakes. The distinct regional characteristics of the lake area are the result of a dynamic coupling of various natural and human factors, including human activity, land use patterns, management practices, climate, hydrology, and topography.

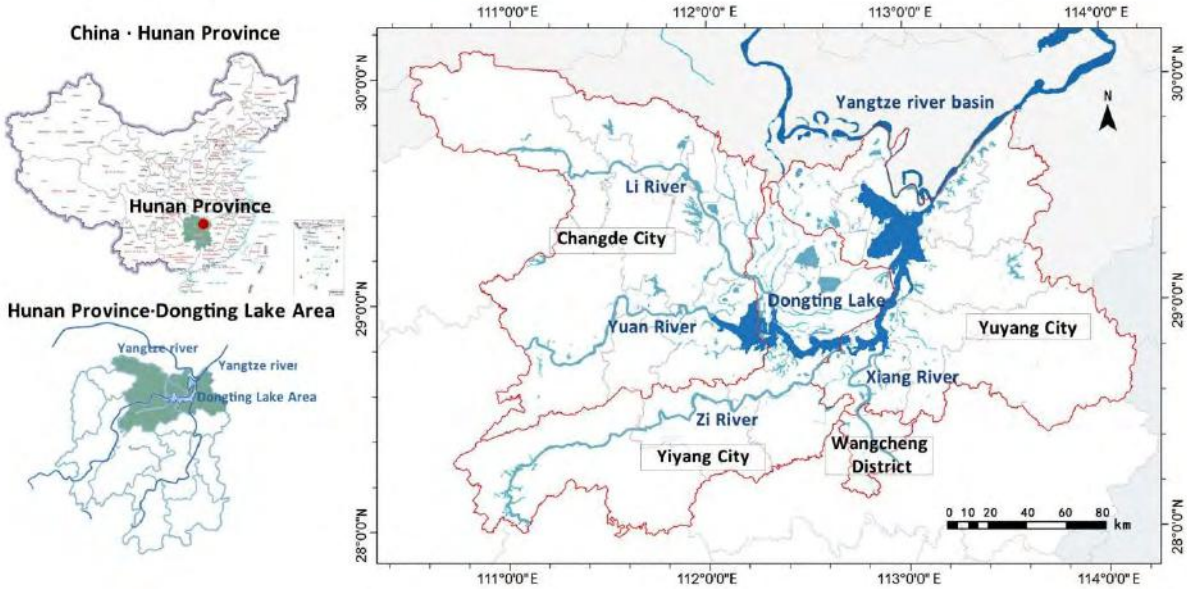


Figure 1. Study area: Dongting Lake Area of Hunan Province. Source: Author self-painted.

2.2. Framework

LCA is clearly defined in the Landscape Character Assessment Guidance for England and Scotland (LCA Guidance). Under the urban-water system, the landscape character assessment process of Dongting Lake area is as follows three steps: character description, value assessment and sustainable development strategies.

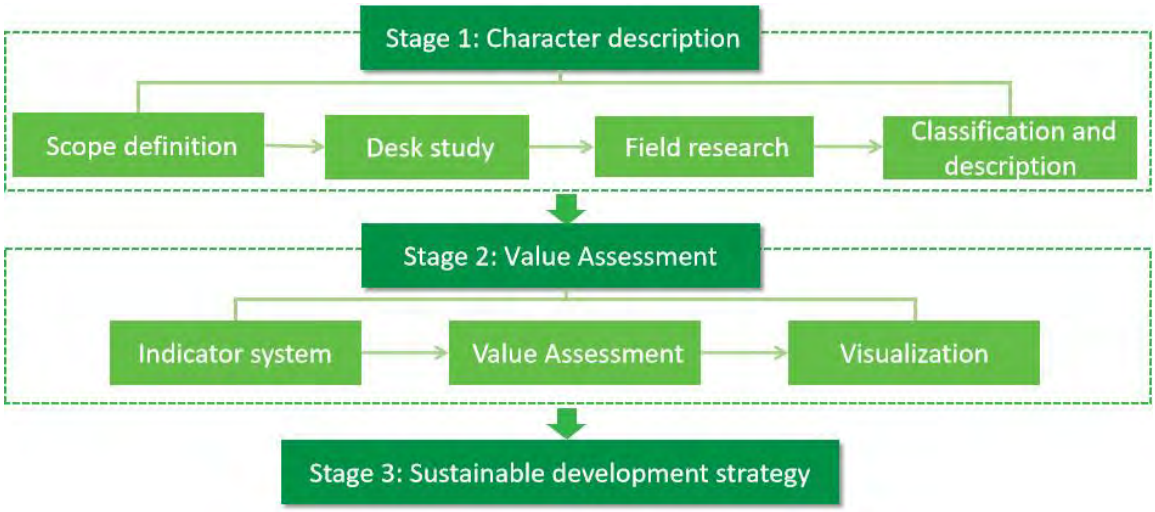


Figure 2. Framework. Source: Author self-painted.

2.3. Method

2.3.1.Evaluation of the indicators and the data sources

To accurately capture the landscape characteristics within the urban-water system, indicators from both urban and water dimensions were selected, encompassing human-social and natural geographic factors. These indicators include the spatial density of built-up areas, rural settlements, water area and wetland, geomorphic features and river-lake system zone. Together, these six indicators provide a comprehensive description of landscape characteristics within the urban-water system.

Table 1. Indicators in Landscape character. Source: Author self-painted.

Level	Name of Indicators	Unit	Source
Urban Level	Spatial density of urban built-up area	Number of points/km^2	The Center for Resource and Environmental Science and Data Research, Chinese Academy of Sciences(http://www.resdc.cn/)
	Spatial density of rural settlements		
Water level	Spatial density of water area		
	Spatial density of wetland		
	Geomorphic features	-	
	River-lake system zoning	-	Dongting Lake meteorological zoning DB43/T 2076-2021

2.3.2.Classification methods for Landscape Character

The Two-Step Cluster is a hybrid clustering technique that integrates both hierarchical and non-hierarchical methods, making it especially effective for handling large datasets with mixed data types (both continuous and categorical variables). This approach involved a two-stage process: an initial pre-clustering followed by a final clustering phase. In this study, we utilized the SPSS platform to conduct second-order clustering for the study area.

Table 2. Cluster method in Landscape character. Source: Author self-painted.

Cluster method	Type of variable	Number of categories	Sample
TWINSPAN	Categorical variables	Automatically determined	Less than 25,000 objects
K-mean cluster	Continuous variables	Fixed classification number	large sample
Two-Step Cluster	Continuous variables + Categorical variables	Automatically determined	large sample

2.3.3.Method for Landscape Character Assessment

To effectively evaluate the landscape value of the region while accommodating diverse value orientations, two primary indicators were selected: natural landscape value and humanistic landscape value. These were supported by five secondary indicators: ecological importance, degree of ecological protection, natural originality, density of important settlements, and density of cultural heritage. By individually calculating and normalizing each indicator, and then overlaying them with equal weights for hierarchical visualization, we derived a comprehensive landscape value index for the lake area, along with separate indexes for natural and humanistic values.

$$\text{Comprehensive value} = a_1EI_i + a_2EP_i + a_1NP_i + a_1SD_i + a_1CHD_i$$

$$\text{Natural value} = a_1EI_i + a_2EP_i + a_1NP_i$$

$$\text{Humanistic value} = a_1SD_i + a_1CHD_i$$

Table 3. Indicators in landscape character assessment. Source: Author self-painted.

First-level index	Weight	Second-level index	Weight	Description	Assess	Value
Natural landscape value	0.5	Ecological importance (EI)	0.2	Sorting and assigning by using the Invest habitat quality assessment	Good Medium Poor	3 2 1
		Degree of ecological protection (EP)	0.15	Sorting and assigning values using protected areas	Protected Unprotected	1 0
		Natural primitiveness (NP)	0.15	Using land use, population distribution, and road traffic to identify natural patches , and assigns values based on size.	Undamaged damaged	1 0
Humanistic landscape value	0.5	Settlements density (SD)	0.25	Using the nuclear density ranking assigned to historical-cultural cities, towns and villages.	Good Medium Poor	3 2 1
		Cultural heritage density (CHD)	0.25	Sorting and assigning values by vusing cultural heritage kernel density	Good Medium Poor	3 2 1

3. Results

3.1. Landscape character zoning under the urban-water system

Fourteen categories of landscape characteristics within the urban-water system were identified and documented in the ArcGIS platform database. Four categories cover over 10 percent of the area, representing the most distinctive landscapes of the Dongting Lake region: low-altitude mountainous landscape near the river (cluster 10), plain landscape surrounding the lake (cluster 4), mid-altitude mountainous landscape (cluster 14), and platform landscape around the lake (cluster 7).

Table 4.Landscape character zoning. Source: Author self-painted.

Cluster	Name	Rate of area
1	Hills landscape around the lake	6.29%
2	Low-altitude mountains landscape around the lake	9.57%
3	Plain lake landscape	5.39%
4	Plain landscape around the lake	12.80%
5	Low-altitude urban landscape	1.28%
6	Low-altitude village landscape around the lake	3.79%

7	Platform landscape around the lake	10.06%
8	Village landscape in the latform around the lake	2.42%
9	Hills landscape near the river	7.21%
10	Low-altitude mountains landscape near the river	13.85%
11	Plain landscape near the river	4.61%
12	Plain wetland landscape	3.33%
13	Platform landscape near the river	9.04%
14	Mid-altitude mountain landscape	10.35%

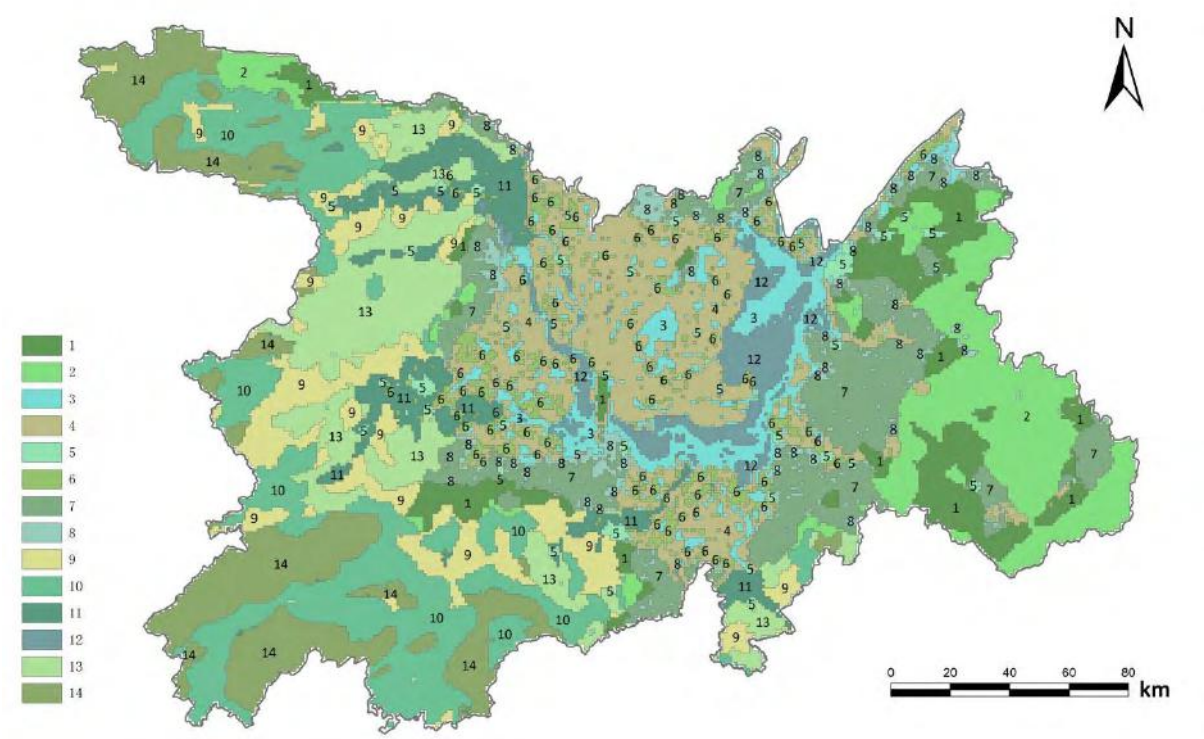


Figure 3. Landscape character zoning. Source: Author self-painted.

3.2. Landscape Character Assessment Results

The natural, humanistic, and comprehensive values of the character area were evaluated through literature analysis and expert scoring, with each divided into 5 grades. Our analysis revealed that landscape types with high natural value include plain lake landscapes (cluster 3), plain wetland landscapes (cluster 12), and mid-altitude mountain landscapes (cluster 14). In contrast, landscapes with high humanistic value encompass low-altitude urban landscapes (cluster 5) and plain landscapes near rivers (cluster 11). By integrating natural and humanistic values, we identified comprehensive value zones, comprising 2 high-value zones, 4 slightly high-value zones, 4 medium-value zones, 1 slightly low-value zone, and 3 low-value zones.

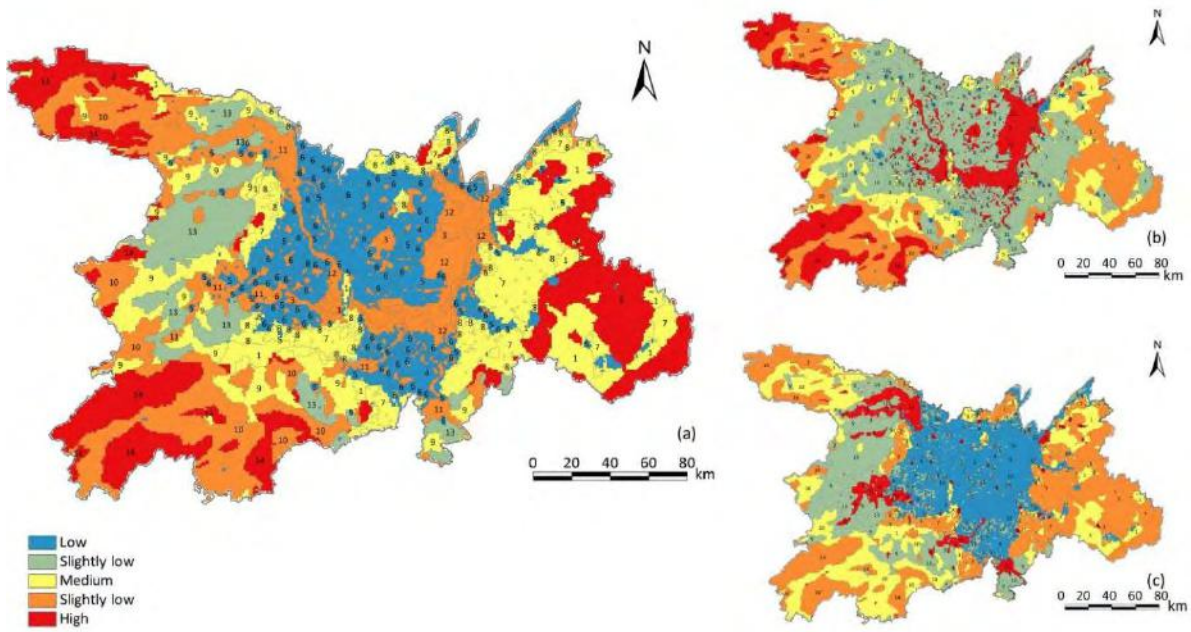


Figure 4. Landscape character assessment zoning. Source: Author self-painted.

(a)Comprehensive value area. (b)Natural value area. (c)Humanistic value area.

Table 5.Landscape character assessment. Source: Author self-painted.

Cluster	Humanistic value	Natural value	Comprehensive value
1	Medium	Medium	Medium
2	Slightly high	Slightly high	High
3	Low	High	Slightly high
4	Low	Slightly low	Low
5	High	Low	Low
6	Slightly low	Slightly low	Low
7	Slightly high	Slightly low	Medium
8	Medium	Medium	Medium
9	Slightly low	Medium	Medium
10	Medium	Slightly high	Slightly high
11	High	Slightly low	Slightly high
12	Low	High	Slightly high
13	Slightly low	Slightly low	Slightly low
14	Slightly high	High	High

3.3. Regional Sustainable Development Strategies

On the basis of the assessment, regional sustainable development strategies were proposed with a view to constructing a livable and resilient town space in the lake area. The results of the study also provided guidelines for the sustainable development of town spaces with similar characteristics.

3.3.1. Protecting the regional landscape features

The primary strategy was to protect regional landscape features. In the Dongting Lake area, the comprehensive high-value zones (clusters 2 and 14) and the slightly high-value zones (clusters 3, 10, 11, and 12) represent the core of the regional landscape characteristics within the urban-water system and

require focused protection. Protective measures for these zones include the designation of specialized protected areas and the establishment of long-term monitoring and evaluation mechanisms. Additionally, landscape changes should be regularly monitored using remote sensing, ground observation, and community feedback to promptly identify potential threats and ensure the effectiveness of protection efforts.

3.3.2. Developing Partition Management Strategies

In order to rationalize the use of multiple resources, areas were zoned based on landscape value assessments, allowing for targeted management approaches. For instance, natural high-value landscape areas are subject to stricter ecological protection and management, while natural low-value areas may permit moderate development or renovation. Humanistic high-value areas focus on preserving cultural heritage, such as historic buildings and traditional villages, through restoration and conservation, ensuring these sites remain integral to modern society as iconic regional features. In contrast, humanistic low-value areas can be further explored and developed to enhance their cultural significance.

3.3.3. Strengthening policy guarantees

The results of landscape character assessment can guide the preparation of upper-level planning, and ensure that landscape characteristics are preserved through the implementation of related regulations. For example, in the face of major changes in territorial spatial planning, LCA can be an important means to protect the natural resource background characteristics and resource endowment. It can guide the landscape control, functional area division and development orientation of the land space planning in Dongting Lake area. By guiding the planning process, LCA helps to rationalize land use, optimize urban and rural spatial layouts, improve ecological quality, and provide a scientific foundation for sustainable economic and social development. Additionally, LCA can direct special planning for nature reserves; comprehensive high-value areas may be designated as nature reserves or scenic spots, while natural high -value areas can be identified for various nature parks based on their primary vegetation types.

3.3.4. Promoting eco-tourism

Ecotourism transforms the landscape’s intrinsic value into economic value, raising conservation awareness among local residents and management. Sustainable development can be achieved by creating specialized tourist routes, constructing eco-friendly facilities, and designing sustainable transportation options. Furthermore, ecotourism planning not only helps preserve ecological balance but also strengthens cultural identity among local residents, fostering sustainable regional development.

4. Conclusion

The Dongting Lake area under the urban-water system has a unique habitat. Identifying regional landscape characteristics and drawing a landscape base map with Dongting Lake characteristics is essential for ensuring comprehensive ecosystem protection and the sustainable use of natural resources. This study identified 14 landscape character zones in the Dongting Lake area and assessed each zone's value by integrating natural resource and cultural heritage factors. The findings included 2 comprehensive high-value zones, 4 higher-value zones, 4 medium-value zones, 1 lower-value zone, and 3 low-value zones. Based on these findings, four sustainable development strategies are proposed: protecting regional landscape characteristics, implementing zoning management, enhancing policy protections, and promoting ecotourism.

This study provides a framework for an understanding the landscape characteristics of the lake area, scientific guidance for the protection, construction and development of multiple resources, as well as for

the preparation of relevant plans. However, a limitation of this study is that it focuses solely on first-level characterization of the urban-water spatial structure, without addressing plant and animal biodiversity. Future research will aim to further refine this study by incorporating second-level characterization under the urban-water system in greater detail.

5. References

Butler, A. and Akerskog, A. (2014) 'Awareness-raising of landscape in practice. An analysis of Landscape Character Assessments in England', *Land Use Policy,* 36, pp. 441-449.

Butler, A. and Berglund, U. (2014) 'Landscape Character Assessment as an Approach to Understanding Public Interests within the European Landscape Convention', *LANDSCAPE RESEARCH,* 39(3), pp. 219-236.

Deng, J.N. and Lin, Q. (2024) 'Landscape Character and Management Zones in Polder Landscapes: A Case Study of the Dongting Lake Area', *Land,* 13(11).

Ding, D., Jiang, Y., Wu, Y. and Shi, T. (2020) 'Landscape character assessment of water-land ecotone in an island area for landscape environment promotion', *Journal of Cleaner Production,* 259.

Herlin, I.S. (2016) 'Exploring the national contexts and cultural ideas that preceded the Landscape Character Assessment method in England', *LANDSCAPE RESEARCH,* 41(2), pp. 175-185.

Koc, A. and Yilmaz, S. (2020) 'Landscape character analysis and assessment at the lower basin-scale', *Applied Geography,* 125.

Liang, J., Yi, Y., Li, X., Yuan, Y., Yang, S., Li, X., Zhu, Z., Lei, M., Meng, Q. and Zhai, Y. (2021) 'Detecting changes in water level caused by climate, land cover and dam construction in interconnected river−lake systems', *Science of The Total Environment,* 788, p. 147692.

Lokocz, E., Ryan, R.L. and Sadler, A.J. (2011) 'Motivations for land protection and stewardship: Exploring place attachment and rural landscape character in Massachusetts', *Landscape and Urban Planning,* 99(2), pp. 65-76.

Lu, Y., Xu, S., Liu, S. and Wu, J. (2022) 'An approach to urban landscape character assessment: Linking urban big data and machine learning', *SUSTAINABLE CITIES AND SOCIETY,* 83.

Niu, Y., Yu, H. and Jiang, X. (2015) 'Within-lake heterogeneity of environmental factors structuring bacterial community composition in Lake Dongting, China', *WORLD JOURNAL OF MICROBIOLOGY & BIOTECHNOLOGY,* 31(11), pp. 1683-1689.

Pan, Y.L., Wu, Y.N., Xu, X., Zhang, B. and Li, W.F. (2022) 'Identifying Terrestrial Landscape Character Types in China', *Land,* 11(7).

She, W., Liu, X. and Chen, X. (2024) 'Characterization of Human-Water Harmony in Fengyan Irrigation District Based on K-Means Clustering Algorithm', *Journal of Jiamusi University(Natural Science Edition),* 42(06), pp. 87-90+133(in Chinese).

Terkenli, T.S., Gkoltsiou, A. and Kavroudakis, D. (2021) 'The Interplay of Objectivity and Subjectivity in Landscape Character Assessment: Qualitative and Quantitative Approaches and Challenges', *Land,* 10(1).

Wang, W., Yuan, W., Chen, Y. and Wang, J. (2018) 'Microplastics in surface waters of Dongting Lake and Hong Lake, China', *Science of The Total Environment,* 633, pp. 539-545.

Xiong, J., Wang, X., Zhao, D. and Zhao, Y. (2022) 'Spatiotemporal pattern and driving forces of ecological carrying capacity during urbanization process in the Dongting Lake area, China', *Ecological Indicators,* 144, p. 109486.

Yang, D., Gao, C., Li, L. and Van Eetvelde, V. (2020) 'Multi-scaled identification of landscape character types and areas in Lushan National Park and its fringes, China', *Landscape and Urban Planning,* 201, p. 103844.

Yu, S., Kong, X., Wang, Q., Yang, Z. and Peng, J. (2023) 'A new approach of Robustness-Resistance-Recovery (3Rs) to assessing flood resilience: A case study in Dongting Lake Basin', *Landscape and Urban Planning,* 230, p. 104605.

Yuan, L., Geng, M., Li, F., Xie, Y., Tian, T. and Chen, Q. (2024) 'Spatiotemporal characteristics and drivers of ecosystem service interactions in the Dongting Lake Basin', *Science of The Total Environment,* 926, p. 172012.

Zhao, Z., Lu, N. and Jiang, C. (2023) 'Village classification and development strategy in the north foot of Qinling Mountains based on SOM neural network', *Journal of Guilin University of Technology,* 43(04), pp. 608-616(in Chinese).

Zhu, Z. and He, Q. (2021) 'Spatio-temporal evaluation of the urban agglomeration expansion in the middle reaches of the Yangtze River and its impact on ecological lands', *Science of The Total Environment,* 790.

Research Paper

Maximizing Urban Vegetalisation

A Comprehensive Data-Driven Strategy for estimating Maximum Vegetation Coefficients

Georgies SROUR, AREP, France

Abstract

This paper introduces a tool designed to estimate the maximum potential for vegetation in densely populated urban areas. By integrating comprehensive data sets, including transportation mode share, underground constraints, flow data, and other key factors—this tool provides a data-driven approach to urban greening.

As urbanization accelerates, the need for green spaces in city planning becomes increasingly urgent to counteract environmental degradation and enhance residents' well-being. However, identifying suitable areas for vegetation in high-density urban settings remains a significant challenge.

The tool uses advanced spatial analysis techniques and data modeling to assess the feasibility of vegetation integration across diverse urban landscapes. By considering a multiplicity of factors, such as people flow potential, urban morphology, underground infrastructure, and vegetation, it provides a powerful tool for decision making to professionals and policymakers

The tool will be applied to the Montparnasse neighborhood as a case study to demonstrate its effectiveness.

Keywords

Renaturation, Graph theory, Ecology, Connectivity, Urban planning

1. Introduction

A shift from an anthropocentric approach to a life-centric one—where cities support diverse forms of life—is a complex but necessary transition. This shift requires not only a change in the professional field of city planning but also the right tools to guide the process. Renaturing cities is necessary for this transformation, in order to repair the landscape, improve biodiversity and create environments that support all forms of life.

While, urban planners, municipalities, and environmental specialists widely acknowledge the necessity of making cities greener, implementing effective vegetation strategies is however quite hard. City planning is composed by a variety of specialists, engineers, designers, transport planners, which makes the field segmented. In addition, multiple stakeholders are often involved within a project, making the process for improving green infrastructure time-consuming and complex.

So, how can we create a tool that helps planting green infrastructure in cities by taking into account different specialities?

A plethora of factors influence the availability of plantable spaces in cities, which can be grouped into three main categories:

1. **Existing Green Patches** – These form the ecological backbone of urban landscapes, a starting point for renaturation efforts.
2. **People flow** – Understanding people moving patterns, around metro and railway stations, or along major streets let us identify the most appropriate locations for vegetation.
3. **Regulatory Constraints** – Restrictions related to underground networks and infrastructure limit planting opportunities.

By combining these three factors, professionals and specialists can develop a systematic approach to identifying high-priority areas for new green spaces. This paper introduces the **Renaturation Potential Coefficient (RCP)**—a tool that models and visualizes plantable areas based on these combined criteria. With an evidence-based framework, the RCP empowers urban planners to make decisions that supports the ecological transition of cities.

RCP allows planners to quickly assess renaturation potential across neighborhoods, considering ecological continuity, accessibility, and infrastructural constraints. This index is particularly useful for professionals who need an efficient tool to inform renaturation strategies in complex urban settings.

This paper will first present the methodology behind the RCP, the data sources and the calculation methods. It will then present the application of the RCP through a case study on the Montparnasse neighborhood in Paris, a densely populated, high-traffic area marked by extensive underground infrastructure and significant urban mineralization, where AREP with the Paris Municipality is currently exploring renaturation possibilities

Creating a Multi-Metric Index for Identifying Renaturation Potential in Urban Areas: Methodology

2.1. Gathering data

Type of data and data sources

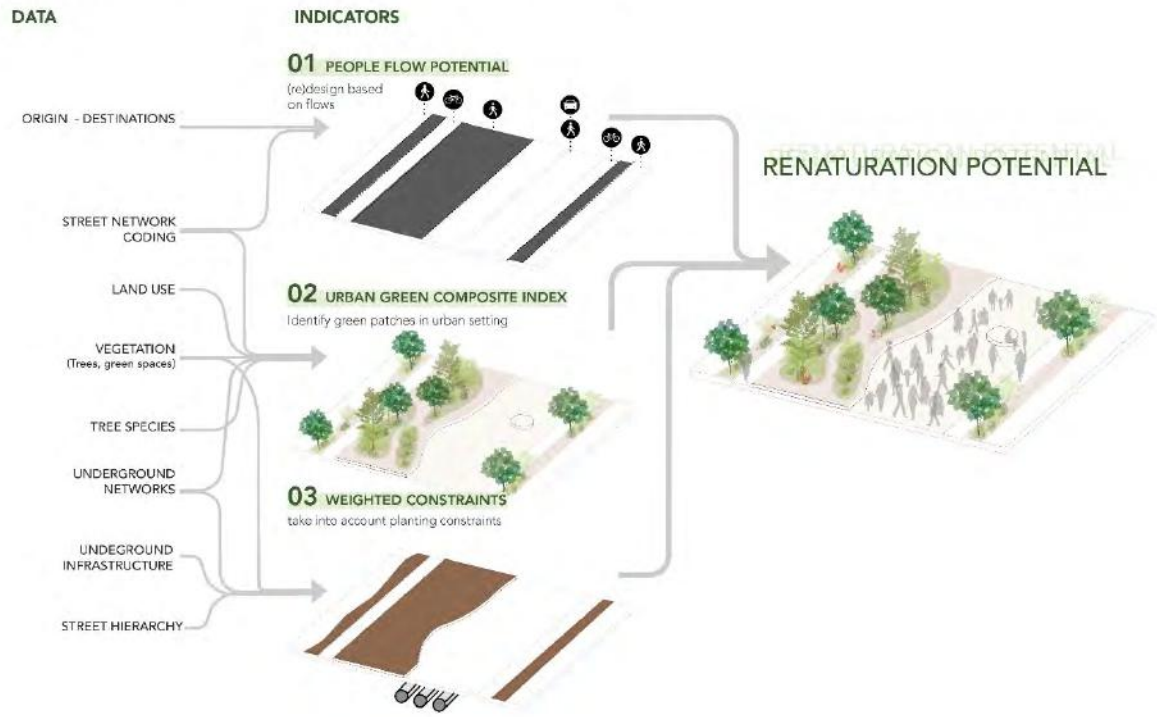


Figure 1 Data sources composing the RCP

Data sources

Data sources are variable they involve :

- Open data from the municipality of Paris [1]
- OpenstreetMap data
- Manual inputs
- Restricted access data

The data was available in GIS format, therefore QGIS an open source software was used to compute the different metrics.

[1] (https://opendata.paris.fr/pages/home/)

Processing the data

In QGIS, we processed the data using a fine-resolution grid of 1x1 meter, enabling detailed spatial analysis across the urban landscape. Data preparation began by categorizing and processing each dataset individually according to three main criteria: green patches, people flow, and constraints.

After processing each dataset within its category, we applied a weighting system within the QGIS Modeler to balance the influence of each metric. Finally, we spatially combined the weighted metrics on the 1x1m grid, yielding an RPC score for each cell. This approach produced a high-resolution map of renaturation potential, which visually highlighted opportunities and limitations for green space development across the area.

2.2. Metrics centred around 3 key themes: green infrastructure, people flow and constraints to define renaturation potential

Urban Greeness Composite Index (UGCI)

Urban greenness composite index is composed by three indicators:

- Green coverage
- Green connectivity
- Green diversity

The computation is based on the spatial network[2] to consider the constraints generated by urban morphology on green connectivity. Trees and their environment are used as the main data source. The metrics integrate both quantitative and qualitative aspects to evaluate green ecosystems in urban areas.

Green coverage

Green coverage measures the number of trees on the spatial network in an infinite radius.

Green connectivity

The connectivity between green spaces (Bunn et al, 2000), measuring how well green areas are connected.

The formula is defined by the following:

$$GC = \sum_{i=1}^{n} \left(C_i \times \frac{1}{d_i} \times E_i \right)$$

Where:

[2] The spatial network modeling is based on graph theory

GC: Green connectivity for a particular reference tree

n: Total number of other trees reachable from the reference tree along the spatial network.

Ci: Green coverage (number of trees) associated with tree i

Di: Distance along the spatial network to tree i

1/di: Inverted distance, giving higher weight to closer trees.

Ei: Environmental score of trees i

Green diversity

Green diversity is based on the tree species and measures their diversity on an infinite range on the spatial network. The formula used is Simpsons Diversity Index (Duelli et al, 2003)., it considers both the number of species present and the relative abundance of each species, it is widely used in ecology to quantify biodiversity.

The formula is the following:

$$D = 1 - \sum_{i=1}^{n} \left(\frac{n_i \times (n_i - 1)}{N \times (N - 1)} \right)$$

Where:

- ni: The number of individuals of species i (or category i) in the dataset.
- N: The total number of individuals on the spatial network across all species in the dataset.
- n: The number of different species (in the dataset.
- ∑: The summation symbol, which indicates that you sum over all species

Pedestrian flow potential

Pedestrian flow potential is computed on the spatial network. A spatial network is a type of graph where nodes (representing locations) and edges (representing connections or paths between these locations) are embedded in a geometric space, often reflecting real-world distances and spatial constraints, such as transportation systems, utility networks, or social connections in physical space.

Pedestrian network coding

The pedestrian network is coded to represent pedestrian movement; therefore, obstacles and shortcuts are represented. The network is coded in 3D, including underground and above ground connections.

Betweenness centrality

Pedestrians usually take the shortest and the most direct path. Betweenness centrality computes their movement on the spatial network by overlaying all the possible paths between segments. The higher the value, the higher the flow potential. SDNA+ which is open source and developed by Cardiff university (Cooper et al, 2020) will be used to compute betweenness centrality for the pedestrian network.

Weighted constraints

Constraints are divided into four categories:

Very high

This includes pipelines, underground networks or underground galleries on which tree planting is forbidden in a certain buffer.

High

Tree planting is prohibited in a specific buffer zone due to the presence of underground networks or pipelines, though these can be relocated if necessary.

Planting is highly restricted on primary roads, where high traffic is expected (Marshall,2004).

Medium

The flexibility of the constraints in these areas depends on project conditions, particularly for secondary roads where traffic lanes might be narrowed or public spaces that could undergo regeneration.

Low

This concerns tertiary roads and public spaces that can potentially be pedestrianised and planted.

2.3. Combining the 3 metrics into one calculation to assess renaturation potential in urban areas

Maximum greenness

Maximum greenness is the result of combining all the metrics together. It reveals all the location that can potentially be planted as well as the existing green areas.

$$M = \left(\frac{1}{B} \times G\right) \times C$$

Where:

M: Represents the maximum greenness index

B: is betweenness (inverted to give more weight to lower values because they represent areas where planting is more feasible, while higher values indicate more restricted planting opportunities)

G: Urban Greenness Composite Index

C: Constraints

Potential renaturation coefficient

Potential Renaturation Coefficient is the result of combining all the metrics together minus the existing green areas. It reveals all the locations that can potentially be planted.

$$R = \left(\frac{1}{B} \times G\right) \times C - G$$

Where:

M: Represents the maximum greenness index

B: is betweenness (inverted to give more weight to lower values because they represent areas where planting is more feasible, while higher values indicate more restricted planting opportunities)

G: Urban Greenness Composite Index, which reflects current greenness in the area. Subtracting G helps to focus the index on areas that are not yet green.

C: Constraints

Application: The case of Montparnasse station neighbourhood

3.1. Context

Montparnasse, one of Paris's most emblematic districts, is located on the left bank of the Seine, between the 14th and 15th arrondissements and close to the 6th arrondissment. Renowned for its artistic and intellectual history, Montparnasse is home to a complex environment organized around several structuring urban entities, including Montparnasse Railway station, a major entry point and hub for national rail transport and a city hub with 4 metro lines.

Until the 17th century, the Montparnasse area was essentially rural, made up of waste from the capital around the Montparnasse hill. Over the centuries, a structuring road network emerged, with the creation of roads such as the Cours du Montparnasse.

At the end of the 17th century the Route du Maine was built, followed by the annexation of the area by the City of Paris in 1860. Until 1950, the area remained mainly composed of small workshops and warehouses. In the 1960s, major real estate projects brought about a significant transformation, including the demolition of the Montparnasse train station and the construction of the Montparnasse tower in 1973 and The Maine tunnel was built in the 1960s.

The 1990s saw the creation of the Jardin Atlantique and the arrival of the high-speed railway (HSR), marked by the construction of the Océane façade for the station.

The complex underground infrastructure, combined with the varying types of public spaces like wide streets, narrow alleys, and plazas, makes this area a compelling case study to apply the renaturation potential coefficient.

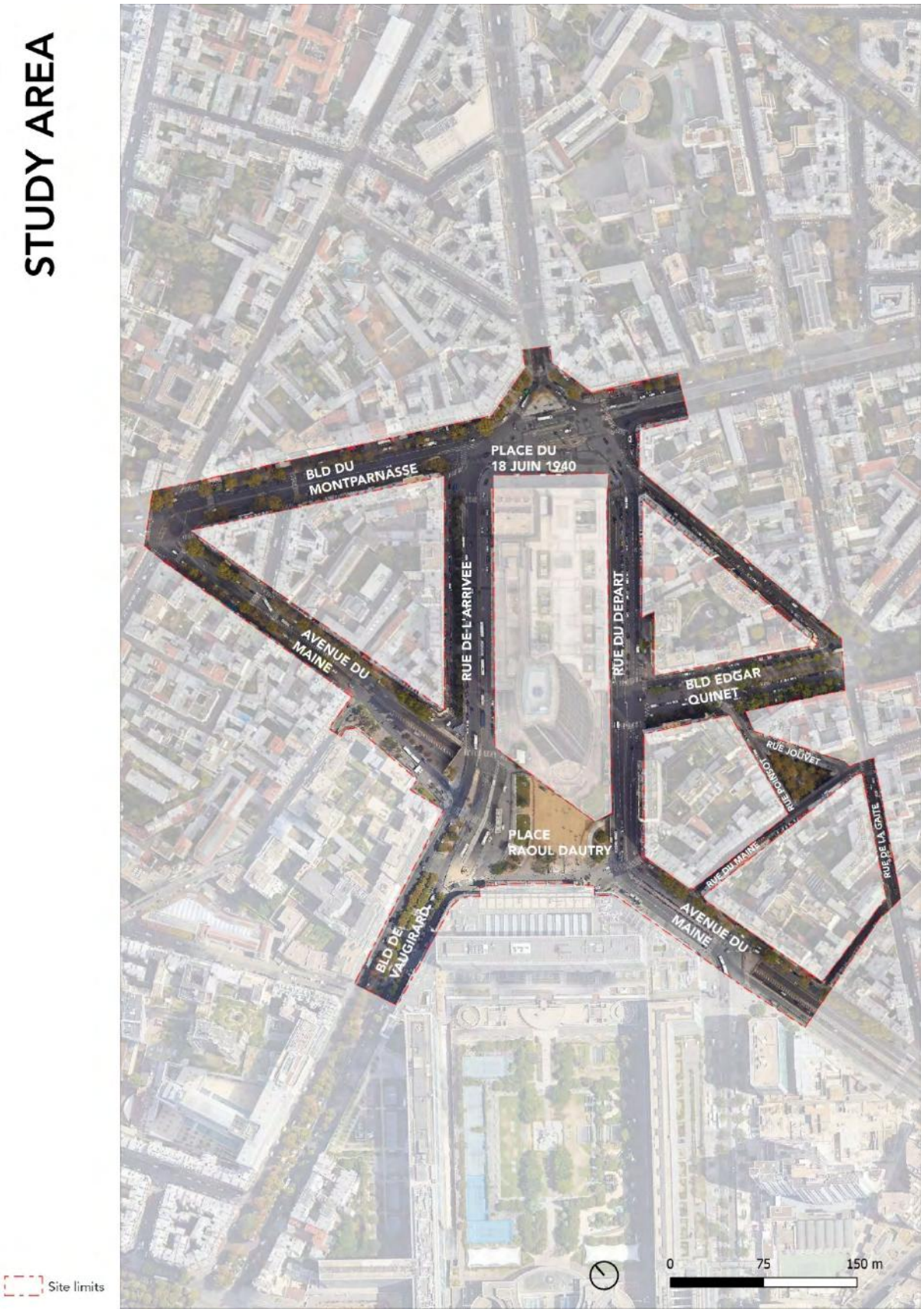


Figure 2 Study area

3.2. Mapping the existing green infrastructure to identify potential green connections

Tree location and planting typologies

Figure 3 Trees location

Trees are mainly planted on urban alignments along sidewalks. They are clustered boulevard Edgar Quinet, boulevard de Vaugirard and Boulevard du Montparnasse. Plazas are mineral with few plantations and narrower streets as well.

We can identify four typologies of plantation:

- Single pit
- Continuous pit for multiple trees
- Planted green spaces on a slab
- Garden/Urban Parks

Figure 4 Typologies of tree planting

Trees planted in individual pits typically lack underground connections to other trees and are not part of a continuous layered green space. Continuous pits offer greater ecological benefits by supporting an herbaceous layer and establishing subterranean connections among trees, but they are constrained by the size of the pit.

Although green spaces on slabs can be larger and more layered than tree pits, they are limited by the underground infrastructure's load capacity. This leads to isolated patches of greenery that benefit the ecosystem but lack underground connectivity, cannot infiltrate water, and provide trees with limited soil volume for growth (Egerer et al, 2024).

In urban parks or gardens, trees are usually part of an extensive underground network and are planted in soil, enabling them to grow more robustly compared to trees that are restricted. They become part of a stratified ecosystem that enhances biodiversity, and with minimal underground restrictions, they can efficiently infiltrate water into the soil.

As a result, trees planted in individual pits receive the lowest score, whereas those in parks and complex ecosystems are given the highest score.

Aligned ornamental street planting: High coverage but low connectivity and diversity impacting biodiversity and wildlife habitats

The study area features aligned street plantings, which help reduce the urban heat island effect (UHI) and offer shaded areas for pedestrians, generally benefiting humans more than ecosystems.

In order to evaluate the quality of urban ecosystems in the study area, we will use the metrics outlined in part two. We will integrate three indicators—green coverage, green connectivity, and green diversity—to calculate the Urban Green Composite Index, which will assess green corridors.

As mentioned in the previous part, green coverage is the number of trees measured on the spatial network in an infinite radius. The darker the colour, the more trees there are.

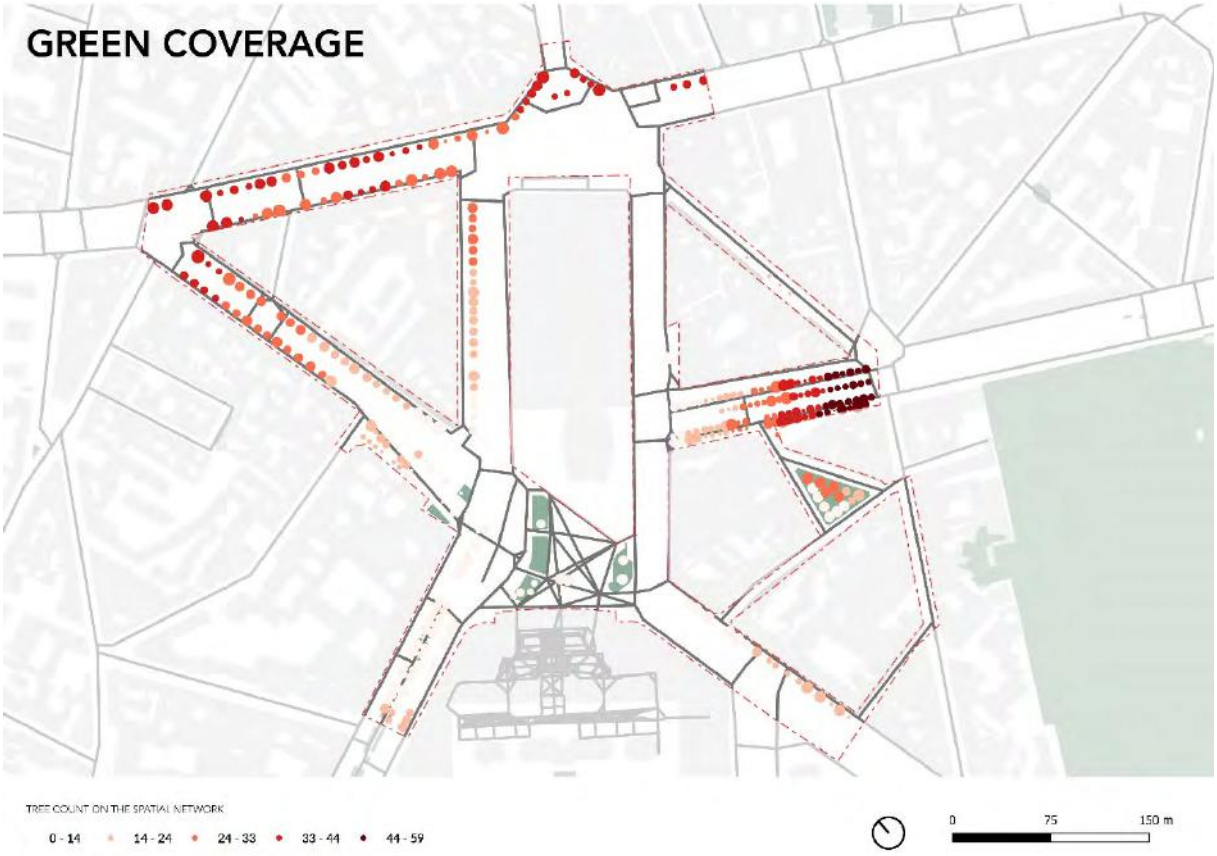


Figure 5 Green coverage

Globally, streets exhibit higher green coverage compared to plazas, largely due to the practice of aligned street planting that is practiced since the 19th century in Paris. The map shows a high cluster of tree coverage of over 44 trees on boulevard Edgar Quinet. Avenue du Maine and Boulevard du Montparnasse

Plazas in this area are quite mineral, due to the presence of underground infrastructure and a car-centric planning around the site, such as the Place du 18 Juin 1940.

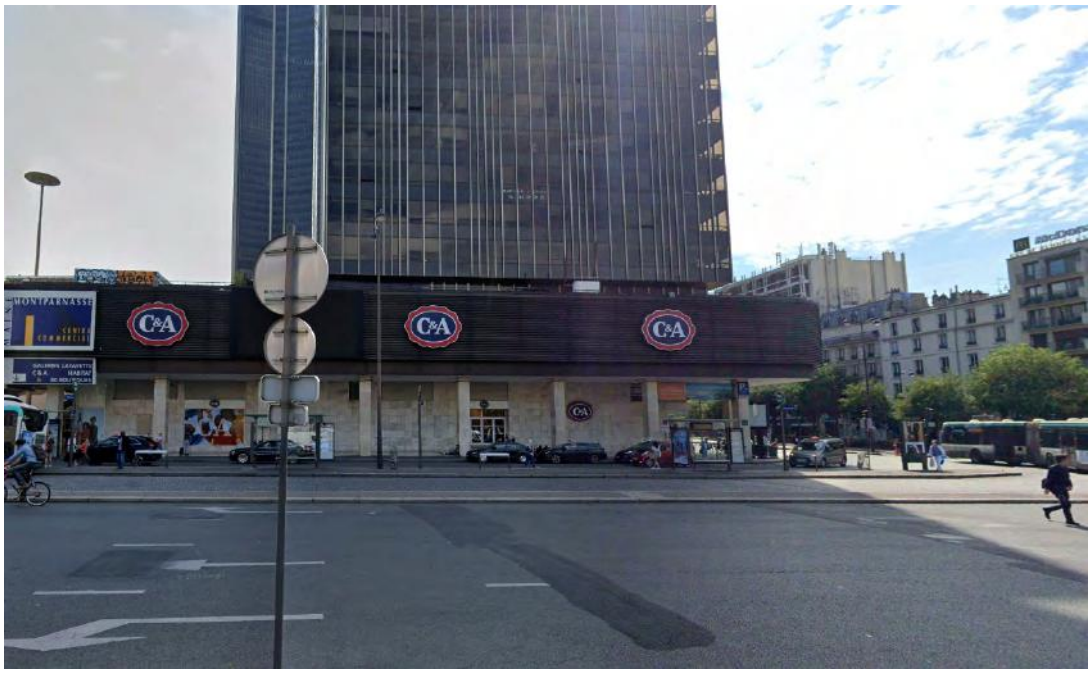


Figure 6 Place du 18 Juin 1940, source Google Streetview

Green connectivity shows how well trees are connected to each other, considering distance and their environment. The higher the value, the better integrated is a tree with other trees.

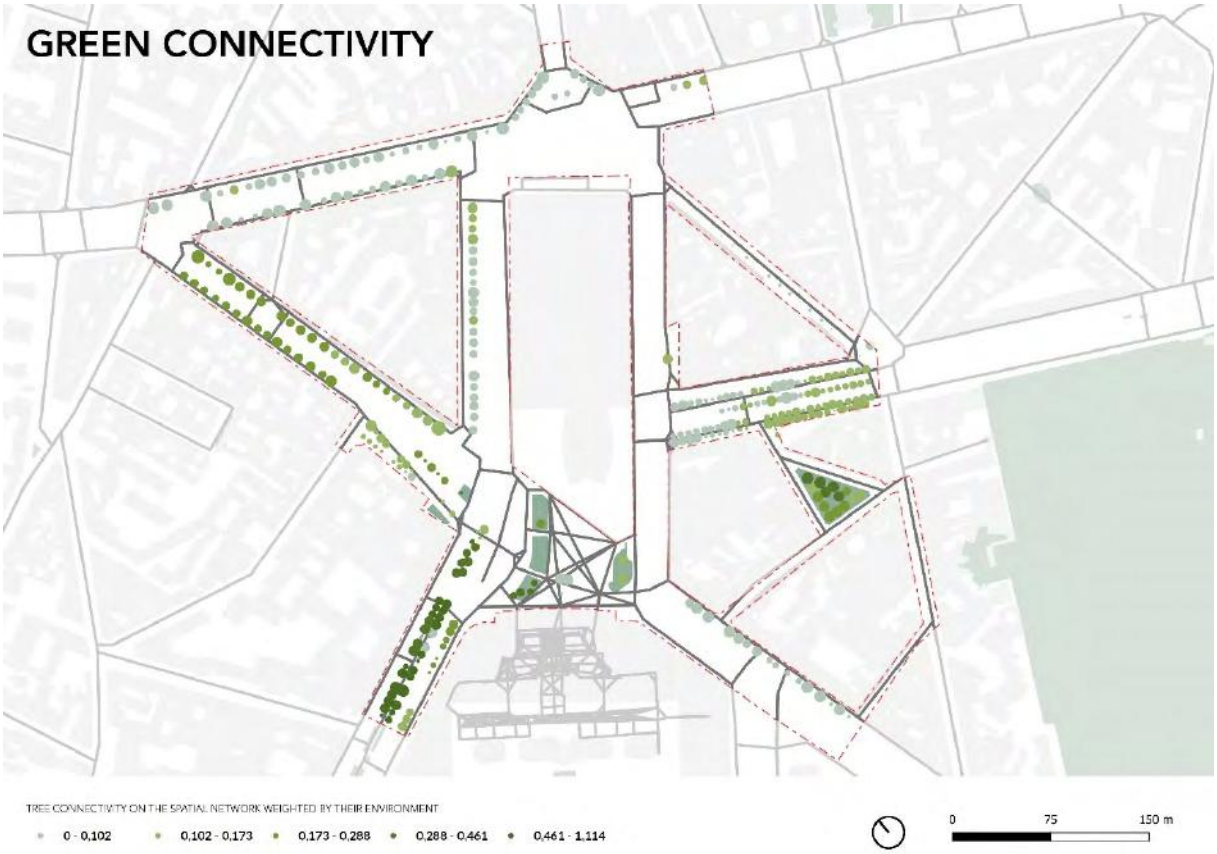


Figure 7 Green connectivity

Connectivity is the highest at Gaston Basty Square and Boulevard de Vaugirard, showing a good integration.

Boulevard de Vaugirard Square Gaston Baty

Figure 8 Planting within the neighborhood

Boulevard de Vaugirard has a high density of trees which are planted in a continuous pit with a more complex ecosystem, improving green connectivity, supporting a wider range of habitats for wildlife than single pits.

Naturally, connectivity is the lowest on streets with single pits, such as Avenue du Maine, with values under 0.1, even though the tree coverage is quite high. Street trees planted in single pits do not provide the diverse habitats needed to support a wide range of wildlife. The lack of undergrowth, shrubs, and varied tree species means fewer opportunities for birds, insects, and other organisms to thrive, leading to an impoverished urban ecosystem.

In addition, single pits often restrict root growth, leading to compacted soils with poor nutrient cycles. Healthy soil ecosystems require a variety of plant roots, organic matter, and microbial life, which are difficult to sustain in isolated tree pits.

High tree coverage achieved through aligned street planting can create an illusion of a green and healthy city. However, without diversified landscape planning, this can lead to a poorly functioning urban ecosystem with low biodiversity. To build truly sustainable and resilient urban environments, it is essential to integrate a variety of planting strategies that support rich biodiversity and provide comprehensive ecosystem services.

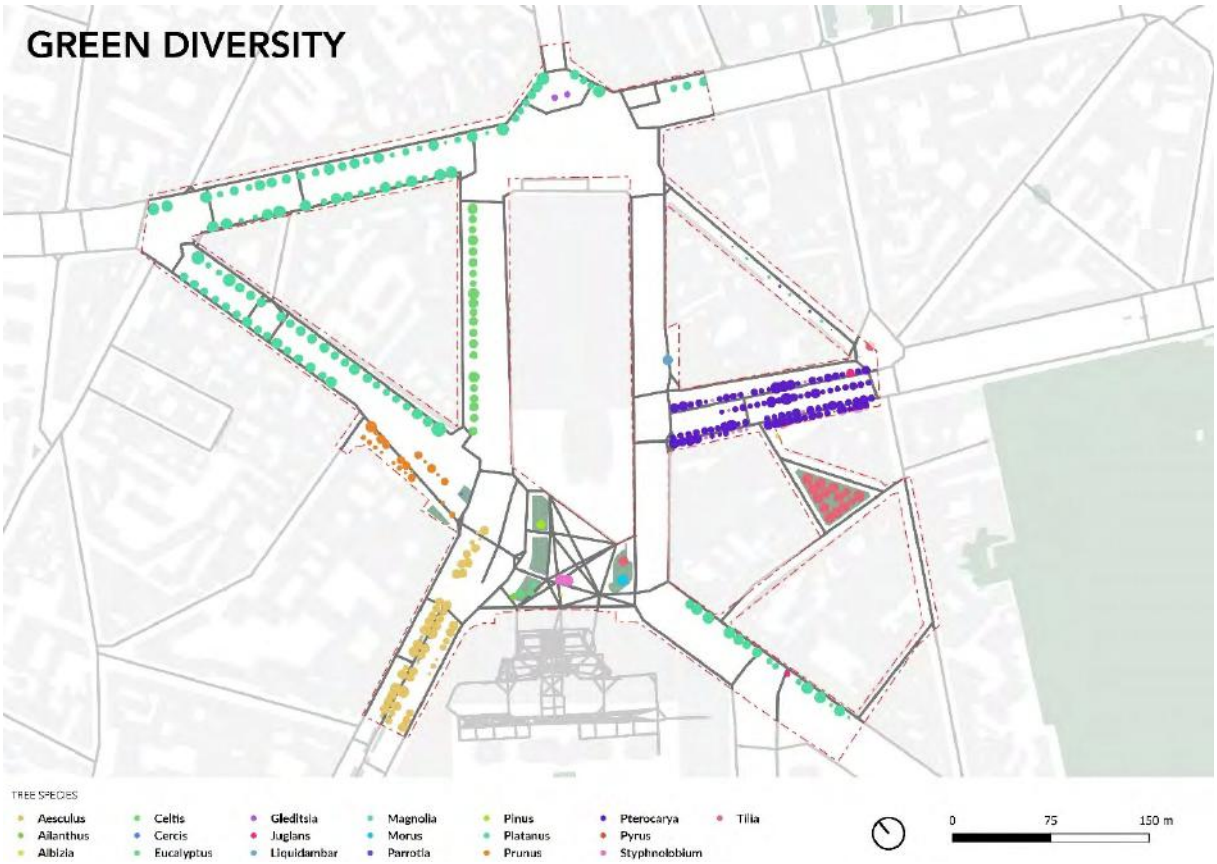


Figure 9 Tree species

There are 18 different essences in the study area, however each street has the same tree species, that are chosen for their uniform appearance, ease of maintenance, or tolerance to urban conditions. This monoculture approach can lead to low biodiversity, where the urban forest lacks a variety of species, both in terms of flora and fauna (Heidt and Neef, 2008). In addition, it makes green spaces more vulnerable to diseases that can spread through monoculture (Andrianjara et al,2021) .

Figure 10 Boulevard Edgar Quinet street planting

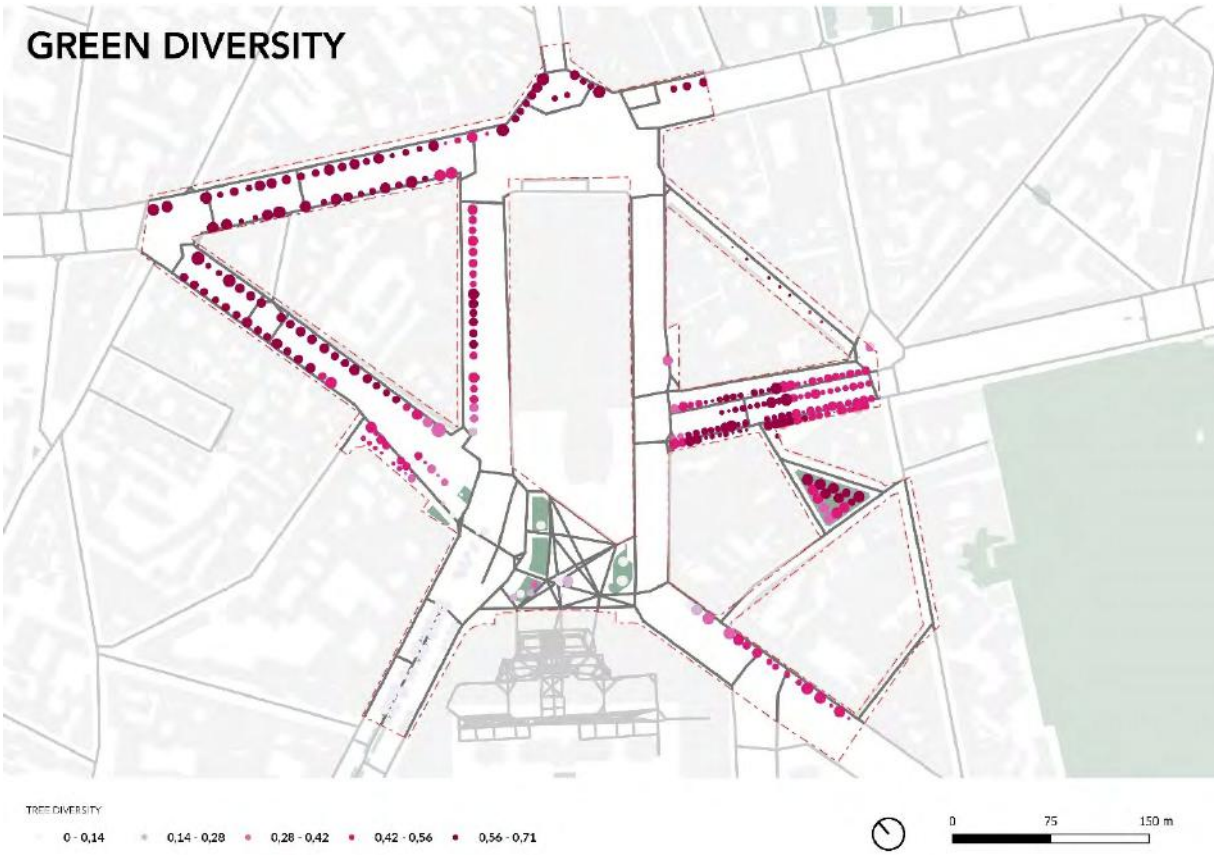


Figure 11 Green diversity

Green diversity has a mean of 0.46 and a median of 0.54, 1 being the most diverse. The fact that the median (0.54) is higher than the mean (0.46) suggests that the distribution of tree diversity is likely right-skewed. This means that while most areas have moderate diversity (as indicated by the median), areas like Boulevard de Vaugirard and Parvis Raould Dautry have very low diversity that are pulling the mean down. Specific strategies should be implemented in areas with the lowest diversity.

Green patches scattered across the site

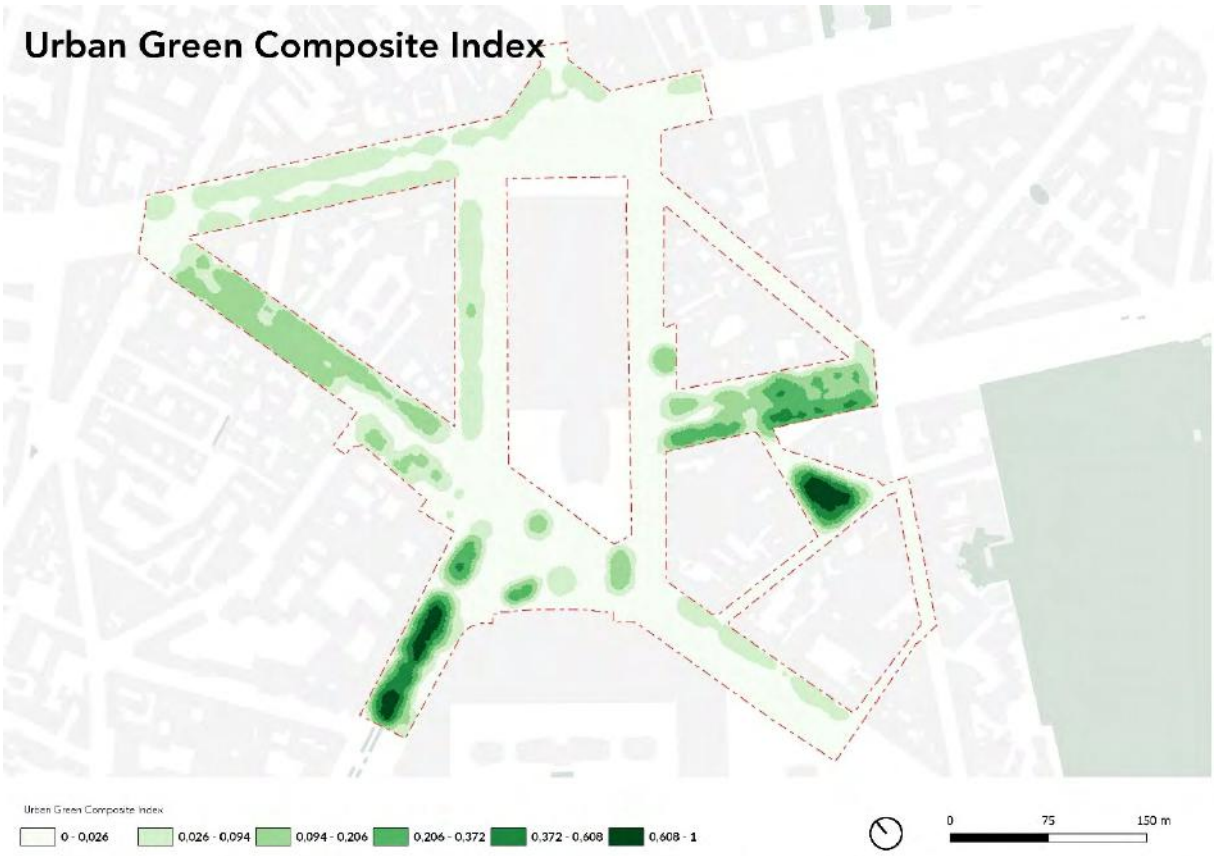


Figure 12 UGCI Output

UGCI values range from 0 to 1, 1 being the highest. High values represent high quality continuous green space. The green patches are clustered in three areas according to the map: Boulevard de Vaugirard, Park Gaston Baty and Boulevard Edgar Quinet.

Existing green patches can be preserved and improved with buffer, while connecting elements can be added to create a continuous and more complex ecosystem. To achieve this, streets need to be thought of an integral part of the green network.

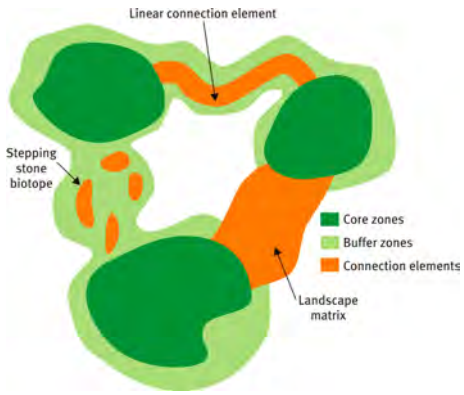


Figure 13 Diagram of an ecological network with its elements, source Revue SET

Based on the UGCI results, a set of measures can be implemented:

- Create a new patch on the Parvis Raoul Dautry. There is an opportunity to create continuous green spaces by vegetating the plaza.
- Improve green connections: The street between Boulevard Edgar Quinet and Gaston Baty Park could benefit from street planting to improve the local ecosystem.
- Use narrow streets to create linear connections: improve their green infrastructure in order to integrate them into a more complex ecosystem.

3.3. Differentiate existing pedestrian flow potential for a tailored vegetation strategy

The spatial network is coded in an 800m buffer of the study area to take into account the site and its surroundings.

To better assess pedestrian movement patterns, the flow potential was calculated from three different origin-destinations on an 800m network radius:

- At the neighbourhood scale to understand movement patterns across and through the site
- From the metro stations to the neighbourhood to evaluate main paths from public transport
- From the railway station to the neighbourhood to assess flow patterns to the HSR station on Raoul Dautry Plaza

These three pedestrian flow potential calculations are combined into one set that reveals the highest flow potential that can happen at peak hour (i.e. from work to the metro station or to the railway station).

The pedestrian flow potential can then be used to have a differentiated street design and propose a tailored vegetation strategy. It can help optimise people's movement through space to respect desire lines and make routes more efficient.

A loose pedestrian network in a car-centric environment

The site was regenerated in the 1960s-1970s, prioritising cars over vegetation and people. This led to wide spaces that are underused and can potentially be planted.

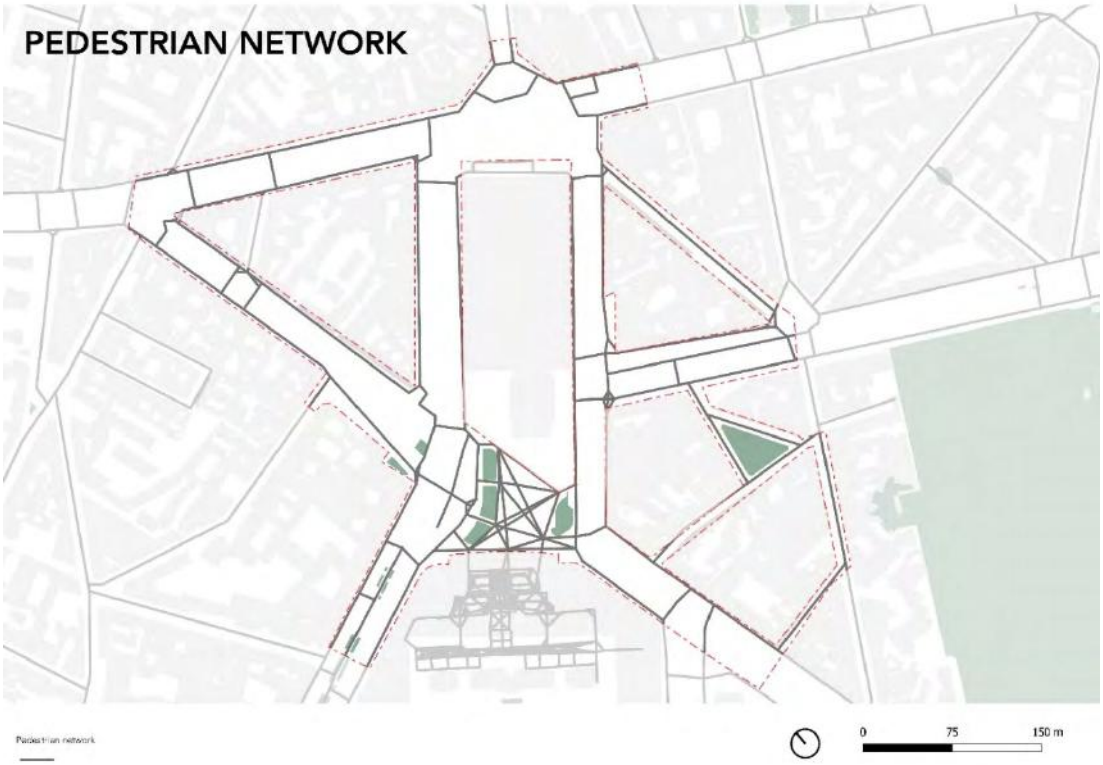


Figure 14 Pedestrian network in Montparnasse neighbourhood

Moreover, pedestrians face many detours and obstacles because of such planning. For example, the lack of crossings can lead to dangerous situations, especially where desire lines do not offer safe passage for pedestrians.

Figure 15 Rue de l'Arrivée, a large street where crossing is difficult for pedestrians

A strong desire line across the Avenue de Maine

The Avenue du Maine – Raoul Dautry plaza – Avenue du Maine has a strong diagonal desire line and high flow potential. It is an efficient route to access the neighborhood, metro stations and the railway station.

High flow potential streets need to have wide footways for pedestrians, well-dimensioned crossings. Additionally, incorporating trees along the footways not only provides shade, enhancing comfort during hot weather, but also contributes to creating green corridors where planting complex and stratified ecosystems is restricted.

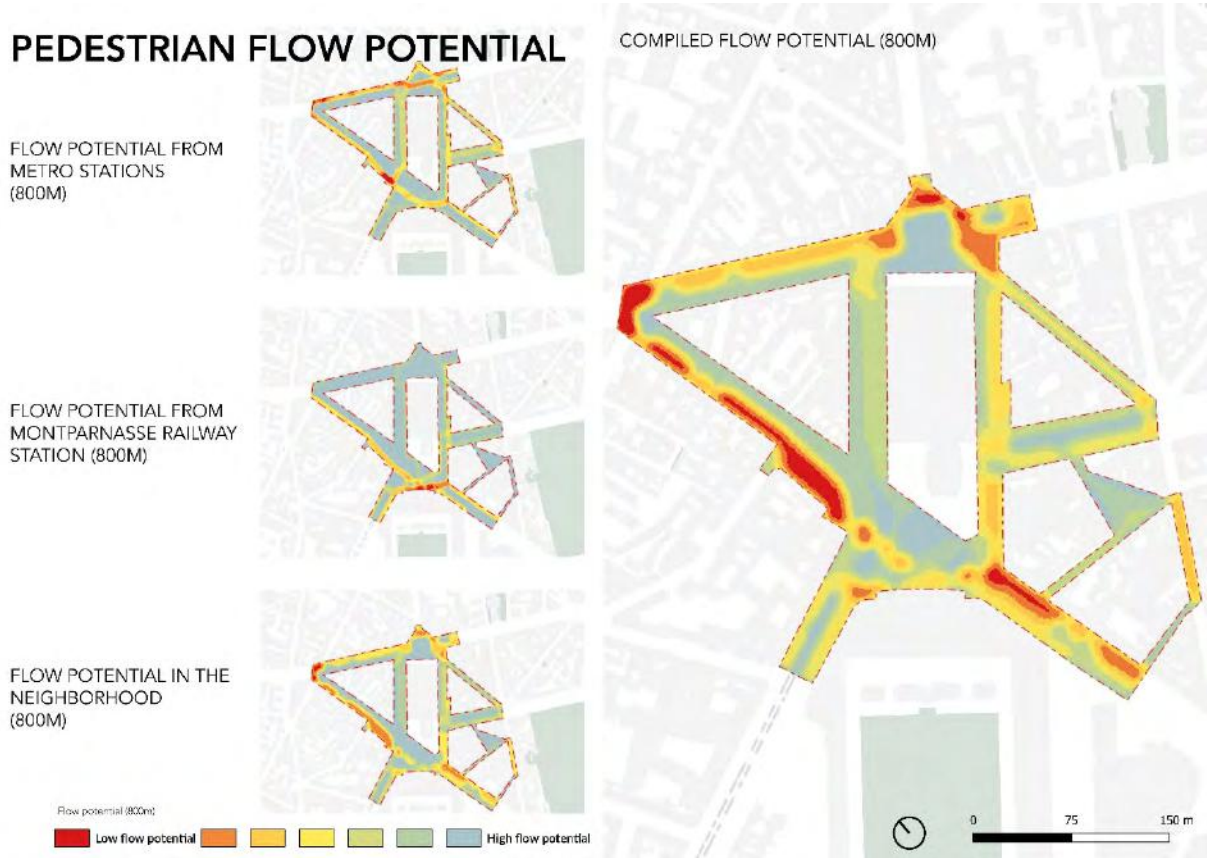


Figure 16 Pedestrian flow potential output

The footway for pedestrians on Avenue du Maine is narrow and cluttered with restaurants terraces, on street clothes selling, which can cause safety issues, reduce accessibility, and create discomfort for walkers.

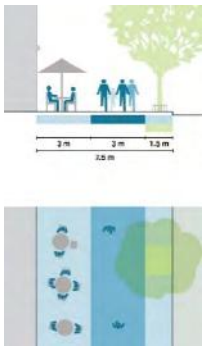


Figure 17 Global Street design guidelines pedestrian path design

Referring to the principles of the Global Street Design Guidelines, the avenue should ensure a clear path of at least 3 meters to facilitate continuous pedestrian flow, allowing people to pass one another comfortably. To enhance the vibrancy of the sidewalk, ground-floor activities from adjacent buildings can be encouraged by providing flexible and dedicated spaces along the sidewalk, adjacent to the clear path.

The street already has planted trees, however green strategies could include green pavements to integrate an herbaceous layer around them and differentiate pedestrian spaces.

Figure 18 Avenue du Maine and Raoul Dautry plaza crossing, source Google Streetview

The pedestrian crossing at the intersection of Avenue du Maine and Raoul Dautry Plaza is insufficiently wide and poorly designed to accommodate the heavy foot traffic, resulting in congestion and potential safety risks. This area could be reconfigured into a plaza with an at-level crossing, unified surface material, and central plantings for shade.

Existing low flow potential streets are designed for motorised vehicles

Streets with low flow potential are designed for cars with minimum footway space, such as rue Vandamme perpendicular to Avenue du Maine. This causes safety issues for pedestrians who are forced to walk on the roadway in order to pass one another. In addition, street parking is occupying one side of the road.

This space can be repurposed for green infrastructure, such as rain gardens, bioswales, or tree pits, which help manage stormwater runoff and improve urban resilience. Incorporating porous pavement within these areas allows water to permeate the surface, reducing the burden on traditional drainage systems and minimizing the risk of flooding.

These streets can be integrated into the ecological network of the site as mentioned in the previous section (30) They offer ecological benefits, such as improving air quality, providing habitat for urban wildlife, mitigating the urban heat island effect.

Figure 19 Rue Vandamme, source Google Streetview

3.4. Identify site constraints for plantation

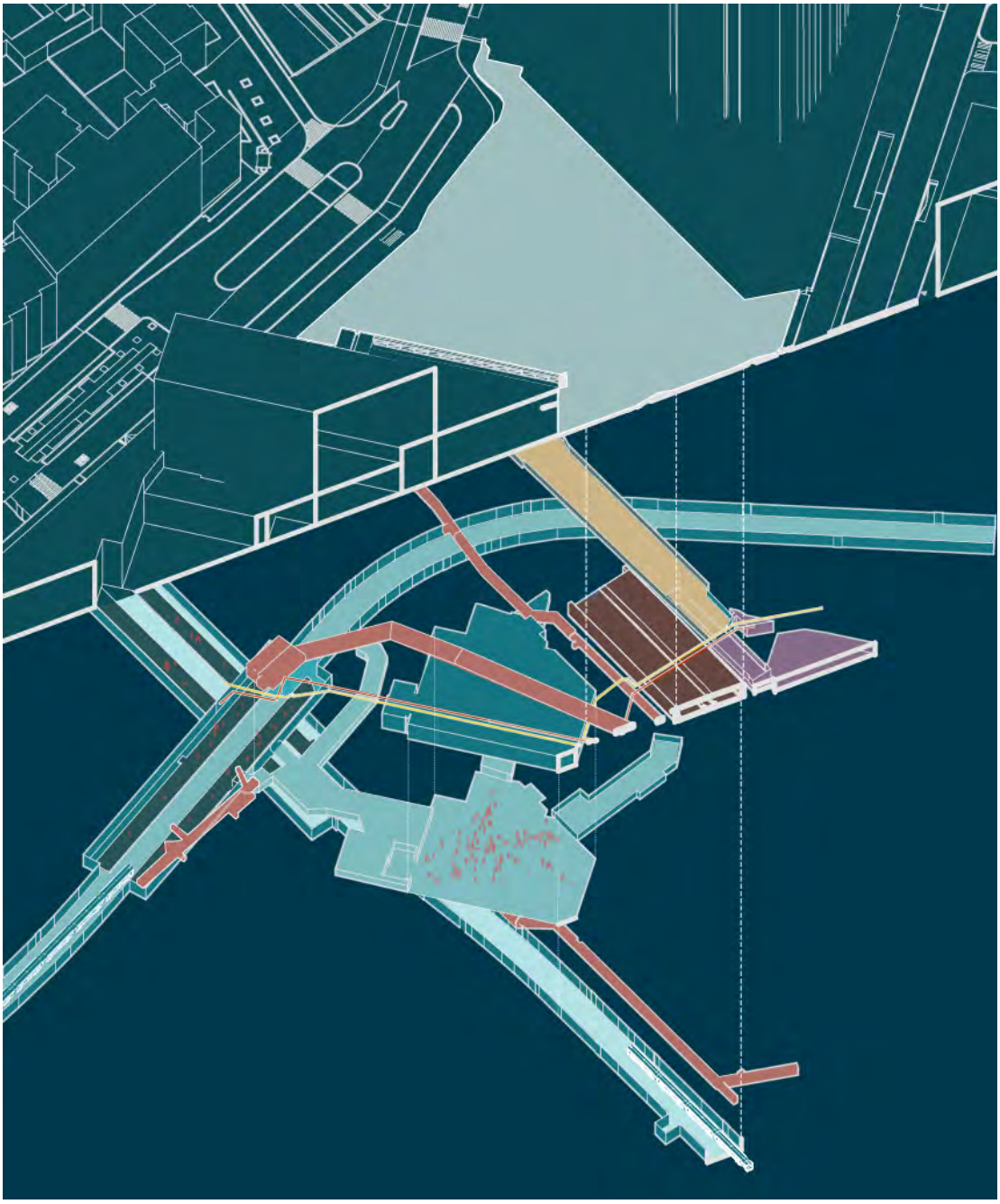


Figure 20 Exploded axonometry of the underground, source AREP

The site has multiple constraints that impact the planting strategy, as mentioned in section 0 the constraints weights are different according to their typology.

For example, as shown in the illustration above, under the Raoul Dautry plaza there are numerous underground infrastructure:

- Two subway lines (line 6 and 13)
- One interchange hall that belongs to the RATP (Parisian Autonomous Transport Administration)
- The Maine tunnel
- A bikepark,
- An abandoned underground ventilation factory
- Underground galleries and cables.

Complex underground infrastructure

Planting above metro stations, the interchange hall, tunnel and the abandoned ventilation factory is allowed according to the regulations. However, the infrastructure needs to be waterproofed to avoid any issues related to water infiltration into the underground infrastructure. For the purpose of this study, no restrictions have been applied to them, since planting is allowed.

Underground galleries and pipes

Figure 21 Planting restrictions across the site

The technical services of the City of Paris have defined protective perimeters around the networks in which tree planting is prohibited. These perimeters vary according to the type and depth of the networks.

The protection perimeters shown in the figure below have been defined as follows:

2m protection buffer for:

- SAP galleries (Paris sanitation department): it is possible to plant trees at 2.00m in XY without any special protection.
- Gas networks
- District heating
- HV/LV
- Eau de Paris (Paris Water department)

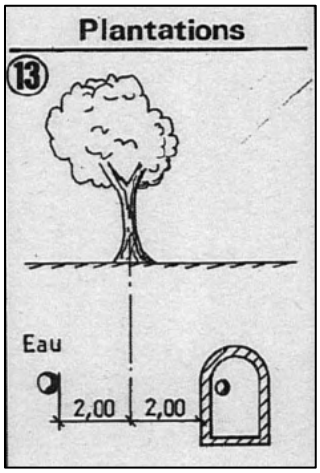


Figure 22 Underground network protection buffer

2m buffers have been computed around such networks, however different weights have been attributed according to their type. Gas, district heating and underground galleries have the highest restrictions whereas HV/LV networks have a high restriction weight.

Road hierarchy

Different restrictions have been applied on roads according to their typology:

- Transport oriented roads that connect major points in the city such as Boulevard du Montparnasse have a high restriction
- Local connectors such as rue de l'Arrivée, rue du Départ have a medium restriction
- Service roads such rue Jolivet or rue Poinsot have low restrictions

This tiered approach allows for tailored planting strategies that align with the functional needs of each road type while maximizing environmental and aesthetic benefits.

3.5. Integrating the three metrics to evaluate the site's potential for renaturation

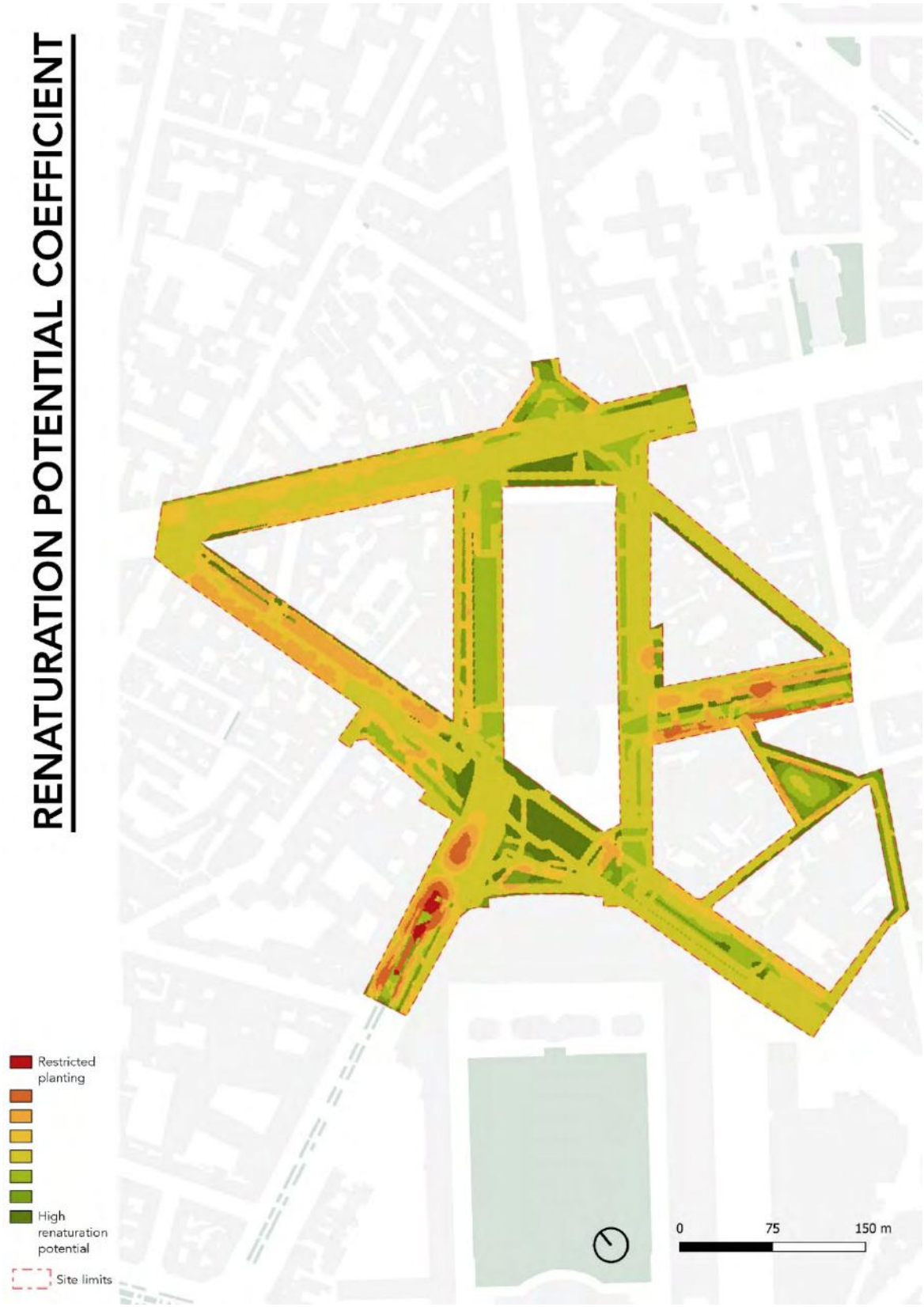


Figure 23 Renaturation Potential Coefficient

Results interpretation

Values range from 0 to 1, where 1 is the highest renaturation potential. Tree planting is possible in green areas, without any specific restrictions other than waterproof the green space in case of underground infrastructure. For example, plazas have the highest renaturation potential score, therefore they can benefit from a planting strategy.

Values in light green represent areas where tree planting is possible but should be discussed or analysed more thoroughly by specialists. For example, rue de l'Arrivée is four lane road which could be transformed into a linear park if car lanes were reduced to two lanes. This could create a new corridor connecting the two squares. On the other side, rue du Départ could benefit from continuous pits for tree planting. The presence of constraints such as pedestrian flow and underground galleries make it difficult to create a linear park or a continuous garden.

Orange to red areas represents either already planted or presents with restrictions such protection buffers around networks that don't allow tree planting.

Limitation and discussion

While the tool is efficient to quickly assess areas that can be potentially planted, there are still some limitations:

Dependence on data accuracy

The tool's effectiveness is limited by the accuracy and completeness of spatial and environmental data, especially regarding infrastructure and green space distribution and underground networks.

While open data is becoming more and more accessible through platforms like OpenStreetMap, remote sensing platforms or official government agencies, specific data are still not available to the public and are difficult to harness. For instance, tree data (including species, height, width) is not available in all the cities and manual coding, on site survey may be necessary. Underground network data can be considered as sensitive and might only be available upon request.

Simplification of complex urban factors

The tool may oversimplify dynamic urban elements such as people flow or green patches, which are critical for successful renaturation projects.

Challenges in balancing multiple metrics

Properly weighting different factors like accessibility, greenness, and constraints can be difficult, potentially leading to overemphasis on certain metrics at the expense of others. Balancing these metrics together need the involvement of specialist from related disciplines.

Conclusion

Supporting the development of green infrastructure is essential in an era where cities face challenges like climate change, urban heat islands, and biodiversity loss.

This paper introduces a valuable tool designed to estimate potential plantable areas within urban environments, employing a methodology that integrates three factors:

Existing Green Patches: By recognizing and utilizing existing green spaces, the tool enhances the ability to identify sites where biodiversity can thrive and ecosystem services can be maximized for all forms of life.

People Flow: Estimating people flow in urban environments involves analyzing how individuals move through spaces, which can inform the planning of pedestrian-friendly areas. In this context, creating a hierarchy of streets based on pedestrian movement is essential. High-flow streets, characterized by greater pedestrian activity, are typically more suitable for planting in a mineral environment while low-flow street are suitable for stratified green infrastructure.

Constraints: The tool hierarchies constraints into four levels, depending on their nature, which has a technical impact on the planting of cities.

The design of this tool enables urban planners to engage with multiple factors simultaneously, allowing for a comprehensive analysis. Municipalities can simulate various scenarios based on different planning strategies. This dynamic capability not only aids in understanding the immediate impacts of proposed interventions but also promotes long-term strategic thinking regarding urban green infrastructure development.

Furthermore, the tool has an adaptable scale, providing both micro-planning and macro-level information. This functionality assists municipalities in prioritizing green infrastructure implementation at a higher level. Identifying high-priority renaturation areas is another significant advantage of this tool. Emphasizing accessibility, green space continuity ensures that renaturation projects are ecologically viable and socially inclusive (Gill et al, 2007).

The tool's ability to simulate project changes and outcomes is a great asset for adaptive management. Planners can monitor how renaturation potential shifts in response to modifications, thus enabling real-time amendments as projects evolve. By visualizing the spatial relationships between existing green patches, pedestrian flow, and urban constraints, planners can develop targeted strategies that maximize environmental benefits by having a holistic understanding of urban ecosystems, leading to more informed decision-making processes (McPhearson et al., 2016).

In conclusion, the tool serves as a robust platform for urban planners and municipalities, facilitating a comprehensive understanding of urban green infrastructure and enhancing the potential for successful renaturation projects. By providing insights into the interplay of multiple factors influencing urban spaces, it allows professionals and stakeholders to make evidence-based decisions that foster the ecological transition in urban spaces.

REFERENCES

Adem Esmail, B. & Geneletti, D. (2018) 'Multi-criteria decision analysis for nature conservation: A review of 20 years of applications', Methods in Ecology and Evolution, 9. doi: 10.1111/2041-210X.12899.

Andrianjara, I. et al. (2021) 'Urban tree management: Diversity of Tilia genus in streets and parks of Paris based on morphological and genetic characteristics', Urban Forestry & Urban Greening, 66, p. 127382.

Artmann, M. et al. (2019) 'How smart growth and green infrastructure can mutually support each other—A conceptual framework for compact and green cities', Ecological Indicators, 96, pp. 10-22.

Bunn, A., Urban, D. & Keitt, T. (2000) 'Landscape Connectivity: A Conservation Application of Graph Theory', Journal of Environmental Management, 59, pp. 265-278. doi: 10.1006/jema.2000.0373.

Cooper, C.H.V. & Chiaradia, A.J.F. (2020) 'sDNA: 3-d spatial network analysis for GIS, CAD, Command Line & Python', SoftwareX, 12, p. 100525. doi: 10.1016/j.softx.2020.100525.

Dwyer, M.C. & Miller, R.W. (1999) 'Using GIS to assess urban tree canopy benefits and surrounding greenspace distributions', Arboriculture & Urban Forestry (AUF), 25(2), pp. 102-107.

Duelli, P. & Obrist, M. (2003) 'Biodiversity indicators: The choice of values and measures', Agriculture, Ecosystems & Environment, 98, pp. 87-98. doi: 10.1016/S0167-8809(03)00072-0.

Egerer, M. et al. (2024) 'The challenges of urban street trees and how to overcome them', Frontiers in Sustainable Cities, 6, p. 1394056. doi: 10.3389/frsc.2024.1394056.

Fedor, P. & Zvaríková, M. (2018) 'Biodiversity Indices', in Encyclopedia of the Anthropocene. doi: 10.1016/B978-0-12-409548-9.10558-5.

Gill, S.E. et al. (2007) 'Adapting cities for climate change: The role of the green infrastructure', Built Environment, 33(1), pp. 115-133.

Heidt, V. & Neef, M. (2008) 'Benefits of urban green space for improving urban climate', in Ecology, Planning, and Management of Urban Forests: International Perspectives. New York: Springer New York, pp. 84-96.

Héran, F. (2009) 'Des distances à vol d'oiseau aux distances réelles ou de l'origine des détours', Flux, 76-77, p. 110. doi: 10.3917/flux.076.0110.

Holl, K.D. & Brancalion, P.H. (2020) 'Tree planting is not a simple solution', Science, 368(6491), pp. 580-581.

Hutt-Taylor, K. & Ziter, C.D. (2022) 'Private trees contribute uniquely to urban forest diversity, structure and service-based traits', Urban Forestry & Urban Greening, 78, p. 127760.

Kohler, Y. (2023) 'The role of alpine protected areas in the spatial planning of ecological connectivity in their regional context', Sciences Eaux & Territoires, pp. 15-20. doi: 10.20870/Revue-SET.2023.43.7383.

Kouneva, T. & Andreeva, D. (2017) 'Street trees-current problems and technologies for construction and planting', Agricultural Sciences/Agrarni Nauki, 9(22).

Lakhani, K. & Magurran, A. (1989) 'Ecological Diversity and Its Measurement', The Journal of Applied Ecology, 26, p. 1101. doi: 10.2307/2403731.

LaPoint, S. et al. (2015) 'Ecological Connectivity Research in Urban Areas', Functional Ecology, 29. doi: 10.1111/1365-2435.12489.

Laurian, L. (2019) 'Planning for street trees and human–nature relations: Lessons from 600 years of street tree planting in Paris', Journal of Planning History, 18(4), pp. 282-310.

Malczewski, J. & Rinner, C. (2015) Multicriteria Decision Analysis in Geographic Information Science. doi: 10.1007/978-3-540-74757-4.

Marshall, S. (2004) Streets and patterns. Routledge.

McPhearson, T. et al. (2016) 'Advancing understanding of the complex nature of urban systems', Ecological Indicators, 70, pp. 566-573.

McPhearson, T. et al. (2016) 'Advancing urban ecology toward a science of cities', BioScience, 66(3), pp. 198-212.

Penn, A. (2003) 'Space Syntax And Spatial CognitionOr Why the Axial Line?', Environment and Behavior, 35, pp. 30-65. doi: 10.1177/0013916502238864.

Phillips, J. et al. (2015) 'Graph Theory in the Geosciences', Earth-Science Reviews, 143. doi: 10.1016/j.earscirev.2015.02.002.

Shaaban, K. et al. (2018) 'A simple method to assess walkability around metro stations', International Journal of Sustainable Society, 10(1). doi: 10.1504/IJSSOC.2018.092651.

Staccione, A. et al. (2022) 'Mapping a Green Infrastructure Network: a framework for spatial connectivity applied in Northern Italy', Environmental Science & Policy, 131, pp. 57-67. doi: 10.1016/j.envsci.2022.01.017.

Subburayalu, S. & Sydnor, T.D. (2012) 'Assessing Street Tree Diversity in Four Ohio Communities Using the Weighted Simpson Index', Landscape and Urban Planning, 106, pp. 44-50. doi: 10.1016/j.landurbplan.2012.02.004.

Tian, Y. et al. (2017) 'Assessing structural connectivity of urban green spaces in metropolitan Hong Kong', Sustainability, 9(9), p. 1653.

van der Ree, R. et al. (2011) 'Effects of Roads and Traffic on Wildlife Populations and Landscape Function Road Ecology is Moving toward Larger Scales', Ecology and Society, 16. doi: 10.5751/ES-03982-160148.

Werbin, Z.R. et al. (2020) 'A tree-planting decision support tool for urban heat mitigation', PLoS ONE, 15(10), p. e0224959.

Wu, C. et al. (2008) 'A method for locating potential tree-planting sites in urban areas: A case study of Los Angeles, USA', Urban Forestry & Urban Greening, 7, pp. 65-76. doi: 10.1016/j.ufug.2008.01.002.

Xavier Girardet, C. & Clauzel, C. (2018) 'Graphab. 14 réalisations à découvrir', Actes de la journée ”Retour d’expérience sur Graphab” du 27 juin 2017, Théma / Ladyss. Available at: hal-01701885.

Zhang, Z. et al. (2018) 'Enhancing Landscape Connectivity through Multi-functional Green Infrastructure Corridor Modeling and Design', Urban Forestry & Urban Greening, 38. doi: 10.1016/j.ufug.2018.10.014

Case Study Report

Exploring Urban Spatial Planning Methods from the Perspective of "Renewable Energy" Development

A Case Study of Spatial Planning Practices in Changzhou, China

Yizhe WANG, Southeast University, China

Abstract

Changzhou is an essential traditional industrial city located in the eastern coastal region of China. It has actively formulated various policies to promote the development of urban renewable energy. We attempt to explore and construct methods through urban planning to advance the process of urban renewable energy transformation from the perspective of urban spatial resource coordination, utilization, and management. This case study identifies the utilization of spatial resources as a critical aspect of urban renewable energy transformation: (1)It constructs a practice framework oriented towards developing "renewable energy." The study focuses on the relationship between renewable energy production and urban space, further clarifying the demands of urban spatial development and the resulting spatial characteristics that should be formed. (2)It examines the energy production and consumption characteristics of various functional spaces in the city from a new "energy-space" perspective, with a focus on urban residential areas, industrial parks, public spaces, and rural areas, forming an understanding of the energy production and consumption assessment of urban spaces. (3)It establishes a method for guiding spatial practices. Based on the spatial characteristics of different urban functional zones, it provides targeted spatial guidance and planning around producing, storing, transmitting, and using renewable energy. This results in a series of toolkits for use in different urban functional zones, promoting the development of urban renewable energy.

Keywords

Renewable Energy, New Energy, Urban Spatial Planning, Changzhou, framework

1. Introduction

1.1. Some striking phenomena are occurring in urban environments.

Renewable energy, led by wind and solar, is transforming global energy. Urban photovoltaic systems, like rooftop panels, are a "striking" phenomenon, signalling a significant shift in urban development logic, with "space" becoming key in energy production. Many researchers have acknowledged that "space" is a critical perspective for the transition to renewable energy (Walker, 1995; Blaschke et al., 2013; Bridge et al., 2013; Huber, 2015).

In recent years, a growing number of scholars have focused on the exploitation of renewable energy from urban rooftop resources (Byrne et al., 2015; Zhang et al., 2023), wall resources (Redweik, Catita, and Brito, 2013; Fath et al., 2015; Sarralde et al., 2015), road space resources (Hu et al., 2022), and general land resources (Trainor, McDonald, and Fargione, 2016), highlighting the critical role of various spatial resources in renewable energy production. However, current research focuses mainly on empirical aspects of spatial

resources, needing a systematic understanding of renewable energy forms and their spatial relationships. The impact of renewable energy on urban space is a crucial issue for spatial planning.

1.2 Reflections on Urban Development in Changzhou Against the Background of Energy Transition.

Changzhou, a developed industrial city in eastern China with 3 million residents, represents China's "Southern Jiangsu industrialization model". It hosts leading renewable energy companies like CATL, BYD Auto, Trina Solar, and Li Auto, positioning it at the forefront of the global industry. To further advance, city managers aim to build a "Renewable Energy City" by leveraging spatial planning to promote energy applications and upgrade urban development.

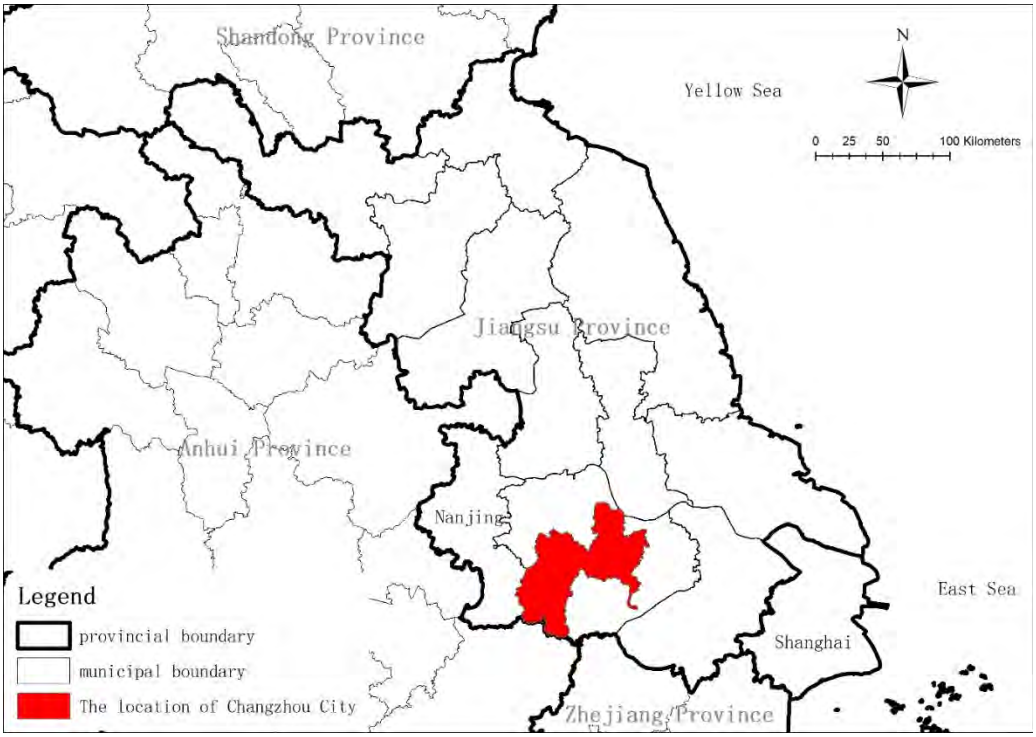


Figure 1. The Location of Changzhou in Eastern China. Source: Self-drawn by the author.

1.3 Definition of "Renewable Energy"

This study will explore the issues surrounding renewable energy and urban spatial systems. Although renewable energy encompasses various forms, photovoltaic (PV) energy is currently the most closely related to urban spatial development. Therefore, this study will emphasise discussing PV energy while also addressing some common characteristics shared by all renewable energy sources.

2. What is a Renewable Energy City?

2.1An Analysis of the Concept of "Renewable Energy" Cities

"Renewable energy" is contrasted with the "non-renewable" nature of "fossil fuels". To comprehend the concept of a "renewable energy" city, it is essential to first understand the relationship between fossil fuels as an energy source and cities (Table 1). In a world structured around fossil fuels, cities are purely energy consumers, heavily reliant on externally sourced petroleum, natural gas, coal, and other such resources. These energy sources flow into cities from mineral-rich regions, forming a highly centralized

energy production and distribution system **(Barry, 2013; Bridge, 2013)**. Within this system, cities typically serve as energy consumers.

Table 1. Differences between fossil energy systems and renewable energy systems. Source: Self-drawn by the author.

Energy System Name	Fossil Energy	Renewable Energy
Historical Period	Around 1800 AD - Present	Starting from Present
System Category	Subsurface Energy System	Surface Energy System
Primary Energy Forms	Coal, Oil, Natural Gas, etc.	Photovoltaic, Solar Thermal, Wind Power, etc.
Energy Formation Mechanism	Formed through millions of years of geophysical and chemical activities from ancient biological deposits	Captured directly or indirectly by wind and solar facilities from solar energy on the Earth's surface
Energy Distribution	Highly Concentrated	Highly Dispersed
Energy System Configuration	Centralized	Decentralized
Correlation between Energy Production and Space	Weak Correlation	Strong Correlation
Logic of Energy Production Expansion	Extracting energy from subsurface spaces with higher efficiency through technological investments	Maximizing energy production by expanding the utilization scale of surface spaces
Role of Urban Space	Energy Consumer	Energy Consumer and Energy Producer

"Renewable energy" harnesses the naturally replenishing energy sources such as wind, sunlight, and water that radiate onto the Earth's surface. Theoretically, any location exposed to sunlight can become an energy production site, enabling cities with abundant spatial resources to take on a new role as energy producer (**Calvert, 2016; Szulecki, 2018)**. "Renewable energy" is characterized by a highly decentralized energy source with a distinct "decentralizing" feature **(Calvert and Simandan, 2010)**. This new energy system will play a pivotal role in developing and shaping urban spaces.

2.2 Key Characteristics of "Renewable Energy" Cities

Energy serves as the most direct measure of the overall level of human productivity, and each energy revolution represents a leap in productivity, leading to significant adjustments in urban spatial morphology **(Wu, 2010).** The core characteristic of "renewable energy" is its "decentralized" energy structure, naturally formed based on widespread energy production sites **(Mitchell, 2009; Yang, Y., Xia, S., and Jin, 2023)**. In contrast, the fossil energy system embodies a "centralized" energy structure that relies on the concentrated input of external energy sources, heavily dependent on constructing large-scale infrastructure and critical projects **(Bridge and Le Billon, 2012)**. Developing of a "renewable energy" system requires the collective participation of governments, large corporations, small and medium-sized enterprises, citizens, and non-governmental organizations to fully realize the comprehensive landscape of a "renewable energy" system.

(1) In terms of energy production: Establishing the principle of "space as energy."

The widespread adoption of renewable energy has endowed numerous new energy consumption spaces in cities, which emerged during the fossil fuel era, with the potential to transform into productive spaces. This shift allows cities to adopt a producer perspective, where space becomes a core element in energy production(Figure 2). The proliferation of renewable energy will an extensive industrial project across surface spaces, requiring vast amounts of land resources **(Frantál, Pasqualetti, and Van Der Horst, 2014; Huber and McCarthy, 2017; Burke and Stephens, 2018)**. This has led to the emergence of a new principle: "space as energy," fundamentally reshaping the relationship between energy and space.

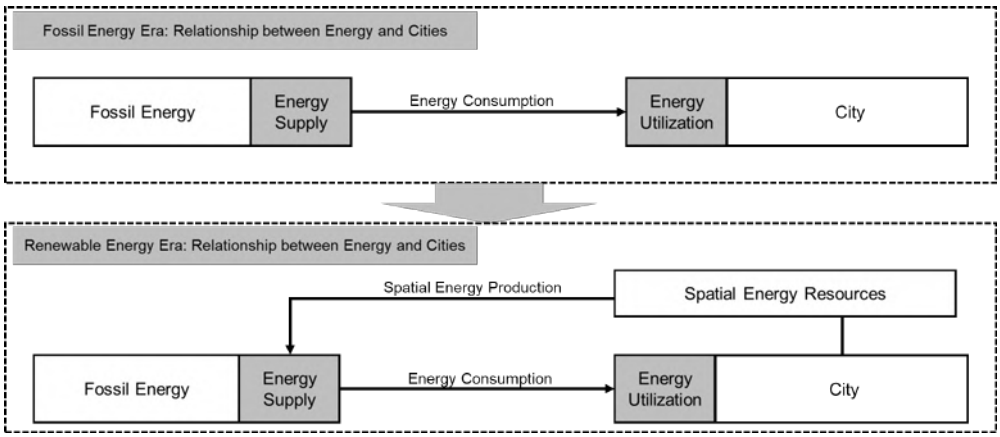


Figure 2. Transition of Urban Roles from Fossil Fuel Era to New Energy Era. Source: Self-drawn by the author.

（2）Regarding of the coordination between energy production and usage, The unstable and intermittent nature of renewable energy creates a "spatio-temporal mismatch."

Renewable energy relies on systems that harness immediate natural energy, characterized by high intermittency and instability **(Hyder, Sudhakar, and Mamat, 2018; Ahmed et al., 2020; Hirsch, Parag, and Guerrero, 2018)**. Compared to the stable demand generated by human production and life, the matching of the two often results in a "spatial-temporal mismatch" between energy production and consumption. This is an inherent characteristic of cities utilizing renewable energy. Consequently, it poses significantly higher requirements for achieving "spatial-temporal balance" of energy across different urban areas than the fossil fuel energy system.

（3）In terms of energy usage: "Standardization" and "electrification" of energy are inevitable development directions.

Fossil fuels can be utilized either as primary energy sources through combustion or as secondary energy sources in the form of electricity. In contrast, renewable energy is inherently destined to exist in the form of electricity, naturally aligning with electrification methods. The diverse forms of energy utilization within the fossil fuel system in the past inevitably implied inefficient energy use and economic value. Across transportation, industrial production, and domestic sectors, the transition to electrification represents an objective trend and a characteristic of the energy usage system inherently required by renewable energy development.

3 ． Current Situation and Spatial Planning Strategies for Changzhou's Goal of Building a "Renewable Energy City"

3.1 Current Status of Renewable Energy Application in Changzhou City

（1） Focusing on "centralized" large-scale renewable energy projects and scenarios while neglecting "decentralized" small-scale projects and scenarios.

In recent years, Changzhou City has invested substantial resources in renewable energy-related power generation, energy storage, transmission, and consumption sectors, with the government driving the construction of a series of "large-scale projects and scenarios" for renewable energy applications. The current model for advancing renewable energy projects in the city still adopts a "centralized" approach to construction and management based on the fossil fuel energy system. Overall, some progress and

benefits have been achieved, but there remains a lack of attention to "bottom-up" channels, and many "decentralized" "small-scale projects and scenarios" are underrepresented.

（2）"Spatio-temporal mismatch" in energy production and sales means a lack of coordination in space and time.

"Renewable energy" is an intermittent form of energy, constrained by diurnal and seasonal rhythms, which can easily cause grid fluctuations due to the instability of electricity production and sales. The energy essence of this characteristic of "renewable energy" is the "spatio-temporal imbalance" between production and sales. The core solution lies in promoting the "balance" of energy production and sales through coordination efforts at both the "temporal" and "spatial" levels, with a focus on energy storage and regional-scale energy balancing. However, the current practice of renewable energy in Changzhou still lacks consideration of this "spatio-temporal" energy dimension.

（3）The phenomenon of "non-standardization" of energy types is prominent in the development process of renewable energy.

Currently, a diverse range of renewable energy sources being explored, including photovoltaic, solar thermal, wind power, and hydrogen energy, each forming distinct technological pathways. In Changzhou's exploration, a relatively diverse energy landscape has also emerged, with some sectors focusing on photovoltaic and wind power while others concentrate on various hydrogen energy applications. This has led to the development of hydrogen-powered electric bicycles, cars, and energy storage tanks. In addition to electricity generation, there are even explorations into directly burning hydrogen as a source of heat for barbecuing, indicating a lack of a clear trend towards "standardization" and "electrification."

3.2 Considerations on the Spatial Planning Path for Changzhou City's Development Goal of Becoming a "Renewable Energy City"

Compared to the actual situation in the fossil fuel era, which emphasized a "top-down" work system, cities in the renewable energy era need to incorporate a "bottom-up" perspective. Therefore, it is necessary to construct a comprehensive urban renewable energy spatial planning framework from the two dimensions of spatial "usability" and human "perceptibility" (Figure 3). Firstly, regarding spatial "usability", the focus is on the energy itself, assuming that a higher proportion of renewable energy in various urban scenarios indicates a more successful transition to renewable energy. Secondly, in terms of spatial "perceptibility", emphasis is placed on citizens' awareness of renewable energy-related phenomena. From the perspective of human cognitive psychology, this approach makes the abstract concept of energy, which is "unknowable and imperceptible", more tangible by integrating it into various activities of citizens, thereby playing a role in education, influence, and shaping a green atmosphere.

3.3 Spatial Planning Strategies for Changzhou City's Development Goal of Becoming a "Renewable Energy City"

（1）Perspective of Spatial "Practicality": Construction of Four Key Spaces

This study focuses on four spatial scenarios from the perspective of "usability," including urban residential areas, industrial parks, public spaces, and rural areas, which cover the main production and living spatial units in Changzhou. On this basis, the study analyzes and evaluates these spaces mainly from ① the matching of total energy production and consumption, ② the spatial-temporal matching of energy production and consumption, ③ the complexity of energy consumption applications, and ④ the spatial property rights. For instance, take industrial parks as an example: First, industrial parks possess abundant

production capacity spaces but are also major energy consumers, with energy consumers usually being the primary focus. Second, energy production and

Table 2. Matrix of Spatial Guidance Measures for Renewable Energy Based on Spatial "Usability". Source: Self-drawn by the author.

space scene		energy production	energy storage	energy delivery	energy use
urban residential areas	emerging residential areas	Architecture: Popularizing the application of photovoltaic rooftop power generation , explore diversified power generation on floors, rooftops, etc.	Supporting facilities: Build shared energy storage devices to smooth community power consumption curves	Supporting facilities: The device is upgraded to adapt to the shared intelligent transmission system	Building: Install sensors to adapt to new energy management systems in homes Supporting facilities: reserve space for new energy transformation and upgrade pipelines Roads and vehicles: 100% of parking spaces in new communities are reserved for charging facilities
	old residential areas		Supporting facilities: Promote safe and reliable small and micro energy storage devices	Supporting facilities: Smart microgrid transformation to optimize community energy efficiency	Supporting facilities: configure new energy utilization facilities to meet the living needs of residents Roads and vehicles: Regional cooperation to increase charging facilities for motor vehicles and non-motor vehicles
Industrial parks	Innovation R&D Park	Building: 100% distributed photovoltaic roof; building photovoltaic integration, photovoltaic curtain wall, ground source heat pump, ice storage and other sustainable technologies	Supporting facilities: intelligent lights, carports with integrated power storage, etc.	Supporting facilities: distributed "new energy + energy storage" microgrid	Roads and vehicles: With the application of new energy equipment as the core, new energy work vehicles, new energy logistics vehicles, and green new energy transportation vehicles are 100% equipped with multiple sets of charging terminals; vegetation landscape: a landscape wall is set up at the entrance of the building Others: full-scenario open new energy experience display center.
	Manufacturing Park		Construction of energy storage power stations to achieve peak shaving and valley filling and peak and valley arbitrage based on energy storage stations		
	Logistics and warehouse				
Public spaces	public building	Architecture: The photovoltaic coverage rate on the roofs of new public buildings is 80%; explore wall photovoltaics and photovoltaic building integration technology	Construction: "Photovoltaic + energy storage" project construction of new buildings in public institutions	—	Others: Demonstrate new energy-related achievements and hold regular science education activities
	public green space	Supporting facilities: use of outdoor photovoltaic products, street furniture, photovoltaic lighting facilities, etc.	Supporting facilities: Add new energy interactive device energy storage	—	Supporting facilities: Promote new energy technology in tourist facilities in scenic spots Others: Build new types of new energy theme parks and conduct outdoor displays
rural areas	production space	1. Photovoltaic power generation 2. Comprehensive utilization of biomass energy	1. Combined heat and power or central heating energy station 2. Biogas (biogas) energy station	Energy transmission pipe network system	Photovoltaic + production
	living space	1.Rooftop photovoltaic 2. Household biogas pool	——	——	1. Popularize new energy in public facilities 2. New energy vehicles going to the countryside

consumption are generally time-matched, with both peaking during the daytime. Third, industrial parks involve various specific production processes and methods, and the forms of energy are diverse and complex, including coal, natural gas, liquefied petroleum gas, etc., which require further electrification and standardization. Fourth, regarding spatial property rights, enterprises are the primary property units in

industrial parks, characterized by a relatively simple spatial property rights structure and significant economies of scale. This study provides systematic guidance for the spatial layout and construction of energy "generation, storage, transmission, and utilization" in these four significant spaces (Table 2).

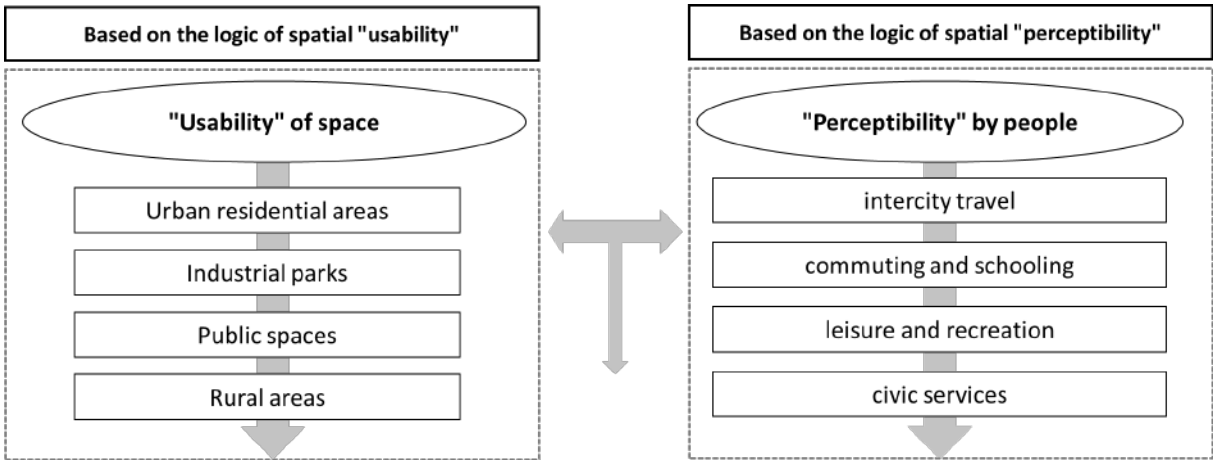


Figure 3. Schematic Representation of Strategic Pathways Based on Spatial "Usability" and "Perceptibility". Source: Self-drawn by the author.

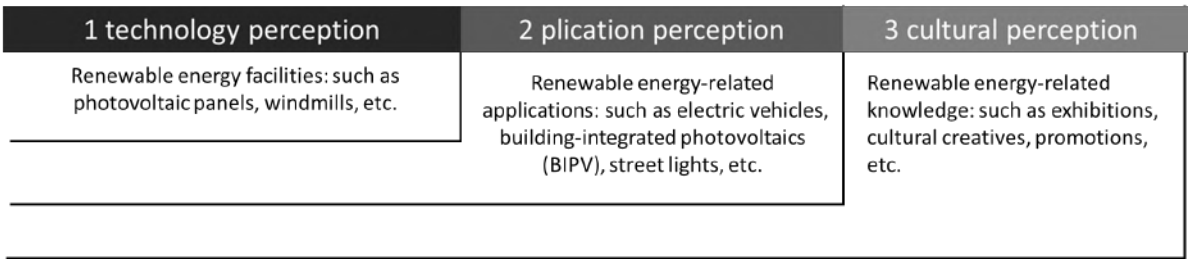


Figure 4. Schematic Representation of Strategic Pathways Based on Spatial "Usability" and "Perceptibility". Source: Self-drawn by the author.

(2) Perspective of Spatial "Perceptibility": Construction of Four Key Elements

This study focuses on four critical aspects from the perspective of "perceptibility," examining the construction of urban renewable energy through human-centric lenses such as citizens' daily life, work, and leisure activities. It covers four domains: intercity travel, commuting and schooling, leisure and recreation, and civic services. This study abstracts the citizen mentioned above activities into a "point"-"path"-"point" process, guiding energy application scenarios around "points" and "lines." Based on people's cognition of renewable energy, three levels are distinguished ① Technical Perception: This primarily refers to facilities, objects, and tools that can directly establish the intention of renewable energy, such as photovoltaic panels, wind turbines, and charging stations. ②Application Perception: This mainly involves objects that utilize renewable energy, such as renewable energy vehicles, buildings integrated with photovoltaic systems, and photovoltaic streetlights. ③Cultural Perception: This primarily encompasses the relatively peripheral aspects of renewable energy, including cultural and creative products, technology exhibitions, and promotional materials (Figure 4). Take intercity travel as an example, it mainly involves transportation areas such as airports, high-speed rail stations, bus stations, and external roads. It is necessary to carry out construction and guidance work in three dimensions: cultural perception, application perception, and technical perception . Ultimately, based on the above framework, construction and planning guidance in these three dimensions will be implemented across citizens' four major application scenarios (Table 3).

Table 3. Matrix for Guiding the Development of Renewable Energy in Urban Spaces Based on Human "Perceptibility". Source: Self-drawn by the author.

Application fields		cultural perception	application perception	technology perception
Intercity travel	hub station	① Large screen for new energy theme science popularization and achievement display ②IP guidance system with new energy design elements for stations and signboards along the line	① Lay out photovoltaic power generation ceilings and building facade structures and energy storage facilities ② IP guidance system with new energy design elements for sites and signage, using small energy storage power generation equipment for luminous display	Small energy storage batteries and other electronic products and equipment energy storage device coverage
	traffic flow		① "Photovoltaic + transportation" practical application scenarios ②Experience new energy public transportation	Utilize idle ground space and lay solar panels along roads
Commuting and Schooling	commuting space	New energy exhibition and promotion on both sides of the road	New energy vehicles, new energy buses, new energy two-wheelers, new energy BRT, new energy subway	Photovoltaic roads, new energy street lights, new energy bus stations
	residential space	New energy exhibition and promotion in the community	Photovoltaic integrated housing	Photovoltaic panels for home decoration, integrated new energy systems for home "send, store, and use", etc.
Leisure and recreation	Scenic spots	①Scenic area open new energy display and experience center, architectural theater, outdoor exhibition gallery, etc.; ② Sites, signboards, new energy design elements, IP guidance systems and new energy urban furniture, new energy theme bulletin boards, carbon emission information walls, etc.	New energy intelligent self-driving yachts, new energy sightseeing cars and other tourist facilities	Scenic area distributed photovoltaic panels, solar power generation components, etc.
	Park and square		Various new energy street installations, landscape facilities, new energy outdoor products, small street furniture, interactive installations, etc.	Photovoltaic street furniture, photovoltaic unmanned vehicle stations, smart sunshade pavilions, new energy street lights
	Slow-paced space		New energy charging facilities, new energy bicycles	
Civic service	business services	Conduct cultural displays with the theme of new energy technology to popularize new energy knowledge	Centralized exhibition of new energy related application products, including: simulation experience, multimedia display, physical exhibits, etc.	Solar panels will be laid on the roof and solar charging stations will be built, and new energy will be used to power the venue.
	Science, education and cultural services			

4. Conclusion

The transition to renewable energy marks a major shift in urban development logic, where "space" becomes pivotal in energy production. Changzhou, a key industrial city in China's new energy sector, aims to harness its industrial strengths to pioneer new energy applications and transform them into competitive advantages for future urban growth. This research projects a "renewable energy path" for Changzhou through spatial planning. It initially defines a "renewable energy city" by comparing it with fossil energy and analyzing its connotations and characteristics to establish essential features. Under a systematic framework, Changzhou's current status in renewable energy city construction is assessed, revealing: ① an over-reliance on "centralized" projects and neglect of "decentralized" small-scale initiatives; ② a "spatial-temporal mismatch" in energy production and sales, lacking coordination; ③ prominent "non-standardization" of energy types. Based on these findings, the study advocates building a comprehensive urban renewable energy system through spatial "usability" and human "perceptibility": ① focusing on four key places for usability; ② emphasizing four key links for perceptibility.

5. References

Ahmed, R., Sreeram, V., Mishra, Y. and Arif, M.D.（2020）. 'A review and evaluation of the state-of-the-art in PV solar power forecasting: Techniques and optimization', *Renewable and Sustainable Energy Reviews*, *124*, p.109792.

Barry, A.（2013）. *Material politics: Disputes along the pipeline*. Oxford: Wiley-Blackwell.

Blaschke, T. Biberacher, M., Gadocha, S. and Schardinger, I., 2013. 'Energy landscapes: Meeting energy demands and human aspirations', *biomass and bioenergy*, *55*, pp.3-16.

Bridge, G.（2013）. 'The Hole World: scales and spaces of extraction', *New geographies*, *2*.

Bridge, G., Bouzarovski, S., Bradshaw, M. and Eyre, N.（2013）. 'Geographies of energy transition: Space, place and the low-carbon economy', *Energy Policy*, *53*, pp.331-340.

Bridge, G. and Le Billon, P.（2012）. *Oil*. Cambridge: Polity Press.

Burke, M.J. and Stephens, J.C.（2018）. 'Political power and renewable energy futures: A critical review', *Energy research & social science*, *35*, pp.78-93.

Byrne, J., Taminiau, J., Kurdgelashvili, L. and Kim, K.N.（2015）. 'A review of the solar city concept and methods to assess rooftop solar electric potential, with an illustrative application to the city of Seoul', *Renewable and sustainable energy reviews*, *41*, pp.830-844.

Calvert, K.（2016）. 'From energy geography to energy geographies Perspectives on a fertile academic borderland', *Progress in Human Geography*, *40*(1), pp.105-125.

Calvert, K. and Simandan, D.(2010). 'Energy, space, and society: a reassessment of the changing landscape of energy production, distribution, and use', *Journal of Economics and Business Research*, *16*(1), pp.13-37.

Fath, K., Stengel, J., Sprenger, W., Wilson, H.R., Schultmann, F. and Kuhn, T.E.（2015）.'A method for predicting the economic potential of (building-integrated) photovoltaics in urban areas based on hourly Radiance simulations', *Solar energy*, *116*, pp.357-370.

Frantál, B., Pasqualetti, M.J. and Van Der Horst, D.（2014）. 'New trends and challenges for energy geographies: Introduction to the special issue', *Moravian Geographical Reports*, *22*(2), pp.2-6.

Hirsch, A., Parag, Y. and Guerrero, J.(2018). 'Microgrids: A review of technologies, key drivers, and outstanding issues', *Renewable and Sustainable Energy Reviews*, *90*, pp.402-411.

Hu, M., Song, X., Bao, Z., Liu, Z., Wei, M. and Huang, Y.(2022). 'Evaluation of the economic potential of photovoltaic power generation in road spaces', *Energies*, *15*(17), p.6408.

Huber, M.（2015）. 'Theorizing energy geographies', *Geography Compass*, *9*(6), pp.327-338.

Huber, M.T. and McCarthy, J.（2017）. 'Beyond the subterranean energy regime? Fuel, land use and the production of space', *Transactions of the Institute of British Geographers*, *42*(4), pp.655-668.

Hyder, F., Sudhakar, K. and Mamat, R.（2018）. 'Solar PV tree design: A review', *Renewable and Sustainable Energy Reviews*, *82*, pp.1079-1096.

Mitchell, T.（2009）. 'Carbon democracy', *Economy and Society*, *38*(3), pp.399-432.

Redweik, P., Catita, C. and Brito, M.(2013). 'Solar energy potential on roofs and facades in an urban landscape', *Solar energy*, *97*, pp.332-341.

Sarralde, J.J., Quinn, D.J., Wiesmann, D. and Steemers, K.（2015）. 'Solar energy and urban morphology: Scenarios for increasing the renewable energy potential of neighbourhoods in London', *Renewable energy*, *73*, pp.10-17.

Szulecki, K.（2018）. 'Conceptualizing energy democracy', *Environmental Politics*, *27*(1), pp.21-41.

Trainor, A.M., McDonald, R.I. and Fargione, J.(2016). 'Energy sprawl is the largest driver of land use change in United States', *PloS one*, *11*(9), p.e0162269.

Walker, G.(1995). 'Energy, land use and renewables: A Changing Agenda', *Land use policy*, *12*(1), pp.3-6.

Wu,L.(2010). 'The impact of new energy development to energy transition and geopolitics', *Pacific Journal*,29(1), pp.62-70.

Yang, Y.,Xia , S., and Jin,Z.(2023). 'Energy transition reshapes geopolitics: Logic and research frontiers', *Acta Geographica Sinica*, *78*(9), pp.2299-2315.

Zhang, Z., Chen, M., Zhong, T., Zhu, R., Qian, Z., Zhang, F., Yang, Y., Zhang, K., Santi, P., Wang, K. and Pu, Y.(2023). 'Carbon mitigation potential afforded by rooftop photovoltaic in China', *Nature Communications*, *14*(1), p.2347.

Research Paper

Correlation between Urban Density and Heat Health Risk in Megacities: A Case Study of Shenzhen

Cunyan JIANG, School of Architecture, Harbin Institute of Technology, China

Zide LIU, School of Architecture, Harbin Institute of Technology, China

Abstract

Global climate change has led to more frequent extreme heat events, while the urban heat island effect exacerbates heat health risk in densely populated cities. Shenzhen, one of China's fastest-growing cities, has undergone rapid urban expansion over the past two decades, resulting in significant challenges related to heat health risk. Balancing accelerated urbanization with sustainable design principles is crucial for developing livable and resilient urban environments. This study aims to elucidate the correlation between building density and the deterioration of the urban thermal environment in megacities by Geographically Weighted Regression Models and to propose planning and policy measures aligned with sustainable design to mitigate heat health risk in high-density urban areas. The results indicate (1) a significant spatial autocorrelation of heat health risk and (2) a significant positive correlation between building density and heat health risk. These findings underscore the importance of urban planning in alleviating heat health risk through the reduction of building density. Using Shenzhen as a case study, this research examines the impact of megacity construction on thermal environment degradation and increased heat health risk and discusses sustainable planning and policy interventions to reduce these risks, offering recommendations for creating livable and resilient cities.

Keywords

Heat health risk, Megacities,Building density, Geographically Weighted Regression Models

1. Introduction

As global climate change intensifies, the intensity, duration, and frequency of extreme heat events will continue to increase, posing a serious threat to human health. The Sixth Assessment Report (AR6) of the United Nations Intergovernmental Panel on Climate Change (IPCC) shows that "Global surface temperature was about 1.1 ° C above 1850-1900 in 2011-2020 (1.09 [0.95 to 1.20] ° C), with larger increases over land (1.59 [1.34 to 1.83]°C) than over the ocean (0.88 [0.68 to 1.01]°C)(Intergovernmental Panel on Climate Change, 2021). Lei Zhao et al. (2021) found by modeling climate projections that many of the world's cities could warm by as much as 4°C if greenhouse gas emissions continue at high levels through 2100. Extreme hot weather overwhelms the human thermoregulatory system, which can lead to heat stroke for residents, significantly the frail, such as children and the elderly, and if not treated in time, can aggravate severe illnesses such as pyrexia, which can then lead to vital organ failure or even death (Yuan et al., 2021).

Due to urbanization, the urban heat island (UHI) effect has become a modern endemic threat to human health and energy consumption, especially in compact urban areas with high population density (Lin et al., 2017). High-density cities have been shown to have a stronger heat island effect (Hien, Jusuf and Jiang,

2019). Cities consist of urban form patterns with different building characteristics and have specific microclimatic characteristics (Chen et al., 2021). In dense urban areas, an increase in building density leads to an increase in surface temperature (Sun, 2020). Shenzhen is one of the most densely populated cities in the world and is also prone to extreme heat events. Therefore, it has become imperative to accurately assess the impact of heat health risk in high-density cities and to propose targeted adaptation strategies and mitigation measures.

Currently, urban thermal environment research mainly focuses on high-temperature risk assessment, the impact mechanism of UHI effect, and risk response strategies (Liu, Chen & Wang 2022). In studies related to urban heat health risk assessment, the indicators employed to reflect the elements of health heat risk are not comprehensive enough to fully express the attributes of the elements. Furthermore, the correlation between building density and heat health risk has not received the attention it warrants. To address the limitations of heat health risk-related studies, this research analyzes multivariate data, such as remote sensing images, to obtain more relevant indicators to construct a more detailed heat health risk assessment. It introduces Geographically Weighted Regression (GWR) analysis to explore the correlation between building density and heat health risk in the spatial dimension to more accurately capture the changing patterns of variables and the extent.

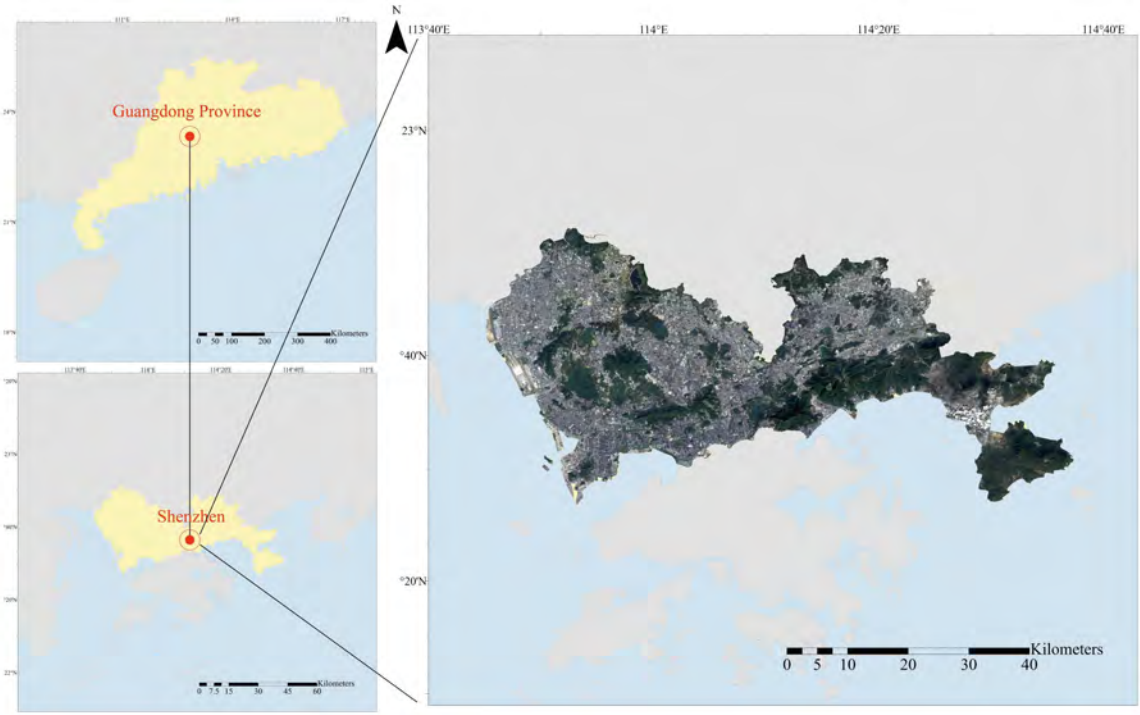


Figure 1. The geographic location of Shenzhen, China.

2. Study area

Shenzhen (22°27′-22°52′N, 113°46′-114°37′E) is located on the southeast coast of China and is a very representative megacity in the Guangdong-Hong Kong-Macau Greater Bay Area(Fig. 1). Since the 21st century, Shenzhen has experienced rapid urbanization, and large-scale urban construction has led to significant changes in spatial structure and surface materials, resulting in increasingly pronounced high temperatures, with a historical extreme maximum temperature of 38.7°C (Zhao et al., 2021). Identifying and assessing heat health risk and proposing related strategies to make Shenzhen a more livable and resilient city has become an important goal for future urban planning in Shenzhen.The scope of this paper

is the whole city of Shenzhen, including Futian District, Luohu District, Yantian District, Nanshan District, Bao'an District, Longgang District, Longhua District, Pingshan District, Guangming District and Dapeng New District. It has a total area of 1,997.47 square kilometers and a permanent population of 17.7901 million.

3. Methodology

The heat health risk assessment model, which is based on the Crichton's risk triangle framework as outlined in the IPCC Fifth Assessment Report, has been widely recognized and applied in academic and professional circles (Hu et al., 2017). In this study, the framework is employed to calculate the components of heat health risk, including heat hazard, heat exposure, and heat vulnerability. The heat health risk index of Shenzhen is obtained through the weighted multiplication of these three factors. This study utilizes methods such as spatial autocorrelation analysis and geographically weighted regression analysis to analyze the correlation between building density and heat health risk, and proposes targeted strategies to mitigate heat health risk based on the results. Fig. 2 illustrates the study flow.

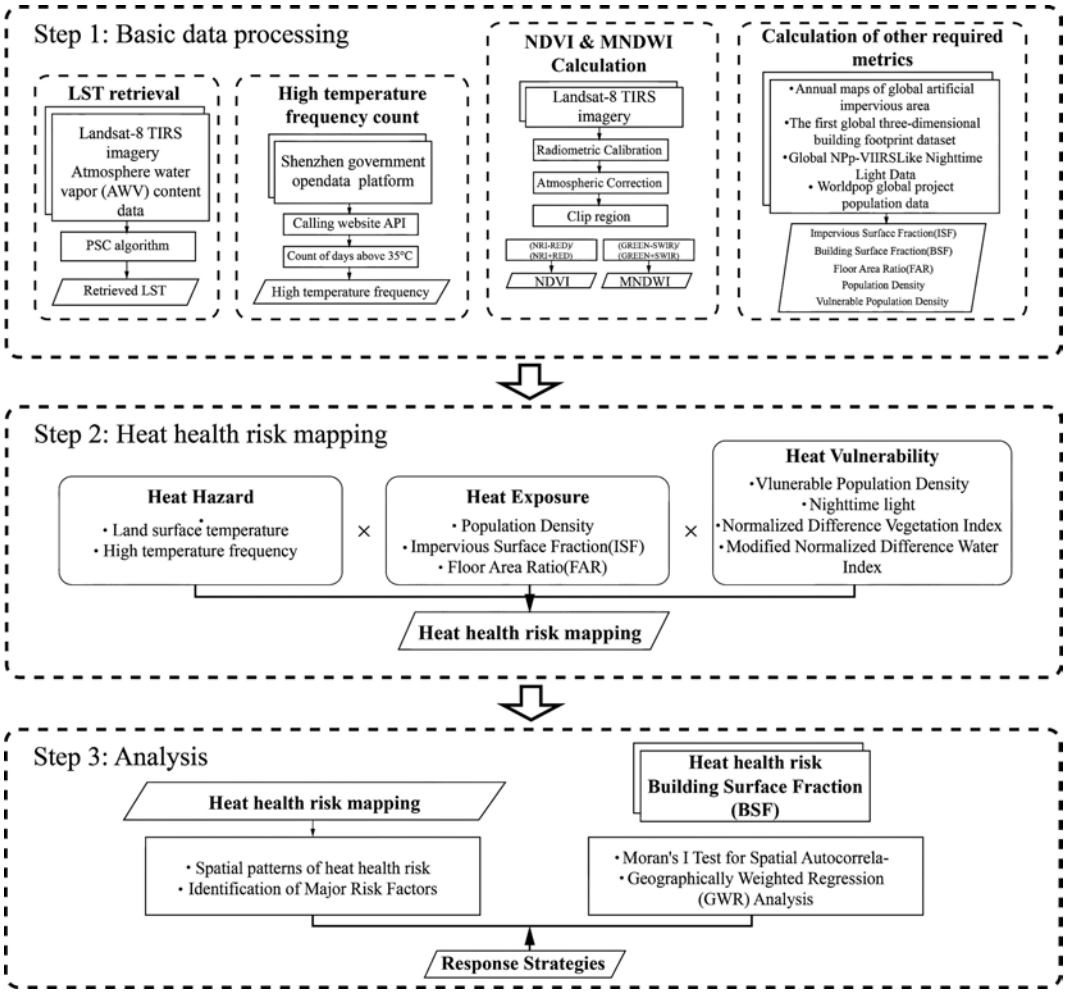


Figure 2. The workflow for this study.

3.1. Data collection and preprocessing

This study mainly collected Landsat 8 remote sensing image data, built environment data (including impervious surface data and building vector data), Shenzhen meteorological data, and socioeconomic

data (including worldpop population density data and nighttime light data) to calculate the components of heat health risk and building density in Shenzhen. The specific sources and applications of each data are shown in Table 1. Considering the resolution of different data, a 300m grid was used as the research unit for data processing, which can well reflect the heterogeneity of urban areas and ensure the macro-control of urban planning.

Table 1. Summarized information of datasets used in this study.

Theme	Sources	Period	Resolution	Application
Landsat-8	Geospatial Data Gloud (https://www.gscloud.cn/)	2021.12.5 and 2021.12.14	30m	NDVI/MNDWI calculation
Impervious surface data	Urban Environmental Monitoring and Modeling (UEMM) team(Gong et al., 2020)	2021	30m	ISF calculation
Building vector data	Zenodo database by Che et al. (2024)	2020	-	Building density and floor area ratio calculation
Meteorological data	Shenzhen Municipal Government Data Open Platform (https://opendata.sz.gov.cn/data/dataSet/toDataDetails/)	2021	-	Hazard calculation
Population density data	WorldPop(https://www.worldpop.org/)(WorldPop, 2018a; WorldPop, 2018b; Nieves et al., 2020a; Nieves et al., 2020b; Pezzulo et al., 2017)	2020	100m	Exposure/ Vulnerability calculation
Nighttime light data	An extended time-series (2000-2023) of global NPP-VIIRS-like nighttime light data by Chen Zuoqi et al. (2021)	2020	500m	Vulnerability calculation

3.2. Framework for heat health risk assessment

Heat health risk assessment is the foundation and research focus of urban heat health risk management. In 2014, the fifth assessment report of the IPCC elucidated the concept and evaluation methodology of climate change risk, indicating that such risk arises from the interaction between climate hazards and human and natural systems, and it is determined by the hazard of the disaster, the exposure, and the vulnerability of the disaster-bearing body (Field et al., 2014). This study will quantify and estimate heat health risk using IPCC-endorsed Crichton's Risk Triangle approach. The indicators will be chosen after a literature study and data availability evaluation.

The heat health risk is calculated through the weighted integration of three indices: heat hazard, heat exposure, and heat vulnerability. Due to the lack of uniformity in the weights of these indices (Johnson et al., 2012), this study employs an equal-weight multiplication and division method to compute the heat health risk index, thereby illustrating the intricate relationship among the indices. The formula is shown below:

$$HRI = \text{hazard} \times \text{exposure} \times \text{vulnerability} \quad (1)$$

In order to ensure the comparability between the three elements as above and to achieve aggregation at the level of indicators and components, this study has standardized all indicators to avoid the appearance of zero values. The standardized calculation formulas for positive and negative impact indicators are shown in formulas (2) and (3):

$$V' = 0.1 + \frac{V - Min}{Max - Min} \times (0.9 - 0.1) \quad (2)$$

$$V' = 0.1 + \frac{Max - V}{Max - Min} \times (0.9 - 0.1) \quad (3)$$

Where V' is the normalized value, V is the original value, Max and Min are the maximum and minimum values of the original value, respectively.

3.2.1 Heat Hazard

Heat hazards are the causes and triggers of heat-related calamities and heat health risks. It focuses on high-temperature heat waves, UHI effect, urban anthropogenic heat sources, transportation heat emissions, and urbanization. This study uses LST and heat wave frequency to assess heat threat. According to Shenzhen Meteorological Bureau records and climatic standards, summer in Shenzhen is April 21–November 2.

In this study, we use the PSC method to compute the average LST from April 21 to November 2, 2021, through GEE, and the formula of the PSC method is as follows (Wang et al., 2019):

$$\text{LST} = \frac{c_2}{\lambda \ln(\frac{c_1}{\lambda^5 \cdot B(T_S)} + 1)} \quad (4)$$

$$B(T_S) = a_0 + a_1\omega + (a_2 + a_3\omega + a_4\omega^2)\frac{1}{\varepsilon} + (a_5 + a_6\omega + a_7\omega^2)\frac{L_{sen}}{\varepsilon} \quad (5)$$

In the formula, LST is the land surface temperature in (K); $B(T_S)$ is the Planck's radiation function based on the temperature T_S; λ is the effective wavelength; L_{sen} is the radiation received by the sensor; ε is the surface albedo; ω is the atmospheric water vapor content; c_1 and c_2 is a constant equal to 1. 19104×108W· μm 4· m2· sr-1, 1.43877×10-4 μm· K; the coefficients a_K (K=0,1,2...) are : -0.4107, 1.493577, 0.278271, -1.22502, -0.31067, 1.022016, -0.01969, 0.036001 in Landsat-8.

The higher the heat wave frequency, the higher the heat wave hazard (Anderson and Bell, 2011). According to the definition of hot weather by the China Meteorological Administration, this study was conducted to calculate the heat wave frequency by counting the total number of days with temperatures higher than 35°C in 2021 in each administrative district of Shenzhen (Dong et al., 2014; Hu et al., 2017). The indicators were standardized and then summed with equal weights to calculate the heat hazard index using the following formula:

$$\text{Hazard} = (\text{LST} + \text{F})/2 \quad (6)$$

In the formula, LST is the average land surface temperature of Shenzhen from April 21 to November 2, 2021, and F is the heat wave frequency.

3.2.2 Heat Exposure

Heat exposure is the objective physical environment in cities that enhances heat health risk and may worsen heat catastrophes. Impervious surface ratio (ISF) and floor area ratio (FAR) might indicate inadequate ventilation, cooling, heat radiation, and reflection. Since urban heat health risk research focuses on individuals, population density indicates heat exposure (Buscail, Upegui and Viel, 2012). FAR is the ratio of total floor area to grid area and indicates building density and development intensity. The formula is:

$$\text{FAR} = \frac{\sum_{i=1}^{n} F_i A_{Bi}}{A_P} \quad (7)$$

A_{Bi} is the floor area of the ith building within the grid, F_i is the number of floors of the ith building within the grid, and A_P is the grid area.

ISF reflects the coverage ratio of impervious surfaces within the grid. The calculation formula is:

$$\text{ISF} = 1 - \text{BSF} - \text{PSF} \quad (8)$$

Population density data are obtained from the WorldPop gridded population density dataset (Unconstrained individual countries 2000-2020) with a resolution of 100m. The heat exposure index is calculated by standardizing the FAR, ISF, and population density and then adding them equally, as follows:

$$\text{Exposure} = (\text{FAR} + \text{ISF} + \text{POP})/3 \quad (9)$$

POP is the population density.

3.2.3 Heat Vulnerability

Heat vulnerability is the city's socio-economic circumstances that raise heat health risk, stressing the losses and injuries urban people or institutions may experience in heat disasters. Vulnerable infrastructure systems, poor economic levels, barren vegetation and water bodies, vulnerable populations (elders and children), etc., are typically reflected by indicators like vulnerable population density, nocturnal light index, NDVI, and MNDWI. The formulas are as follows:

$$\text{NDVI} = \frac{\text{NRI} - \text{RED}}{\text{NIR} + \text{RED}} \quad (10)$$

$$\text{MNDWI} = \frac{\text{GREEN} - \text{SWIR}}{\text{GREEN} + \text{SWIR}} \quad (11)$$

NIR is the near infrared band (B5); RED is the red light band (B4); GREEN is the green light band (B3); and SWIR is the shortwave infrared band 1 (B6). Previous studies have shown that nighttime light data can reflect socioeconomic levels. Residents over the age of 65 and under the age of 5 are generally considered to be more vulnerable to high temperatures. Therefore, the density of these vulnerable populations is selected as an indicator of heat vulnerability in the heat health risk assessment. NDVI, MNDWI, and nighttime light Index are higher, the lower the heat vulnerability, so the three are used as

negative effect indicators, and the density of vulnerable populations is normalized and then subtracted in equal weight to calculate the Heat Vulnerability Index. The formula is as follows:

$$\text{Vulnerability} = (\text{POP}'\text{-NDVI-MNDWI-NL})/4 \quad (12)$$

POP' is the density of vulnerable people, NDVI is the normalized difference vegetation index, MNDWI is the modified normalized difference water index, and NL is the nighttime light index.

3.3. Geographically weighted regression analysis model

3.3.1 Spatial autocorrelation analysis

A variable shows spatial autocorrelation when it shows regularity rather than random distribution in space. Moran (1948) applied the one-dimensional correlation coefficient in two-dimensional space to study random distribution phenomena in two-dimensional space and then proposed Moran's index (Moran, 1950). Moran's index can be used to assess the degree of spatial autocorrelation between variables at adjacent locations.

3.3.2 Geographically weighted regression analysis

Studies have shown that there is spatial non-stationarity in the relationship between LST and its forcing factors (Lu et al., 2021; Liu et al., 2019). For this reason, scientists have introduced the method of geographically weighted regression analysis (Guo et al., 2020; Liu et al., 2021). Geographically weighted regression is a spatial analysis technique proposed by Fotheringham et al. (1998) to deal with spatial heterogeneity (Lu et al., 2020). It can be used to quantify the correlation between variables and their spatial heterogeneity (Li, Zhao and Xu, 2017). In this paper, after verifying the spatial heterogeneity of thermal health risks, a geographically weighted regression model is introduced to further analyse the relationship between building density and thermal health risks.

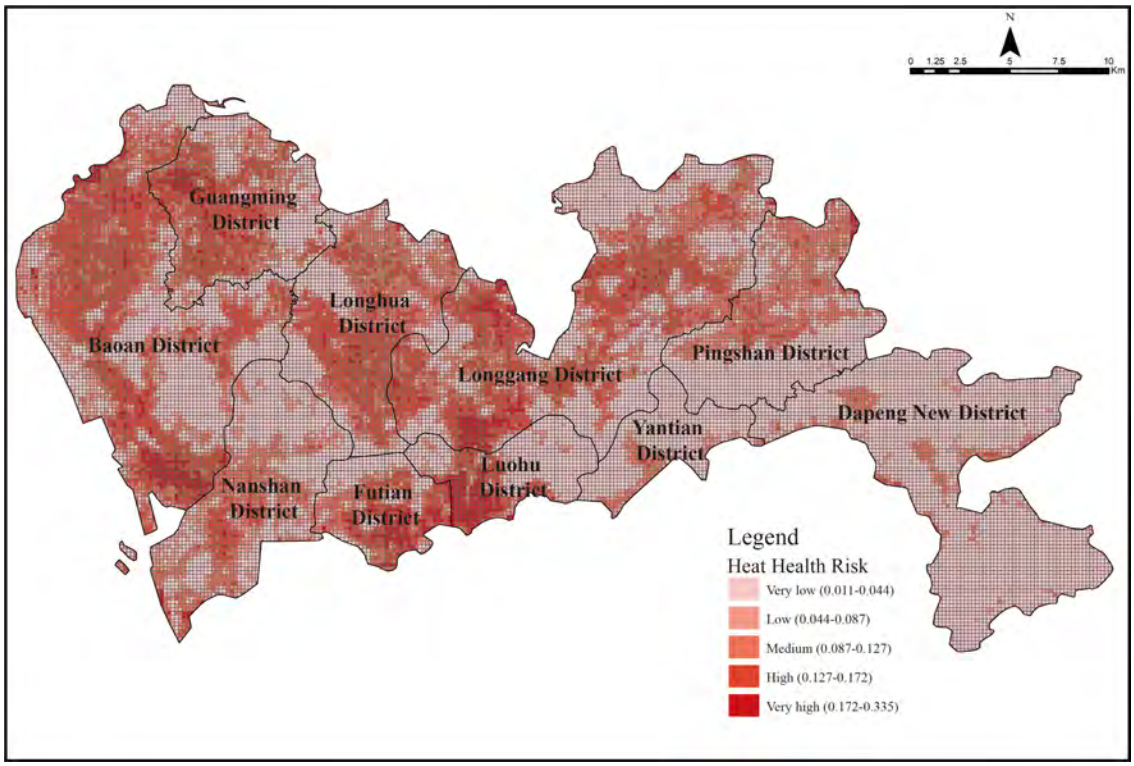


Figure 3. Heat health risk assessment result.

4. Results

4.1. Shenzhen Heat Health Risk Assessment Results

ArcGIS Pro was used to overlay the heat hazard, heat exposure, and heat vulnerability indices to obtain a heat health risk index, which was then classified into five levels: very high, high, medium, low, and very low using the natural breakpoint classification method (Fig. 3).

4.2. A study on the correlation between building density and heat health risk

As can be seen from the above analysis, differences in geographical location may have an impact on heat health risks, leading to spatial heterogeneity in heat health risks. The OLS results (as shown in Table 2 and Table 3) show that building density is significant at the 0.01 level, and the joint F statistic passes the significance test, which model is statistically significant; the probability of the Koenker (BP) statistic is less than 0.01, indicating statistical significance, which indicates that the model is unstable and there may be spatial heterogeneity, so it is necessary to introduce a GWR model for further analysis.

Table 2. OLS Model Estimation.

Variable	P-value
BSF	0.000000**

Table 3. OLS Diagnostic Results（"" indicates statistical significance at the 0.01 level (two-tailed).）.**

Diagnostic	
R2	0.508884
Adjusted R^2	0.508862
Joint Chi-square Statistic	17114.727069**
Joint Chi-square P-value	0.000
Joint F-statistic	23248.718771**
Joint F-statistic P-value	0.000
Akaike Information Criterion (AICc)	-81919.767888
Koenker (BP) Statistic	76.613268**
Koenker (BP) P-value	0.000

4.2.1 Moran's index test

Before conducting a GWR analysis, it is first necessary to check whether there is spatial autocorrelation in heat health risks. The Moran's I index is used to analyze whether the hypothesis of spatial autocorrelation of heat health risks is valid. The results of the Moran's I analysis are shown in Fig. 4. The z-score is as high as 170.787853, which is much higher than the usual significance threshold, indicating that there is a positive correlation. The p-value is 0.000000, which is much smaller than 0.01, meaning that the possibility of the data being randomly distributed is less than 1%, indicating that the heat health risk has spatial agglomeration characteristics within Shenzhen, and the possibility of the results being random can be almost completely ruled out. Therefore, the GWR is introduced in this study for further analysis.

4.2.2 Geographically weighted regression analysis

Moran's I test shows that the heat health risk in Shenzhen has a significant spatial correlation. Traditional regression models cannot incorporate geographical location information, while the GWR model can be used to effectively explore the issue of local heterogeneity between independent variables and dependent variables caused by geographical location.

Table 4. Comparison of OLS and GWR Model Parameters.

Analysis Model	OLS	GWR
AICc	-81919.767888	-98087.047183
R2	0.508884	0.775181
Adj-R2	0.508862	0.765121

AICc, R^2, and Adi-R^2 can be used to analyze the performance of models. The higher the values of R^2 and Adi-R^2 and the lower the value of AICc, the better the model performance (Li, Zhao and Xu, 2017). A comparison of the parameters of the GWR and OLS models is shown in Table 4. The AICc value of the GWR model is - 98087.047183, which is lower than the OLS model's -81919.767888; the adjusted R^2 is 0.765121, which is higher than the OLS model's 0.508862, indicating that the GWR model performs better. The Std. Residual can be used to determine if there are local problems with the results of the GWR analysis—areas with a standardized residual that is more than 2.5 times the Std. Residual should be investigated. Judging from the visualization of the Std. Residual given by the GWR analysis results (as shown in Fig. 5), there are basically no areas with a Std. Residual greater than 2.5 times the Std. Residual, indicating that the analysis results are reliable.

The GWR analysis shows that there is spatial heterogeneity in the effect of building density on heat health risks, i.e., there are differences in the direction and strength of the effect in different spatial locations. The regression coefficient reflects the effect of building density on heat health risks. The sign of the coefficient indicates the direction of the effect of the independent variable on the dependent variable, and the magnitude of the absolute value of the coefficient indicates the strength of the effect. Table 5 shows that the regression coefficient of building density is positive in each grid, indicating that it contributes to heat health risks. The increase in building density caused by urban development exacerbates the heat health risk. The heat health risk index ranges from 0.011 to 0.335, while the average value of the regression coefficient of building density is 0.278665, indicating that the effect of building density on heat health risk is significant.

Table 5. Regression Relationship between Building Density and Heat Health Risk

	Regression Coefficient			R^2
	Minimum	Maximum	Mean	
BSF	0.003474	2.168746	0.278665	0.775181

From the results of the building density regression coefficient grid (Fig. 6), it can be seen that the impact of building density on heat health risk is generally more significant in unbuilt areas, which is manifested by the fact that the areas with higher regression coefficients (where the impact of building density is higher) are concentrated in the southeast and north of Shenzhen, especially in parts of Dapeng New District and Longhua District, indicating that the impact of building density on heat health risk in these areas is very significant. In contrast, the regression coefficients are lower for built-up areas such as Nanshan District, Bao'an District, Futian District, and Luohu District. These areas were developed and

built relatively quickly at an early stage, and the building density has already reached a very high level. Urban construction has a relatively small impact on increasing heat health risks.

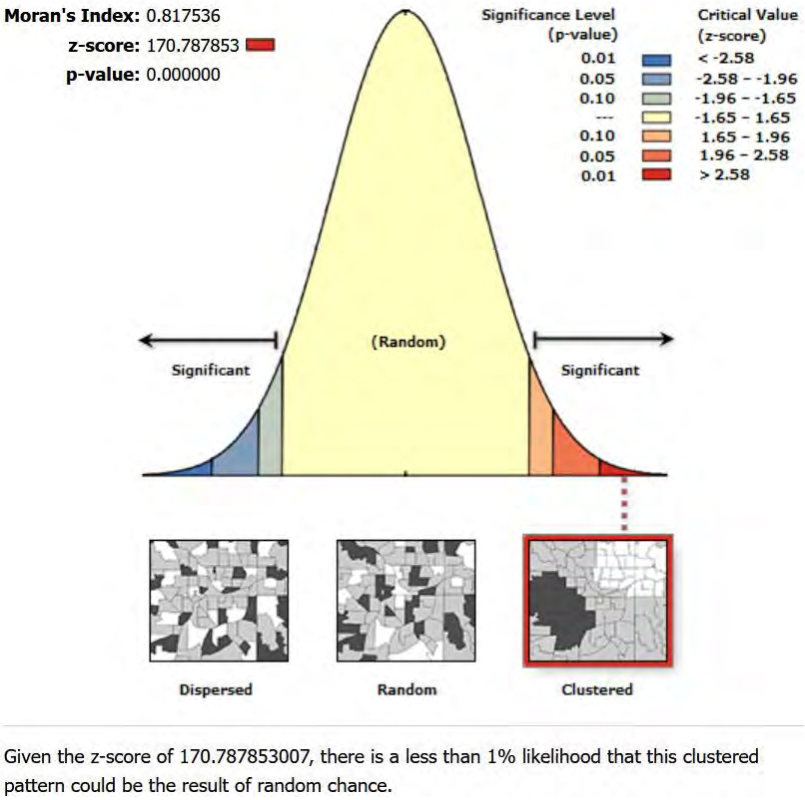


Figure 4. Moran's Index test result.

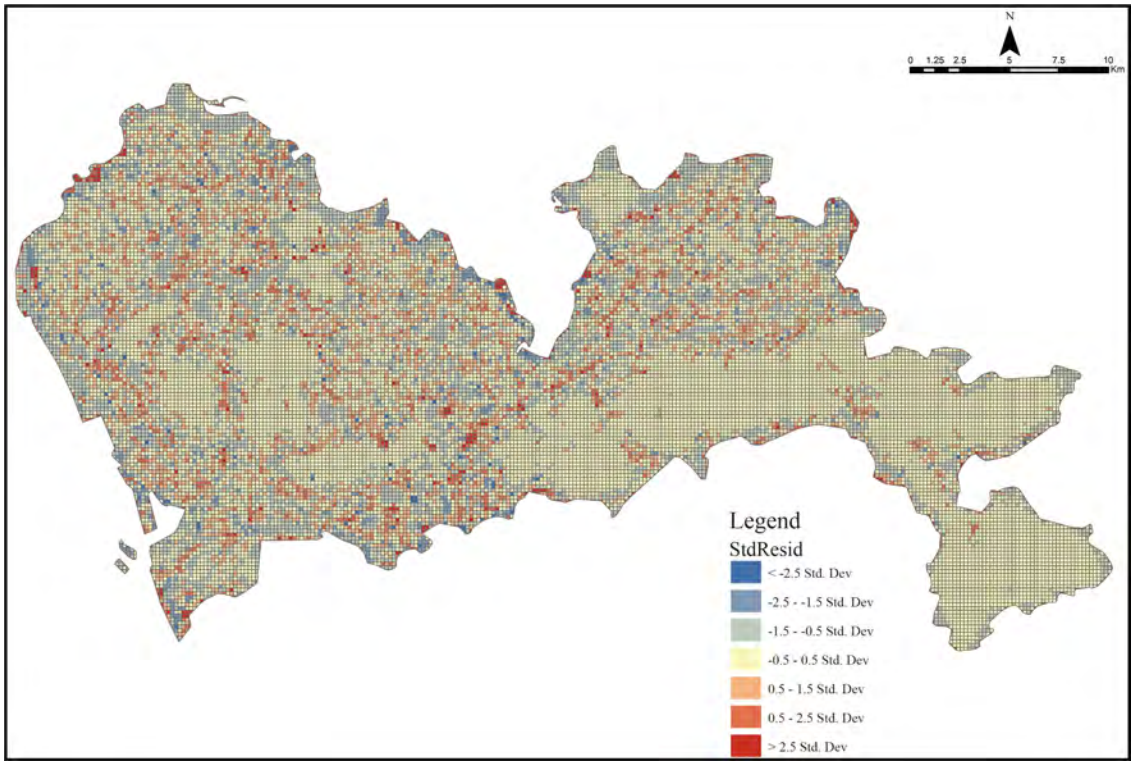


Figure 5. GWR Analysis Std. Residual Visualisation Results of Shenzhen.

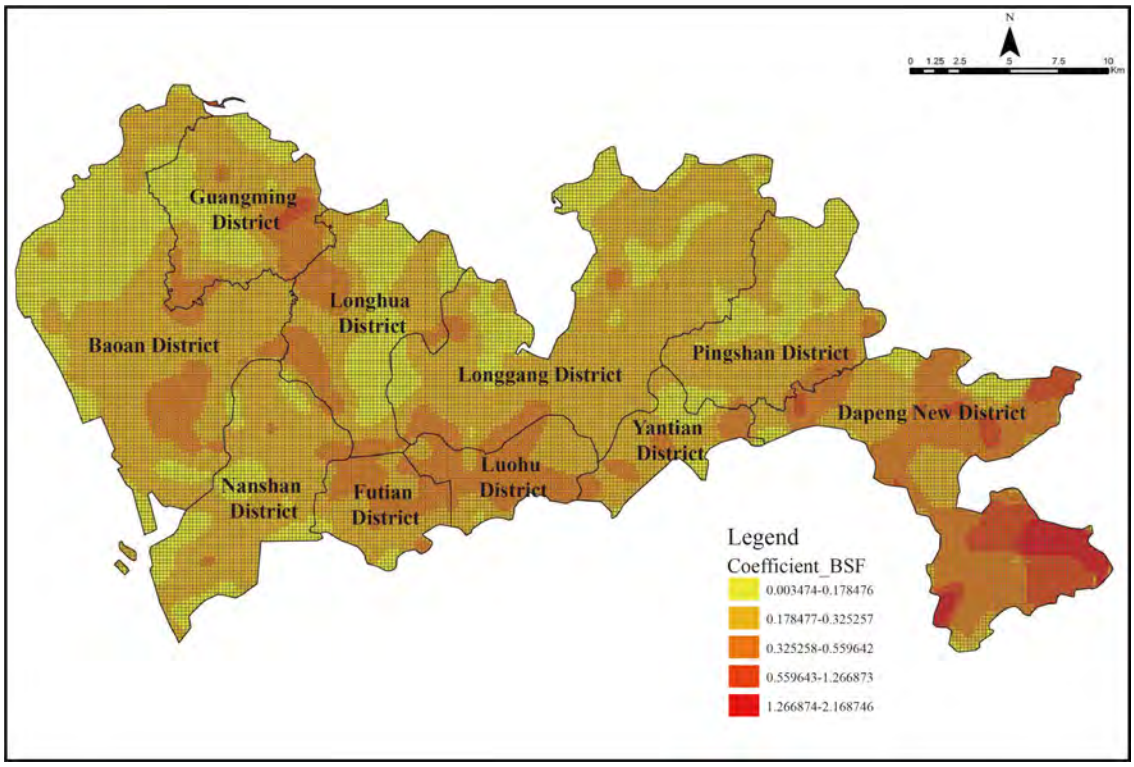


Figure 6. The results of the building density regression coefficient grid

5. Strategy

5.1. Planning stage

There is still a large amount of undeveloped land in outlying urban areas such as Shenzhen's Yantian and Dapeng New Districts. Therefore, during the planning phase, urban planning regulations must be established or amended, and urban master plans, along with detailed plans, should be implemented to accurately define functional zoning and impose restrictions on building density in each area, thereby preventing excessive construction that could intensify heat-related health risks. Promoting a polycentric and multi-level urban layout is essential to avoid single-center, high-density growth and mitigate the strain on the thermal environment. Mitigating heat health concerns in urban environments can be achieved by the strategic design and development of low-density residential zones or satellite cities to encourage people to relocate to these regions.

5.2. Urban construction stage

During urban construction, developers should use highly reflective building materials, solar energy, and green vegetation to cover buildings in Dapeng New District and other uncompleted areas of Shenzhen, increase tree canopies and water bodies, improve blue-green space integrity and connectivity, increase road surface permeability, and reduce high-density low-rise residential areas and open low-lying grasslands. Minimize converting blue-green places, including forests, grasslands, arable land, and water bodies, to construction land to reduce deterioration.

5.3. Urban renewal stage

By the end of 2022, urban villages in Shenzhen will account for more than 40% of the city's total building volume, and the actual resident population will account for about 60% of the city's actual population (China Development Institute (Shenzhen), 2023). During the urban renewal stage, old communities are renovated, and self-built illegal structures are demolished to reduce building density while increasing public space, green areas, water bodies, and infrastructure. In low-density neighborhoods, the demolished building areas can be converted into lawns, community parks, etc., while in high-density neighborhoods, corner plots and vacant lots can be used to create pocket parks and increase the area of blue and green space in the neighborhood.

6. Conclusion

This study constructs Crichton's risk triangle model, integrates multi-source data such as remote sensing image data, selects nine indicators to assess heat health risk in Shenzhen, and uses geographically weighted regression model to explore the effect of building density on heat health risk. It was found that there is significant spatial autocorrelation in heat health risk, and that building density has a significant positive effect on heat health risk. This study further investigates heat health risk mitigation strategies from the perspective of urban planning, providing a foundation and recommendations for Shenzhen to implement heat environment optimization initiatives. Nonetheless, certain limitations persist in the current research. The analysis is confined to the overall status of heat health risks in Shenzhen for 2021; future studies could incorporate data from additional years to examine the spatio-temporal evolution characteristics of these risks. With rapid urban expansion, the influence of heat health risks is progressively extending beyond individual cities into urban agglomerations. Consequently, exploring heat health risk within urban agglomerations represents a critical area for future inquiry, particularly regarding the Guangdong-Hong Kong-Macao Greater Bay Area.

7. References

Anderson, G.B. and Bell, M.L. (2011) 'Heat waves in the United States: Mortality risk during heat waves and effect modification by heat wave characteristics in 43 U.S. communities', *Environmental Health Perspectives*, 119(2), pp. 210–218. [online]. Available at: https://doi.org/10.1289/ehp.1002313 (Accessed: 15 August 2024)

Buscail, C., Upegui, E. and Viel, J.-F. (2012) 'Mapping heatwave health risk at the community level for public health action', *International Journal of Health Geographics*, 11(1) [online]. Available at: https://doi.org/10.1186/1476-072x-11-38 (Accessed: 15 August 2024)

Che, Y., Li, X., Liu, X., Wang, Y., Liao, W., Zheng, X., ... and Dai, Y. (2024) '3D-GloBFP: the first global three-dimensional building footprint dataset', *Earth System Science Data Discussions*, 2024, pp. 1–28 [online]. Available at: https://doi.org/10.5194/essd-2024-217. (Accessed: 15 August 2024)

Chen, Q., Chen, Q., Chen, Y., et al. (2021) 'The influence of sky view factor on daytime and nighttime urban land surface temperature in different spatial-temporal scales: A case study of Beijing', *Remote Sensing*, 13(20), pp. 4117–4117. [online]. Available at: https://doi.org/10.3390/rs13204117 (Accessed: 15 August 2024)

Chen, Z., Yu, B., Yang, C., Zhou, Y., Yao, S., Qian, X., Wang, C., Wu, B. and Wu, J. (2021). An extended time series (2000–2018) of global NPP-VIIRS-like nighttime light data from a cross-sensor calibration.

Earth System Science Data, 13(3), pp.889–906. [online]. Available at: https://doi.org/10.5194/essd-13-889-2021 (Accessed: 15 August 2024)

Dong, W., Liu, Z., Liao, H., Tang, Q., and Li, X. (2014) 'Assessing heat health risk for sustainability in Beijing's urban heat island', *Sustainability*, 6(10), pp. 7334–7357. [online]. Available at: https://doi.org/10.3390/su6107334 (Accessed: 15 August 2024)

Field, B.C., Barros, R.V., Dokken, J.D., et al. (2014) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Cambridge: Cambridge University Press [online]. Available at: https://doi.org/10.1017/CBO9781107415379 (Accessed: 24 August 2024)

Fotheringham, A.S., Charlton, M.E. and Brunsdon, C. (1998) 'Geographically weighted regression: A natural evolution of the expansion method for spatial data analysis', *Environment and Planning A: Economy and Space*, 30(11), pp. 1905–1927. Available at: https://doi.org/10.1068/a301905 (Accessed: 15 August 2024)

Gong, P., Liu, H., Zhang, M., et al. (2020) 'Annual maps of global artificial impervious area (GAIA) between 1985 and 2018', *Remote Sensing of Environment*, 236, p. 111510. [online]. Available at: https://doi.org/10.1016/j.rse.2019.111510 (Accessed: 15 August 2024)

Guo, A., Zhang, Y., Zhu, L., et al. (2020) 'Impact of urban morphology and landscape characteristics on spatiotemporal heterogeneity of land surface temperature', Sustainable Cities and Society, 63, pp. 102443–102443. [online]. Available at: https://doi.org/10.1016/j.scs.2020.102443 (Accessed: 15 August 2024)

Hien, W.N., Jusuf, S.K., Samsudin, R. and Jiang, S.W. (2019) 'Modeling the impact of urban planning on climate in high-density cities: A case study of the Singapore CBD', *Urban Planning Journal*, (04), p. 124.

Hu, K., Zhang, Y., Xu, Z., Li, B., and Jin, L. (2017) 'Spatially explicit mapping of heat health risk utilizing environmental and socioeconomic data', *Environmental Science & Technology*, 51(3), pp. 1498–1507. [online]. Available at: https://doi.org/10.1021/acs.est.6b04355 (Accessed: 15 August 2024)

Intergovernmental Panel on Climate Change (2021) *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Johnson, D.P., Stanforth, A., Lulla, V. and Luber, G. (2012). Developing an applied extreme heat vulnerability index utilizing socioeconomic and environmental data. *Applied Geography*, 35(1-2), pp.23–31. [online]. Available at: https://doi.org/10.1016/j.apgeog.2012.04.006 (Accessed: 15 August 2024)

Li, C., Zhao, J. and Xu, Y. (2017) 'Examining spatiotemporally varying effects of urban expansion and the underlying driving factors', *Sustainable Cities and Society*, 28, pp. 307–320. [online] Available at: https://doi.org/10.1016/j.scs.2016.10.005 (Accessed: 15 August 2024)

Lin, P., Li, X., Yuan, X., Liu, Q. and Li, Z. (2017) 'Effects of urban planning indicators on urban heat island: a case study of pocket parks in high-rise high-density environment', *Landscape and Urban Planning*, 168, pp. 48–60. [online]. Available at: https://doi.org/10.1016/j.landurbplan.2017.09.024 (Accessed: 15 August 2024)

Liu, J., Chen, T., & Wang, L. (2022) 'Identification, assessment, and urban design interventions for heat health risks in high-density cities from a climate change perspective: A case study of Macau', *Urban*

Planning International, pp. 1-14. [online]. Available at: https://doi.org/10.19830/j.upi.2022.135 (Accessed: 15 August 2024)

Liu, H., He, Y., Tang, J., et al. (2019) 'Seasonal variation of the spatially non-stationary association between land surface temperature and urban landscape', Remote Sensing, 11(9), pp. 1016–1016. [online]. Available at: https://doi.org/10.3390/rs11091016 (Accessed: 15 August 2024)

Liu, Y., Wu, K., Li, X., et al. (2021) 'Complexity of the relationship between 2D/3D urban morphology and the land surface temperature: a multiscale perspective', Environmental Science and Pollution Research, 28(47), pp. 66804–66818. [online]. Available at: https://doi.org/10.1007/s11356-021-15177-7 (Accessed: 15 August 2024)

Lu, B., Ge, Y., Qin, K., et al. (2020) 'A review of geographically weighted regression analysis techniques', *Journal of Wuhan University (Information Science Edition)*, 45(09), pp. 1356–1366. [online]. Available at: 10.13203/j.whugis20190346.(Accessed: 15 August 2024)

Lu, Y., Chen, Y., Liu, S., and Xu, Q. (2021) 'Investigating the spatiotemporal non-stationary relationships between urban spatial form and land surface temperature: A case study of Wuhan, China', *Sustainable Cities and Society*, 72, pp. 103070–103070. [online]. Available at: https://doi.org/10.1016/j.scs.2021.103070 (Accessed: 15 August 2024)

Moran, P.A.P. (1948) 'The interpretation of statistical maps', *Journal of the Royal Statistical Society Series B: Statistical Methodology*, 10(2), pp. 243–251. [online]. Available at: https://doi.org/10.1111/j.2517-6161.1948.tb00012.x (Accessed: 15 August 2024)

Moran, P.A.P. (1950) 'Notes on continuous stochastic phenomena', *Biometrika*, 37(1–2), pp. 17–23. [online]. Available at: https://doi.org/10.1093/biomet/37.1-2.17 (Accessed: 15 August 2024)

Nieves, J.J., Sorichetta, A., Linard, C., Bondarenko, M., Steele, J.E., Stevens, F.R., Gaughan, A.E., Carioli, A., Clarke, D.J., Esch, T., and Tatem, A.J. (2020) 'Annually modelling built-settlements between remotely-sensed observations using relative changes in subnational populations and lights at night', *Computers, Environment and Urban Systems*, 80, p. 101444. Available at: https://doi.org/10.1016/j.compenvurbsys.2019.101444 (Accessed: 15 August 2024)

Nieves, J.J., Bondarenko, M., Sorichetta, A., Steele, J.E., Kerr, D., Carioli, A., Stevens, F.R., Gaughan, A.E., and Tatem, A.J. (2020) 'Predicting near-future built-settlement expansion using relative changes in small area populations', *Remote Sensing*, 12, p. 1545. Available at: https://doi.org/10.3390/rs12101545 (Accessed: 15 August 2024)

Pezzulo, C., Hornby, G., Sorichetta, A., et al. (2017) 'Sub-national mapping of population pyramids and dependency ratios in Africa and Asia', *Scientific Data*, 4, p. 170089. [online]. Available at: https://doi.org/10.1038/sdata.2017.89 (Accessed: 15 August 2024)

Sun, Z. (2020) 'Impact of morphological elements in high-density urban areas on thermal environment: A case study of the area within the Fifth Ring Road in Beijing', *Journal of Ecology and Environment*, (10), pp. 2020–2027. [online]. Available at: https://doi.org/10.16258/j.cnki.1674-5906.2020.10.012 (Accessed: 15 August 2024)

Wang, M., Liang, S., Zeng, Y., Li, X., Yu, L., and Cheng, J. (2019) 'A practical single-channel algorithm for land surface temperature retrieval: Application to Landsat series data', *Journal of Geophysical Research: Atmospheres*, 124(1), pp. 299–316. [online]. Available at: https://doi.org/10.1029/2018jd029330 (Accessed: 15 August 2024)

WorldPop (2018) *Global High Resolution Population Denominators Project - Funded by The Bill and Melinda Gates Foundation (OPP1134076)*. School of Geography and Environmental Science, University of Southampton; Department of Geography and Geosciences, University of Louisville; Departement de Geographie, Universite de Namur, and Center for International Earth Science Information Network (CIESIN), Columbia University. Available at: https://dx.doi.org/10.5258/SOTON/WP00675 (Accessed: 15 August 2024)

WorldPop (2018) *Global High Resolution Population Denominators Project - Funded by The Bill and Melinda Gates Foundation (OPP1134076)*. School of Geography and Environmental Science, University of Southampton; Department of Geography and Geosciences, University of Louisville; Departement de Geographie, Universite de Namur, and Center for International Earth Science Information Network (CIESIN), Columbia University. Available at: https://dx.doi.org/10.5258/SOTON/WP00646 (Accessed: 15 August 2024)

Yuan, Q., Meng, J. and Leng, H. (2021) 'Urban spatial impacts and planning interventions of health risks from climate change', *Urban Planning*, 45(03), pp. 71–80. [online]. Available at: https://doi.org/10.11819/cpr20210309a (Accessed: 15 August 2024)

Zhao, L., Oleson, K., Bou-Zeid, E., Frolking, S., Krayenhoff, E.S., Bray, A., Zhu, Q., Gao, Z. and Liu, Y. (2021) 'Global multi-model projections of local urban climates', *Nature Climate Change* [Preprint]. [online]. Available at: https://doi.org/10.1038/s41558-020-00958-8 (Accessed: 15 August 2024)

Zhao, Y., Wang, N., Liu, Y., et al. (2021) 'Quantification of ecosystem services supply-demand and the impact of demographic change on cultural services in Shenzhen, China', *Journal of Environmental Management*, 304, pp. 114280–114280. [online]. Available at: https://doi.org/10.1016/j.jenvman.2021.114280 (Accessed: 15 August 2024)

Research Paper

Linking Ecosystem Service Supply and Demand to Resilience of Blue-green Space: A Conceptual Framework

Hong LENG, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Jiayi LUAN, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Qing YUAN, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

Blue-green space, with its natural barrier function in disaster prevention and risk avoidance, has become an important part of urban resilience research. Blue-green space resilience has therefore become an important support for the resilience of urban social-ecological systems. The evaluation of the comprehensive resilience of urban blue-green space is of great significance for improving the overall resilience of cities. Since ecosystem services and the comprehensive resilience of urban blue-green space are both key components of the resilience of urban social-ecological systems. Therefore, this study attempts to establish a correlation between ecosystem services and urban blue-green space resilience, integrate human society and blue-green space material systems through ecosystem services, and propose a PPD evaluation model based on the comprehensive resilience of blue-green space, revealing the two types of interference scenarios faced by the comprehensive resilience evaluation of urban blue-green space, namely "sudden natural disaster risk" and "chronic stress risk". Based on this, a comprehensive resilience evaluation framework for urban blue-green space is constructed through the logical method of "measuring the resilience level to cope with two types of interference-identifying blue-green space that is vulnerable to threats and imbalanced supply and demand-evaluating the comprehensive resilience of urban blue-green space", providing novel research ideas and practical theoretical guidance for the comprehensive resilience measurement of urban blue-green space.

Keywords

Blue-green spaces; Resilience; Ecosystem services; Supply-demand balance; Stress and pulse

1. Introduction

In the context of climate change, The frequent occurrence of extreme weather events reflects the inadequacy of urban emergency response capabilities. As a part of the urban system, blue green space have natural disaster prevention and also can improve the resilience of cities by providing ecosystem

services. However, in the existing research on enhancing urban resilience in blue-green spaces, only a single dimension of resilience has been considered (Wang and Wang, 2020), and insufficient consideration has been given to the chronic pressures and intervention measures generated by the human social system.

In this context, our study focuses on exploring the comprehensive resilience assessment method of urban blue-green space, clarifying the correlation between ecosystem services and urban blue-green space resilience, and proposing a comprehensive assessment system based on blue-green space.

2. Progress in research on urban blue-green space resilience assessment

Many researches have concentrated on the impact of blue-green space on human well-being and social justice (Andersson et al., 2019; Dobson, 2021), as well as the role of blue-green space in promoting urban climate resilience and disaster resilience (Lu, Sun and Steffen, 2023). Existing studies have problems such as a single perspective on the resilience of urban blue-green spaces, insufficient dimensions of resilience evaluation factors, and an imperfect resilience evaluation system.

Therefore, considering the multi-type interference brought to cities by climate change uncertainty, this study takes the various natural disaster threats faced by blue-green spaces and the progressive pressures exerted on them by human society as considerations for assessing their resilience, and defines its resilience assessment results as the comprehensive resilience of blue-green spaces.

3. Analysis of the relationship between ecosystem service supply-demand and blue-green space integrated resilience

3.1. Ecosystem services as a key component of urban social-ecological system resilience

Collins (Collins et al., 2011) and other scholars pointed out in 2011 that ecosystem services can connect natural ecosystems with human social systems. Urban socio-ecological system resilience aims to promote positive interactions between natural and social ecosystem. Ecosystem services refer to the terminal natural components generated by ecosystems that contribute to human well-being (Gao et al., 2024). The two are highly compatible at the level of connotation, components and goals (Figure 1), and the concept of urban socio-ecological system resilience is more complex and broader. Therefore, ecosystem services can be considered a key component of urban socio-ecological system resilience.

3.2. Interdependence between ecosystem services and blue-green space resilience

First, blue-green spatial resilience interacts with sustainable ecosystem provisioning. Blue-green spatial resilience determines the ability of cities to maintain their ecological functions under high environmental pressures, such as extreme climate events and anthropogenic interventions, and thus influences the provision and generation of ecosystem services.

Second, blue-green spatial resilience is one of the pathways to achieve ecosystem service goals. Blue-green spaces can not only mitigate environmental pollution and regulate flooding, but also provide positive support for urban residents by providing water resources for living, creating opportunities for water-friendly recreation, and providing aesthetic values (Thiele et al., 2020), and many studies have confirmed that blue-green spaces can enhance human health and well-being (Fisher et al., 2021).

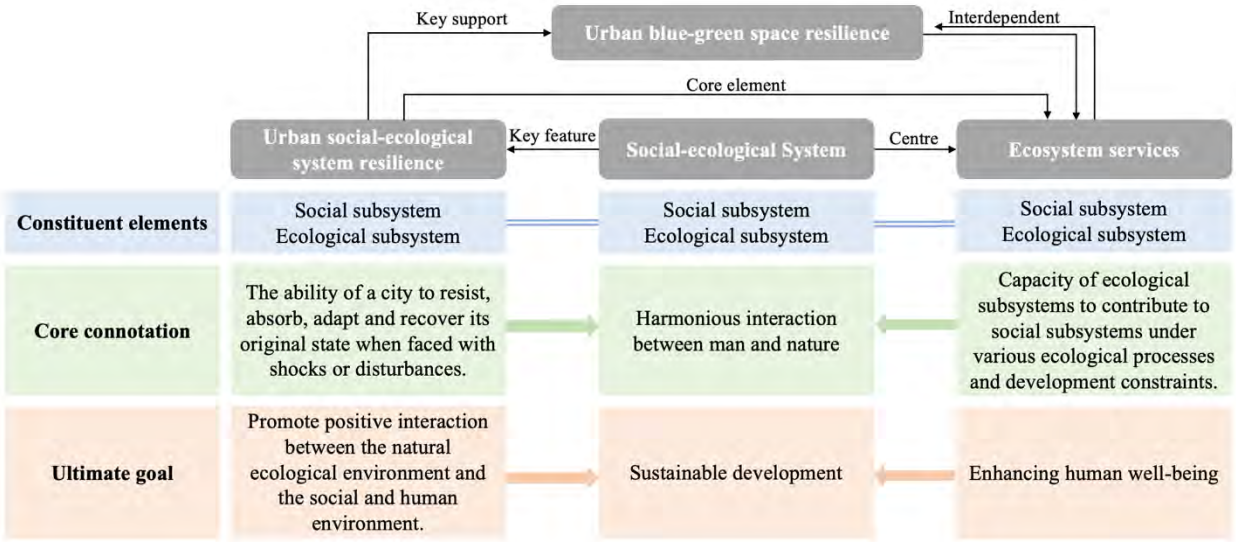


Figure 1. Correlation between ecosystem services and urban blue-green space resilience. Source: Authors.

4. Construction of urban blue-green space integrated resilience assessment system from the perspective of ecosystem service supply-demand balance

Based on the exploration of various types of risks faced by urban blue-green spaces, we constructed a theoretical framework for the comprehensive resilience assessment of urban blue-green spaces; defined indicators for assessing the comprehensive resilience of blue-green spaces; quantified each assessment indicator; and integrated the indicators to construct a comprehensive evaluation model.

4.1. Comprehensive resilience assessment framework for urban blue-green spaces from the perspective of ecosystem service supply-demand balance

Based on the resilience assessment framework of "resistance-adaptability-resilience", this paper incorporates the interaction between the social subsystem and the ecological subsystem into the influencing factors of resilience assessment, that is, through the supply and demand relationship of ecosystem services, to guide the comprehensive resilience assessment of urban blue-green spaces.When the various services provided by the ecological subsystem cannot meet the needs of the human social system, the city will face "slow-onset pressure" risk, and will also be affected by natural disturbances such as rainstorms, typhoons, floods, and fires brought about by climate change, that is, "sudden pulse" risk. Therefore, the urban blue-green space resilience mentioned in this paper is composed of "slow-onset pressure" risks and "sudden pulse" risks. Based on the Press-Pulse Dynamics Model (PPD) of social-ecological systems proposed by Collins (Collins et al., 2011), we further focuses on the comprehensive resilience of blue-green spaces, constructs a PPD assessment framework based on the comprehensive resilience of blue-green spaces, and integrates human society and blue-green space systems through ecosystem services, thereby providing novel research ideas and practical theoretical guidance for the comprehensive resilience assessment of urban blue-green spaces (Figure 2).

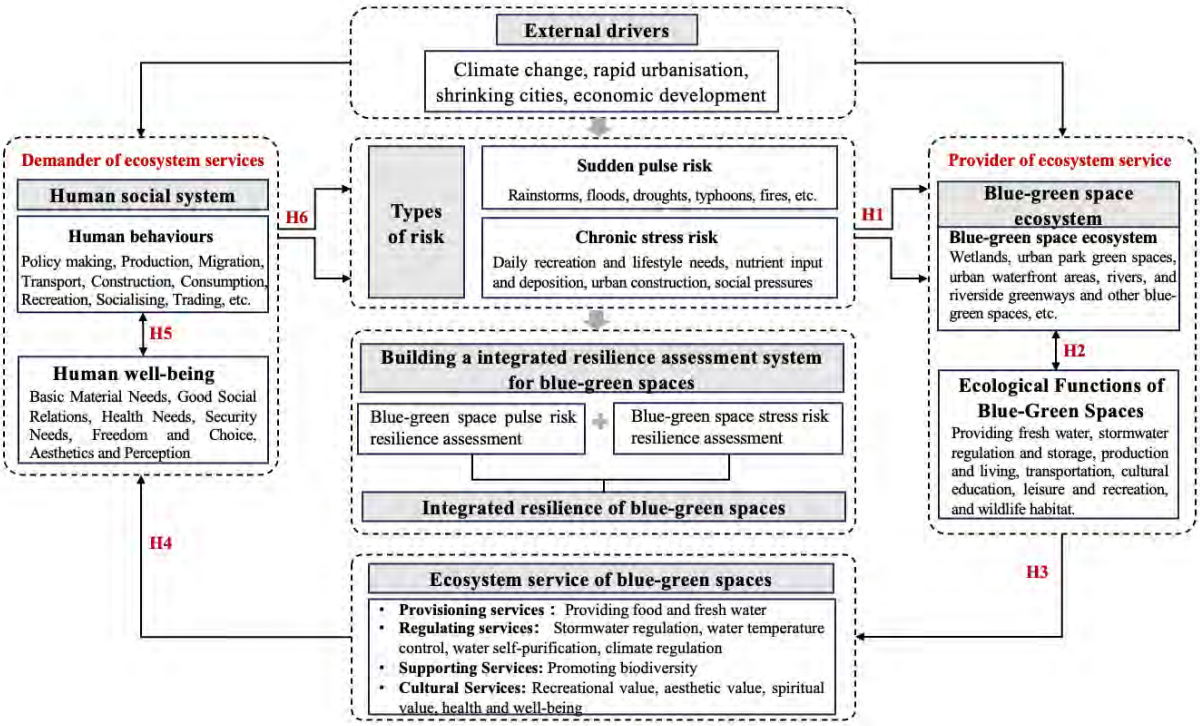


Figure 2. PPD model based on integrated blue-green space resilience. Source: Authors.

4.2. Indicator system of urban blue-green space integrated resilience assessment from the perspective of ecosystem service supply-demand balance

4.2.1 "Sudden pulse risk" resilience assessment indicator system

"Sudden natural shocks" refer to common natural disasters brought to cities by climate change. Combined with the risk avoidance functions of urban blue-green spaces, extreme high temperature weather, rainstorms and floods, and forest fires are selected to represent the common disasters faced by urban blue-green spaces. The three basic characteristics of resilience are matched one by one with the time sequence of disaster occurrence, namely resistance (before disaster), recovery (during disaster), and adaptability (after disaster). Urban blue-green space resilience assessment indicators are selected from three different time sequences, thereby we constructed an urban blue-green space resilience assessment indicator system coping with multiple disaster types and multiple time sequences (Table 1).

Table 1. Indicators for assessing the resilience of urban blue-green spaces to "sudden pulse risk". Source: Authors.

Disaster type	Disaster occurrence timing	Evaluation index	Relevance
Extreme heat weather resilience	Resistance (Pre-disaster)	Landscape pattern risk resistance index	+
	Recovery (During disaster)	Blue-green space area	+
		Blue-green space proportion	+
		Blue-green space mixing degree	+
		Vegetation coverage rate	+
		Arbor and shrub vegetation coverage	+
		Proportion of arbor to shrub	+
		Coverage of native tree species	+
		Water body coverage ratio	+
		Water body area	+

		Riparian vegetation buffer width	+
		Distance between green space and water body	-
		Water system morphology index	+
		Patch dominance	+
		Patch regularity	+
		Patch cohesion	+
Flood resilience	Resistance (Pre-disaster)	Percentage of green form types	+
		Number and richness of wind-resistant tree species	+
		Tree growth space	+
		Tree daily maintenance efforts	+
		Tree layout and form in narrow wind-through areas	+
	Recovery (During disaster)	Water system connectivity index	+
		Land runoff coefficient	+
		Permeable underlying surface ratio	+
		Rainwater storage facility completeness	+
		Water body shore type	+
		Vegetation index	+
	Adaptability (Post-disaster)	Vegetation coverage rate	+
		Proportion of water body area where aquatic plants are cultivated	+
		Riparian vegetation buffer width	+
Forest fires resilience	Resistance (Pre-disaster)	Proportion of fire-resistant tree species	+
		Width of compound firebreaks	+
		Plant diversity	+
		Degree of understory cover of flammable dead wood	-
	Adaptability (Post-disaster)	Proportion of fire-resistant and regenerative plants	+

When facing extreme high temperature weather, blue-green space can regulate urban microclimate and enhance urban biodiversity (Wang and Yang, 2023). The risk resistance index of blue-green space before disaster can reflect the ability of blue-green space to cope with extreme high temperature weather (Chen et al., 2022). Area, proportion and mixing degree of blue-green space all play a positive role in promoting the cooling capacity of blue-green space (Liao et al., 2021; Wang, Sheng and Wang, 2024; Zhou et al., 2023). High vegetation coverage can enhance the system's resistance to disturbances (Chen, Zhou and Chi, 2021). The carbon sink and transpiration effects of vegetation can effectively alleviate urban heat island effect (Chen et al., 1998). Trees and shrubs can also reduce the ambient temperature (Huang and Wang, 1998). In addition, native tree species have better adaptability and resilience to high temperature environments than introduced plants (Yang, Yang and Qiu, 2022). Water bodies can reduce temperature by changing surface radiation (Xiu, Wei and Wang, 2018). At the same time, vegetation in riverbank buffer zones can also reduce water temperature (Zeng, Huang and Xiao et al., 2010), and green spaces close to water bodies can improve thermal comfort (Huang et al., 2021). In addition, different patch combinations can affect the spread of local cooling sources (Wang, Sheng and Wang, 2024).

During typhoon and flood disasters, blue-green space plays a certain role. Before the disaster occurs, the complexity of the tree, shrub and grass layer structure has a positive effect on the wind protection effect (Wang, Shen and Wang et al., 2023). The damage to park green space caused by strong typhoons is caused by natural factors (Xiao and Feng, 2014) and human factors (Liu and Xu, 2020; Guo et al., 2020). In addition, high-rise dense buildings or canyon terrain aggravate the damage to green space caused by strong winds or typhoons (Liu et al., 2020). When a disaster occurs, a smooth and circulating water system can effectively improve the system's ability to recover from flood disturbances (Gao et al., 2020). The flood infiltration capacity of the underlying surface also has a certain impact on its resilience (Vijayraghavan et al., 2021). In addition, rainwater reuse systems can alleviate urban waterlogging (Wang and Palazzo, 2021). Ecological revetments of water bodies can buffer flood impacts (Qiao, Liao and Randrup, 2020), and improving vegetation index is the key to improving stormwater resilience (Li et al., 2023). The adaptability of blue-green space to stormwater resilience is mainly reflected in the purification

of water bodies after the disaster. Plants can purify water quality with their adsorption and barrier capabilities (Wang and Zhang, 2016). In addition, riparian vegetation buffer zones can effectively intercept and retain sediment. Additionally, the wider the riparian vegetation, the more obvious the decontamination effect (Zhou and Wang, 2014).

During forest fires, before a disaster occurs, the ratio of highly fire-resistant tree species and the width of the multi-layer fire-prevention forest belt can help enhance the blue-green space's resistance to fire risks. The coverage of flammable also impact its resistance. After a disaster occurs, fire-resistant and regenerative plants have strong post-disaster sprouting capabilities, which can improve the park's green space's ability to self-repair from fires (Yang, Yang and Qiu, 2022).

4.2.2 "Chronic stress risk" resilience assessment indicator system

1）Ecosystem service supply indicators for blue-green space

According to the classification of Millennium Ecosystem Assessment (MEA), the ecosystem services of urban park green spaces can be divided into four types: provisioning services, regulating services, supporting services, and cultural services (Xiao, et al. 2020). This study selected three categories of ecosystem services that are most relevant to human well-being, seven dimensions of provision, and 23 evaluation indicators (Table 2).

Table 2 Indicators of ecosystem service provisioning in urban blue-green spaces. Source: Authors.

Ecosystem service types	Supply dimension	Evaluation index	Relevance	Literature source
Regulation services	Flood management	Impervious pavement ratio	-	Shen, 2012
		NDVI	+	Wang and Wang, 2020
	Water quality purification	Proportion of cobblestone or muddy shores in bank porosity	+	Cong, 2009
		Proportion of concrete or other rigid shores in bank porosity	-	Cong, 2009
		Proportion of aquatic plants	+	Wu et al., 2001
		Width of riparian vegetation buffer strip	+	Zhou and Wang, 2014
		Percentage of pollutant input	-	Murrain, 1984
		Water surface coverage	+	Fang et al., 2021
		Percentage of ecologised bank slopes	+	Fang et al., 2021
	Microclimate regulation	Cold island effect		Wang and Wang, 2020
		Arbor coverage rate	+	Liu and Lin, 2015
		Plant space structure	+	Liu and Lin, 2015
Supporting Services	Biodiversity	Habitat richness	+	Zeng et al., 2020
	Habitat health	River meandering	+	Yu et al., 2021
		River connectivity	+	Fu et al., 2020
Cultural services	Provision of recreational opportunities	Number of recreational activity types	+	Xiao and Du, 2011
		Number of recreational space types	+	Tang et al., 2013
		Recreational site area	+	Xiao and Du, 2011
		Number of service facility types	+	Xiao and Du, 2011
		Richness of waterside facilities	+	Zhang and Yao, 2004
		Visibility of water features	+	Tang et al., 2013
		Richness of landscape furnishings	+	Zhang et al., 2015
	Historical and cultural heritage	Number of ancient and famous trees	+	Xiao and Du, 2011

2）Ecosystem service demand indicators for blue-green spaces

At present, researches have different understandings of ecosystem service demand. This paper understands it as "basic materials, good social relations, health needs, security needs, freedom and choice, aesthetics and perception required to achieve human well-being". This study draws on the research results of Wang Mangmang et al. and use demand quantity and quality to represent ecosystem service indicators(Table 3).

Table 3 Indicators of demand for ecosystem services in urban blue-green spaces. Source: Authors.

Ecosystem service demand types	Evaluation index	Literature source
Demand quantity	POI density	Wang and Wang, 2020
	Floor area ratio	Wang and Wang, 2020
	Population density	Zhai et al., 2019
	Construction land ratio	Zhai et al., 2019
Demand quality	Population density over 60	Wang and Wang, 2016
	Population density under 18	Wang and Wang, 2016
	Unemployed population density	Wang and Wang, 2020
	Non-local population density	Wang and Wang, 2020
	Recreational satisfaction	Wang and Wang, 2020

4.2.3 Urban blue-green space integrated resilience assessment index quantification and evaluation model

On the basis of building a resilience assessment index system, the index weights were determined and a comprehensive evaluation model was established. Through the three steps of "measuring the resilience level to two types of disturbances - identifying blue-green spaces that are vulnerable to threats and imbalanced supply and demand - evaluating the comprehensive resilience of urban blue-green spaces", the resilience assessment of urban blue-green spaces was achieved. The specific research framework is shown in Figure 3.

In the process of measuring the resilience of "sudden pulse risk", an urban blue-green space resilience assessment index system is constructed to cope with various types of disasters and consider the multi-temporal dynamics of "before-during-after-disaster", and the indicators are integrated through a comprehensive evaluation method. In the process of measuring the resilience of the risk of "chronic stress risk", the supply and demand relationship of ecosystem services is used to characterize its resilience level. Finally, the blue-green space that is vulnerable to disasters is superimposed on the blue-green space with unbalanced supply and demand, and the comprehensive resilience evaluation results of the blue-green space are obtained, which will guide the comprehensive resilience planning of the blue-green space.

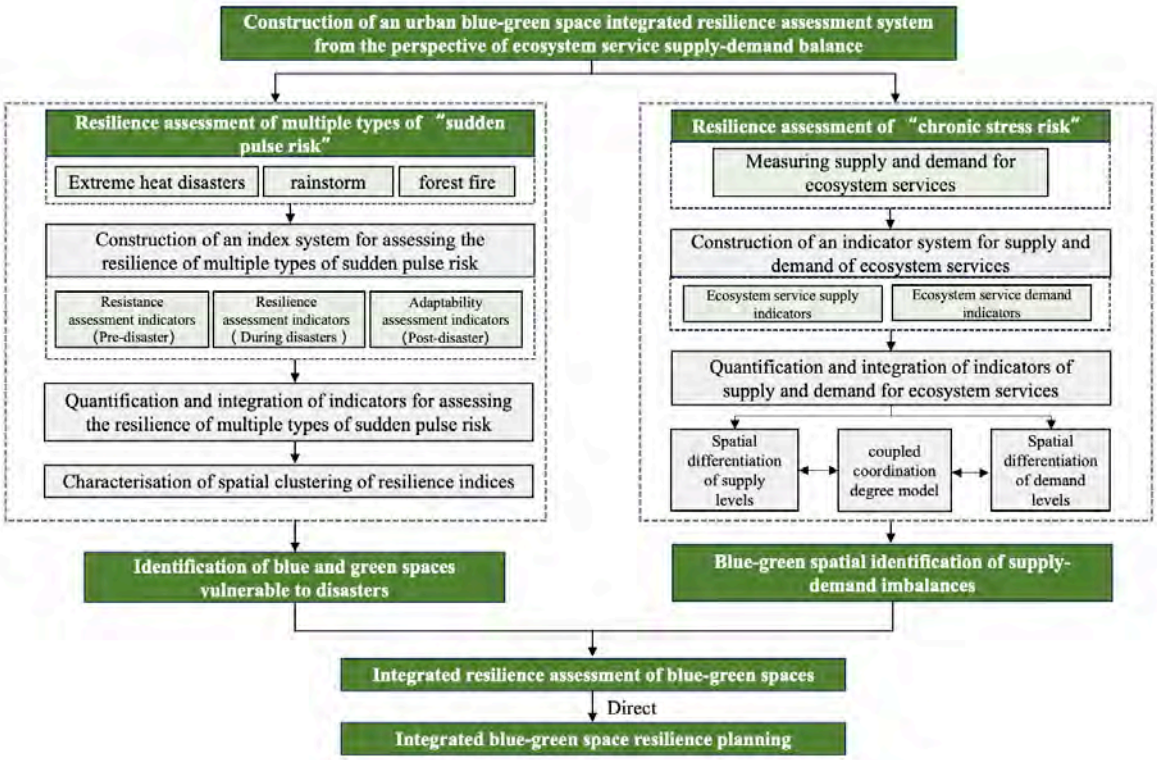


Figure 3. Urban blue-green space integrated resilience assessment model. Source: Authors.

5. Conclusion

This paper conducts a correlation analysis between "ecosystem service supply and demand relationship" and "blue-green space resilience", and constructs a conceptual framework for urban blue-green space resilience assessment from the perspective of ecosystem service supply and demand balance. In the future, we should further explore the factors and influencing mechanisms that affect the comprehensive blue-green spacial resilience, integrate the resilience planning into the multi-level spatial planning system, and use the comprehensive resilience assessment results of blue-green space to guide urban blue-green space resilience planning.

6. Funding

Research on the Coupling Coordination of Small Towns' Shrinkage and Resilience of Social-Ecological Systems and Differential Planning Response——Take Northeast China as An Example (No. 52278056)

7. References

Andersson, E., Langemeyer, J., Borgström, S., et al. (2019) 'Enabling green and blue infrastructure to improve contributions to human well-being and equity in urban systems', *Bioscience*, 69(7), pp. 566-574.

Fisher, J.C. et al. (2021) 'Perceived biodiversity, sound, naturalness and safety enhance the restorative quality and wellbeing benefits of green and blue space in a neotropical city', *The Science of the Total Environment*, 755(Pt 2), p. 143095.

Chen, J.J., Zhou, L. and Chi, Y.G. (2021) 'Research review on the spatial pattern and influencing mechanisms of land ecosystem stability', *Chinese Agricultural Meteorology*, 42(7), pp. 552-560.

Chen, Q.T., Yin, H.R., Li, Y.H., et al. (2022) 'Spatio-temporal differentiation of ecological risks in the Qinba Mountain area', *Soil and Water Conservation Bulletin*, 42(3), pp. 239-246.

Chen, Z.X., Su, X.H., Liu, S.Z., et al. (1998) 'Research on the ecological benefits of urban landscaping in Beijing (3)', *Chinese Garden*, (3), pp. 51-54.

Collins, S.L., Carpenter, S.R., Swinton, S.M., et al. (2011) 'An integrated conceptual framework for long-term social–ecological research', *Frontiers in Ecology and the Environment*, 9(6), pp. 351-357.

Cong, G.Y. (2009) 'Ecological revetment: An effective way to control urban water pollution', *Anhui Agricultural Bulletin (Half Monthly)*, 15(17), pp. 156, 177.

Dobson, J. (2021) 'Wellbeing and blue-green space in post-pandemic cities: Drivers, *debates and departures', Geography Compass*, 15(10), e12593.

Fang, X., Hu, G.L., Fan, Z.H., et al. (2021) 'Ecological health evaluation of Zhengzhou Dongfeng Canal based on AHP', *Journal of Henan Agricultural University*, 55(3), p. 7.

Fu, G.P., Zhao, L., Wu, J.F., et al. (2020) 'Evaluation and restoration strategies for ecological functions of rivers in urban built-up areas: A case study of the Dasha River in Shenzhen', *Journal of Shenzhen University (Science and Technology Edition)*, 37(4), pp. 372-380.

Gao, Y., Shen, Z. and Zhang, Z.H., et al. (2024) 'Research progress on the simulation of social-ecosystem coupling from the perspective of ecosystem services', *Geographical Journal*, 79(1), pp. 134-146.

Gao, Y.Q., Liu, Y.P., Yan, G.H., et al. (2020) 'Analysis of water system structure and connectivity changes in the Qinhuai River Basin', *Advances in Water Conservancy and Hydropower Science and Technology*, 40(5), pp. 32-39.

Guo, Z.Y., Ke, Y.Q., Li, H.Y., et al. (2020) 'Study on the causes of damage to landscape trees in Xiamen due to typhoon hazards', *Chinese Garden*, 36(1), pp. 122-127.

Huang, H.C., Ma, Y. and Yang, H.L., et al. (2021) 'Exploration of geographical design methods for ventilation corridors in megacities', *Planner*, 37(13), pp. 66-71.

Huang, X.L. and Wang, S.G. (1998) 'Research on the green value groups of urban living environments (3) — Quantitative research on the functions of urban green spaces at home and abroad', *Chinese Garden*, (3), pp. 55-57.

Jiang, L., Liu, S., and Liu, C. (2021) 'The Contributions of Blue-Green Infrastructure to Building Urban Climatic Resilience -Bibliometric Analysis Based on Co-citation Networks', *Landscape Architecture Frontiers*, 9(6), pp. 8-23.

Li, C.H., Zhu, P.H., Li, K.X., et al. (2023) 'Empirical study on the relationship between urban morphology and climate resilience: A case study of rain and flood events in Macau', *International Urban Planning*, 38(4), pp. 48-57.

Liao, W., Cai, Z. and Feng, Y., et al. (2021) 'A simple and easy method to quantify the cool island intensity of urban greenspace', *Urban Forestry & Urban Greening*, 62, 127173.

Liu, B.Y. and Lin, J. (2015) 'Study on the relationship between environmental microclimate and spatial profiles in urban waterfront zones: A case study of the Suzhou River in Shanghai', *Landscape Architecture*, (6), p. 9.

Liu, R.X. and Xu, X.X. (2020) 'Study on wind disaster damage and wind resistance of urban landscape trees after strong typhoons: A case study of the Shenzhen University Houhai Campus', *Chinese Garden*, 36(9), pp. 116-121.

Liu, X.Q., Liu, S.C. and Liu, H., et al. (2020) 'Study on the ventilation performance of traditional residential houses in northeastern Hubei', *Journal of Architecture*, (S1), pp. 33-37.

Lu, P., Sun, Y. and Steffen, N. (2023) 'Scenario-based performance assessment of green-grey-blue infrastructure for flood-resilient spatial solution: A case study of Pazhou, Guangzhou, Greater Bay Area', *Landscape and Urban Planning*, 238, 104804.

Mo, F., Xu, Y., Fu, Y.R., et al. (2022) 'Evolution of urban biodiversity conservation strategies in London from the perspective of blue-green space management (2002—2021)', *Landscape Architecture*, 29(4), pp. 101-106.

Mukherjee, M. and Takara, K. (2018) 'Urban green space as a countermeasure to increasing urban risk and the UGS-3CC resilience framework', *International Journal of Disaster Risk Reduction*, 28, pp. 854-861.

Murrain, P. (1984) 'The granite garden: Urban nature and human design', *Landscape Planning*, 11(3), pp. 265-267.

Kenny, G.P. et al. (2010) 'Heat stress in older individuals and patients with common chronic diseases', *CMAJ : Canadian Medical Association Journal*, 182(10), pp. 1053–1060.

Peng, J., Yang, Y. and Xie, P., et al. (2017) 'Construction zoning of green space ecological networks in Guangdong Province based on ecosystem service supply and demand', *Acta Ecologica Sinica*, 37(13), pp. 4562-4572.

Shao, Y. and Xu, J. (2015) 'Urban resilience: Concept analysis based on international literature review', *International Urban Planning*, 30(2), pp. 48-54.

Shen, J.K. and Wang, Y.C. (2017) 'Planning and design framework for urban communities based on resilience characteristics', *Landscape Architecture*, (3), pp. 98-106.

Shen, Q.J. (2012) 'Urban ecological environment: Principles, methods, and optimization', *Shanghai Urban Planning*, (5), p. 1.

Tang, Y.Q., Guo, J.K., Jin, S.J., et al. (2013) 'Research on the evaluation system for recreational quality of suburban parks', *Journal of Shanghai Jiao Tong University (Agricultural Science Edition)*, 31(5), pp. 79-88.

Thiele, J., Albert, C., Hermes, J., et al. (2020) 'Assessing and quantifying offered cultural ecosystem services of German river landscapes', *Ecosystem Services*, 42, 101080.

Vijayraghavan, K., Biswal, B.K., Adam, M.G., et al. (2021) 'Bioretention systems for stormwater management: Recent advances and future prospects', *Journal of Environmental Management*, 292, 112766.

Voskamp, I.M. and Van de Ven, F.H.M. (2015) 'Planning support system for climate adaptation: Composing effective sets of blue-green measures to reduce urban vulnerability to extreme weather events', *Building and Environment*, 83, pp. 159-167.

Wang, J.Q., Shen, T.Y., Wang, M., et al. (2023) 'Coupling design of blue-green space in urban waterfront areas to address rain and flood challenges', *Gardening*, 40(3), pp. 47-54.

Wang, M. and Wang, Q. (2016) 'Study on user perceptions of ecosystem services in urban parks based on the Q method: A case study of Huangxing Park in Shanghai', *Chinese Garden*, 32(12), pp. 97-102.

Wang, M.M. and Wang, Y.C. (2020) 'Construction of a resilience measurement system for urban parks' green space under the guidance of ecological intelligence', *China Gardens*, 36(6), pp. 23-27.

Wang, M.M., Sheng, S. and Wang, Y.C. (2024) 'Scenario simulation of the cooling effect of multidimensional collaborative urban blue-green spaces: A case study of downtown Shanghai', *Southern Architecture*, pp. 1-13.

Wang, S. and Palazzo, E. (2021) 'Sponge City and social equity: Impact assessment of urban stormwater management in Baicheng City, China', *Urban Climate*, 37, 100829.

Wang, W.W., Liang, S. and Yang, H.Z. (2023) 'Influencing factors and distribution characteristics of the cool island effect of urban riparian blue-green spaces: A case study of Wuhan, Nanjing, and Hangzhou', *Journal of Western Human Settlements*, 38(6), pp. 22-29.

Wang, W.W., Yang, S.Z. and Liu, L.J. (2023) 'Study on the spatio-temporal evolution and driving mechanisms of blue-green spaces and thermal environment in Hangzhou', *Urban Issues*, (11), pp. 35-45.

Wang, Z.X., Lü, Z.G. and Zhang, Q. (2016) 'Typical applications of supermagnetic separation technology in water environment', *China Water Supply and Drainage*, 32(12), pp. 34-37.

Wu, Z.B., Qiu, D.R., He, F., et al. (2001) 'Study on the water quality purification effect of aquatic plants on eutrophic waters', *Wuhan Botanical Research*, (4), pp. 299-303.

Xiao, J.S. and Feng, J.H. (2014) 'Study on the typhoon resistance of landscape trees in South China', *Chinese Garden*, 30(3), pp. 115-119.

Xiao, X. and Du, K. (2011) 'Study on the satisfaction of urban park visitors: A case study of Guangzhou', *Human Geography*, 26(1), pp. 129-133.

Xiu, C.L., Wei, Y. and Wang, Q. (2018) 'Urban resilience assessment of Dalian based on "scale-density-morphology"', *Geographical Journal*, 73(12), pp. 2315-2328.

Yang, W.Y., Yang, R.Y. and Qiu, Y.J. (2022) 'Research on the assessment indicator system of disaster prevention resilience in urban park green spaces in South China', *Chinese Garden*, 38(8), pp. 105-110.

Yang, W.Y., Yang, R.Y. and Qiu, Y.J. (2022) 'Research on the assessment indicator system for disaster prevention resilience of urban park green spaces in South China', *Chinese Garden*, 38(8), pp. 105-110.

Yu, Z.C., Zhao, J.Y., Wang, Q., et al. (2021) 'Quantitative study on the impact of urban river meandering on ecological environment', *China Rural Water and Hydropower*, (7), pp. 72-80, 86.

Zeng, L.X., Huang, Z.L., Xiao, W.F., et al. (2010) 'Functions of riparian vegetation buffer zones and their design and management', *Forest Science*, 46(2), pp. 128-133.

Zeng, P., Wang, Y.K., Liu, Y.Y., et al. (2020) 'Evaluation of urban river habitats in the Taihu Basin based on reach-scale assessment', *Chinese Journal of Applied Ecology*, 31(2), pp. 581-589.

Zhai, T.L., Wang, J. and Jin, Z.F., et al. (2019) 'Analysis of the changes and correlations in the supply-demand patterns of ecosystem services in the Yangtze River Economic Belt', *Acta Ecologica Sinica*, 39(15), pp. 5414-5424.

Zhang, C.Z. and Yao, Y.F. (2004) 'Research on waterfront landscape design and historical cultural representation: A case study of the Qinhuai River in Nanjing', *Chinese Garden*, (10), pp. 27-30.

Zhang, H., Huang, Z.F., Fang, Y.L., et al. (2015) 'Research on environmental education perception of tourists in wetland nature reserves: A case study of Yancheng National Nature Reserve for Red-crowned Cranes and Milu', *Acta Ecologica Sinica*, 35(23), pp. 7899-7911.

Zhou, S.S. and Wang, D.M. (2014) 'Research progress on the pollution reduction mechanisms and influencing factors of riparian buffer zones', *Chinese Soil and Water Conservation Science*, 12(5), pp. 114-120.

Zhou, W., Cao, W., Wu, T., et al. (2023) 'The win-win interaction between integrated blue and green space on urban cooling', *Science of The Total Environment*, 863, 160712.

Research Paper

Bird biodiversity Conservation on Older Urban Settlements Renewal

A Case Study of Yu'er Village, Shenzhen

Lulu CHEN, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Haoting TANG, School of Architecture and Design, Harbin Institute of Technology, China

Qing YUAN (Correspondence), School of Architecture and Design, Harbin Institute of Technology, Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China; hityuanqing@hit.edu.cn; Tel.:+86-135-0450-2966

Abstract

The complicated ecological challenges of high-density urban environments severely hinder the conservation of bird biodiversity in older urban settlements. The work presented in this study focuses on how to enhance and conserve bird biodiversity based on the ecological renewal of older settlements in densely populated metropolitan settings. This study employed field surveys, online data collection, literature reviews, case studies, and data analysis to evaluate urban renewal strategies for protecting bird biodiversity in old settlements on a community scale. First, the study identified the key bird distribution hotspots and habitat characteristics of birds in Yu'er Village. Next, the grid analysis method was utilized to select 10 research points within Yu'er Village to investigate spatial morphology and bird biodiversity. Then, the study explored the mechanisms by which spatial morphological indicators that can be adopted for the renewal of older urban settlements influence the conservation of local bird biodiversity through data analysis. The qualitative and quantitative results verified the correlation between spatial morphological features and bird biodiversity in older urban settlements. Moreover, from the perspective of bird survival needs, renewal measures such as creating a habitat chain system between high-density coastal urban areas and inland areas, creating rooftop gardens for birds and humans, and intervening in artificial water sources and habitats are beneficial for bird biodiversity conservation and enhancement.

Keywords

Bird biodiversity, Renewal, Yu'er Village, Old settlements, Rooftop gardens.

1. Introduction

The services of urban ecosystems are related to healthy living standards and social well-being(Ives, Giusti, Fischer, *et al.* 2017). Rapid urbanization has led to fragmentation of natural habitats and loss of habitats, resulting in a serious decline in urban biodiversity(McKinney 2006). Birds are important indicator species of urban biodiversity(Blair 1999; Gregory, Noble, Field, *et al.* 2003). The conservation and enhancement of bird diversity is an important part of the urban biodiversity conservation system, which is of great significance for maintaining the ecological safety and balance of the urban system and improving the urban habitat(Gan and Wu, 2018).

High-density construction in Shenzhen has led to a serious decline in urban biodiversity in urban areas, especially in old settlements(Ferreira, Walsh & Ferreira 2018). For example, the lack of consideration for natural space and urban biodiversity in the Fisherman's Village settlement in Shenzhen has led to ecological problems in the old settlements, which have had a negative impact on bird diversity(Su et al., 2023). The Circular on Urban Renewal Demonstration Work issued by the Ministry of Finance of the People's Republic of China proposes to “strongly support the renewal and reconstruction of old districts with the goal of eco-livability”, which provides policy support for the renewal of old districts and the implementation of avian biodiversity conservation, and ushers in a new opportunity for the ecological renewal of Shenzhen's old urban districts. Therefore, this study aims to investigate how to propose a mechanism for influencing bird diversity in high-density urban old settlements based on old settlement renewal actions, and to propose a renewal strategy for bird biodiversity conservation in old settlements.

Therefore, this study aims to investigate how to propose a mechanism for influencing bird biodiversity in high-density urban older settlements based on the renewal of older urban settlements, as well as a strategy for the renewal of older urban settlements aimed at bird biodiversity conservation.

This study selects Yu'er Village as the object of empirical research, analysing the characteristics and problems of the spatial form elements and bird biodiversity of Yu'er Village through field research. By combining methods such as literature review, field investigation, case study, and statistical data analysis, we systematically propose a renewal strategy for older urban settlements oriented toward the conservation of bird biodiversity, from the perspective of birds' survival needs. This strategy aims to integrate the conservation of bird biodiversity into spatial planning and renewal implementation to enhance and preserve bird biodiversity through the renovation of older urban settlements. The goal is to balance the relationship between human settlements and urban ecosystems, gradually forming an urban habitat network, and ultimately achieving the enhancement and conservation of bird biodiversity through the renewal and renovation actions of older urban settlements. We systematically propose a strategy for the renewal of older urban settlements to protect bird biodiversity from the perspective of birds' survival needs, aiming to integrate bird biodiversity protection into spatial planning and renewal implementation. This will enhance and protect bird biodiversity through the renewal and renovation of older settlements, balancing the relationship between human habitats and urban ecosystems, gradually forming urban habitat networks, and ultimately achieving the purpose of bird biodiversity protection and the construction of ecological settlements.

2. Literature review

Currently, most urban regeneration studies on bird biodiversity conservation focus on urban and regional scales(macro). At these scales, bird biodiversity conservation aims to strengthen the horizontal landscape connectivity(Tarabon, Calvet, Delbar, *et al.* 2020) of urban blue-green spaces through the establishment of nature reserves or ecological corridors(Hostetler, Allen & Meurk 2011; Soulé, Bolger, Alberts, *et al.* 1988). For example, greenway networks(Lopes et al., 2023) are constructed to connect ecologically relevant urban green areas, and potential ecological corridors are generated using the least-cost distance model to improve urban ecological networks(Cui et al., 2020). Some neighbourhood-scale bird biodiversity conservation studies have focused on the structure or characteristics of bird habitats at the meso-micro scale, such as urban green parks (Luo, Wu, Bai, *et al.* 2019; Pšeničková & Horák 2022), exploring the influence mechanisms(Puan et al., 2019) of different habitat characteristics on bird biodiversity. However, fewer studies have been conducted on settlements. For instance, Lu(2007)found that vegetation structures with good growth, an abundance of shrub and grass layers, and proximity to water sources are more suitable for bird survival(Lu et al., 2007). Nonetheless, few studies have

examined the micro-scale of older urban settlements to integrate bird biodiversity conservation with their renewal, based on the survival needs of birds.

The current research on the renewal of older urban settlements has significant limitations in terms of bird biodiversity conservation. Existing studies have focused on optimizing the horizontal connectivity of urban green infrastructure, such as ecological corridors and ecological network systems, while the construction of small-scale vertical ecological zones, such as three-dimensional greening and green building façades, has received insufficient attention, and systematic studies are lacking (Salisbury et al., 2023). Additionally, in modern urban environments, particularly in easily recognizable green spaces like urban green areas, certain bird species show significant urbanization adaptations. However, direct design studies on urban bird habitats are still scarce. Urban environments offer a diverse range of potential habitats, including man-made environments such as rooftops and building façades, as well as more natural environments like urban wastelands. Yet, the effective utilization of these environments to create artificial habitats supporting avian biodiversity has not been fully explored. In current research on renewal strategies for older urban settlements, the integration of ecological landscapes and urban construction management is often used as the entry point, with human needs as the main research perspective. However, there is a lack of planning from a biological perspective (Douglas and Evans, 2022), an overemphasis on management, and insufficient public participation, leading to ineffective implementation in the end.

3. Methodology

3.1. Case selection

Yu'er Village (22°48’45’’E, 113°92’92’’N) is a neighbourhood in the geographic middle of Shekou Street, Nanshan District, Shenzhen City, Guangdong Province, and spans roughly 9 hectares. The residential area is bordered by Golden Century Road and Zhengwang Commercial City to the east, Dajinchuan Apartment and Old Street New Apartment shops to the west, Nanshui Pedestrian Street and Shekou to the north, and Wanghai Road to the south (Figure 1). It is 300 meters from the coastline port, 500 meters from Shekou Mountain, and just two kilometres from Shenzhen Bay's green recreational zone. The study area's eastern limit is near Shekou Square, a "stepping stone"(Saura, Bodin & Fortin 2014) in Shenzhen's bird migration corridor.

Yu'er Village is located in the Guangdong-Hong Kong-Macao Greater Bay Area (GBA), which is rich in bird resources and is considered the wintering ground and transit station for the global migratory route of migratory birds, "East Asia-Australia-West Asia". Due to its proximity to natural landscapes and ports, it may attract a broad range of birds to roost and stay, which is a natural geographical advantage for Shenzhen's bird biodiversity conservation.

The existing buildings in Yu'er Village were completed in 2007, totalling 64 buildings and relatively high-quality structures with a 17-year building age. However, the building density is high and varies in height, the distance between buildings is between 1-2 meters, there are many illegal buildings, and the illumination is inadequate. Above all, Yu'er Village embodies the characteristics of Shenzhen's older urban settlements and serves as a model for the renewal of other older urban settlements.

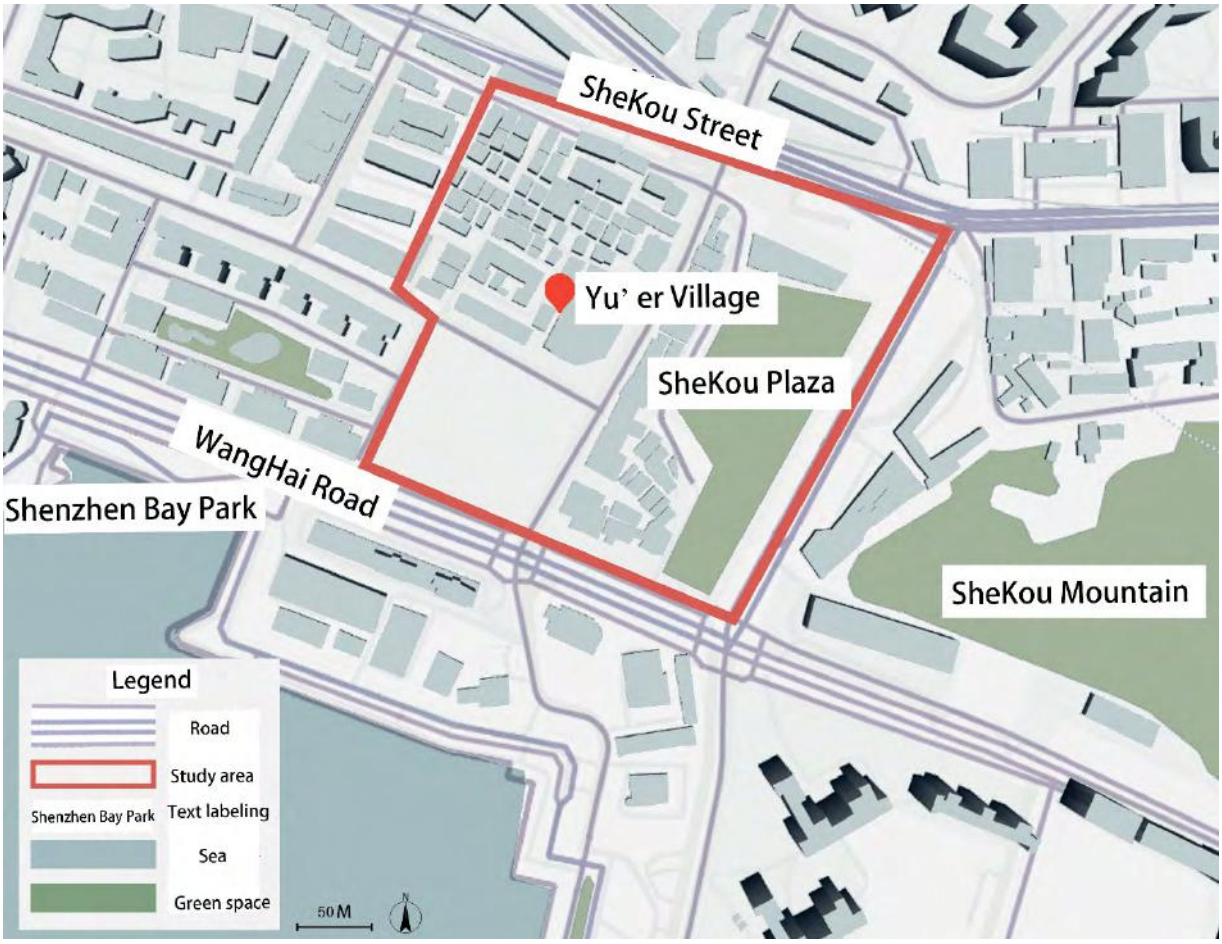


Figure 1. Study area. Source: Drawn by the author.

3.2. Research framework

Firstly, this study identifies the research scope and biodiversity indicators through a pre-survey. Utilizing a Baidu map and street photos, the study analyzed the spatial morphology and ecological situation of older settlements in Shenzhen and selected the Yu'er Village as the study area. It also evaluated the spatial morphology characteristics and problems of the Yu'er Village. It also conducted a qualitative analysis of the relevant literature and standards to determine that birds are indicative of urban biodiversity and the index of bird biodiversity measurement.

Secondly, the case study method is used to explore the existing cases of bird biodiversity conservation in the context of urban renewal of older settlements, focusing on the physical and spatial carriers and strategies of renewal, and summarizing the experience.

Again, the field research method was used to record the material space elements and collect data on bird biodiversity. Ten research sites in the Yu'er Village were selected to record the characteristics and current condition of the physical space in the Yu'er Village, cluster the physical space elements based on bird survival needs, and identify physical space carriers that can be used for renewal. The point count method was used to combine field observation and data collecting on bird biodiversity through video and audio capture.

Finally, taking the Yu'er Village as an example, we propose a strategy for the renewal of older settlements oriented to the conservation of bird biodiversity, based on the existing problems and characteristics of the village, the necessary conditions for bird survival (water, food, nesting sites, and living space), and the data and information gathered from the field research (Figure 2).

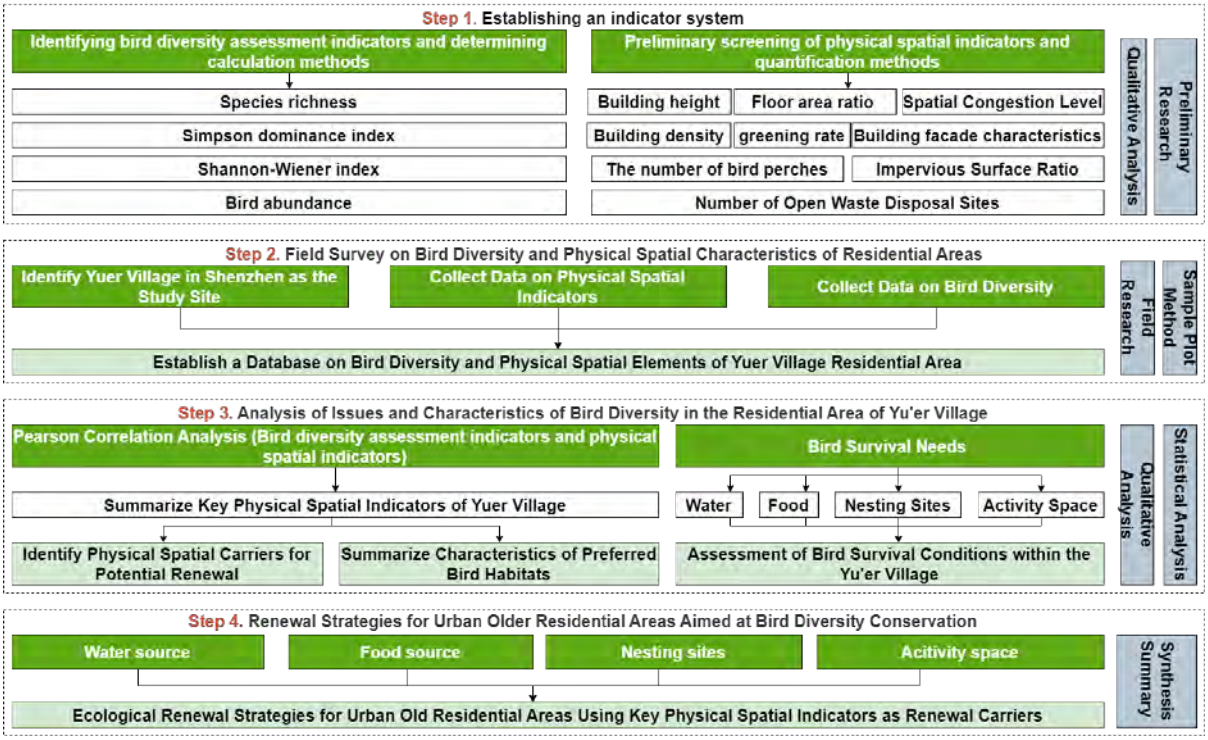


Figure 2. Research Framework. Source: Drawn by author.

3.3. Data collection

A Grid Sampling method was used to select 10 research points (FID) in Yu'er Village, and the land type and location of the research points were recorded (Table 1), with a 50-meter separation between them. The survey data and information were categorized, with bird observation records as the bird biodiversity survey data, and settlements environmental characteristics as plant environment elements, built environment elements, and other environmental aspects. Bird observation records include species names, numbers, and location descriptions of birds. Vegetation environmental elements include vegetation hierarchy, vertical greening percentage, greening management level, and vegetation species. Other environmental components were open trash cans, bird-stopping poles, and asphalt types.

The bird data survey was conducted from April 11, 2024 to April 17, 2024 from 6:00 a.m. to 9:00 a.m. (after sunrise) and from 16:00 p.m. to 19:00 p.m. (before sunset), for a total of six days of bird data survey. The weather during the six days was sunny or cloudy with no precipitation, the average temperature was between 22°C and 28°C, and the air quality was excellent, which was suitable for the bird diversity survey. During the survey, we traveled at a speed of 25 meters per minute and stayed at each site for 8-15 minutes, depending on the habitat of the site, to identify and record bird diversity data through 8x binocular observation, photography and video and audio recording.

Table 1. The land type and location information of Research points. Source: Author.

Research points	Land type	Location information
FID 1	(A) Construction land	Building 1 in the north of the residential area, mid-rise roof area. Close to the road, traffic and human interference.
FID 2	(A) Construction land	Roof of Building 42, mid-level roof area, north of the residential area.
FID 3	(A) Construction land	Building 24 in the northwest of the residential area, mid-level roof area, near the Dajinchuan apartment on the west.
FID 4	(B) Public land	The entrance of the building gathering area is open, the environment is open, but the flow of people is large and the interference is more.
FID 5	(B) Public land	In the middle of the residential area, the empty space between the buildings is surrounded by high-rise buildings, and the space is depressed.
FID 6	(C) Office land	Marina Building (abandoned) in the middle of the residential area, super high-rise roof area.
FID 7	(A) Construction land	Building 38 in the middle of the residential area, the roof area of low-rise buildings is surrounded by commercial shops, and human interference is greater.
FID 8	(D) Ecological land	Shekou Square has complex vegetation structure and good ecological environment.
FID 9	(A) Construction land	Commercial buildings in the south of the residential area, low-rise building roof area, surrounded by commercial shops, human interference is greater.
FID 10	(D) Ecological land	It is located in the entrance area of Shekou Square, with large human disturbance and good ecological environment.

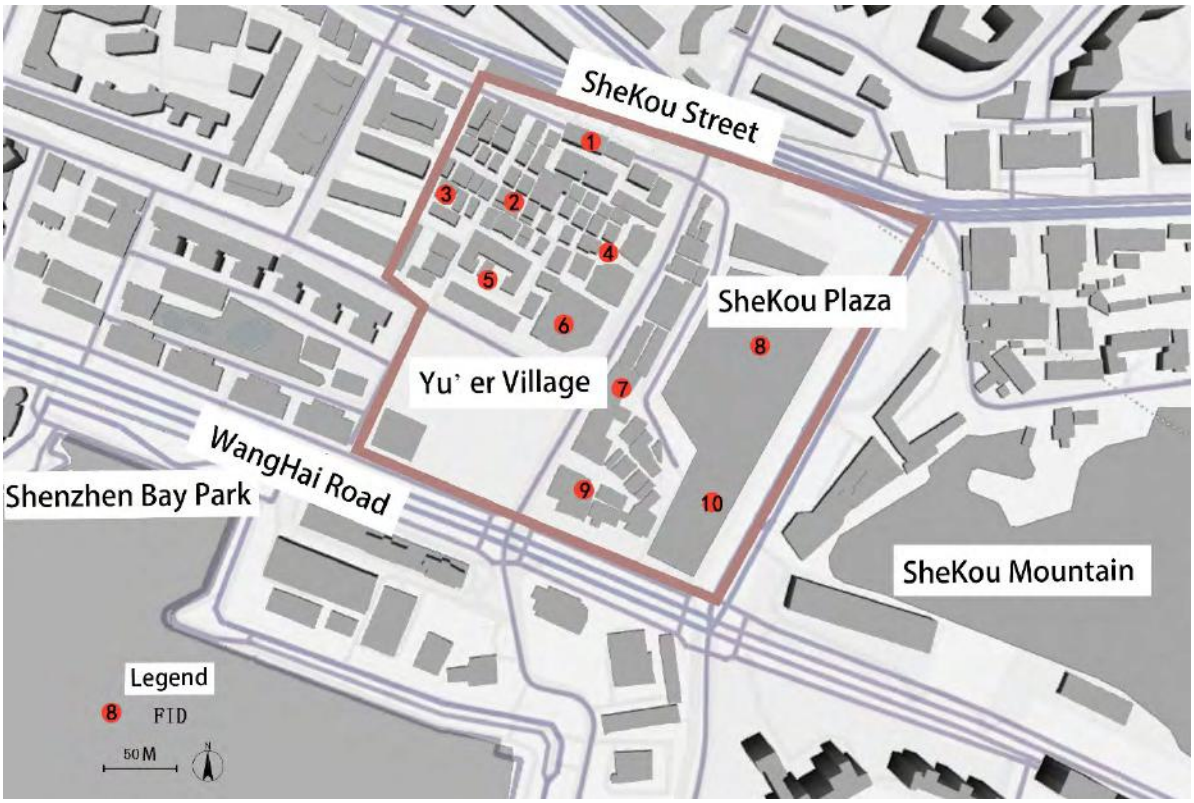


Figure 3. Research points location. Source: (Drawn by author).

3.4. Data analysis

By combining the field research data with the bird statistics of Shenzhen, the study conducted descriptive statistical analysis and Pearson correlation analysis on the environmental factors and bird richness and abundance in the Yu'er Village, and identified the key distribution hotspots and habitat characteristics of birds in the Yu'er Village. Based on non-linear regression analyses, the study summarizes the mechanisms by which spatial morphological indicators that can be adapted in the renewal of older urban settlements influence the conservation of local bird biodiversity. The results indicate that rational spatial planning, vegetation arrangement, and water source management, among other factors, have a significant impact on bird biodiversity.

4. Findings and discussions

4.1. Analysis of Bird Preferred Habitat Characterization Elements

Combining literature studies and field research, this study identified four types of habitat characterization elements in older urban settlements that have a greater impact on the conservation of bird biodiversity, including distance to a specific site, vegetation environment elements, green space characterization elements, anthropogenic disturbance elements, and built environment elements. Among them, the negative impacts of built environment elements and the positive impacts of vegetation environment elements were the most significant.

Bird diversity preferred ecological habitats have the following characteristics (Table 2): (1) proximity to water bodies and food sources; (2) large green space areas; (3) rich vegetation communities with complex structures; (4) semi-natural habitats with low management intensity; (5) low anthropogenic

interference and low noise; (6) aggregation of green space patches and strong connectivity; (7) low building density.

Table 2. Habitat characteristics of bird biodiversity. Source: Author.

Habitat characteristics		Correlation	bibliography
Distance to specific sites	water source	+: The closer you are to the water source, the richer the bird diversity is	(Xie et al., 2022; Zhuang et al., 2012)
	food source	+: Closer proximity to food sources increases bird diversity	(Ortega-Álvarez and MacGregor-Fors, 2009)
Vegetation environmental elements	flowering plant	+: The more flowering vegetation, the greater the diversity of birds	(Mbiba et al., 2021)
	vegetation structure	+: The more complex the vegetation structure (e.g., tree-shrub-grass), the greater the diversity of birds	(Han & Keeffe 2021)
	Plant species	+: Native tree species, the more nectar species, the greater the bird diversity	(Zorzal, Diniz, Oliveira, *et al.* 2021)
	vertical greening	+: The higher the percentage, the greater the diversity of birds	(Salisbury et al., 2023)
	planting density	+: The higher the planting density, the greater the diversity of birds	(陆, 唐, 史, *et al.* 2007)
Green Space Characterization Element	area	+: The larger the area, the greater the diversity of birds	(Zorzal et al., 2021)
	degree of separation	-: The higher the level of isolation, the more deprived the bird diversity is	(Janus & Lesinski 2018)
	heterogeneity	+: The higher the heterogeneity, the greater the diversity of birds	(Callaghan et al., 2019)
	degree of aggregation	+: The more aggregated the green space patches, the greater the bird diversity	(Soifer et al., 2021)
Elements of human interference	static (in a signal)	-: The more noise there is, the less bird diversity there is.	(Janus & Lesinski 2018)
	flow of people	-: The more people there are, the less bird diversity there is	(Bötsch, Tablado & Jenni 2017)

Elements of the built environment	Notches/holes	Notched holes can provide shelter for birds	(Janus & Lesinski 2018)
	plot ratio	-: The greater the plot ratio, the greater the lack of bird diversity	(Mbiba et al., 2021)
	distance between buildings	-: The greater the distance between buildings, the less bird diversity there is	(Mbiba et al., 2021)
	Open garbage spots	Human food scraps and other trash can provide food for birds	(Ortega-Álvarez and MacGregor-Fors, 2009)
Other environmental elements	bird holding pole	Staying poles can provide resting places for birds	(Schaub, Pradel, Jenni, *et al.* 2001)
	landscape light	Landscape lighting negatively affects nighttime rest of birds	(Wilson et al., 2021)
	impervious surface	The higher the cover of impervious surfaces (e.g., concrete), the more deprived the bird diversity is	(Souza et al., 2019)

Note: "+" indicates positive correlation and "-" indicates negative correlation.
Source: Organized by the authors based on research findings.

4.2. Status of Bird Survival Conditions in Yu'er Village

According to the literature and habitat characterization that affects the diversity of birds, the ecological needs of birds include sufficient water and food, suitable nesting sites, and a suitable environment for their survival. According to the results of the study, there are no conditions for birds to live and roost in the settlement of Yu'er Village.

In terms of water source, the fresh water resources near the coast mainly rely on the residents' domestic water, which is often accompanied by high intensity human interference, resulting in the lack of necessary water sources for birds to survive in the village and the distance from the water source.

In terms of food conditions, the vegetation cover in Yu'er Village is sparse, with street trees dominating the area, and from the results of the study, there are few flowers and fruit trees that rely on insects for pollination, which makes it difficult to attract insects, resulting in a lack of adequate food sources for birds in Yu'er Village. Research has shown that human leftovers can provide some food for urban birds, including food crumbs, bread crumbs and watermelon rinds in garbage. but this does not mean that all birds can benefit from it. This part of human leftovers alone is not enough to serve as the main food for birds.

In terms of nesting sites, the Yu'er Village settlement was not built with birds' nesting needs in mind, and therefore there are no natural nesting sites and conditions for birds. Spontaneous nesting activities were observed in a small number of street trees and building recesses and holes, but the number of birds was sparse. In addition, the nesting materials used by birds are dead branches and hay, etc. However,

urbanization has reduced the number of nesting sites and made it difficult to find nesting materials, which has a significant impact on the survival of the birds. At present, the Yu'er Village settlement has low vegetation cover, low greening rate, impermeable surface accounting for 80% of the total surface volume, and low ecological service function. A few residents practice rooftop farming on their own initiative, however, the main purpose is to grow vegetables and fruits, etc., and the number is scarce, most of the roofs are used for drying clothes or idling, and the unused space on the roofs can provide space for birds to roost. The research also found that the building facades of Yu'er Village settlements have a complex composition with elements such as concave and convex shape features, holes and window frames, pipes and eaves, which can be utilized to provide nesting space for birds.

From the perspective of suitable living environment for birds, the survival of birds also requires suitable temperature, air and enough living space. The climate of Shenzhen attracts a large number of migratory birds to spend the winter here, so the temperature and air conditions will not be discussed too much. In the city, birds are mainly active in the parts of buildings and structures below 16 meters (including building façades, sky gardens and passages, etc.), and more than 90% of the birds are active in the heights below six storeys, with the largest number of birds stopping at the fifth storey, which is the area and height where birds are mainly active. However, Yu'er Village has more than 5 storeys, with 8 storeys being the most common, and the overall lighting quality of the village is poor.

5. Conclusions

The renewal of older urban settlements for bird diversity conservation is a long-term and arduous systematic project, and the practice of bird diversity conservation can be effectively implemented through urban renewal, and the results of renewal can benefit both residents and birds. How to promote the harmonious coexistence of human habitat and bird habitat in the ecological regeneration of older urban settlements with high-density construction is an important direction for the development of ecological regeneration planning in Chinese cities nowadays. Starting from the survival needs of birds and taking Yu'er Village settlement as the empirical object, this study explores the habitat characteristics of bird diversity conservation at the scale of urban settlements through case study and data analysis, and proposes a renewal strategy for older urban settlements oriented to bird diversity conservation by combining the survival needs of birds with the current physical space status of Yu'er Village settlement. The study initially proposes corresponding renewal strategies, such as constructing 3D ecological corridors, enhancing the ecological connectivity between the coast and the inland, intervening in artificial water sources and artificial habitats, and providing food sources for birds. The results of the study can provide new ideas and references for urban renewal oriented to the conservation of bird diversity, which can further support the urban renewal strategy and the sustainable development of cities, and supplement the lack of biological perspectives in the ecological renewal of settlements in urban renewal studies.

Funding

This research was funded by National Natural Science Foundation of China, grant number 52308059 and 52278056; China Postdoctoral Science Foundation, grant number 2023M730861; Heilongjiang Provincial Natural Science Foundation of China, grant number LH2023E050; Heilongjiang Province Social Science Research Planning Foundation, grant number 22GLC275; and Heilongjiang Postdoctoral Found, grant number LBH–Z22158.

References

Blair, R.B., (1999) 'Birds and Butterflies Along an Urban Gradient: Surrogate Taxa for Assessing Biodiversity? ', *Ecological Applications,* 9(1), p164–170.

Bötsch, Y., Tablado, Z., Jenni, L., (2017) 'Experimental evidence of human recreational disturbance effects on bird-territory establishment', *Proceedings of the Royal Society B: Biological Sciences,* 284(1858) [online]. Available at:https://royalsocietypublishing.org/doi/full/10.1098/rspb.2017.0846 (Accessed:11 November 2024)

Ferreira, C.S.S., Walsh, R.P.D., Ferreira, A.J.D., (2018) 'Degradation in urban areas'. *Current Opinion in Environmental Science & Health*, *Sustainable soil management and land restoration*, 5, p19–25.

Gregory, R.D., Noble, D., Field, R., Marchant, J.H., Raven, M.J., Gibbons, D.W., (2003) 'Using birds as indicators of biodiversity'. *Ornis Hungarica*, 12, p11-24.

Han, Q., Keeffe, G., (2021) 'Promoting climate-driven forest migration through large-scale urban afforestation'. *Landscape and Urban Planning*, 212, 104124.

Hostetler, M., Allen, W., Meurk, C., (2011) 'Conserving urban biodiversity? Creating green infrastructure is only the first step'. *Landscape and Urban Planning*, 100, p369–371.

Ives, C.D., Giusti, M., Fischer, J., Abson, D.J., Klaniecki, K., Dorninger, C., Laudan, J., Barthel, S., Abernethy, P., Martín-López, B., Raymond, C.M., Kendal, D., von Wehrden, H., (2017) 'Human–nature connection: A multidisciplinary review'. *Current opinion in environmental sustainability,* 26, p106-113.

Janus, K., Lesinski, G., (2018) 'Birds and bats using buildings as a place of breeding or shelter'. *Annals of Warsaw University of Life Sciences-SGGW. Animal Science,* 57.

Luo, K., Wu, Z., Bai, H., Wang, Z., (2019) 'Bird diversity and waterbird habitat preferences in relation to wetland restoration at Dianchi Lake, south-west China'. *Avian Research,* 10, p1-12.

McKinney, M.L., (2006) 'Urbanization as a major cause of biotic homogenization'. *Biological Conservation,* 127(3), p247–260.

Pšeničková, T., Horák, J., (2022) 'Influence of forest landscape on birds associated with lowland water bodies'. *Forest Ecology and Management*, 513, p120199.

Saura, S., Bodin, Ö., Fortin, M.-J., (2014) 'EDITOR' S CHOICE: Stepping stones are crucial for species' long-distance dispersal and range expansion through habitat networks'. *Journal of Applied Ecology*, 51(1), p171–182.

Schaub, M., Pradel, R., Jenni, L., Lebreton, J.-D., (2001) 'Migrating birds stop over longer than usually thought: An improved capture–recapture analysis'. *Ecology*, 82(3), p852–859.

Soulé, M.E., Bolger, D.T., Alberts, A.C., Wrights, J., Sorice, M., Hill, S., (1988) 'Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands'. *Conservation Biology*, 2(1), 75–92.

Tarabon, S., Calvet, C., Delbar, V., Dutoit, T., Isselin-Nondedeu, F., (2020) 'Integrating a landscape connectivity approach into mitigation hierarchy planning by anticipating urban dynamics'. *Landscape and Urban Planning*, 202, 103871.

Xie, S., Marzluff, J.M., Su, Y., Wang, Y., Meng, N., Wu, T., Gong, C., Lu, F., Xian, C., Zhang, Y., Ouyang, Z., (2022) 'The role of urban waterbodies in maintaining bird species diversity within built area of Beijing'. *Science of The Total Environment*, 806, 150430.

Zorzal, R.R., Diniz, P., Oliveira, R.D., Duca, C., (2021) 'Drivers of avian diversity in urban greenspaces in the Atlantic Forest'. *Urban Forest &* Urban Greening, 59, 126908.

Gan J., Wu Z.Q., (2018) 'Review of urban biodiversity planning research and countermeasures'. *Planner*, 34(1), p87-91.

Zhuang Y.M., Kong F.H., Yin H.W, Zhang L.L., Sun Z.R., (2012) 'Research progress on the effects of urban green space pattern on bird community'. *Journal of Nanjing Forestry University (Natural Science Edition)*, 36(3), p131-136.

Su R.F., Chen R.S., Guo X.N., (2023) 'Biodiversity conservation strategies in urban community renewal: a case study of Habitat Garden in Changning District, Shanghai'. *Biodiversity,* 31(7), p194-207.

Lu Y.W., Tang S.X., Shi H.L., Ding Z.F., Bo S.Q., He X., (2007) 'Relationship between bird community characteristics and habitat in urban green space in Shanghai in winter'. *Journal of zoology*, (5), p125-130.

Research Paper

Research on high-density community renewal and design guidelines based on health promotion

a case study of Guangzhou, China

Zihao Wang, South China University of Technology, China

Chunyang Zhang, South China University of Technology, China

Abstract

With the growth of population and the acceleration of urbanization, the contradiction between the scarcity of land resources and the demand for extensive space is becoming increasingly acute. The high-density construction of many big cities not only uses land intensively and provides convenient infrastructure, but also causes a series of new public health problems. As population gathering areas in the city, the renewal of high-density communities often encounter the balance between environmental quality and economic benefits. In the context of market economy, it is necessary to promote the implementation of renewal with a higher floor area ratio and construction volume. Therefore, how to achieve sustainable urban density and balance the relationship between population growth and sustainable development has become a crucial issue to be solved. By comparing and discriminating the concept of density, this paper indicates the public health problems caused by high-density development, compares the built environment factors concerned in the current urban design guidelines in the world, and concludes the path of integrating the concept of health promotion into urban planning and design. Finally, the paper puts forward the renewal strategy of high-density community and the optimization strategy of design guidelines to provide reference for the construction of healthy community.

Keywords

High-density communities, Health promotion, Design guidelines, Urban renewal, Guangzhou

1. Introduction

With the transformation of China's urban construction from high-speed development to high-quality development, under the guidance of the "Healthy China" strategy, establishing a sustainable public health system has become an urgent task in the new era (Wang, 2016; Tian, 2016). As early as the 19th century, urban planning was associated with public health. One of the main reasons for the advent of modern urban planning was to address public health issues brought about by rapid industrialization and urbanization, such as environmental deterioration and air pollution (Shi, 2023; Ewing, 2015). Countries around the world have participated in the construction of healthy cities, and through the Global Health Promotion Conference to promote the concept, method and practice of healthy city development (Zhang, 2017; Wang, 2015). In the context of China's rapid urbanization, the characteristics of high population density and high building density often lead to urban problems such as traffic congestion, environmental pollution, housing shortage, and space congestion. Consequently, how to achieve a more healthy living environment through urban planning has become an urgent challenge.

Community is the basic unit of residents' life and urban governance, and the main spatial carrier for residents' daily life, social interaction and access to various services. Community environment has various influences on health behaviors and health outcomes. However, in terms of theoretical research, the complex relationship between built environment and public health has been studied a lot, but its connection with the planning system is not clear. And it is not clear what strategies can be used in planning to produce health benefits. In terms of practical exploration, traditional spatial planning tools are often difficult to implement public health requirements and solve complex environmental health problems. Therefore, based on the current situation of high-density urban development in China, this paper discusses how to integrate the concept of healthy livable into planning, design and community renewal, achieve the balance between sustainable urban development and population growth, and build a healthy livable community environment.

2. Built environment and public health

2.1. Public health problems

The World Health Organization (WHO) has clearly stated that individual health is affected by a combination of many factors, including genetics, residential environment, lifestyle, health services and so on. Human living environment refers to the space where human beings live together, including natural ecology, built environment, social environment and other elements. According to the United Nations report, by 2030, more than 60% of the world's population will live in cities, and the number of megacities with a population of more than 10 million will increase to 43, of which the number of Chinese cities will account for about one-fifth (HABITATUN, 2015). High-density and intensive construction methods can improve urban land use efficiency, which is in line with the basic situation that most cities in China have more people and less land, but too high scale and density will inevitably lead to negative external effects and "urban diseases" (Liu, 2024). The risk of chronic diseases such as obesity, cardiovascular disease and diabetes is increasing year by year, which has seriously threatened people's health (Xiao, 2016). A great deal of empirical research has shown that the increased threat of these chronic diseases is associated to modern urban lifestyles. One of the reasons for the rapid increase in these chronic diseases is people's lack of physical exercise, working too long at desks, and relying on motor vehicles to travel (Liu, 2016).

2.2 Sustainable urban density and high-density communities

The term "Density" is derived from the concept in physics, which refers to the measure of mass within a specific volume, computed by dividing mass by volume. In the field of urban planning, density is often used as a concept to describe the efficiency of resource allocation and Morphological characteristics in the spatial environment (Wu,2014; Li, 2020). Density can help people identify and control the physical environment in the city, and plays an important role in the process of urban development. In addition, the conceptual connotation of density is quite rich, which can be divided into Physical density and Perceived density. Physical density refers to the quantitative description of the concentration degree of people or buildings in a specific geographical unit, which is an objective, quantitative and neutral spatial index. Perceived density refers to an individual's perception and estimation of the number of people, space and layout of an area, and is the result of the interaction between an individual and the external spatial environment (Wu, 2014).

People's understanding of the relationship between density and urban development has gone through a long process. In the mid-19th century, William Farr, the founder of British medical statistics, analyzed the impact of the cholera epidemic in London between 1853 and 1854. He proposed that the spread of

infectious diseases is closely related to population density, and defined high population density in parts of cities as a public health problem. His research was the first to establish a connection between urban density and urban environmental quality (Tian, 2016). At the end of the 19th century, density began to appear in various urban planning concepts as a concept to describe the relationship between people and their living environment. For example, Howard's Garden City concept advocates a decentralized urban layout and pointed to the public health problems that could be caused by the extremely crowded workers' quarters in British industrial cities. He proposed that the population should be diluted horizontally to improve the quality of urban environment, and the optimal population density was 7500 people /km² (HOWARD, 1902). Le Corbusier's Radiant City concept advocates a centralized urban layout, breaking the linear relationship between population density and residential patterns. He proposed that the city should develop in a vertical direction, envisiving a central area with a population density of 80,000 people /km² (LE CORBUSIER, 1967). In the 1990s, governments and scholars of various countries put forward a series of high-density urban development models based on the realistic conditions of suburban sprawl, ecological environment destruction and economic benefit consideration. For example, new urbanism, smart growth, compact city and other development concepts provide new ideas for urban construction. In conclusion, it can be found that the discussion of sustainable density has always been the focus of the built environment and public health. This paper combs the evolution of the concept of density and urban development (Table 1).

Table 1. Density and Urban Development. Source: Self-painted.

Period	Proposer	Planning Concept	Population Density	Main Content and Significance
Mid-19th Century	William Farr	Density and Public Health	Disease spread and population density	Analyzed the impact of the cholera epidemic in London, proposing that the spread of infectious diseases is closely related to population density.
Late 19th Century	Ebenezer Howard	Garden City	7,500 people/km²	Population density and residential form have correspondence. Concentration implies crowding, decentralization implies livability.
1930s	Frank Lloyd Wright	Broadacre City	625people/km²	Emphasized individuality in urban settings, opposed to collectivism, expressing dissatisfaction with the modern urban environment, and reflecting the harmony between people and the environment before the Industrial Revolution.
1930s	Le Corbusier	Radiant City	Central area: 80,000 people/km²	High-density development in central areas using vertical expansion through tall buildings, breaking the linear relationship between population density and residential form.
1960s	Jane Jacobs	Urban Diversity	200 units/acre (173,000 people/km²)	The vitality and diversity necessary for a livable neighborhood are built on high density. Diversity is the main feature that distinguishes cities from other living environments.
1990s	Andrés Duany	New Urbanism	Eliminate suburban sprawl	Advocated for the creation and redevelopment of rich, diverse, walkable, compact, and mixed-use communities.

The conceptual connotation and defining standards of high-density communities have not yet been unified in academia (Zhang, 2017; Liu, 2024). This is mainly because high density is subjective and relative, and different backgrounds and regions, as well as individuals, can lead to varying definitions of high density. For example, In the UK, if there are fewer than 20 homes per hectare, it's considered low-density development. If there are 30 to 40 homes per hectare, it's medium-density. And if there are more than 60 homes per hectare, it's high-density. In the United States, 25-40 homes per hectare are considered low-density, 40-60 homes per hectare are medium-density, and more than 110 homes per hectare are high-density. In Israel, 20-40 homes per hectare are considered low-density, while more than 290 homes per hectare are high-density (Wu,2014). The variation in judgments and evaluations of high density across different societies, cultures, and individuals creates difficulties in establishing definitive standards for high-density. Different scholars, employing various predictive methods and data, have put forward differing criteria. Finally, this paper argues that high-density communities should exhibit characteristics of spatially intensive construction, highly integrated functions, frequent social interactions among residents, and a compact and intensive design.

2.3. Action path exploring

The relationship between urban built environment and residents' public health is the main issue in the public health field of urban planning and design. A large number of studies have discussed the relationship between urban built environment and public health, and constructed urban built environment index system from qualitative and quantitative perspectives and analyzed its impact on public health. In 2008, Cervero et al. built a "3D" built environment quantification system, including three dimensions: density, diversity and design (Cervero, 2008). Subsequently, Ewing et al. added destination accessibility and distance to transit, and proposed a more complete “5D” built environment element (Ewing, 2010). In addition, many studies have identified pathways between built environmental factors and public health. For example, Wang summarized the role of urban planning elements on public health into three aspects: reducing health risks, providing health facilities and promoting social communication, and constructed a method of integrating public health into the urban planning system (Wang, 2021). In terms of coping strategies, relevant studies mainly focus on four levels: land use, spatial form, road traffic and open space. Based on existing studies and spatial characteristics of high-density communities, this paper summarizes the role path of built environmental factors on public health as follows (Figure 1).

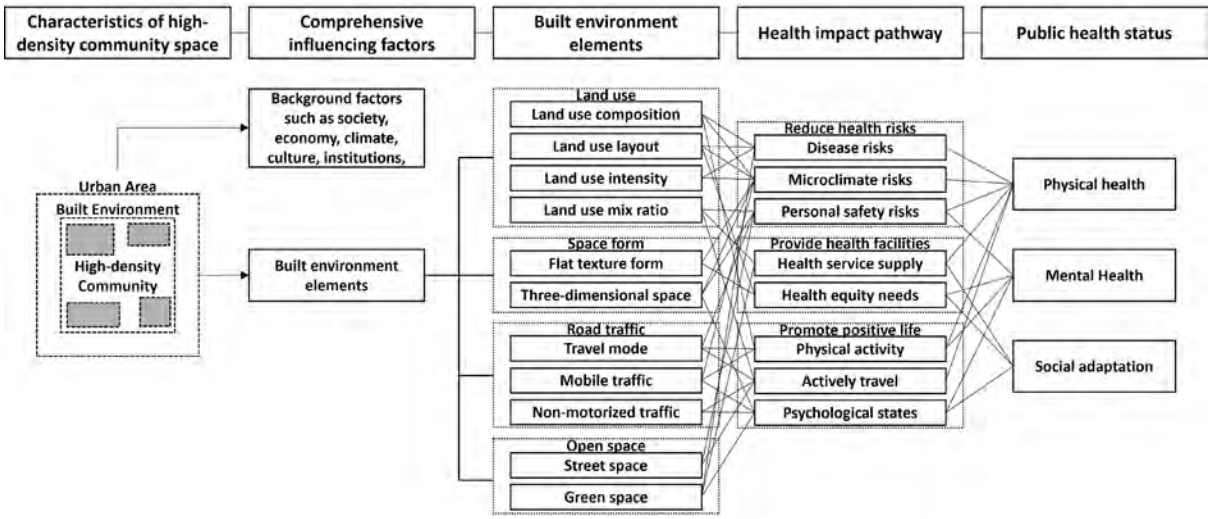


Figure 1. Pathways of built environment on public health. Source: Self-painted.

3. Design guidelines for community based on public health

3.1. Guidelines for the Design of Healthy Communities in the World

Since the 1990s, with the improvement of economic standards and the rapid advancement of urbanization, obesity and related chronic diseases have gradually emerged as significant threats to the health of urban citizens. The urban design guidelines and control indicators originally established were largely formulated based on the construction of new districts during the rapid urbanization phase, with inadequate consideration given to residents' public health (Zhang, 2017). For example, in road traffic planning, existing urban design guidelines do not adequately consider the continuity and convenience of slow mobility such as walking. In the process of planning implementation, when the ecological red line becomes a mandatory control requirement, some ventilation corridors in the city may be compromised for economic development. In this context, various countries and regions began to develop health-oriented urban design guidelines (Table 2), aiming to integrate health concepts into planning and design practices.

Table 2. Guidelines for the Design of Healthy Communities in the World. Source: Self-painted.

Country	Designation	Time	Institution	Content
America	WELL Community standard	2017	IWBI GBCI	Ten dimensions: air, water, nutrition, light, fitness, thermal comfort, sound environment, materials, spirit, and community. Emphasize the inclusiveness, integration, fairness, social interaction, and resident identity of the community.
America	LEED for Neighborhood Development	2018	USGBC	Five dimensions: community site selection and surrounding environment, community planning and layout, green buildings and facilities, innovation, and community superiority. Emphasis should be placed on people-oriented communities, mixed functions, etc.
America	Healthy Communities Policy Guide	2017	APA	It involves multiple dimensions such as healthy living, healthy environment, emergency disaster prevention, healthy food system, and social cohesion.
America	CDC's Healthy Communities Program	2008	CDC	Emphasis is placed on chronic disease prevention and community health promotion, including self-management of health, promotion of physical exercise, and provision of medical services.
Canada	Healthy Communities Practice Guide	2012	CIP	It includes several parts such as health services, social governance, economic development, community planning, ecosystem health, public space, infrastructure, architectural design, food health, healthy society, and health services.
Singapore	The Healthy Living Master Plan	2014	MOH	To achieve a healthy lifestyle by managing the relationship between people (a healthy and socially

				inclusive community), places (favorable environments for healthy living), and prices .
Australia	Victorian Public Health and Wellbeing Plan 2011–2015	2011	Department of Health	A healthy community should aim to promote residents' health and increase community resilience, and form a management system in the planning system that includes problem assessment, planning research, multi-party discussion and participation, planning formulation, and planning implementation.

3.2. The current urban design guidelines and control system in China

As China's urban construction changes from high-speed development to high-quality development, more and more regions compete in urban design competition. These areas hope to improve the quality of urban living environment through urban design. As the controlling and guiding result after planning, urban design guidelines play a guiding role in the subsequent planning implementation. This paper reviews the current urban design guidelines of some provinces and cities in China, and summarizes their index element system. We found that the compilation level of urban design guidelines in various provinces and cities in China is usually divided into 2-4 layers from the overall level to the local plot. For example, the design guidelines of Guangzhou, Shenzhen, Chongqing and Zhengzhou are divided into three layers of "overall urban design - district urban design - block urban design". In 2017, based on the current conditions of urban development in China, the Ministry of Housing and Urban-Rural Development formulated the “Technical Guidelines for Urban Design” on the basis of the “Measures for the Administration of Urban Design”. The document divides the urban design guidelines into three levels, providing a more authoritative reference for the preparation of various urban design. Moreover, Guangzhou's urban design guidelines system has formed a "1+5+N" compilation system. Among them, "1" is the general principles of Guangzhou Urban Design Guidelines, "5" is the sub-principles of street, architecture, traffic, landscape, and municipal administration, and "N" is the design manual and guideline of N items such as landscape design, road elements, and renovation of old residential areas. Based on the Technical Guidelines for Urban Design mentioned above and the control system of Guangzhou Urban Design Guidelines, this paper extracts the control content of existing guidelines. The management and control contents are sorted out according to the compilation levels of "overall urban design - district urban design - block urban design". Finally, this paper selects other recent and typical local guidelines from both domestic and international sources to integrate into this framework, exploring optimization strategies under the concept of public health (Table 3).

Table 3. The current urban design guidelines and control system in China. Source: Self-painted.

Locational level	Control elements		Design guidelines control content
Overall urban design	Ecological landscape resources	Mountains, water systems/ecological parks/basic farmland, etc.	Setback from surrounding buildings, building height control, reserved public corridors, etc.
	Overall urban spatial form	Urban space layout mode	Group type, strip type, etc.
		Special landscape corridors	Visual corridor zoning, visual corridor height control, etc.

	Landscape features	Style division/axis/node	Architectural style guidance, building height control, skyline control, etc.
	Public space	Open spaces	Open space system and its environmental quality.
		Slow-moving system/traffic organization	Road network form, layout, orientation, etc., traffic organization model.
		Scale and capacity	Development intensity, land use scale, environmental capacity control
	Landscape style	Height zoning/skyline	Ventilation corridor section form, skyline form
	Public space	Open space	Spatial scale, terrain shaping, plant planting, etc.
	Slow-moving system	Walking system	Control and guidance of pedestrian density and average spacing in different urban areas
		Cycling system	Path design, cycling traffic network control and guidance
		Slow traffic facilities	Control and guidance of the number and scale of slow traffic facilities
	Streets	Block scale	Propose block scale guidance for different functional plots
	Architectural form	Group combination	Combination form, building volume control and guidance
		Urban interface	Continuous and neat urban interface, commercial street and main public space interface control

3.3. Comparative analysis and optimization strategies

3.3.1. Transform from Design to Control - Focus on the Implementation of Urban Design Guidelines

For a long time, due to the "non-statutory" nature of urban design and the lack of institutionalized technical tools, urban design projects have generally suffered from issues such as the "inadequate realization" of urban design intentions or the "diluted implementation" of urban design outcomes during the implementation process (Jin, 2018). This has resulted in the built environment failing to achieve the established urban design goals, and concepts such as public health cannot be implemented. In future urban design control, based on the existing statutory planning, urban design elements should be selectively and progressively integrated into statutory planning, for example, by incorporating them as additional diagrams into regulatory detailed planning, making them a direct additional condition for land transfer. This approach not only maintains the original order of statutory planning but also effectively leverages the role of urban design in planning and construction.

3.3.2. Integrate the Concept of Public Health into the Index Elements of Urban Design Guidelines

The original control indicators for urban design guidelines were largely formulated based on the construction of new districts during the rapid urbanization stage, and did not fully consider the public

health of residents. For example, in road traffic planning, there was little consideration given to pedestrian systems and bicycle lanes, and urban ventilation corridors often yielded to economic development during the planning implementation process when ecological red lines were being controlled. Therefore, based on a review of the current elements of urban design guidelines, this paper proposes to add, adjust, and optimize the control indicators. For instance, in the guidelines for the overall urban spatial form, content on urban spatial layout should be added to promote a compact land use layout and strictly control urban development boundaries. In the urban design of the key areas, the design guidelines should be added in favor of slow traffic. For example, traffic interchange points will be set up in densely populated areas, and pedestrian facilities will be arranged rhythmically along the street to enhance pedestrian safety.

4. A case of renewal design of a high-density community in Guangzhou

4.1. Site background

The western district of the Nanda main line is located in the northern gateway of Panyu District, Guangzhou, within the core area of Wanbo. The area bordered by Xingnan Avenue to the south, South China Expressway to the west, Jinxin Avenue to the east, and Sanzhixiang riverway to the north. It is also adjacent to the South China Expressway and Nansha Port Expressway, enjoying unique advantages in transportation hubs, industrial upgrading, and scientific research innovation. Consequently, it is necessary to conduct planning research and design to enhance the overall comprehensive quality of the areas along the Nanda main line. However, the current situation in the area is concentrated in many urban villages. There are problems such as insufficient public service facilities, poor urban appearance, and mismatch with the future development goals of the area. Therefore, the area is necessary to improve the living environment and urban appearance through urban renewal. At the same time, with the transformation of the positioning of the northern region of Panyu, it is also necessary to reverse the image of the "sleeping city" through the renovation of the gateway area. Finally, this paper aims to integrate the concept of public health into the planning and design practice to create a healthy and livable urban environment.

Based on an assessment of the current development status of the area and the surrounding development resources, this urban design positions the area as a healthy city that is innovative, ecological, and livable within the Greater Bay Area. The goal of this urban design is to create a future-oriented healthy community lifestyle. Design principles include eco-friendliness, smart innovation, safety and convenience, friendly neighborhood, green and low carbon, and then implement planning through urban design guidelines.

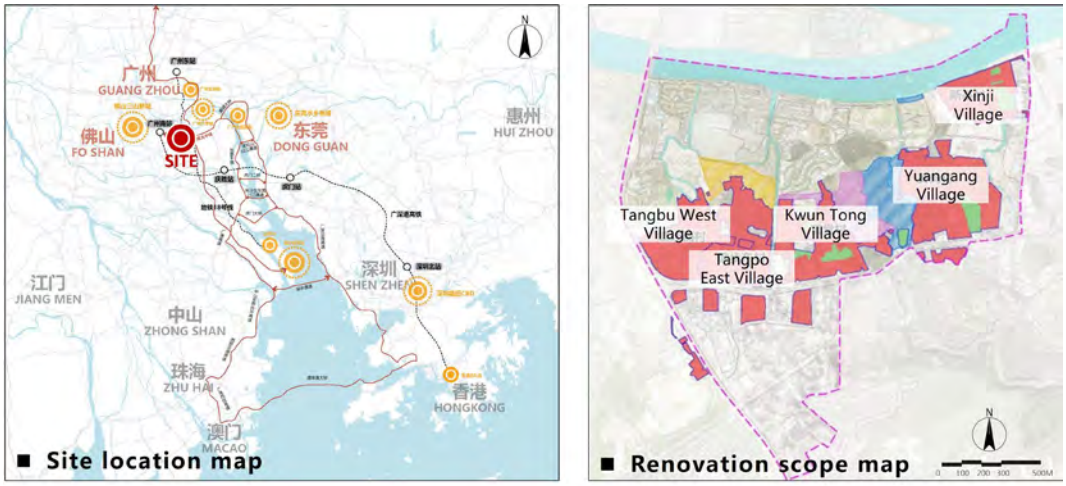


Figure 2. Analysis of the current site conditions. Source: Self-painted.

4.2 Urban Renewal Strategies and Design Guidelines under Health Orientation

4.2.1. Land use layout

The layout of land use mainly includes adjusting the nature of land use, balancing the relationship between occupation and housing and controlling the intensity of development. The current land use planning of the area mainly includes non-construction land such as garden and forest, which is inconsistent with the future development direction of this region. The design is based on the status quo controlled detailed plan to increase the residential and commercial land area. In addition, it is necessary to provide a complete set of public service facilities at different levels. The design will further optimize the land use of the existing control planning management units and promote the development of cities on both sides of the Nanda main line.

4.2.2. Road Traffic

Road transport mainly includes improving road connectivity, increasing road density and diversifying travel modes. This design combines the current construction situation and planning plot indicators, and improves the regional traffic level by opening branch roads, standardizing plots, and fine-tuning road networks to meet future development needs. We focus on creating a balanced, highly accessible, comfortable and leisurely slow transit system that ensures public living Spaces can be reached slowly within five minutes, thereby reducing the amount of motor vehicle traffic generated by daily urban life.

4.2.3. Public service facilities

Public service facilities mainly include improving the layout concept of public service facilities supporting facilities, living circle and commuting circle, and hierarchical agglomeration layout. This design takes the 5-minute living circle and 15-minute commuting circle as the layout concept of public service facilities. And create “community (street level) - neighborhood (neighborhood committee level) - group center” three-level public service facility system. We wanted to create more compact, higher volume ratios, more mixed functions, clear boundaries and pedestrian-friendly residential units. In order to realize the public health concept of community environment construction.

4.2.4. Ecological corridor

Ecological corridor mainly includes controlling the nature of land use to preserve the ecological corridor, building height on both sides of the corridor and interface control. The design is based on the regional open space of the North Pearl River and the central Forest Park. The scheme combines mountains, rivers, historical sites and other elements to create a permeable open space network of "three corridors, two belts and multiple gardens". In the design guidelines, the building height, slope and function on both sides of the corridor are controlled to ensure the implementation of the planning.

4.2.5. Block layout

The block layout mainly includes the function of the block, the microclimate environment and the building layout. The traditional block layout mode has some problems, such as monotonous form and single function. Therefore, the mixed block model is proposed to introduce diversified urban business forms into the block. Under the same development intensity background, mixed block mode introduces more commercial forms and community service facilities to increase community vitality. At the same time, considering the influence of block layout on microclimate, the multi-layer greening system is constructed. We wanted to optimize street space and roads by adjusting the layout of buildings within the block. This reduces the average temperature within the block and brings wind into the city through the wind gallery.

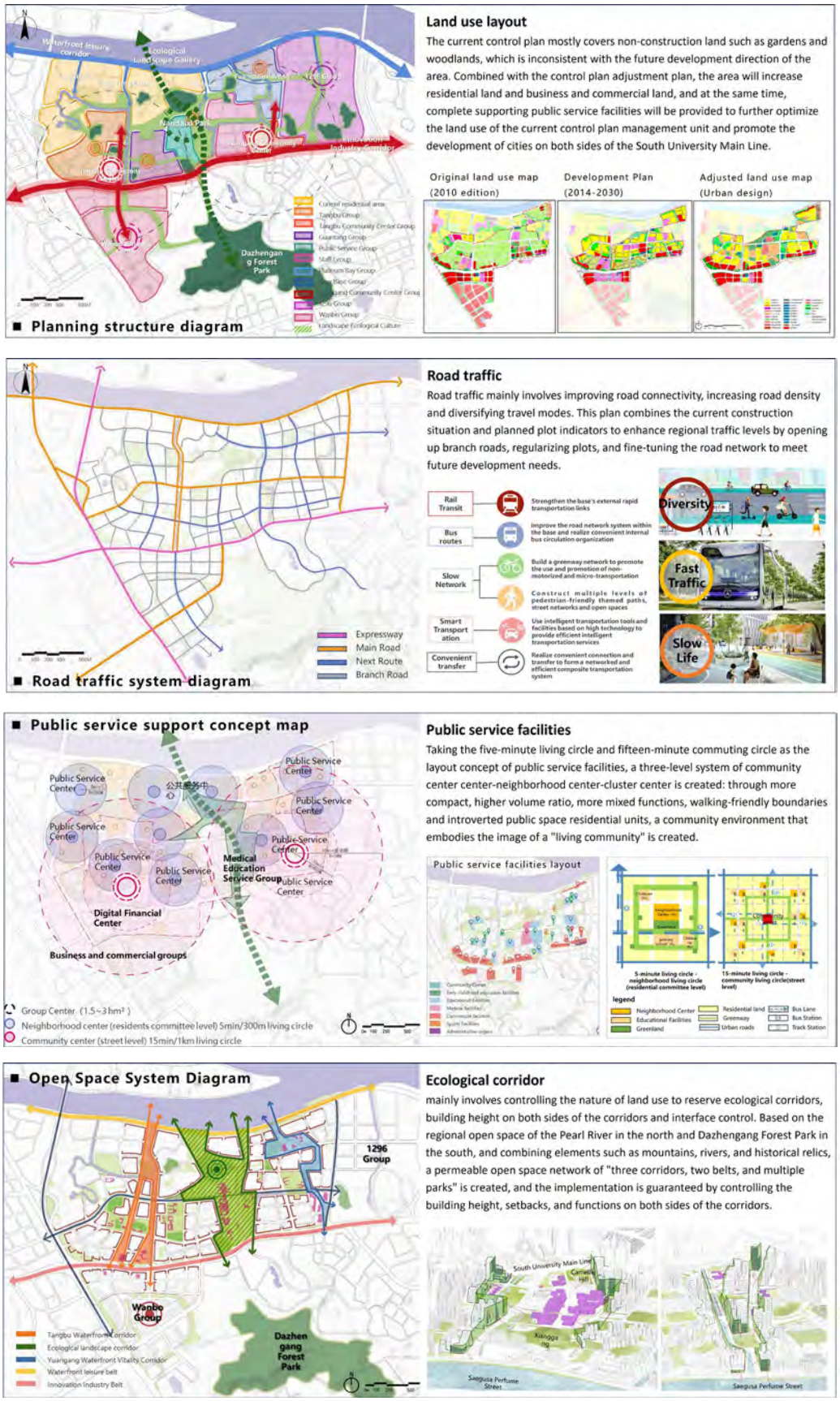


Figure 3. Urban Renewal Strategies and Design Guidelines under Health Orientation. Source: Self-painted.

5.Conclusion

As the urbanization process in our country continues to advance, health issues related to the urban environment are becoming increasingly prominent. The COVID-19 pandemic, floods, haze weather, chronic diseases, etc., all pose threats to people's public health. Traditional medical services can no longer meet the demands of public health. It is necessary to commence with improving the urban built environment and control it through the urban design guidelines indicator system to achieve the aim of reducing health risks, providing health facilities, and promoting activities and exchanges. Only in this manner can we prevent problems before they arise and achieve the transition from "treating existing diseases" to "preventing diseases before they occur". However, the current urban design guidelines still have issues such as insufficient feasibility and less attention paid to public health. It is still necessary to transform urban design from design-oriented to control-oriented to ensure the implementation and accurate realization of design intentions. At the same time, the concept of public health should be integrated into the design guidelines indicator elements, and the indicator elements should be augmented, adjusted and optimized on the basis of the existing guidelines system to construct a path for achieving public health through urban design guidelines, so as to enhance the public health level of residents.

6. References

Cervero, R. & Kockelman, K. (1997) 'Travel demand and the 3Ds: Density, diversity and design', Transportation Research Part D: Transport and Environment, 2(3), pp. 199–219.

Cervero, R. & Day, J. (2008) 'Suburbanization and transit-oriented development in China', Transport Policy, 15(5), pp. 315–323.

Chen, W.Q., Zhang, S.W. & Zou, X.N. (2010) 'Evaluation on the incidence, mortality and tendency of lung cancer in China', Thoracic Cancer, 1(1), pp. 35–40.

Dye, C. (2008) 'Health and urban living', Science, 319(5864), pp. 766–769.

Ding, G.S., Wei, C.Y. & Jiao, S. (2017) 'Planning for public health – Study on health impact assessment of urban planning', Urban Planning, 41(07), pp. 16–25.

Dong, L., Feng, M.M. & Zhang, Y. (2021) 'Comparative study of domestic and foreign street design guidelines oriented towards health and healing', Residential District, (04), pp. 43–47.

Duan, J., Lan, W.L. & Shao, R.Q. (2017) 'From "design-oriented" to "control-oriented" – Thoughts on the standardization of urban design technology in our country', Urban Planning, 41(06), pp. 67–72.

Ewing, R. & Cervero, R. (2010) 'Travel and the built environment: A meta-analysis', Journal of the American Planning Association, 76(3), pp. 265–294.

Ewing, R. & Hamidi, S. (2015) 'Measuring sprawl and its impacts: An update', Journal of Planning Education and Research, 35(1), pp. 35–50.

Shi, J.M., Liu, X.T. & Feng, Z.X. (2023) 'Age-friendly cities and communities and cognitive health among Chinese older adults: Evidence from the China Health and Retirement Longitudinal Studies', Cities, 132, p. 104072.

Glaeser, E. (2011) 'Cities, productivity, and quality of life', Science, 333(6042), pp. 592–594.

Huang, W. (2005) 'Urban design control policy in the United States – A case study of Portland, Seattle and San Francisco', Planner, (08), pp. 91–94.

Li, L.P. (2003) 'Healthy city planning abroad', Planner, (S1), pp. 40–43.

Li, Y. & Zhu, W.Y. (2013) 'New York City public health space design guidelines and their implications for Beijing', World Architecture, (09), pp. 130–133.

Li, Y.W., Yang, M.C., Peng, C. & Li, B.F. (2020) 'Optimization strategy of urban design guidelines for healthy microclimate environment', Southern Architecture, (04), pp. 28–33.

Liu, T.Y. & Song, Y. (2015) 'Evidence-based design and multi-party cooperation in healthy city planning – A case study of the formulation and implementation of New York City's "Public Health Space Design Guidelines"', Planner, 31(06), pp. 27–33.

Liu, Z.Y. & Yang, D.F. (2016) 'Planning for health: The complex challenges of environmental health and planning responses', Journal of Urban Planning, (02), pp. 104–110.

Liu, Z.R. & Liu, C. (2024) 'The association between urban density and multiple health risks based on interpretable machine learning: A study of American urban communities', Cities, 153, p. 105170.

Ma, L., Dong, L. & Zheng, Y. (2017) 'The development and thinking of "Healthy Cities" in China', Medicine and Philosophy (A), 38(03), pp. 5–8.

Tang, Z.L. & Fu, L. (2002) 'Urban design control in developed countries and regions', Journal of Urban Planning, (06), pp. 1–8, 79.

Tian, L. et al. (2016) 'The relationship between urban and rural planning and public health and the concept of an interdisciplinary research framework', Journal of Urban Planning, (02), pp. 111–116.

Wang, H.W. & Zhang, C.Y. (2022) 'A review of the impact of residential space environment on residents' health at home and abroad', Southern Architecture, pp. 1–12 [Online]. Available at: [Accessed 15 February 2022].

Wang, L. & Catherine, R. (2016) 'Healthy city planning and evaluation: The rise and trend', International Urban Planning, 31(04), pp. 1–3.

Wang, L. et al. (2020) 'Urban space intervention strategies for the prevention and control of infectious diseases', Urban Planning, 44(08), pp. 13–20, 32.

Wang, L. et al. (2021) 'Construction and practical exploration of the method of integrating health into the overall planning of national space', Journal of Urban Planning, (04), pp. 81–87.

Wang, L., Sun, W.Y. & Gu, J.Y. (2018) 'Method construction and practical exploration of health-oriented urban design – A case study of Huangpu District, Shanghai', Journal of Urban Planning, (05), pp. 71–79.

Wang, S.F. & Xu, Y. (2020) 'Practical review of urban design drawings and adaptive control thinking', Urban and Rural Planning, (05), pp. 21–28.

Wang, Y. (2015) 'Community planning under the guidance of healthy cities', Planner, 31(10), pp. 101–105.

Xiao, M. (2016) '"Active Design" to create a healthy city – A new perspective on urban planning and design to support a healthy lifestyle', International Urban Planning, 31(05), pp. 80–88.

Zhang, Y.L. & Wang, L. (2017) 'Exploration of health-oriented planning and design guidelines: Based on the experience of New York and Los Angeles', Southern Architecture, (04), pp. 15–22.

Zolnik, E. (2011) 'The effect of sprawl on private-vehicle commuting outcomes', Environment and Planning Part A, 43(8), p. 1875.

Research Paper

Research on the Spatial Evolution and Overall Scale of Pudong New Area in China under the Guidance of National Strategy

Hao CHEN, Shanghai Tongji Urban Planning & Design Institute, China
Jing YU, Shanghai Tongji Urban Planning & Design Institute, China
Xuanyuan GU, Shanghai Tongji Urban Planning & Design Institute, China

Abstract

Aiming at the "out-of-focus" problem of the overall urban design in recent years in the gradual expansion of the control content and elements, the study takes the overall urban design of Pudong New Area as an example, closely follows the main line of work of "refocusing", and takes the spatial evolution of the new area under the guidance of the national strategy as a clue. On the basis of connecting the municipal overall urban design and incorporating it into the district-level master plan, the study proposes an overall scale control idea based on the unit form type method and policy-guided zoning as the implementation path, so as to improve Pudong's "holistic" spatial order, and help Pudong accelerate the construction of the "leading district for the construction of socialist modernization". to help Pudong accelerate the construction of "the leading area of socialist modernization".

Keywords

overall urban design, Pudong New Area, spatial scale, control and guidance

1. Background

General urban design is a global control of the built environment based on urban design thinking, and is an overall conceptualization and arrangement of the overall spatial pattern and urban form (Tang et al., 2020). Since 2000, cities such as Beijing, Shanghai, Nanjing and Zhengzhou have been preparing general urban design individually or as a topic of the master plan, and have achieved positive results in terms of the improvement of the city's characteristics and spatial order (Zhou et al., 2017). However, it is worth alerting that in recent years, some cities have tended to "generalize" the content of the preparation, some excessive pursuit of integration and comprehensiveness, including the economic industry and infrastructure content, while others carry out multi-level studies covering macro, meso and micro, and even screen out hundreds of key elements at the micro level, the work of the work of the content of the complex, the project is difficult to apply the results of the problem has gradually aroused concern. The problem of complicated work and difficulty in applying the results of the project has gradually aroused concern. As a matter of fact, the allocation of limited design resources to multi-system and multi-level studies of the city in the preparation of the overall urban design will easily lead to the blurring of the key

issues and control contents in the mass of planning intentions, so how to strike a balance between completeness and pertinence, and how to realize the “re-focusing” of the work by closely following the main lines of work is a major practical challenge at present. Therefore, how to balance between completeness and relevance and realize “refocusing” by closely following the main line of work is a major practical challenge now.

2. Spatial evolution of Pudong New Area under the guidance of national strategy

The study of urban spatial evolution is a basic study to grasp the layered and idiosyncratic nature of the overall pattern of the city, and it is a precondition for the next step of accurately refining the key elements, deconstructing and reconstructing the overall pattern. Pudong is the wind vane of China's reform and opening up and a symbol of modernization, and after more than 30 years of development, it has changed from an agricultural-oriented area to a modern new city with a concentration of functions, complete elements and advanced facilities, and Lujiazui, Zhangjiang Science City and the World Expo Park have become the iconic areas of Shanghai that display the image of a global city. 2021, the “State Council of the Communist Party of China (CPC) Central Committee's Opinion on Supporting the Reform and Opening Up of Pudong New Area at a High Level” will be issued to the Pudong New Area. In 2021, the Opinions of the CPC Central Committee and State Council on Supporting High-Level Reform and Opening Up of Pudong New Area to Create a Leading Area for Socialist Modernization were issued, further proposing to create a leading area for socialist modernization. National strategies and policies are the primary factors influencing the overall spatial pattern of Pudong New Area, which is divided into four stages in terms of influencing mechanism and spatial evolution.

2.1. Long-term planning stage (1929-1989): Shanghai's “eastward” strategy and the budding of a modernized new area

Since 1929, the Great Shanghai Plan and other versions of the city's master plan have all planned for the development of the Pudong area, but constrained by the high cost of cross-river development, how Shanghai's “eastward” spatial strategy has been unresolved. In April 1986, Tongji University and Shanghai Urban Planning and Design Institute jointly launched the “Modernization of Pudong Area Development Pattern Study”. In October of the same year, the State Council approved the “Shanghai City Master Plan”, which was the first city master plan approved by the state in the history of Shanghai, and the approval pointed out that “at present, special attention should be paid to the planned construction and transformation of Pudong New Area, so as to make Pudong become a modernized new area”.

2.2. Development and Opening-up Stage (1990-1999): Cross-river Development and Four Major Development Zones

In 1990, the Party Central Committee and the State Council formally announced their agreement to develop and open Pudong, and China's first state-level new area was established. Cross-river transportation facilities came first, and during the Eighth Five-Year Plan period, the focus was on promoting “two bridges and one road”, i.e., Nanpu Bridge, Yangpu Bridge, and the widening of Yanggao Road; during the Ninth Five-Year Plan period, the focus was on promoting During the Ninth Five-Year Plan period, the focus will be on promoting the “Three Ports and Two Lines”, i.e. the aviation port, deep-water port, information port, Metro Line 2 and the Pudong section of the Inner Ring Road. In accordance with the concept of “Functional Zoning and Stage Development”, four major national development zones, namely

Lujiazui, Waigaoqiao, Jinqiao and Zhangjiang, were established one after another, corresponding to the four major development companies that became the main body of development. During this period, the Oriental Pearl Tower and Jinmao Tower in Lujiazui area were completed one after another, and the construction of the World Financial Center was started, which became the benchmark place to show the "height of China".

2.3. "Window to the World" Stage (2000-2010): World-class Events and Six Functional Areas

In 2001, China formally joined the World Trade Organization (WTO). Under the influence of major events such as the Asia-Pacific Economic Cooperation (APEC) meetings, the Shanghai World Expo (EXPO), and large-scale theme parks, the Comprehensive Development Plan of Pudong New Area (2003) put forward the goal of "an outward-looking, multi-functional and modernized new urban area of world-class level", dividing the then 535 square kilometers of Pudong New Area into six functional areas. The 535 square kilometers of Pudong New Area was divided into six functional areas, the original four development zones of Waigaoqiao, Zhangjiang, Jinqiao and Lujiazui were gradually transformed to the integration of industry and city, the planning and construction of the newly added Sanlin Expo Area was accelerated, and the Chuansha Area was strategically reserved for the space of large-scale theme park projects.

2.4. Full liberalization phase (2009-present): Free Trade Zone and the new pattern of "World River and Sea

In 2009, the State Council approved the merger of Nanhui District into Pudong New Area, and the area of Pudong New Area after the "merger of the two districts" was expanded to 1,405 ^{km2}. 2019 Shanghai Pudong New Area Territorial Spatial Master Plan (2017-2035) puts forward the overall spatial structure of "a main, a new, an axis and three corridors, Four circles" overall spatial structure. Among them, "one main" Pudong main urban area located in the world-class waterfront area and "one new" Nanhui New City located in the world-class coastal area are positioned as the core functional area and strategic new space of the global city respectively. From north to south, from "Lujiazui" on the banks of Huangpu River, which guards the joints of the river and the Pu River, to "Nanhui Mouth" at the confluence of the Qiantang and Yangtze Rivers, along with the realization of the policies of the Free Trade Zone and the Free Trade Harbor, Pudong is moving toward a more open Pudong is moving towards a more open new pattern of "the world river and sea".

3. Key Issues in the Overall Urban Design of Pudong New Area

The division, reorganization and evolution of the functional zones in Pudong New Area are closely related to national strategies and policy directions. From the four development zones during the period of development and opening up, to the six functional zones during the period of "window to the world", to the two major urban areas (containing multiple functional zones) during the period of full opening up, Pudong has achieved rapid urbanization development by virtue of the independent zones that are moving forward in tandem, but from the point of view of the spatial "totality", there is a lack of spatial connection and unity among the functional zones. However, from the point of view of spatial "wholeness", there is a lack of spatial connection and unified order between various functional areas. In addition to Lujiazui and Yanggao Road west of the riverside belt and other high-quality lots, generally showing a large-scale, cluster-like development characteristics, there is an urgent need to sort out and improve the spatial order from the "holistic". In particular, the current management mode of nested and superimposed policy zones

undoubtedly puts forward higher requirements for spatial "holistic" governance. From the perspective of modernized governance, a global and simplified control framework based on cross-functional districts is conducive to reducing the cost of coordination and communication between different districts, which is more in line with the real needs of the overall urban design of Pudong New Area.

Compared with the municipal practice, there is a lack of research related to district-level overall urban design, which mainly focuses on incorporating into the overall planning of the same level of land space, and rarely involves the interface with the overall urban design of the upper level. This district-level theme is centered on the exploration of "carrying on the top and starting the bottom", and the clear work positioning includes: ① connecting with the implementation of the Shanghai 2035 Master Plan and the Shanghai Overall Urban Design; ② supporting and incorporating into the Pudong 2035 Master Plan; ③ guiding the planning and urban design of the lower district.

4. Overall scale and control guidance

There are many factors affecting the overall scale of the city, but for new modernized districts with flat topography and short completion time, the urban height pattern is often the key or even the primary factor. As the external expression of urban space in the vertical dimension, the "hierarchical order" behind the height reflects the power system of a city society. The emergence of urban high-rise buildings expands the urban spatial scale and enriches the spatial hierarchy and combination of low, medium and high levels in the city. In this regard, the differences in the height patterns of different areas in Pudong New Area are extremely obvious, both in the Lujiazui area, where super-high-rise buildings are polarized, and in the Lingang industrial area, where large-scale and low-rise buildings are dominant. Building height is the most influential and intuitively covered basic element of Pudong's urban scale, which is closely related to the modernization and overall spatial feeling of the whole area.

4.1. Spatial scale control zoning

Analyzing the current spatial scale is the premise of control zoning, and the current scale of Pudong forms three levels: ① The first level is within the inner ring road and the riverfront area: Lujiazui and along Century Avenue, as the representative global center of the functional space, are featured by super-high-rise and high-rise public buildings, while the other areas, including the riverfront area to the west of Yanggao Road, are characterized by medium- and high-rise settlements; ② The second level is the area within the outer ring road, in addition to the scope of the first level: the residential area is characterized by medium- and high-rise settlements. (ii) The second level is the area within the outer ring besides the scope of the first level: the residential area is mainly multi-storey, and the industrial park is mainly low-rise. Compared with the first level, there are relatively few spatial levels, and there is a lack of spatial recognition and gradient order in the sub-centers. (iii) The third level is the area outside the outer ring: new towns, industrial boards and other countryside spaces are dominant, and the spatial level is flat. Only regional centers such as Chuansha, Zhuqiao and Lingang form a small number of clusters, and the building heights of different levels of urban/regional centers do not differ much, with weak spatial recognition.

Figure 1. Overall Scale Control Schematic. Source: author.

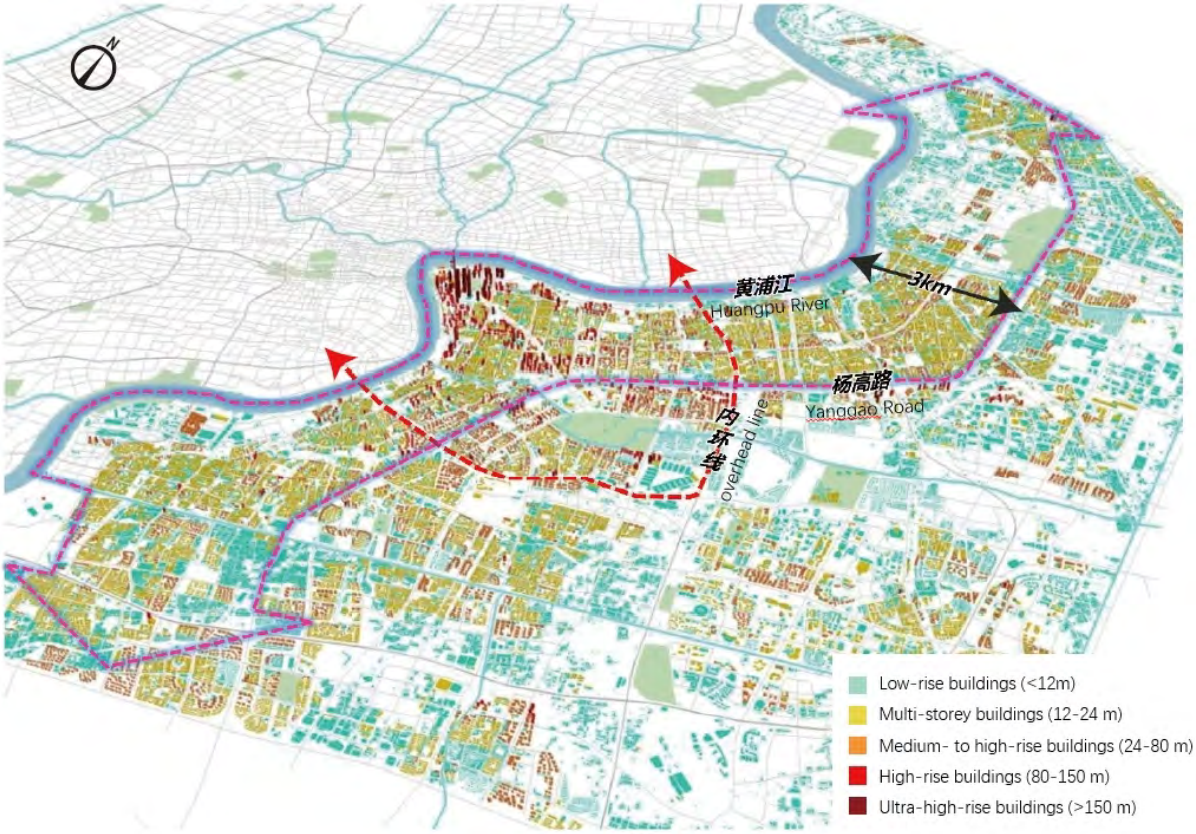


Figure 1. Building Height in Pudong New Area (Center City). Source: author.

To cope with global problems such as insufficient spatial hierarchy and weak gradient order, in terms of urban height control technology, the study adopts the unit morphology type method, i.e., based on the heights of building blocks in the current situation of mapped topographic maps, analyzed by the ArcGIS software, and with the accuracy of 100m*100m simulated grid cells, using single-element full-coverage data, iterated and clustered several times to form more "Abstract" cell morphology type base map. This method is more suitable for larger scale city scope, with stock order optimization oriented management-oriented overall urban design. Compared with the multi-factor element balance method, it highlights the spatial texture, spatial height and other morphology issues, and avoids the loss of focus on core issues brought by exploring location, traffic, land use, ecology, security and other elements at the same time.

The unit morphology type base map, connecting the district master plan functional center system, Shanghai overall urban design "urban spatial scale control zoning" (Pudong sub-district), Pudong coordinated the delineation of three types of spatial scale control zoning, namely, the special area, marking the area, the general area, and in the follow-up to the implementation of the policy area way to control and guide. At the same time, on the basis of the benchmark heights and marking heights of the various zones proposed in the overall urban design of Shanghai, Pudong has further corrected the accuracy and refined it to the level of the district, so as to better guide the lower urban planning or design carried out by each functional area.

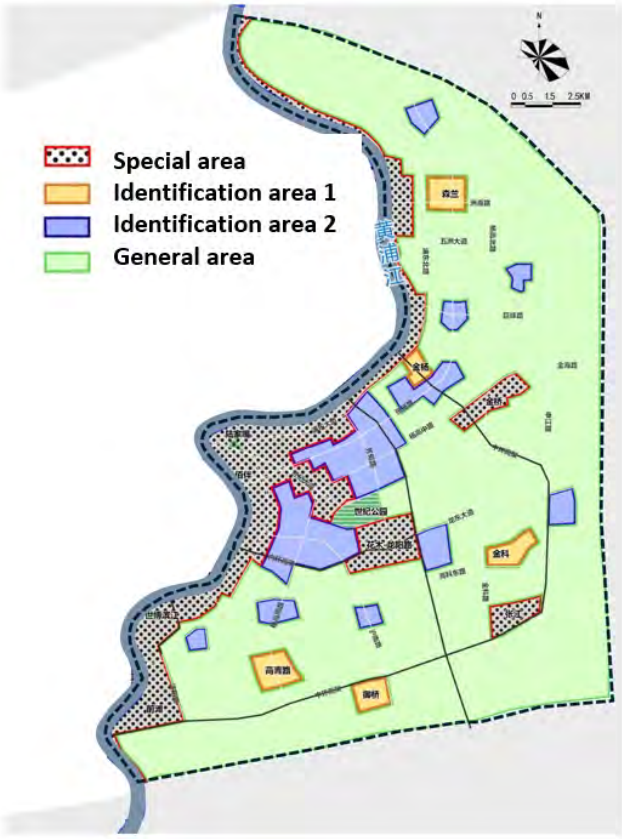


Figure 2. Overall Scale Control Schematic. Source: author.

4.2. Special Areas

Special areas refer to strategic spatial scopes that affect the spatial pattern of the city or show the characteristics of the city, including along the Huangpu River, Lujiazui Municipal Center, Foreshore Municipal Center, Century Boulevard Area, Huamu Sub-center, Zhangjiang Sub-center, Jinqiao Sub-center and so on. Special areas shall prepare a separate urban design to control the area and form a citywide landmark area. The central area of the special area should be polarized scale characteristics, shaping the visual core of the central city of Pudong. A river and an axis area, i.e. along the Huangpu River and the Lujiazui - Huamu - Zhangjiang - Chuansha - Zhuqiao - Pudong Airport axis, shall emphasize the core landscape corridor and the undulating and changing spatial characteristics along the shoreline; the height of the special area shall not be limited. The height zoning of special areas shall not be limited, and shall be determined through subsequent demonstration of urban design in key areas, but the height of the logo shall not be higher than the height of the highest building in Lujiazui.

4.3. Marking area

Marking area refers to the spatial scope that shows the image of the city or a certain area, such as the center of the area, important roads, gateway nodes and so on. According to the city image and landscape image enhancement strategy focuses on different, divided into two categories: ① marking area 1 is distributed in Gaocheng Road, Beicai, Jinko Road, Senlan and other areas, focusing on strengthening the image of the regional center and gateway nodes, especially for the height and proportion of the signage to control, and the formation of the staggered distribution of clusters and the urban center of each other; ②

marking area 2 is distributed in the Lianyang, Pujian Road, Pu San Road and other areas, focusing on Sorting out the spatial scale relationship between the two sides of important roads and rivers, combining with the natural landscape segmentation control, highlighting the roads and rivers as the characteristics of the city's basal veins; signage area focuses on the control of the signage height, it is recommended that the residential ≤ 100m, public buildings ≤ 180m.

4.4. General area

General area refers to other areas other than those mentioned above. On the whole, the role of “setting off” is the main focus, and the spatial scale of the general area is strictly controlled, with low-rise and multi-storey as the main focus, and locally as a sub-district center or community center, with the layout of medium- and high-rise buildings; there are limitations on the height of the marking of the general area and the baseline height, and it is recommended that the baseline height of Pudong be controlled at 20-30m, and the marking height be controlled at residential ≤ 60m, public building ≤ 100m. Considering Pudong's large scale and new area type background conditions, the height limit is relatively loose compared to the scale control of Puxi's general area.

5. Conclusion and Prospect

The main line of work of the overall urban design is to maintain spatial order, behind which is the dialectical discussion about the “unity” and “diversity” of urban space. For the overall spatial form of the city, when the unity is manifested as uniformity, the beauty of the city exists as diversity; and when the diversity is manifested as disorder, the beauty of the city exists as unity. Balancing unity and diversity, integrating wholeness and specificity according to local conditions is the art of urban aesthetics pursued by “Beautiful China”.

Through the practice of Pudong, the study concludes that overall scale control is an important means of integrating spatial wholeness and specificity, and is a key factor affecting the effectiveness of overall urban design. In the context of the gradual transition of the center of gravity to the era of inventory, the government's financial constraints, and the pressure on the design industry, the “refocusing” of the main lines of work and results of the overall urban design is imperative. How to maximize the optimization of urban space and form with the lowest administrative cost and the most streamlined control content is an important challenge nowadays.

6. References

Tang, Z., Zhang, Z., Fu, L., et al. (2020) ‘Transmission mechanism and control methods of overall urban design: Practical exploration of Xiaguan area in Dali City’, Urban Planning Journal, (5), pp. 18–24.

Zhou, J., Yu, J., Chen, Y., et al. (2017) ‘Shanghai overall urban design spatial research and management guidance’, Urban Planning Journal, (S1), pp. 101-108.

Research Paper

The correlation between neighborhood environmental characteristics and travel distance:
an analysis using origin-destination data in Harbin, China

Yujiao Wei, School of Architecture and Design, Harbin Institute of Technology, China
Xu Guo, School of Architecture and Design, Harbin Institute of Technology, China
Hong Leng, School of Architecture and Design, Harbin Institute of Technology, China

Abstract

The neighborhood environmental characteristics of residential areas (including population density, employment density, road density, mixed land use, and facility accessibility) could affect the travel distance of residents. The daily travel behaviors of residents include commuting, shopping, entertainment, exercise, and etc. If residents need to travel long distances to reach their destination, it will lead to an increase in carbon emissions from urban transportation. In the context of global warming , optimizing the built environment characteristics of neighborhoods to promote short distance travel is crucial for sustainable urban transportation. This article used 74406 travel data from 261 residential areas to study the relationship between the built environment characteristics within a 1500m buffer zone of residential areas and the travel distance in Harbin, and used residential housing prices to characterize socio-economic status. The results indicate that residential areas in new urban areas and suburbs have longer travel distances than those in inner cities. Population density, employment density, land use mixed entropy are negatively correlated with travel distance indicating that employment-residence balance and improving facility accessibility can promote short distance travel for residents. The research results can guide the construction of 15 minute cities that promote short distance and low-carbon travel.

Keywords

Neighborhood environment; Travel distance; OD data; spatial analysis

1. Introduction

In recent years, the severe global climate change and frequent extreme weather events are mainly attributed to energy consumption and carbon emissions from human activities(Wang *et al.*, 2020, 2022). Environmental change affects the global ecosystem and human society, and threatens sustainable development. Reducing CO2 emissions is the key to addressing climate change. Urban greenhouse gas emissions account for about 75% of the global total. Transportation is an indispensable part of daily life for urban residents, with the transportation sector accounting for 24.48% of total greenhouse gas emissions. Residents' daily travel behaviors include commuting, shopping, entertainment, exercise, etc. The urban spatial structure and built environment factors have an impact on residents' daily travel behavior, which in turn affects urban transportation carbon emissions through travel distance, travel mode, travel frequency,

etc., among which travel distance is closely related to transportation carbon emissions. If it is necessary to travel a long distance to reach the destination and located in suburban areas with a lack of public transportation, residents tend to prefer private car travel, resulting in higher carbon emissions. When traveling short distances, residents usually walk or ride bicycles to reach their destination, and non motorized modes of transportation have lower carbon emissions.

Neighborhood environment usually refers to the built environment characteristics and socio-economic features within a 15 minute walking distance of a block. The characteristics of the built environment include factors such as population density, employment density, road density, mixed land use, and facility accessibility. Socioeconomic characteristics include housing prices, etc. In previous studies on the impact of built environment on residents' travel behavior and carbon emissions, the research on neighborhood environment at the scales started relatively late and yielded fewer results compared to the macro scale(Qian *et al.*, 2018; Zhu and Hu, 2023). Previous studies have shown that neighborhood environment in residential areas has a significant impact on residents' travel distance. Based on OD travel data from the central urban area of Harbin on November 3, 2023 (with an accuracy of 100×100m), 74406 travel data from 261 residential areas were used to analyze the built environment characteristics, the correlation characteristics between residential housing prices and travel distance, and spatial differentiation within the 1500 meter residential buffer zone. The distribution of residential areas for long-distance travel in Harbin was identified, and the impact of neighborhood built environment characteristics and residential housing prices on travel distance was explored. The research results can guide the construction of 15 minute cities that promote short distance low-carbon travel.

2. Materials

2.1. Study area

The research residential areas need to meet the following two conditions: (1) The number of departure points of travel data within the residential area is more than 50; (2) There is housing price information(https://cd.fang.com/) on the Fangtianxia website. After filtering the data, 74406 travel data from 261 residential areas in the central urban area of Harbin were included in the study. Among them are old residential areas located in the inner city, with medium to low floors and high building density. There are also high-rise newly-built residential communities located in urban new areas, with medium to low building density. The housing prices in new residential areas are generally higher than those in old urban areas.

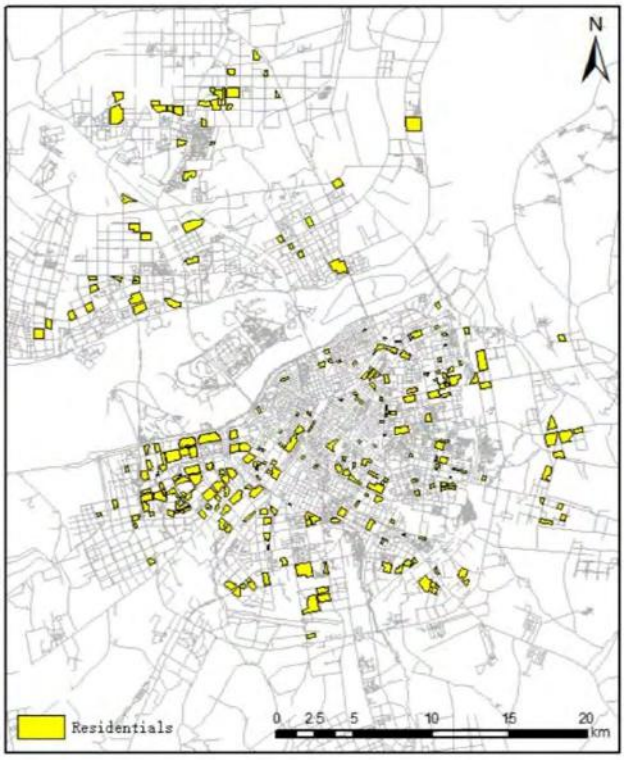


Figure 1. The distribution of study residential areas. Source: self drawn.

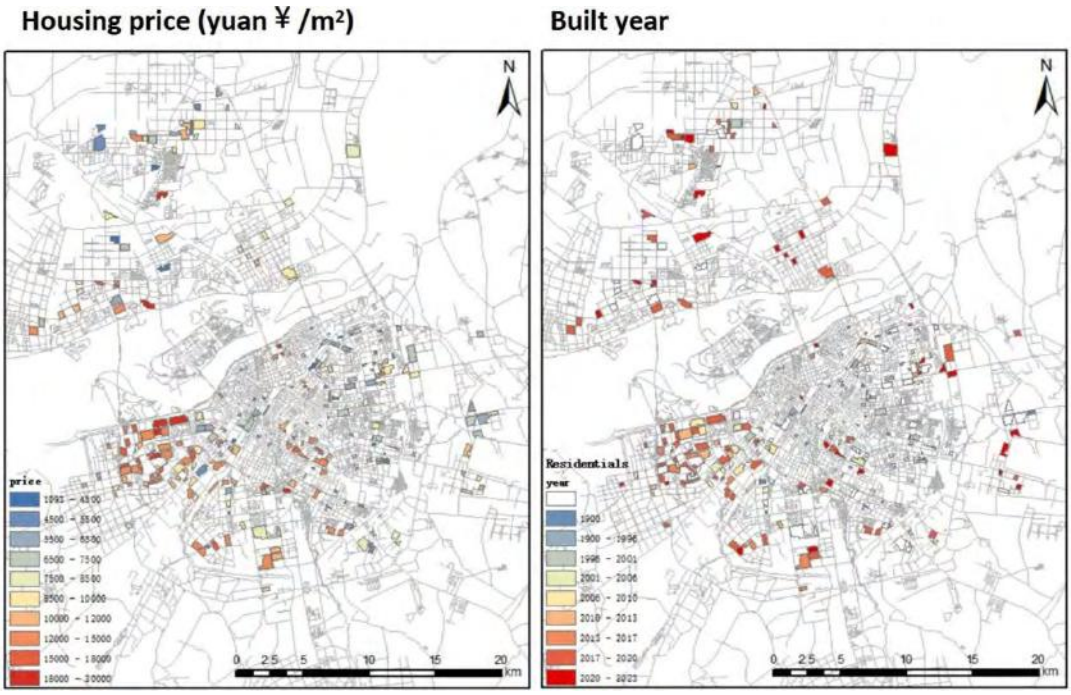


Figure 2. The housing price and built year of residential areas. Source: self drawn.

2.2. Research data and variables

Based on ArcGIS platform, using community AOI data, road network data, public transportation station POI, various service facility POI data(from Baidu Maps), and population density data (2022 LandScan global population density spatial distribution data, from https://landscan.ornl.gov/) to calculate neighborhood built environment variables. Using the 1500 meter buffer zone of residential areas as the neighborhood statistical range, calculate population density, building density, plot ratio, employment density, bus station accessibility, road density at all levels, land use mixed entropy index, and accessibility of various facilities. The method for measuring facility accessibility is to first use road network analysis tools to calculate the facility accessibility range, and then calculate the proportion of the facility accessibility area to the 1500 meter buffer zone (Figure 3: an analysis of primary school accessibility). The housing prices and built year information of the residential area can be crawled up from the Fangtianxia website(https://cd.fang.com/) to measure socio-economic attributes. OD travel data is sourced from Baidu Maps.

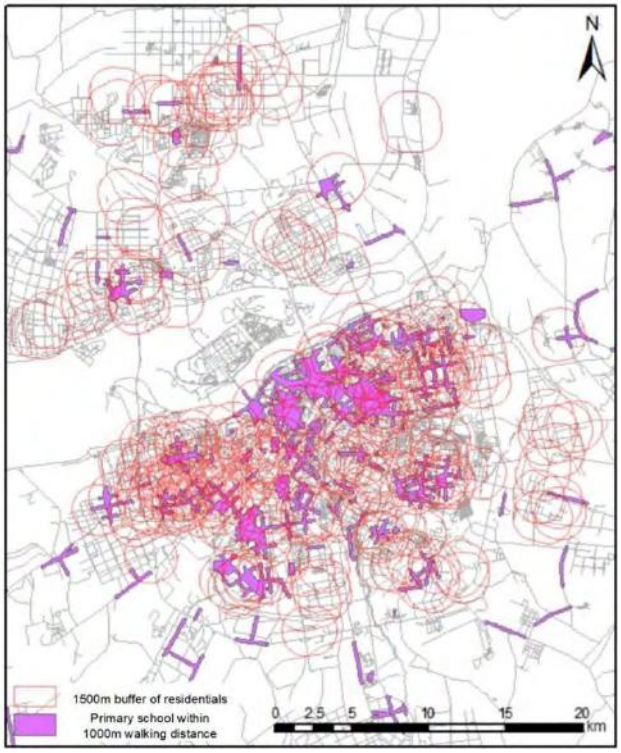


Figure 3.Calculation method for facility accessibility. Source: self drawn.

2.3. Methods

Select OD travel data with departure points located within residential areas, and then conduct spatial auto-correlation analysis and hot-spot analysis on residents' straight-line travel distance (Euclidean distance) , finally identify the spatial distribution of communities with longer travel distances. Spatial auto correlation (Moran I) analysis is used to check the spatial correlation of variables. When the dependent variable has spatial correlation, hot-spot analysis (Getis Ord Gi *), clustering and outlier analysis (Anselin Local Moran I) can be further used to identify high-value clustering and low value clustering areas of the dependent variable. Above steps were completed in ArcGIS 10.8 software. When the dependent variable has spatial correlation, spatial regression methods can be used to analyze the influencing factors of the dependent variable(Zheng, Huang and Sun, 2022). The Moran I calculation formula is as follows:

$$\mathrm{I} = \frac{n\sum_{i=1}^{n}\sum_{i=1}^{n} W_{ij}\,(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n}\sum_{i=1}^{n} W_{ij}\sum_{i=1}^{n}\ (x_i - \overline{x})^2}$$

Then conduct correlation analysis on the built environment variables, housing prices, and straight-line travel distance of residential neighborhoods, and explore the key factors that affect residents' travel distance.

3. Results

3.1. The spatial distribution characteristics of neighborhood built environment variables

The population density, building density, plot ratio, employment density, and mixed entropy of land use in old urban areas are higher than those in newly built and suburban areas. The total density of roads in the inner city is higher than that in the new area, and there is not much difference in the density of highways and city level roads between the inner city and the new area. The density of block roads in the inner city is higher than that in the new district, and the density of cycling and pedestrian roads in the new district is higher than that in the inner city. The accessibility of subway stations in residential areas of the inner city is generally good, while some residential areas in the new district have good accessibility, and some residential areas have poor accessibility. The accessibility of bus stops in the inner city community is slightly better than that in the new district. In terms of facilities, the accessibility of various facilities in the inner city is better than that in the new district. The accessibility of fresh food stores, vegetable markets, kindergartens, and cultural facilities in the new residential area is weak. Overall, the road network is sparse, the land use is single, the distribution of public service facilities is limited and accessibility is poor in the new district.

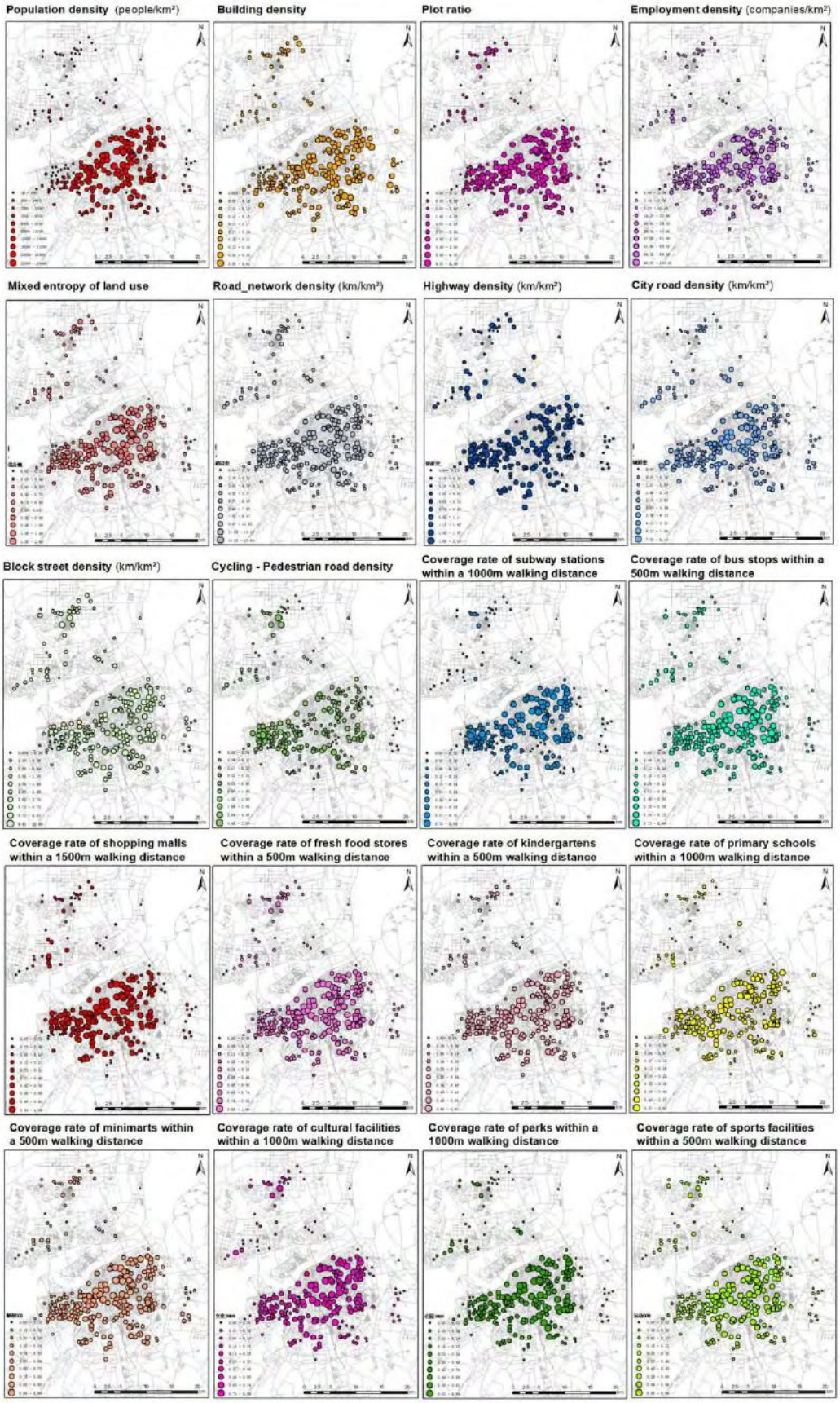


Figure 4. The Spatial distribution of built environment variables. Source: self drawn.

3.2. Spatial auto-correlation analysis of travel distance

Calculate the Euclidean distance (i.e. straight-line distance) of OD travel pairs, conduct spatial auto-correlation analysis and hot-spot analysis on residents' straight-line travel distances, and identify the spatial distribution of communities with longer travel distances. Spatial auto-correlation (Moran I) analysis is used to examine the spatial correlation of variables. The distribution of travel distance has significant spatial correlation. The Moran I results showed that the z-score was 12.22, greater than 2.35, and the p-value was 0.005, less than 0.05, indicating that the distribution of travel distance exhibited certain spatial clustering characteristics. Hot-spot analysis showed that the travel distance of residents in new urban areas and suburbs exhibits high-value clustering, while the travel distance of residents in old urban areas exhibits low value clustering.

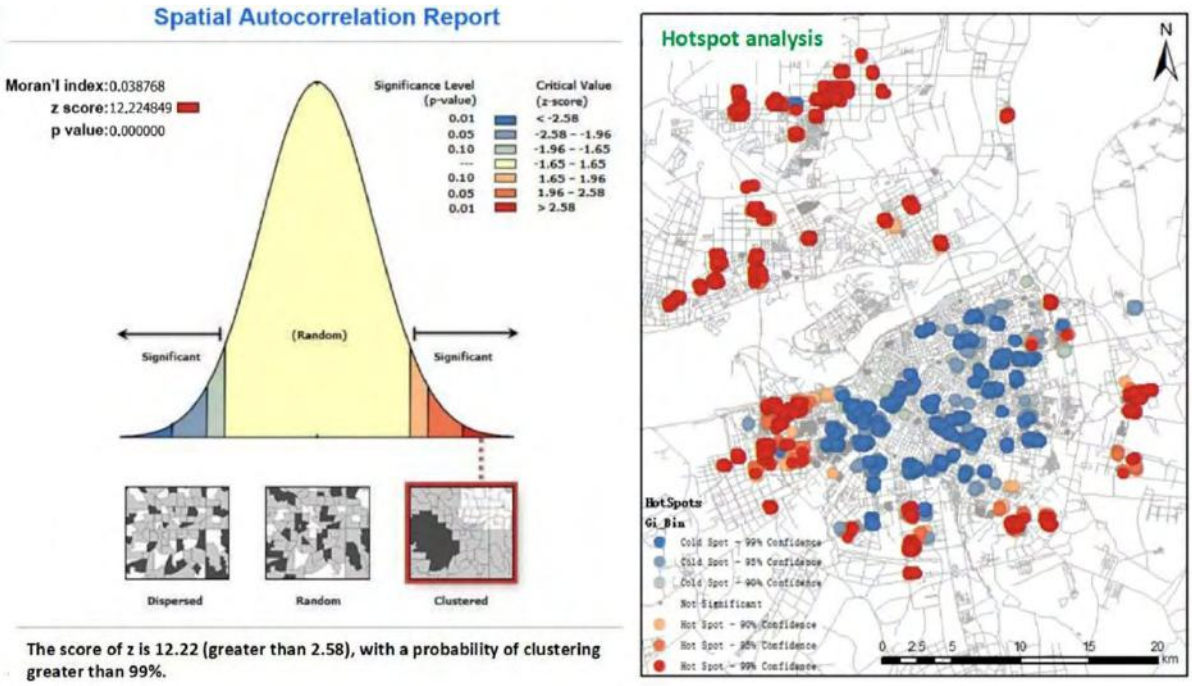


Figure 5. Spatial auto-correlation and hot-spot analysis of travel distance. Source: self drawn.

3.3. Correlation between neighborhood environmental characteristics and travel distance

Calculate the proportion of short and long-distance trips to the total number of trips in each community. Short distance trips are defined as trips with a straight-line distance of less than or equal to 1.5km Increasing the proportion of short distance travel for residents is beneficial for reducing urban transportation carbon emissions.

The least squares regression analysis of neighborhood environmental variables and travel distance shows that population density, employment density, and land use mixed entropy are negatively correlated with travel distance, indicating that employment residential balance and improving facility accessibility can promote residents' short distance travel. In terms of facility accessibility, the coverage of fresh food stores within a 500 meter walk, cultural facilities within a 1000 meter walk, parks within a 1000 meter walk, sports facilities within a 500 meter walk, kindergartens within a 500 meter walk, and middle schools within a 1500 meter walk are all negatively correlated with travel distance.

The communities with a low proportion of short distance travel include low-income communities with housing prices ranging from 5000 to 10000 yuan/m^2, as well as high-income communities with housing prices exceeding 18000 yuan/m^2. The former is because low-income residents find it difficult to afford rent in the city center and have to live in the suburbs, resulting in longer commuting distances; The latter is mainly due to the tendency of residents in high-end residential areas in new urban areas to use private cars for long-distance travel for daily activities such as work and life.

The relationship between population density, plot ratio, building density, and short distance travel ratio shows an inverted U-shaped trend. The population density of residential areas with a high proportion of short distance travel is between 8000-24000 people/km^2, and the mixed entropy of neighborhood land use is approximately between 0.6-1.2. For residential areas with a high proportion of short distance travel, the coverage of the neighborhood bus stop within a walking distance of 500m is approximately between 0.45-0.7. The density of expressways and city level roads in residential areas with a high proportion of short distance travel is lower than other residential areas, while the density of block roads and slow lanes is higher than other residential areas. This indicates that reducing the density of wide lanes, increasing the appropriate scale, and adapting to pedestrian and cycling density are conducive to promoting residents' short distance travel, and encouraging zero carbon transportation modes such as non motorized travel, which can greatly reduce urban transportation carbon emissions.

In residential areas with a high proportion of short distance travel, the coverage of many facilities within walking distance is relatively high (between 0.4-0.7) compared to other residential areas, including fresh food stores and markets, convenience stores, kindergartens, primary schools, secondary schools, cultural facilities, parks, and sports facilities. Some residential areas with a high proportion of short distance travel have a lower coverage of walking distance for shopping malls. The reason is that there are many small shopping facilities in the old city area, such as vegetable markets, fresh food stores, convenience stores, and clothing stores. Residents can reach various small shopping points within a short distance, while there are fewer concentrated large supermarkets. Large shopping malls are often located in new areas with fewer facilities, single land use, wide roads, and low road network density. Residents in new areas tend to prefer long-distance shopping with private cars, and may not necessarily shop nearby.

Research has found that the accessibility of neighborhood facilities has a significant impact on residents' travel distance. In the future 15 minute community life circle planning, emphasis should be placed on facility accessibility indicators, including bus stop accessibility, slow lane density, school accessibility, shopping facility accessibility (such as fresh produce stores and markets), cultural facility accessibility, park and sports facility accessibility, etc.Enhance the attractiveness of neighborhood centers to promote residents' short distance travel, including school, shopping, entertainment, and other travel behaviors. Short distance travel is beneficial for reducing urban carbon emissions, which is crucial for promoting the construction of low-carbon neighborhoods and cities.

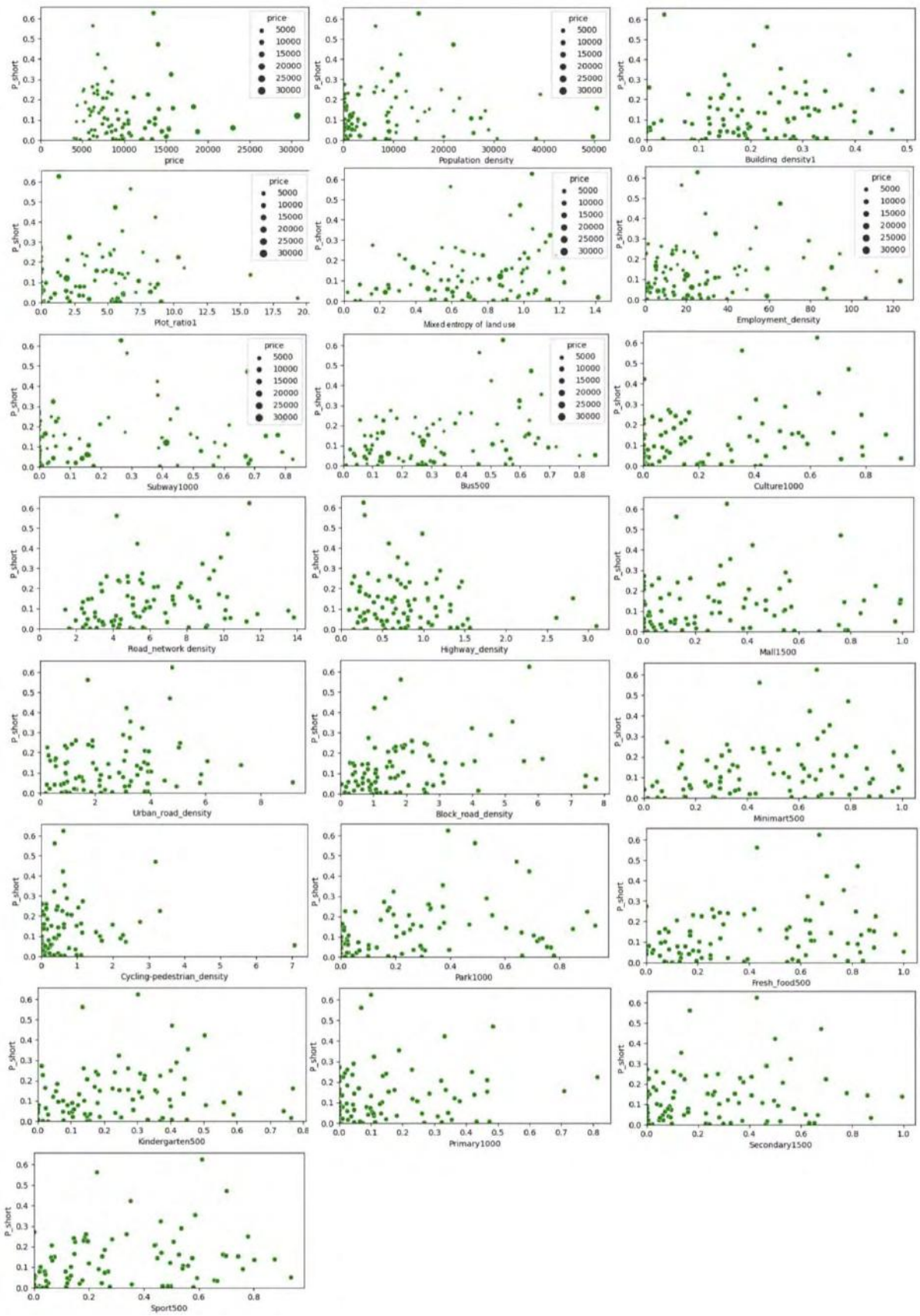


Figure 6. Correlation analysis between neighborhood environment characteristics and travel distance. Source: self drawn.

4. Planning strategy

Developing satellite cities with balanced employment and housing, as well as self-sufficient multi center cities, can greatly reduce the emissions of high emitters. Cultivating multi center city forms and satellite cities with balanced employment and housing is a key step in reducing transportation carbon dioxide emissions in the future. Improve the service level of urban sub centers and satellite cities, allowing residents to travel nearby to their destinations instead of going to traditional city centers.

From the perspective of the entire life cycle, the life cycle emissions of riding a bicycle can be more than ten times lower than those of riding a car. Research in Riyadh, the capital of Saudi Arabia, has shown that the success of the subway requires a very favorable walking environment, prompting people to choose the subway over cars or taxis(Anwar *et al.*, 2023). Therefor, the construction of a slow traffic environment around subway stations and residential neighborhoods is crucial. For example, in the old urban area of Pucheng County, a bicycle travel mode is being developed with bicycle lanes spaced 350-450m apart; The proportion of pedestrian roads to the total road area should be 15-20%, and the road width should be limited(Hou *et al.*, 2019).

Create compact and self-sufficient communities, ensure the rationality and convenience of surrounding infrastructure, and strengthen the guiding role of external living environment on residents' lifestyles. The daily travel behavior of residents is closely related to the external environment, and increasing land use mix and accessibility will improve residents' low-carbon behavior level. Therefore, it is necessary to guide residents' daily travel patterns through measures to improve the built environment, such as improving land use combinations, shortening the distance between bus stops, and improving accessibility(Zhang *et al.*, 2019). The research results in the old urban area of Pucheng County suggest that the coverage rate of bus stops with a 150 meter radius buffer is 40-50%, the coverage rate of shopping services with a 50 meter radius buffer is 45-60%, and the coverage rate of entertainment facilities with a 100 meter radius buffer is 50-70% (Hou *et al.*, 2019).

5. Conclusion

This study analyzed the relationship between the built environment characteristics and socio-economic attributes of neighbors and residents' travel distance through 74406 OD travel data from 261 residential areas in Harbin, China. The neighborhood environment affects people's travel behavior, which in turn affects urban carbon emissions. Promoting residents' short distance travel is beneficial for reducing transportation carbon emissions. Research has found that the relationship between population density, mixed entropy of land use, and short distance travel rate exhibits an inverted U-shaped trend. Improving the density of neighborhood streets and cycling pedestrian roads can promote residents' short distance travel in the neighborhood. The accessibility index of facilities in the 15 minute community living circle is very important. Higher accessibility of educational, cultural, shopping, and sports facilities is conducive to promoting residents' short distance travel, including school, shopping, entertainment, and other travel behaviors.

There are some limitations in this study. There is a non-linear relationship and threshold effect between some neighborhood environmental feature variables and driving distance and short distance driving ratio, which requires further research using machine learning methods such as gradient enhanced decision trees. Due to the lack of records of residents' transportation modes in OD travel data, it is necessary to collect more information about transportation modes to calculate the carbon emissions of residents' travel, in order to study the impact of neighborhood building environmental characteristics on residents' travel

carbon emissions, clarify neighborhood building environmental indicators that help reduce travel carbon emissions, and guide 15 minute community life circle and block planning for low-carbon travel.

6. References

Anwar, A.M., Oakil, A.T., Muhsen, A. and Arora, A., 2023. What would it take for the people of Riyadh city to shift from their cars to the proposed metro?. Case studies on transport policy, 12, p.101008.

Hou, Q., Zhang, X., Li, B., Zhang, X. and Wang, W., 2019. Identification of low-carbon travel block based on GIS hotspot analysis using spatial distribution learning algorithm. Neural Computing and Applications, 31, pp.4703-4713.

Qian, C., Zhou, Y., Ji, Z. and Feng, Q., 2018. The influence of the built environment of neighborhoods on residents' Low-Carbon travel mode. Sustainability, 10(3), p.823.

Wang, S., Gao, S., Huang, Y. and Shi, C., 2020. Spatiotemporal evolution of urban carbon emission performance in China and prediction of future trends. Journal of Geographical Sciences, 30(5), pp.757-774.

Wang, S., Xie, Z., Wu, R. and Feng, K., 2022. How does urbanization affect the carbon intensity of human well-being? A global assessment. Applied Energy, 312, p.118798.

Zhang, J., Zhang, L., Qin, Y., Wang, X. and Zheng, Z., 2019. Impact of residential self-selection on low-carbon behavior: Evidence from Zhengzhou, China. Sustainability, 11(23), p.6871.

Zheng, S., Huang, Y. and Sun, Y., 2022. Effects of urban form on carbon emissions in china: Implications for low-carbon urban planning. Land, 11(8), p.1343.

Zhu, Y. and Hu, Y., 2023. The correlation between urban form and carbon emissions: a bibliometric and literature review. Sustainability, 15(18), p.13439.

Research Paper

The Relationship Between Innovation Districts and the Management of Shrinking Cities

XinYi LIU, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Yibo LIU, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Xiaoxiang YI, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Abstract

As the population gradually gathers in large cities and the population aging continues to be severe, urban shrinking has gradually become a global trend. While the population is shrinking, cities are facing problems such as vacant land, declining architectural appearance, declining employment rates, loss of urban vitality, and the loss of urban vitality due to declining employment rates. Seeking the balance between urban resources and demographic changes in the process of urban construction has become an important condition for sustainable urban development. Currently, China's strategies for shrinking governance mainly focus on three aspects: form and style control, land use change, and financial policy support. However, these strategies have a strong dependence on external regulation of the system, poor sustainability, and a lack of stimulation for internal vitality of the system. Existing studies have pointed out that the " innovation districts" composed of universities and research institutes as the main "anchor" innovation elements are an effective method to activate the surrounding districts of the city. "Anchor" institutes have an effective and sustainable means of urban shrinking governance. Therefore, this study focuses on the development paths and construction priorities of innovation districts by reviewing the relevant international experiences of innovation districts in shrinking governance, combined with different development backgrounds. Innovation districts are divided into opportunity development type, policy guidance type, and strategy construction type. The feasibility of innovation districts as a strategy to alleviate urban shrinking is explored from four construction focuses: spatial layout, network carrier, service system, and policy support. Corresponding strategies are proposed for cities with different development conditions in China to use innovation districts for urban governance. This study takes the construction of innovation districts as the starting point, activates urban shrinking areas through the implantation of innovation elements. This study combines practical situations to address urban problems caused by population contraction, providing new ideas for urban contraction governance and sustainable development.

Keywords

Innovation districts, Urban shrinkage, International experience

1. Introduction

Since the mid-20th century, urban shrinkage has expanded from Western countries to a global scale. The agglomeration effect in megacities has escalated living costs, triggering population outflow, structural imbalances, and declining employment rates (Yi, X.X. 2020). The mismatch between resources and population growth has further resulted in building vacancies within urban built-up areas, accelerating spatial decay. The lack of maintenance in these vacant areas leads to resource waste, environmental degradation, and a continual decline in economic levels. Currently, the Chinese government and researchers focus on three main strategies for addressing shrinkage: managing urban form and aesthetics, changing land use, and providing financial policy support (Zhou, K. 2020). Among these, management of urban form and financial support heavily relies on external factors, while changes in land use can better stimulate the endogenous motivation for regional sustainable development.

In the early 1990s, technological innovation and the knowledge economy gradually garnered attention as significant driving forces for sustainable development (Vasquez-Urriago, A.R. 2016). Internationally, the spatial carriers of innovation have undergone multiple transitions: early-stage isolated industrial parks in suburbs were replaced by urban creative communities, while recent trends focus on open, multifunctional "innovation cells" that emphasize connectivity (Wang, Wang, Y.L. 2020; Yigitcanlara, T. 2020).

As a novel paradigm in urban innovation spaces, the concept of innovation districts was initially proposed by the Brookings Institution in 2014. This model positions universities and research institutions as "anchors," fostering an integrated ecosystem that combines enterprises, capital, and service providers to achieve synergies in industry-academia-research collaboration. These districts feature compact structures, convenient transportation, mixed functions, developed commercial activities, and ample employment opportunities, forming a new economic space within cities (Zhuo, Z.L. 2023) (Dong, L.X. 2023).

Amidst the increasing emphasis on technological innovation in China's urban development, driven by national strength (General Office of the State Council, 2024), innovation districts play an active role in promoting the aggregation, transformation, and flow of innovation elements. They also help stimulate internal vitality and drive the development of surrounding areas. Many countries have incorporated innovation districts as a key strategy in urban planning. There is a consensus in academia regarding the importance of high-quality development of innovative functions within urban spatial systems (Zhang, X. 2017). Existing studies predominantly focus on conceptual frameworks (Deng, Z.T. 2017), theoretical systems (Pan, W.W. 2019), and economic evaluations of international cases (Shi, Y.S. 2022), yet few explore context-specific pathways for implementing innovation districts in China's heterogeneous urban environments.

This study adopts innovation districts as a framework, comparing international models and adapting them to local contexts. It explores their potential in repurposing vacant spaces under urban shrinkage governance, offering a new paradigm for fostering endogenous regional vitality. This approach aims to attract, integrate, and develop innovation elements to activate the endogenous motivation of regions and promote sustainable development.

2. Development process of innovation districts and their relationship with shrinking cities

2.1. Development process of innovation districts

The development of innovation systems in urban areas has undergone a series of changes, transitioning from initially closed and isolated characteristics to open, diverse, and integrated forms, as illustrated in Figure 1.

Space Type	Location	Characteristic	Facilities	Environment	Leading Unit
Industrial Park	·City dge ·Convenient external transportation	·Relatively closed and isolated ·Composed of industrial and residential components	·Abundant land resources ·Basic production and living facilities	·The natural environment outside the park is relatively good	·Government lead ·Enterprise lead ·Collaboration between government and enterprises
High-tech Park	·Urban outskirts or suburbs ·Nearby universities and research institutions ·Convenient internal public transportation	·The interaction between enterprises, universities, and research institutions is very limited	·Laboratory, research center, technology center ·Incubator, maker space ·Complete living facilities	·Beautiful natural environment ·There is a public communication space available	·Collaboration between universities, private enterprises, and governments to design and establish
Creative Community	·City boundary or near the central area ·Convenient internal public transportation	·Diverse cultural industries ·The creative industries are closely interconnected	·Complete living facilities ·Flexible office space	·There are some cultural and living facilities	·Collaboration between private enterprises and governments
Innovation Districts	·Within or at the center of the city ·The facilities for internal environmentally friendly transportation are fully equipped	·Functional complexity and diversity ·The close connection between enterprises, research institutions, and universities ·Openness and social integration	·Shared Office Space ·Shared laboratory ·Rich supporting facilities for daily life	·Diversified public spaces that promote communication ·Integrated development and sustainability within and outside the region	·Triple helix (school+enterprise+government) ·Four fold spiral (school+social organization+enterprise+ government)

Figure 1. Development Process of Innovation. Source: Author.

As urban innovation spaces develop, the emphasis on service functions and knowledge transfer within these spaces has increased. Surabhi Pancholi identified that public spaces can facilitate knowledge transfer. In 2014, the concept of innovation districts was proposed by Professor Bruce Katz of the Brookings Institution (Katz, B. 2014), highlighting the importance of integrated development and sustainability both within and outside the region. On an immaterial level, innovation districts serve as compact, comfortable gathering areas that strengthen the connections between service facilities and knowledge elements, positively impacting the development of surrounding regions by breaking the isolation of innovation systems. Materially, these districts rely on universities and research institutions to diversify the previously singular functional model of knowledge spaces, integrating multiple functions within the district and emphasizing the establishment of complex regional systems.

Currently, international research on innovation districts is relatively comprehensive regarding mixed development, policy orientation, and development strategies, providing useful references. In China, studies on innovation districts are still limited, primarily focusing on concept interpretation, international case analyses, and planning paths. Researchers like Zeng Zhiming have analyzed the construction of regional innovation districts supported by U.S. universities from three dimensions: knowledge production, institutional support, and talent cultivation and aggregation (Zeng, Z.M. 2023). Zhou Kebin and others have clarified specific measures for achieving industrial upgrading, spatial improvement, and vitality stimulation, offering theoretical insights for the transformation and renewal of China's industrial zones (Zhou, K.B. 2022).

2.2. The relationship between innovation districts and shrinking cities

Population loss, imbalanced population structure, economic recession, declining employment rate, deteriorating urban environment, and vacant land and housing in urban shrinkage areas. The advantages and positive effects of innovation districts during construction can enhance population attraction and land utilization, thereby improving the negative impact of urban shrinkage. Therefore, this article discusses the construction of innovation districts as a new approach to urban shrinkage governance.

Research on international cases shows that the construction and development of innovation districts are closely related to urban development status. The urban elements available in different city development contexts influence the construction and growth of innovation districts. This study categorizes innovation districts into opportunity-driven, policy-guided, and strategy-based types of urban shrinkage, aiming to provide references for Chinese cities developing innovation districts in varying contexts, as shown in Figure 2.

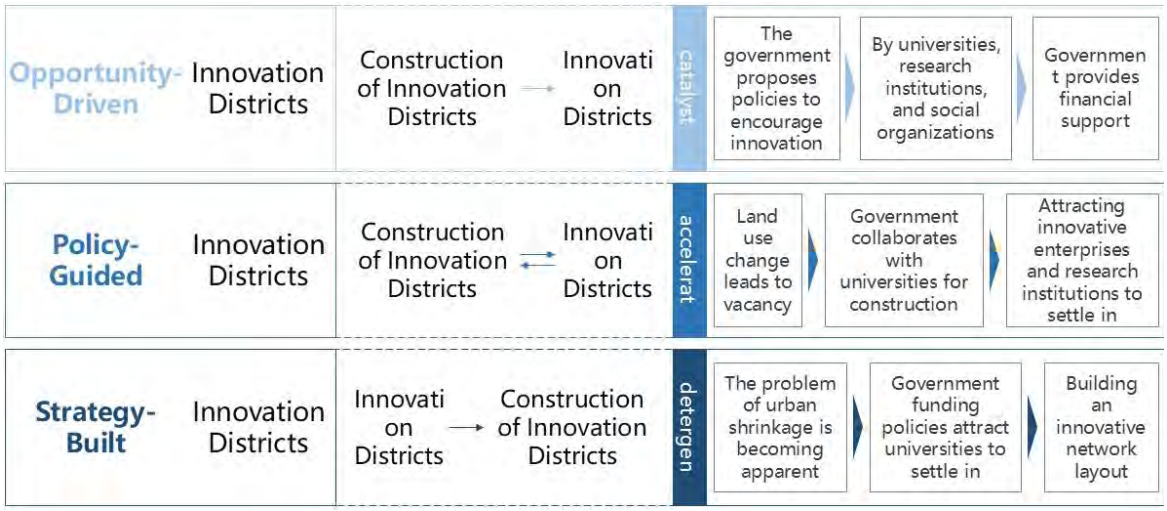


Figure 2. Classification of innovation districts. Source: Author.

3. Opportunity-driven innovation districts

Opportunity-driven innovation districts have a rich history and focus on preserving cultural and district characteristics during their planning and development to enhance residents' pride and sense of belonging. The Macquarie Park Innovation District (MPID) in Australia exemplifies this classification. Its development strategy emphasizes spatial layout and network frameworks. The land use transitioned from original Indigenous land to a rural village and later underwent redevelopment to form a mixed residential area. Although the district temporarily lost vitality due to population decline, the construction of the innovation district has attracted a return of residents.

3.1. Spatial layout

The "anchor" institutions, such as universities and research organizations, often serve as the core of innovation development, responding to government innovation policies by facilitating knowledge exchange and promoting the conversion of research to revitalize surrounding areas. This creates a knowledge network formed by multiple strong magnetic innovation points within the region, focusing on balancing the spatial layout among these "anchor" institutions to promote equitable development across the district.

In Macquarie Park, universities are a key focus in developing the innovation district, with Macquarie University being particularly significant. The university emphasizes mixed land use, enhancing the movement of district residents within the knowledge "anchor" points and visualizing student research (City of Ryde Council 2022).

Opportunity-driven innovation districts create an innovative atmosphere through the collaboration of existing "anchor" institutions, attracting emerging innovative enterprises and educational organizations. They emphasize building community relationship networks centered around universities, encouraging students to engage with the community. As Macquarie Park's facilities improve and knowledge elements within the district become more active, the clustering of innovation elements attracts more enterprises, fostering knowledge and innovation exchanges between universities and businesses.

However, during planning and construction, the efficient flow of knowledge within the region may lead to an invisible exclusion of low-educated and disadvantaged groups from public spaces, resulting in social inequality. As the innovative talent in Macquarie Park continues to grow, the existing elderly residents may struggle to adapt to the fast-paced lifestyle and activities. Additionally, an excessive emphasis on constructing innovation companies during planning can hinder the integration of the district with surrounding areas, gradually turning it into an isolated "knowledge island" within the city (Pancholi, P. 2020).

3.2. Network frameworks

Opportunity-driven innovation districts often possess a strong academic atmosphere and a foundational academic social network during their early development stages. Incorporating innovation elements to build more diverse, complex, and stable social networks is an effective means to reduce gentrification.

In the initial planning phase, universities typically lead the planning and implementation efforts. Subsequently, development relies heavily on government funding and policy support. These districts often strengthen the sustainability of urban governance by creating multi-stakeholder social networks. Macquarie Park, for instance, has established a network that promotes collaborative development among the community, businesses, government, and academia. In the later stages of construction, the government made significant financial investments to develop a comprehensive basic service system.

With the advancement of planning, Opportunity-driven innovation districts have begun to emphasize the diversity of land use within the area, aiming to provide residents with a more convenient living environment while integrating the district into the overall urban development. Macquarie Park focuses on the functional mix of land use and integration with surrounding areas, planning diverse housing options to reduce commuting distance for innovative talents. The construction of highways and railways has enhanced connectivity within and outside the region, while the development of shopping centers and living stations has continuously improved the quality of life for residents.

4. Policy-guided innovation districts

Policy-guided innovation districts rely on government innovation policies in their development process. Implement policies to attract higher education talents and attract technical talents. In addition, policies that promote public participation have facilitated the connection between existing regional conditions and planned development.

Kendall Square is adjacent to the Massachusetts Institute of Technology and began to develop into an industrial center centered on manufacturing in the mid-19th century. In 1950, it was upgraded to an industrial park, and in 1989, a part of it was redeveloped into a multifunctional campus, forming the

prototype of the innovation zone (Deng, Z.T. 2018). The area integrates laboratories and office spaces used by universities and companies, allowing businesses to access highly educated talent while combining commercial and public spaces to accommodate residents' daily activities.

4.1. Spatial layout

Policy-guided innovation districts utilizes innovative vitality to rapidly transform abandoned land, fully utilizing the transportation, facilities, functions, and employment opportunities in the area. However, most employment opportunities are often targeted towards people with higher education, which may hinder the development of a diverse population structure.

In the development of Kendall Square, the main strategy focuses on the comprehensive development of three types of spaces: residential, office, and informal public gathering spaces. This comprehensive approach helps to create a livable environment for knowledge workers, promote an atmosphere of "work study life recreation" (Gaoa, T. 2023), and attract more knowledge workers. It also promotes the competitive development of regional knowledge output and creates a positive cycle for improving the regional environment.

4.2. Policy support

Policy-guided innovation districts are constructed under the guidance of government policies and financial support, led by schools, enterprises, or social organizations. These areas are accelerators for upgrading and optimizing certain areas in the city center. This development is based on a strong policy driven spatial framework that requires comprehensive consideration of economic, demographic, and land use factors to utilize existing knowledge elements and reserve space for future development. However, due to strong government intervention, sustainable development may face challenges in the later stages, which may lead to policy driven contraction.

At Kendall Square, the government has invested heavily in public space development and implemented various incentive measures to retain innovative talent. In addition, local governments have also planned and constructed infrastructure and public transportation. The gathering of enterprises, the strengthening of facilities, and the gathering of talents have made Kendall Square a comfortable, livable, and vibrant area filled with knowledge elements, prompting some previously relocated businesses to return to their original entrepreneurial locations.

5. Strategy-built innovation districts

Strategy-built innovation districts focuses on attracting high-tech companies to enhance regional vitality and solve urban problems, with a focus on updating transportation systems, infrastructure, and land use. With the development of London, there are signs of decline in the city center. Initially, the British government's urban renewal approach involved large-scale demolition and reconstruction, which damaged the structure of the old city.

In the new wave of urban renewal, the construction of innovation zones relies on "anchor" institutions such as universities and research institutions. In these cases of strategic construction, regions often face population decline before planning, and strong policy guidance may lead to social inequality and regional isolation due to rising land prices in the later stages of development.

The London Silicon Ring, located on the old streets of East London, reflects this phenomenon. This area is gradually becoming known for its poor building quality, dirty urban environment, and concentration of low-income residents, but it also provides affordable rent, convenient transportation, and proximity to six

world-renowned universities. With the development of innovation zones, London Silicon Ring has become one of the most densely populated areas for technology companies and talent in the UK.

5.1. Service system

The attraction and retention ability of innovation districts for talents in the later stage mainly depends on the level of the service system. The construction of the service system not only includes the allocation of infrastructure and public service facilities but also includes the number and types of housing, laboratory configuration, and Internet services. Building a walkable road structure and a diversified housing system is an inevitable requirement to meet the needs of a reasonable population structure.

London Silicon Ring has become the third-largest technology enterprise cluster in the world through its development this year. The overall environment of the district has been greatly improved, providing a large number of employment opportunities for innovative talents and driving the renewal of related commercial facilities in the surrounding areas. However, as tech companies expand their spatial and land needs, rising property prices have led to gentrification, spatial segregation, and the marginalization of certain groups, resulting in social inequality and regional isolation.

5.2. Network frameworks

Strategy-built innovation districts emerge from the renewal of vacant areas, using these districts as catalysts to address existing issues. The construction of the district aims to incorporate knowledge elements without disrupting the region’s original social networks, ensuring sustainable development. Updating the spatial conditions emphasizes the preservation and transmission of existing social networks and memories, creating informal spaces for interaction that blend work and academia.

When planning the London Silicon Ring, utilize existing advantages and improve urban issues through the construction of innovation zones. This involves artistic renewal to enhance the urban landscape, reshape regional perception, and upgrade infrastructure to meet urban needs. By attracting technology, digital, and creative enterprises, the region has cultivated a cluster effect. In addition, tax incentives alleviate the burden on startups, while transforming old buildings into unique public spaces helps protect the city's memory.

6. Results

The construction of innovation districts plays a crucial role in addressing issues arising from urban shrinkage, such as economic decline, urban sprawl, exacerbated social inequalities, and ongoing environmental degradation. Different types of innovation districts exhibit varying developmental characteristics in their initial phases due to the influence of multiple factors. This paper analyzes development strategies corresponding to these districts through four dimensions: spatial layout, network carriers, service systems, and policy support, as illustrated in Figure 3. By synthesizing these aspects, the study extracts and summarizes applicable planning strategies from international experiences that can inform urban shrinkage governance in Chinese cities.

	Opportunity-Driven Innovation Districts	Policy-Guided Innovation Districts	Strategy-Built Innovation Districts
Spatial Layout	Location Selection	Location Selection	Location Selection
	Innovative Elements	Innovative Elements	Innovative Elements
Network Frameworks	Cultural Framework	Cultural Framework	Cultural Framework
	Social Activation	Social Activation	Social Activation
Service System	Pre-existing Facilities	Pre-existing Facilities	Pre-existing Facilities
	Availability of Space	Availability of Space	Availability of Space
Policy Support	Public Initiative	Public Initiative	Public Initiative
	Public-private Partnerships	Public-private Partnerships	Public-private Partnerships
	Tax Incentives	Tax Incentives	Tax Incentives

Figure 3. Key Strategies for Different Types of Innovation District Development. Source: Author.

6.1. Spatial layout

Innovation districts shape a multidimensional and open urban innovation spatial system pattern by leveraging the positive effects of proximity and innovation spillover brought about by the aggregation of innovation elements within the region. The multi-dimensional and open spatial layout has a great impact on the construction and later development of innovation districts. As an innovation district with strong complexity, multidimensionality, and collaboration in urban systems, it is conducive to forming a networked development model and providing potential for sustainable development in the later stages of development.

Using innovation districts as accelerators to upgrade and optimize certain areas in the city, it is necessary to comprehensively consider factors such as economy, population, and land in planning, fully utilize the advantages of existing innovation elements, and reserve space for the later development of the district, reducing resource waste caused by the large gap between planning and reality due to the lack of timely adjustment of planning policies.

6.2. Service System

In the later stage, the ability of innovation districts to attract and retain talent mainly depends on the level of the service system. The construction of the service system includes not only the configuration of infrastructure and public service facilities but also the number and types of housing, laboratory configuration, and Internet services. When it comes to affordable housing prices, most residents choose to live in places that are walkable, bike-friendly and have short commuting times to avoid congestion and

time-consuming long-distance commuting. Building walkable road structures and diverse housing systems is an inevitable requirement to meet the demands of a reasonable population structure. By utilizing the existing resources of the city, the buildings within the site can be renovated and updated by matching the types of housing with the job opportunities provided in the district.

6.3. Network Frameworks

Public spaces in innovation districts serve as the physical network that carries social networks and cultural structures, acting as a hub for knowledge flow and research transformation. These spaces connect knowledge elements like businesses and educational institutions, including squares, green spaces, streets, museums, exhibition halls, co-working spaces, public dining areas, cafés, and entertainment zones.

As more knowledge elements are integrated into innovation districts, building diverse, complex, and stable social networks becomes an effective strategy to reduce gentrification. Developing a pedestrian-friendly road network can attract residents to engage in public activities, facilitate the flow of people, and accelerate the transformation of research.

When updating existing spaces, preserving and preserving the original social networks and memories is beneficial for combining community life activities with knowledge innovation, creating informal communication spaces, and providing interaction opportunities for residents during working hours.

6.4. Policy Support

The construction of innovation zones relies on the government's innovation policies. Policies related to talent attraction, tax incentives, and residential incentives are beneficial for attracting individuals with higher education, while public-private partnerships, financing incentives, and tax policies help attract innovative enterprises. In addition, policies that promote public participation have facilitated the connection between the current situation and planned development in the region. In the construction of policy driven innovation zones, strong government policy guidance is crucial. Incorporating public participation into policy frameworks can reduce redundant construction and resource waste caused by delays in adapting to real-world conditions.

7. Conclusion

At present, research in China mainly focuses on theoretical case studies. This study takes the construction and planning of innovation zones as the starting point, aiming to activate vacant urban areas by integrating knowledge elements to solve the problems caused by vacancy. Based on different types of innovation zones, applicable strategies for urban shrinkage governance under different backgrounds have been proposed. The goal is to determine a more suitable planning direction for the future development of China's innovation zones and provide new ideas for effectively implementing urban shrinkage governance and sustainable development.

8. References

Yi, X.X., Zhao, T.W. and Wu, Y.F. (2020) '"Crisis" or "Opportunity"? ——International Experiences in Dealing With Vacancy in Shrinking Cities', *Urban Planning Forum*, 02, p95-101.

Zhou, K. Liu, L.L. and Dai, Y.G. (2020) 'The Governance of Urban Shrinkage: Theoretical Models, International Comparisons and Key Policy Issues', *Urban Planning International*, 02, p12-19+37.

Vasquez-Urriago, A.R., Barge-Gil, A. and Rico, A.M. (2016) 'Science and Technology Parks and cooperation for innovation: Empirical evidence from Spain', *Research Policy*, 45, p137-147.

Wang, L.Y. and Xue, Y. (2020) 'Urban renewal, innovative neighborhoods, and high-quality urban development', *Urban Development Studies*, 27(01), p67-74.

Yigitcanlara, T. and Adu-McVie, R. (2020) 'How can contemporary innovation districts be classified? A systematic review of the literature', *Land Use Policy*, 03.

Zhuo, Z.L. and Zhou, L. (2023) 'Integration of Science and Technology: A New Trend for Higher Education to Promote the Evolution and Development of Science and Technology Parks', *Research in Educational Development*, 43(05), p68-76.

Dong, L.X. and Wang, S.P. (2023) 'Research on the Status Quo and Countermeasures of Innovation District Development', *Henan Science and Technology*, 42(13), p150-154.

General Office of the State Council (2024) 'Government Work Report--At the Second Session of the 14th National People's Congress on March 5, 2024', *Chinese government website*, [online]. Available at: https://mag.fznews.com.cn/fzrb/2024/20240313/20240313_001/20240313_001_6.htm (Accessed: 13 March 2024)

Zhang, X. and Zheng, Q.L. (2017) 'Innovation District: Defining Connotation and Constructing Model', *Science & Technology Progress and Policy*, 34(22), p8-12.

Deng, Z.T. (2017) 'Research on Innovative Street Blocks: Conceptual Connotation, Intrinsic Motivation, and Construction Path', *Urban Development Studies*, 24(08), p42-48.

Pan, W.W. and Deng, Z.T. (2019) 'Innovation District: Defining Connotation and Constructing Model', *Nanjing Journal of Social Sciences*, 03, p64-73.

Shi, Y.S., Mao, Y.X. and Zheng, J.W. (2022) 'The Development Experience and Challenges of Silicon Valley Urban Agglomeration in the United States and Its Implications for the Construction of Innovative Cities in China', *Shanghai Land & Resources*, 43(02), p1-7+45.

Katz, B. and Wagner, J. (2014) 'The Rise of Innovation Districts: A New Geography of Innovation in America', *Washington: Brookings Report*, 05.

Zeng, Z.M. and Jia, X.J. (2023) 'American universities support the construction of regional innovation blocks: dynamic mechanism and engineering education path', *Journal of World Education*, 36(12), p57-67.

Zhou, K.B., Shi, H.C., Wang, S.F., et al. (2022) 'From Industrial Area to Innovation District: The Regeneration Path and International Experience Under the Perspective of Urban-Innovation Integration', *Urban Planning International*, 37(05), p90-97.

Scott, H. and Hoona, J.H. (2017) 'Industry mix and 3D urban heterogeneity: insights into innovation districts', *Procedia Engineering*, 07, p549-561.

Fernandez, M. and Bentley, T. (2021) 'Early Evolution of an Innovation District: Origins and Evolution of MID and RMIT University's Social Innovation Precinct in Melbourne's City North', *Journal of Evolutionary Studies in Business*, p1-35.

City of Ryde Council. (2022) 'Macquarie Park Planning Priority growth areas and precincts', *A NSW Government website*. [online]. Available at: https://www.planning.nsw.gov.au/plans-for-your-area/priority-growth-areas-and-precincts/macquarie-park

Pancholi, S., Yigitcanlar, T., Guaralda, M., et al. (2020) 'University and innovation district symbiosis in the context of placemaking: Insights from Australian cities', *Land Use Policy*, 99, p105-109.

Deng, Z.T. (2018) 'Activating the Vitality of Urban Innovation Blocks through the Third Space - Experience from Kendall Square in Cambridge, USA', *Beijing Planning Review*, 01, p178-181.

Gaoa, T., and Lim, S. (2023) 'Socio-spatial integration in innovation districts: Singapore's mixed-use experiment', *Cities*, 140, p104-405.

Parisi, L., and Donyavi, S. (2023) 'The Hubs of Transformation Dictated by the Innovation Wave: Boston as a Case Study. Exploring How Design is Emerging as an Essential Feature in the Process of 'Laboratorization of Cities', *Regional and City Planning*, 34(03), p248-269.

Research Paper

Balancing Urban Densities: Exploring Retail and Population Distribution for Sustainable Indian Cities

Anindita PRIYADARSINI, Indian Institute of Technology Kharagpur, India

Dr. Sumana GUPTA, Indian Institute of Technology Kharagpur, India

Abstract

Urban districts exhibit substantial complexity, characterized by diverse urban densities across various neighborhoods in different city regions. There is a substantial disparity between the prevailing trends of urbanization and the prerequisites for sustainable urban development. India's commercial industry keeps evolving every day with newer concepts, leading to significant changes in the retail density to cater to the demand. The rise in population density proportionately affects the concentration of retail establishments. This study explores the relationship between retail and population density to provide insights into sustainable urban development in Indian neighborhoods. It focuses on two main areas: the city core and the outskirts. This discrepancy affects urban sustainability pertaining to transportation, as well as economic vitality. The results illustrate major variations in the density of retail businesses across urban cores and peripheries, influencing characteristics such as the number of establishments, social interactions, and economic activity. The research also explores important urban strategies to balance retail and population densities effectively. These have immense implications for augmenting sustainable urban development practices. This research improves our understanding of the dynamics of urban density and, therefore, provides practical insights for city planners and policymakers seeking to create livable and environmentally sustainable cities.

Keywords

Urban Density, Retail Density, Sustainable development approach

1. Introduction

An urban structure is a collection of complex spatial arrangements and their respective activities, impacting a city's morphology and functional life (Shen, 2017). The urban structure of the city is an amalgamation of its various degrees of connectivity and accessibility marked by land use diversity (Zhong *et al.*, 2017; Kotni, 2019). Accessibility is significantly determined by spatial arrangement, which determines the function of the city's functionality (Hillier, 1996). The urban spatial structure is a collection of spatial relationships associated with the interactions among diverse urban entities and the urban form (Anas, Arnott, and Small, 1998). Urban spaces are intrinsically dynamic, continuously influenced by consumer demand and the adaptive supply systems that address these requirements, resulting in the gradual evolution of commerce. This ongoing transition is integral to a larger movement toward cities that tackle the issues presented by static sites and the dynamic nature of urban functional movements to uncover more intricate spatial configurations (Sui, 2015). Rapid urbanization, in tandem with industrialization, has significantly altered the global land use pattern (Pritipadmaja and Garg, 2022). As a result, increasing population demands,

instigate a vicious cycle of infrastructure development and city centre development in urban and peri-urban areas. This leads to migration to urban areas for better living standards and economic opportunities, which further increases resource demand. An urban spatial structure can thus be understood as the generalized interpretation of a spatial layout of the city, together with the organizational structure underpinning those interconnections that characterize its form of urban design (Foley, 2016).

Economic transactions tend to cluster in different places within a city. This agglomeration of economies led to the creation of business districts, also known as urban centers. The formation of centers is caused by factors like Spatial Inhomogeneities, Internal, and External Scale Economies, and Imperfect Competition (Murphy, Shleifer and Vishny, 1989; Anas, Arnott and Small, 1998). The urban structure can thus be classified into Monocentric and Polycentric in terms of economic agglomerations, according to the degree of clustering and dispersion.

Commercial centres are urban centres or business districts that nurture economic and employment opportunities. The Indianapolis 2012 document states that commercial areas emphasize commercial transactions and business, encompassing establishments such as offices and shopping centres. The theory of commercial location posits that the interaction among different rent structures, market supply-demand dynamics, and the strategies of aggregation and diffusion predominantly shape the evolution of urban business districts (Chen *et al.*, 2016). Commercial spaces are fundamental to urban interactions, connecting space and functionality. The necessity for trade among or across groups emerged as social populations began to coalesce into cohorts (Benton, 2019). It was conceived when housewives traded food products during times of necessity, evolving from Barter Systems to QCommerce thereafter (Casson and Lee, 2011). The maximal degree of commercial transactions transpires when there exists a substantial disparity, intense demand, and minimal distance (Guy, 1998).

Commercial spaces have emerged as an integral part of land-use planning to address the growing demand in urban areas (Jhamb and Kiran, 2012). The rapid proliferation and unsustainable development of commercial sectors have resulted in significant obstacles, including encroachment, the emergence of informal sectors, pressure on existing infrastructure, waste production, and environmental issues, such as deteriorating air quality and the urban heat island phenomenon. However, a contrast between planned strategies and reality has hindered infrastructure development and effective urban governance in Indian cities.

This gulf is often caused by inadequate holistic analysis of the market area, which leads to dead commercial places with low footfall and low economic cycles (Ganesh, Aithal and Kirubadevi, 2020). Considering that retail is a continuously changing sector, comprehending the dynamic characteristics of commercial settings and their adaptive methods within competitive contexts has become imperative (Turhan, Akalın and Zehir, 2013). Analyzing the distribution patterns of commercial operations and examining the associated trends are essential for forecasting future adaptations and facilitating sustainable urban planning (Porta *et al.*, 2009; Xing and Meng, 2020).

Sustainable urban development is increasingly focused on compact cities (Soltani *et al.*, 2022). Density is an integral part of a compact city since it promotes the functionality of cities (Frank *et al.*, 2010), livable neighborhoods, and thriving local economies (Page *et al.*, 2024). There are also negative sustainability effects associated with density, particularly within the contexts of ecology and social sustainability (Bramley *et al.*, 2009; Page *et al.*, 2024). This aims to ensure that consumers have easy reachability to a range of vital services within walkable distances from their houses, hence leading to the creation of multiple retail clusters across the city (Yoon, 2018; Gower and Grodach, 2022; Thornton *et al.*, 2022). Retail clusters require a significant customer base for profitable sales revenue; hence, fluctuations in this base

strongly correlate with the overall performance of commercial areas. Factors such as a rise in residential and transient populations, along with asset developments and enhancements in public transit, may lead to an expanded consumer base (Teller and Reutterer, 2008; Schuetz, 2015; Yoon, 2018).

Commercial precincts are predominantly situated in regions with high population density, facilitating convenient access for consumers (Huff, 1964). The volume of local sales is crucial to the retail clusters, especially when consumers are hesitant to drive considerable distances for a product. The increase in consumer demand stimulates commercial operations, hence promoting economic growth and improving urban quality of life, thus indicating that demography significantly influences the economic transactions inside an urban precinct (Wang *et al.*, 2018; Xing and Meng, 2020; Lima *et al.*, 2024). The socio-economic and ecological impacts of urban expansion also help us achieve a holistic understanding of commercialization (Leichenko, 2001; Wentz *et al.*, 2006).

Thus, this research will explore the relationship between retail and population density in order to provide insight into sustainable development within urban neighborhoods in India. The objectives of the study are to assess the interaction of retail and population densities in selected city cores and outskirts and the socio-economic distribution in the residential neighborhoods of Indian cities. This study also strives to identify sustainable urban strategies to balance retail and population densities. This study explores the residential and commercial land coverage and does not include the number of floors or multiple households in a single unit. Public and Semi-Public land use is not considered.

2. Study Area, Data and Methods

2.1. Study Area

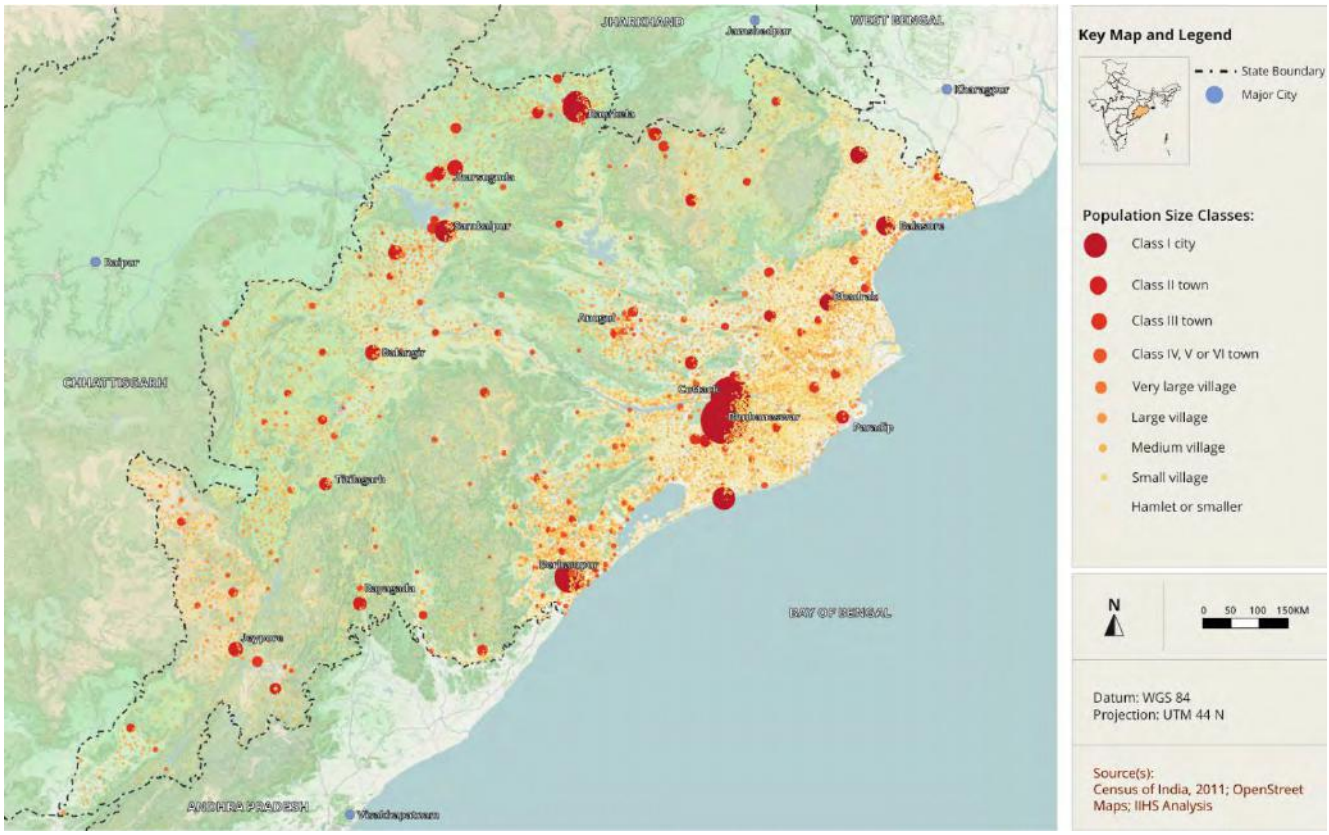


Figure 1 . Map showing Bhubaneswar. Source(s): Census of India, 2011; OpenStreet Maps; IIHS Analysis

Bhubaneswar, the capital of Odisha, is a significant urban centre in eastern India, distinguished by its distinctive combination of old city charms and planned neighbourhood concept. Also known as Ekamra Kshetra or the Temple City, it accounts for approximately 2% of the state's urban population. It was designed in 1946 by the German architect Otto H. Königsberger for administration and residential use for a target population of 50,000 (Mohanty, 2015). The city depicts a unique integration of linear planning and organic growth. It follows a neighborhood-centric approach in terms of layout, which makes it ideal for analyzing commercial space within residential blocks. The city has grown predominantly towards the southwest as there reserve forests are found in the northwest and flood plains in the east region (Pathy and Panda, 2012).

According to the 2011 census, the population of Bhubaneswar Municipal Corporation stands at 844,000, which has been rapidly escalating, approaching the milestone of 1 billion. The percentage of commercial land use in Bhubaneswar stood at 2.17%, a figure that has seen a notable increase over the last twenty years. The city's decadal growth rate stands at an impressive 30.2%, signifying that Bhubaneswar is experiencing substantial growth (Anand and Deb, 2017). The city has experienced notable expansion both horizontally and vertically in recent years. Within the jurisdiction of the BMC, approximately 32% is allocated for residential use, while 15% is designated for commercial and industrial activities. (Datey *et al.*, 2012; Roy and Basu, 2020).

Over the past few decades, due to urban expansion and diversification, the housing and commercial sectors are adjusting to demographic and economic changes. Rapid urbanization has increased demand for a variety of housing types, from single-family homes to high-rise apartments, and commercial spaces, especially near major residential zones, have developed to meet local demands and improve convenience. The Smart City status of Bhubaneswar has brought in investments in modem infrastructures, encouraging integrated residential and commercial schemes and sustainable urban development (Kar *et al.*, 2016). Bhubaneswar, which was once a residential metropolis, has now turned into a multifunctional urban space, thus making it is an excellent location to analyze residential and commercial developments. It is essential to comprehend the indicators that contribute to the significant expansions of the city's commercial landscape in order to formulate strategic plans for improved commercial establishments.

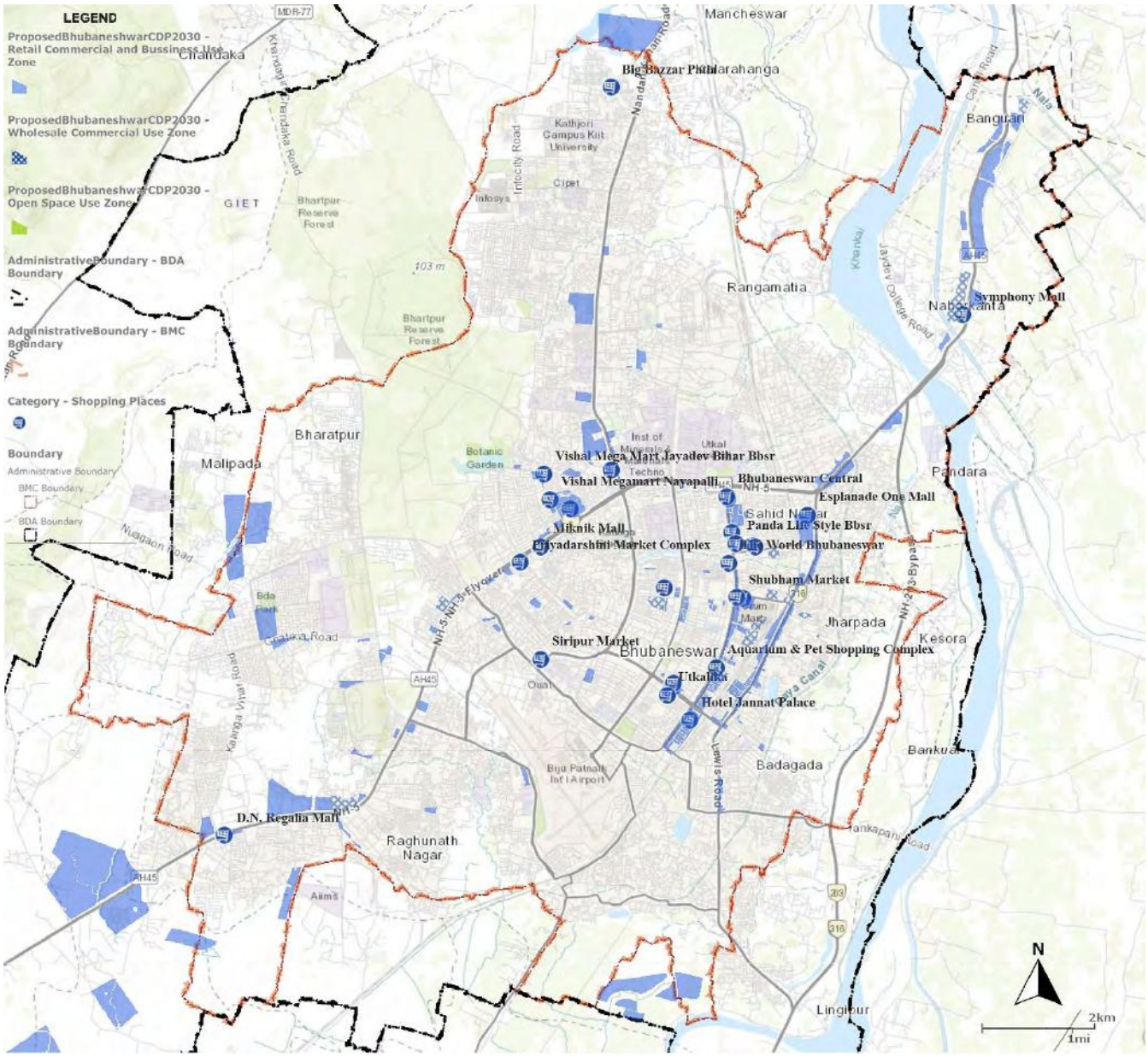


Figure 2. shows the map of the commercial areas of Bhubaneswar, Odisha . Source: Bhubaneswarone.in

2.2. Data Collection

A Reconnaissance Survey was conducted to understand the neighborhoods' spatial layout and socio-economic distribution. Discussion with the shopkeepers and the head of the market committee was also conducted to understand the market's current situation. The data collected for this study was spatially oriented. Google Earth Pro and OpenStreetMap were utilized to acquire the spatial location data of residential and commercial buildings.

Wards are regarded as the most fundamental political and administrative division in India. There have been evidence of studies that have relied on ward-level data due to the unavailability of finer spatial scales (Bharathi *et al.*, 2021). Two wards, i.e., ward no. 40 and 24, in Bhubaneswar, were chosen for the survey, one in the city core characterized by high population density and concentrated retail establishments, and

the other in the city outskirts towards the growth direction of the city, often marked by lower population density and dispersed retail environments. They are situated along major road network axes of Bhubaneswar and have a Königsberger neighborhood layout and informal growth for residential areas. They have government-allocated markets that serve the local neighborhoods and have a broader catchment area, supplying goods to the entire ward.

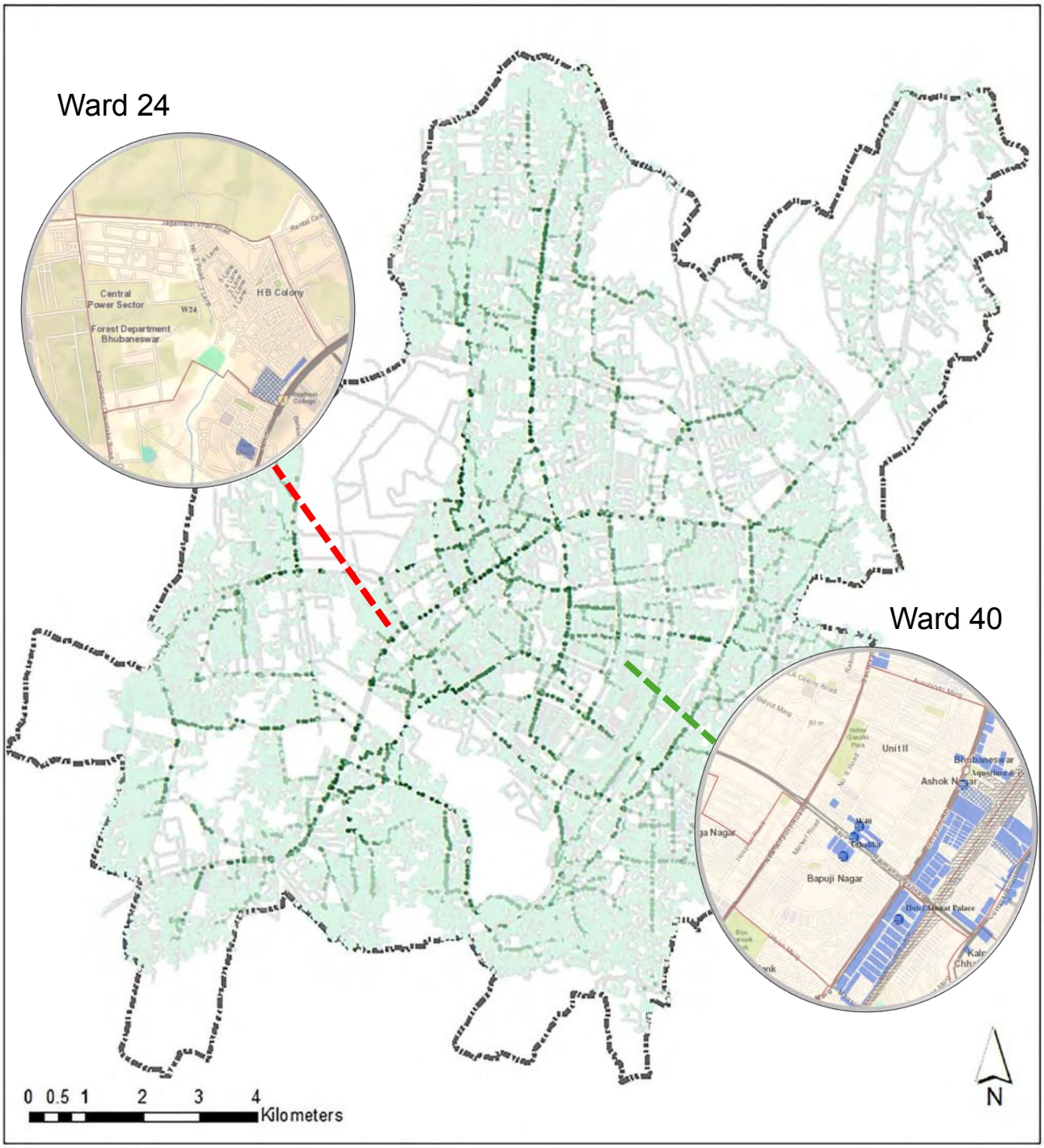


Figure 3. shows the road network of Bhubaneswar and the selected wards for the studt. Source: Bhubaneswarone.in and author

Figure 4 . The present condition of commercial spaces of Ward 40 i.e. at the city Centre. Source: author

Figure 5 . Present condition of commercial spaces of Ward 24 i.e., at the growth direction. Source: author

2.3. Methodology

The commercial landscape is experiencing substantial transformations attributed to evolving lifestyles and accelerated urbanization (Dahiya, 2017). This research study used a systematic approach to examine the interaction between residential and commercial density. This methodology represents an extensive approach for analyzing spatial and socio-economic aspects that affect urban density distribution. The methods adopted in the study are as follows:

1. A Reconnaissance Survey was conducted to identify major commercial places and socio-economic characteristics of residential areas. The demographic and economic data to understand market scenarios and population distribution, was also collected.
2. Spatial mapping was done using OpenStreetMap and Google Earth to outline the road network and map the spatial locations of commercial and residential buildings.
3. Kernel Density Estimation (KDE), a GIS tool, was used on the mapped residential and commercial spatial points to create density maps, envisaging the spatial distribution.

4. The spatial density map was assessed to the clusters and variations in commercial and residential density against the socio-economic distribution.
5. The KDE density values were converted into spatial data points for both residential and commercial density values using Arc GIS.
6. Pearson's Correlation coefficient was calculated for the derived data points with density values to assess the strength and direction of the relationship between residential and commercial density distributions of different wards.
7. Reconnaissance insights, KDE patterns, and correlation results were integrated to interpret the influence of residential density on commercial density within the socio-economic context of the study area.

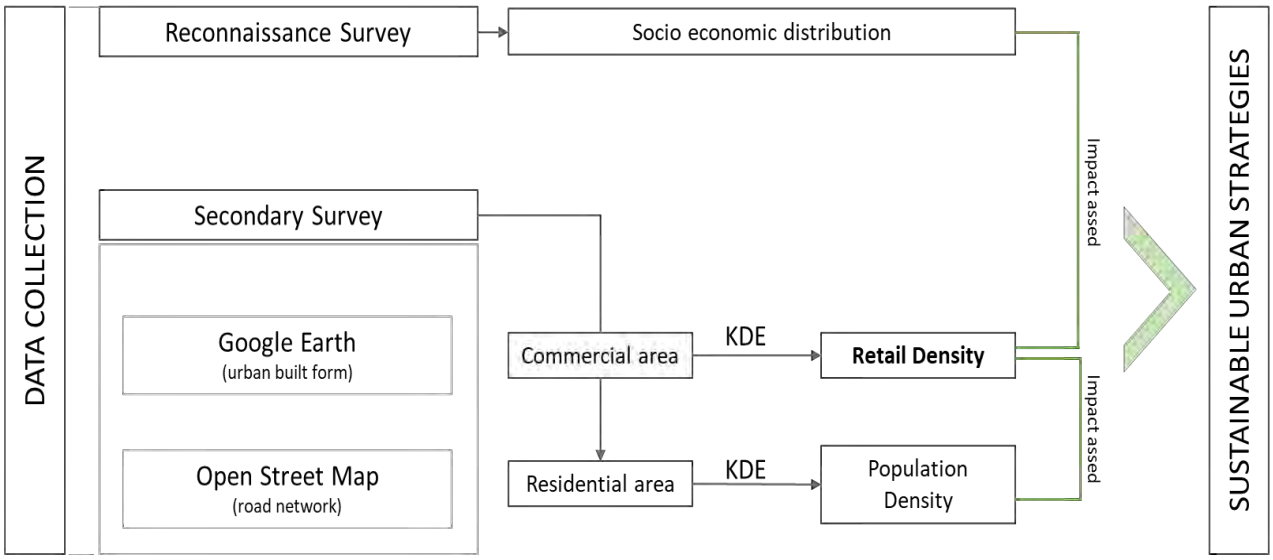


Figure 6 shows the methodology used in this study. Source: Author

3. Findings and Discussions

The spatial data procured from Google Earth mapping, in tandem with the road network from Open Street Map, was evaluated using ArcGIS tools to examine the relationship between residential density and retail density, to achieve a balance that enhances economic performance and improves residents' quality of life while upholding the cultural attributes and the spirit of the urban area.

Figure 7 and 8 illustrates the residential and commercial locations that have been mapped in wards 40 and 24. Whereas the colour green denotes the residential areas, the commercial areas are distinguished by the colour grey. The commercial places are found to be clustered around a main road network, around public and semi-public structures, and in close proximity to dwellings belonging to high-income groups. Additionally, it was seen that smaller pockets of slums and squatters emerged surrounding the denser retail cluster to meet the demand for employment in the neighbourhoods it was located in.

Figure 7 shows the map of residential and commercial locations in Ward 40. Source: Author

Figure 8 shows the map of the residential and commercial locations in Ward 24. Source: Author

Figure 9 and 10 shows the density distribution of residential and commercial locations of ward 40 using Kernel Density Estimation in Arc GIS. The lighter shades show lighter density distribution, while darker shades show denser clustering. It was seen that there was denser retail clustering around denser residential clusters and the major government-allocated commercial markets, i.e., Unit 1 and 2.

Legend

Ward 40: Residential Density

- 0 - 0.000285308
- 0.000285308 - 0.000570617
- 0.000570617 - 0.000855925
- 0.000855925 - 0.001141233
- 0.001141233 - 0.001426541
- 0.001426541 - 0.00171185
- 0.00171185 - 0.001997158
- 0.001997158 - 0.002282466
- 0.002282466 - 0.002567774

N

Kilometers

0 0.05 0.1 0.2 0.3 0.4

Figure 9 Map showing the density distribution of residential locations of Ward 40. Source: Author

Legend

Ward 40: Commercial Density

- 0 - 0.000127964
- 0.000127964 - 0.000255927
- 0.000255927 - 0.000383891
- 0.000383891 - 0.000511855
- 0.000511855 - 0.000639818
- 0.000639818 - 0.000767782
- 0.000767782 - 0.000895746
- 0.000895746 - 0.001023709
- 0.001023709 - 0.001151673

N

Kilometers

0 0.05 0.1 0.2 0.3 0.4

Figure 10 Map showing the density distribution of commercial locations of Ward 40. Source: Author

Figure 11 and 12 shows the density distribution of residential and commercial locations of ward 24 using Kernel Density Estimation in Arc GIS. The lighter shades show lighter density distribution, while darker shades show denser clustering. It was seen that there was denser retail clustering around denser residential clusters.

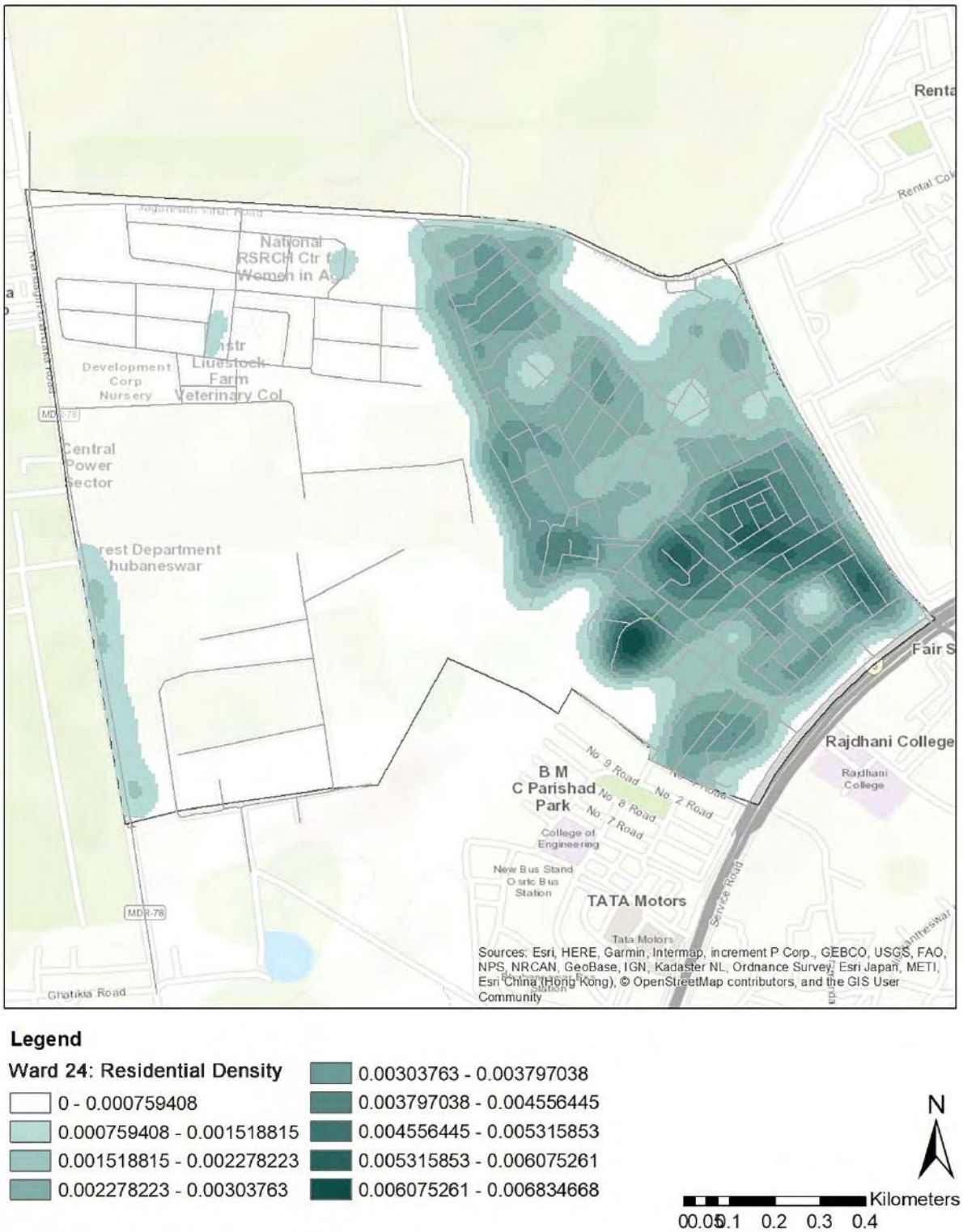
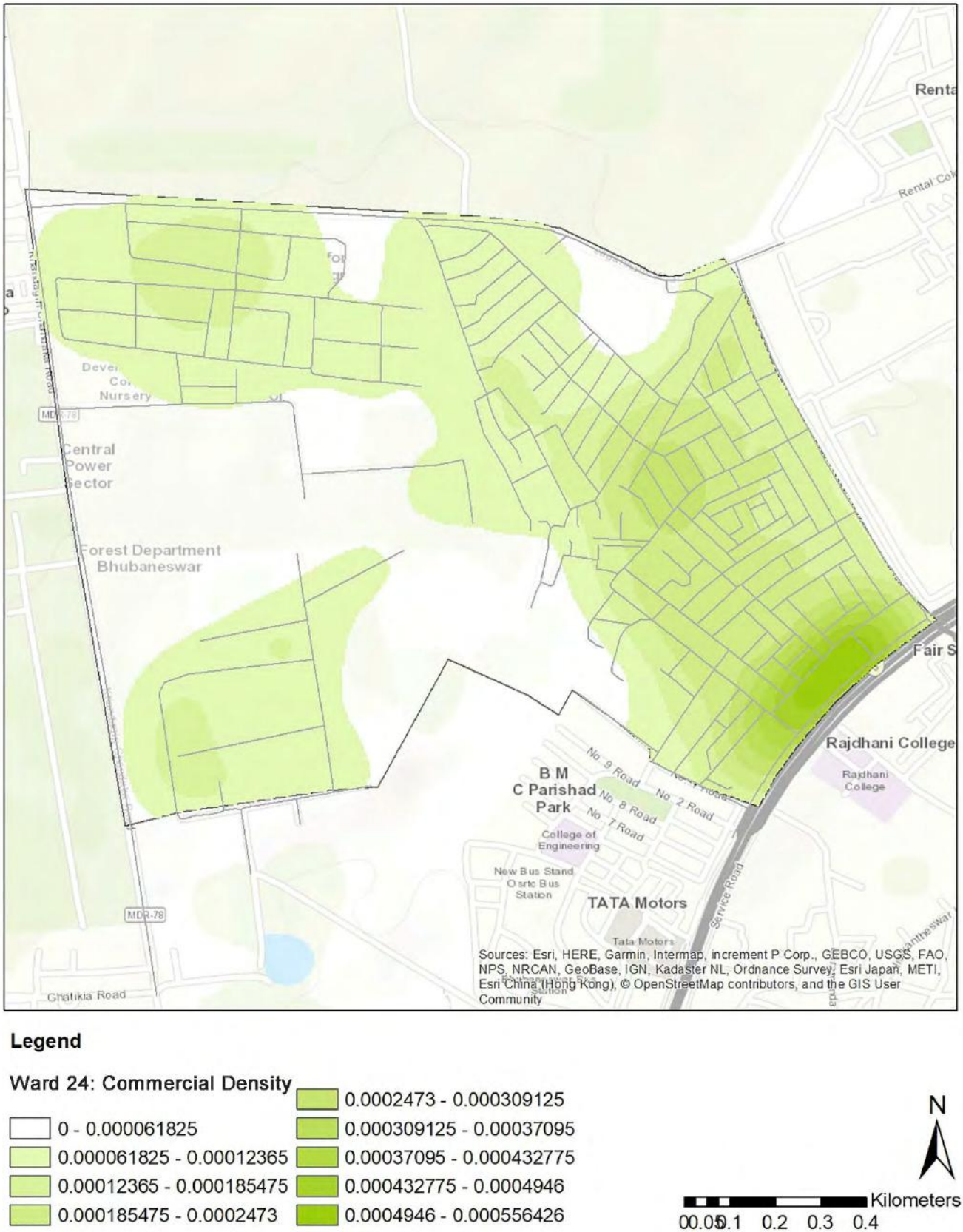


Figure 11 Map showing the density distribution of residential locations of Ward 24. Source: Author



Legend

Ward 24: Commercial Density

- 0 - 0.000061825
- 0.000061825 - 0.00012365
- 0.00012365 - 0.000185475
- 0.000185475 - 0.0002473
- 0.0002473 - 0.000309125
- 0.000309125 - 0.00037095
- 0.00037095 - 0.000432775
- 0.000432775 - 0.0004946
- 0.0004946 - 0.000556426

N

Kilometers

0 0.05 0.1 0.2 0.3 0.4

Figure 12 Map showing the density distribution of commercial locations of Ward 24. Source: Author

The Pearson's coefficient was determined by conducting a correlation analysis on the density values that were obtained using SPSS Software. A Pearson correlation is only acceptable when there is a linear relationship between the two variables (Chee and Queen, 2016). In order to ascertain whether a linear relationship existed between the density values, a scatter plot was generated. Figures 13 and 14 illustrate the scatter plot of the density values for Ward 40 and 24, respectively, which indicate a positive correlation between the strings. Table 1 and 2 shows the Bivariate Correlation analysis of wards 40 and 24, respectively, that demonstrate a strong correlation between residential and commercial densities, with a Pearson correlation coefficient of 0.610 and 0.634, respectively, and a significance level of < 0.001.

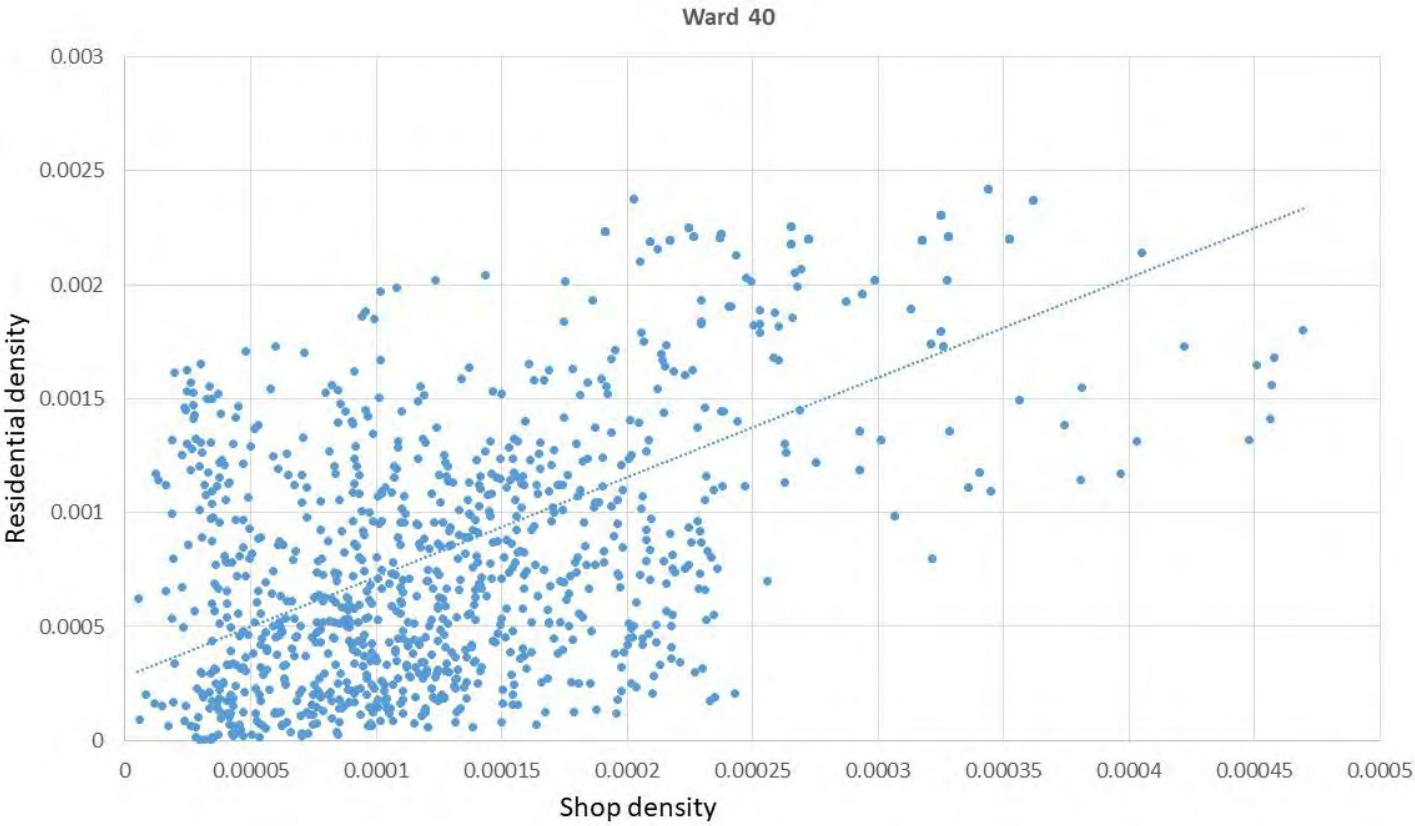


Figure 13. Scatter plot diagram of density values of Ward 40

Table 1. shows the Pearsons correlation coefficient of the residential & commercial density values of Ward 40

Correlations

		VAR00005	VAR00006
VAR00005	Pearson Correlation	1	.610**
	Sig. (2-tailed)		<.001
	N	1071	1071
VAR00006	Pearson Correlation	.610**	1
	Sig. (2-tailed)	<.001	
	N	1071	1071

**. Correlation is significant at the 0.01 level (2-tailed).

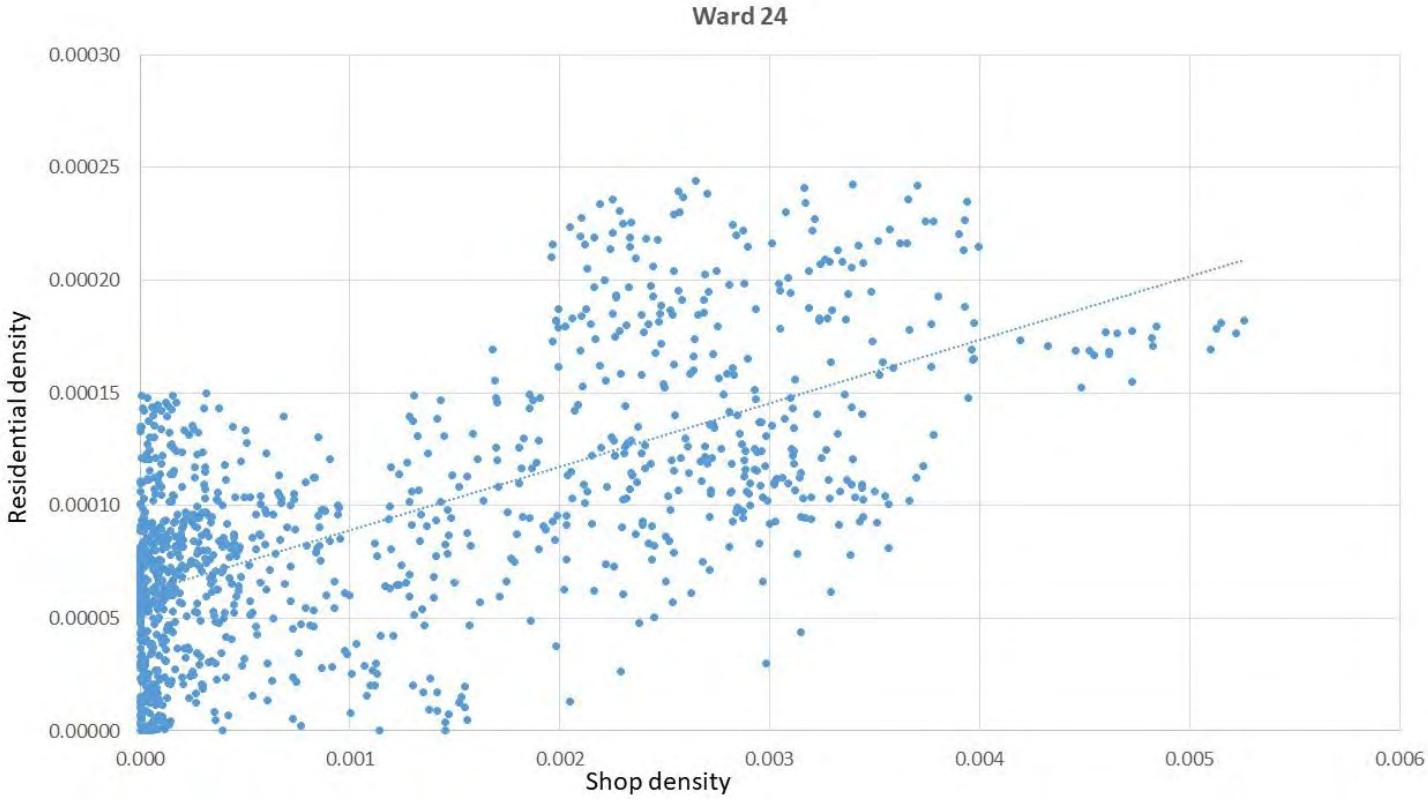


Figure 14. Scatter plot diagram of density values of Ward 24

Table 2. shows the Pearsons correlation coefficient of the residential & commercial density values of Ward 24

Correlations

		VAR00007	VAR00008
VAR00007	Pearson Correlation	1	.634**
	Sig. (2-tailed)		<.001
	N	1211	1211
VAR00008	Pearson Correlation	.634**	1
	Sig. (2-tailed)	<.001	
	N	1211	1211

**. Correlation is significant at the 0.01 level (2-tailed).

This study analyses the impact of residential density, spatial locational attributes, and socio-economic factors on commercial density in Bhubaneswar. These interconnected elements significantly influence commercial density, as witnessed by the results of Pearson correlation analysis and kernel density estimation. Commercial establishments are attracted to regions with a higher residential density due to the constant demand for products and services. The proximity of consumers fosters an optimal setting for commercial interactions, thus promoting further commercial development. A positive correlation between residential and commercial density, as demonstrated by our findings, substantiates this relationship. High

residential density also leads to organic expansion in commercial establishments. This results in increased congestion, infrastructure strain, and environmental degradation in densely populated areas despite the fact that it fosters economic opportunity.

The analysis demonstrates that the commercial landscape is influenced by the socio-economic status of the establishments, which determines the quantity, quality, and type of these establishments. The purchasing power of residents in higher-income areas attracts more diverse and sophisticated commercial ventures. In contrast, wards with lower socio-economic indicators may experience restricted commercial development or commercial growth that is focused on essential products and services. The unequal distribution of commercial opportunities and amenities across the city is frequently exacerbated by this selective development, which is driven by socio-economic disparities.

The commercial density is also significantly influenced by the locational attribute, specifically the proximity of a ward to the city center. The city center is frequently distinguished by its superior connectivity and accessibility, which render it an ideal location for commercial activity. Ward 40, which is situated closer to the city center, exhibits a higher level of commercial density. Additionally, the strategic nature of Bhubaneswar's growth orientation is reflected in the accelerated commercial development of Ward 24, which is located along growth corridors. Commercial transactions anticipate and capitalize on population growth, which leads to commercial densification that corresponds with urban expansion patterns. Moreover, both wards have experienced a substantial increase in retail clusters due to their proximity to public and semi-public areas, as well as the primary road network.

Although residential density, socio-economic factors, and locational factors contributed to organic growth, which promoted commercial density, they also presented a variety of obstacles. Congestion, infrastructure strain, increased pollution, and reduced quality of life for residents can result from rapid, unanticipated commercial expansion. In high-density areas, the overuse of public utilities and the overcrowding that resulted from unchecked commercial development pose a threat to public health and safety. Further, the absence of strategic interventions in organic development patterns has exacerbated socio-economic inequality by restricting access to amenities in lower-income areas and concentrating resources in affluent zones or city-center wards.

Strategic interventions are essential to prevent the adverse effects of unplanned commercial expansion and assure the cohesive development of urban areas. The prioritization of balanced commercial distribution in sustainable urban planning is essential to ensure that growth is consistent with the city's strategic development objectives and infrastructure capacity. These concerns emphasize the pressing necessity of reevaluating sustainable development in urban settings, where managing the effects of urban growth is essential for the preservation of economic vitality, social equity, and Sustainable Development (Chen *et al.*, 2022; Kalfas *et al.*, 2023). As cities expand, harmful impacts at both local and global scales can be mitigated with sustainable development practices such as Mixed-Use Development, Green Building and Energy Efficiency, Compact Retail Formats, Walkability & Accessibility, and others must be integrated with infrastructure growth and improved transportation for environmental sustainability (Dambeebo and Jalloh, 2018; Wang *et al.*, 2022; Alizadeh, Doostvandi and Zandsalimi, 2024).

4. Conclusion

The research further examines sustainable urban strategies for effectively balancing population densities and retail, which has important ramifications for encouraging sustainable urban development methods. By improving our knowledge of urban density dynamics, this research offers useful advice to legislators and city planners who are working to build livable and ecologically sustainable cities. Higher residential

densities, which are also impacted by socio-economic factors and the distance from major transit hubs and city centers, are often supported by higher commercial densities. These results support the idea that strategic planning is essential for urban growth. Unplanned, organic growth can result in traffic, strain on the infrastructure and unequal access to amenities. It can also spur economic vibrancy due to the natural clustering of residential and commercial areas.

Since high residential density and socio-economic opportunities are inherently correlated with commercial density, strategic urban interventions are necessary to balance development and avoid resource overuse. This study's combination of statistical analysis and spatial mapping also shows how effective it is to combine qualitative and quantitative methods for a thorough evaluation of the relationships between urban densities. These techniques provide urban planners with a flexible framework for maximizing commercial development in harmony with residential expansion.

There are a number of directions for future research that could build upon and improve these findings to establish cohesion between residential and commercial densities. Analyzing the change in residential and commercial densities over time may provide information about urban sprawl dynamics and growth trends. Monitoring these changes in density clusters and their socio-economic effects through longitudinal research would be beneficial in guiding proactive planning as opposed to reactive planning. A more thorough understanding of how residential density affects commercial density may be possible through a multi-layered analysis that takes into account additional socio-economic variables, local cultural characteristics, and environmental factors. The study will also be enhanced by investigating appropriate sustainable strategies to achieve a balance between the densities.

In conclusion, this study lays the foundation for comprehending and controlling the relationships between urban densities. Urban planners can create cities that are harmonious, balanced, and economically vibrant by carefully addressing the factors that affect residential and commercial density. Thus, the research emphasizes that the commercial density of Bhubaneswar is considerably influenced by residential density, socio-economic factors, and locational attributes. The absence of strategic, sustainable interventions can also result in environmental stress, congestion, and uneven development. A balanced, cohesive urban environment that supports both economic performance and quality of life can be achieved by adopting a structured approach to urban planning that includes green infrastructure, targeted development corridors, improved transit, and mixed-use zoning.

5. References

Alizadeh, H., Doostvandi, M. and Zandsalimi, M. (2024) 'Redefining sustainable urban development: A critical analysis in the wake of COVID-19', *Sustainable Development*, (March 2023), pp. 1–19. doi:10.1002/sd.3018.

Anand, G. and Deb, A. (2017) 'Planning, Violations, and Urban Inclusion : A Study of Bhubaneswar', *Indian Institute for Human Settlements*, (March), pp. 1–60. Available at: http://iihs.co.in/knowledge-gateway/wp-content/uploads/2017/11/Bhubaneswar-Final.pdf.

Anas, A., Arnott, R. and Small, K.A. (1998) 'Urban Spatial Structure', *Journal of Economic Literature*, 36(3), pp. 1426–1464. doi:10.1007/978-1-349-04537-2_6.

Benton, R.A. (2019) 'Unit I', *Spoken Pangasinan*, pp. 1–34. doi:10.2307/j.ctv9hvspb.9.

Bharathi, N. *et al.* (2021) 'Fractal urbanism: City size and residential segregation in India', *World Development*, 141, p. 105397. doi:10.1016/j.worlddev.2021.105397.

Bramley, G. *et al.* (2009) 'Social sustainability and urban form: Evidence from five British cities', *Environment and Planning A*, 41(9), pp. 2125–2142. doi:10.1068/a4184.

Casson, M. and Lee, J.S. (2011) 'The origin and development of markets: A business history perspective', *Business History Review*, 85(1), pp. 9–37. doi:10.1017/S0007680511000018.

Chee, J.D. and Queen, T. (2016) 'Pearson ' s Product-Moment Correlation : Sample Analysis Pearson ' s Running head : Pearson ' s Product Moment Correlation Pearson ' s Product Moment Correlation : Sample Analysis', *ResearchGate* [Preprint], (May 2015). doi:10.13140/RG.2.1.1856.2726.

Chen, M. *et al.* (2022) 'Identifying interlinkages between urbanization and Sustainable Development Goals', *Geography and Sustainability*, 3(4), pp. 339–346. doi:10.1016/j.geosus.2022.10.001.

Chen, X.H. *et al.* (2016) 'Are investors rational or perceptual in P2P lending?', *INFORMATION SYSTEMS AND E-BUSINESS MANAGEMENT*, 14(4), pp. 921–944. doi:10.1007/s10257-016-0305-z.

Dahiya, M. (2017) 'Study on E-Commerce and it's Impacts on Market and Retailers in India', *Advances in Computational Sciences and Technology*, 10(5), pp. 1495–1500. Available at: http://www.ripublication.com.

Dambeebo, D. and Jalloh, C.A. (2018) 'Sustainable Urban Development and Land Use Management: Wa Municipality in Perspective, Ghana', *Journal of Sustainable Development*, 11(5), p. 235. doi:10.5539/jsd.v11n5p235.

Datey, A. *et al.* (2012) 'Walking and Cycling in Indian Cities: A Struggle for Reclaiming Road Edges Centre for Urban Equity (An NRC for Ministry of Housing and Urban Poverty Alleviation, Government of India) CEPT University'.

Foley, D.L. (2016) 'An Approach to Metropolitan Spatial Structure', *Explorations into Urban Structure*, pp. 21–78. doi:10.9783/9781512808063-004.

Frank, L.D. *et al.* (2010) 'Carbonless footprints: Promoting health and climate stabilization through active transportation', *Preventive Medicine*, 50(SUPPL.), pp. S99–S105. doi:10.1016/j.ypmed.2009.09.025.

Ganesh, H.R., Aithal, P.S. and Kirubadevi, P. (2020) 'Ideal Store Locations for Indian Retailers – An Empirical Study', *International Journal of Management, Technology, and Social Sciences*, (May), pp. 215–226. doi:10.47992/ijmts.2581.6012.0090.

Gower, A. and Grodach, C. (2022) 'Planning Innovation or City Branding? Exploring How Cities Operationalise the 20-Minute Neighbourhood Concept', *Urban Policy and Research*, 40(1), pp. 36–52. doi:10.1080/08111146.2021.2019701.

Guy, C.M. (1998) 'Classifications centres : Some methodological issues', *GeoJournal*, 45(1), pp. 255–264.

Hillier, B. (1996) 'Cities as Movement Systems', *Urban Design International*, 1(1), pp. 41–60.

Huff, D.L. (1964) 'Defining and Estimating a Trading Area', *Journal of Marketing*, 28(3), p. 34.

doi:10.2307/1249154.

Jhamb, D. and Kiran, R. (2012) 'Emerging trends of organized retailing in India: A shared vision of consumers and retailers perspective', *Middle East Journal of Scientific Research*, 11(4), pp. 481–490.

Kalfas, D. *et al.* (2023) 'Urbanization and Land Use Planning for Achieving the Sustainable Development Goals (SDGs): A Case Study of Greece', *Urban Science*, 7(2), pp. 1–23. doi:10.3390/urbansci7020043.

Kar, S. *et al.* (2016) 'Pattern of Road Traffic Accidents in Bhubaneswar, Odisha', *Clinical Epidemiology and Global Health*, 4(3), pp. 115–119. doi:10.1016/j.cegh.2015.07.003.

Kotni, V.V.D.P. (2019) 'A Literature Review on Impact of FDI on Indian Retail Sector', (January).

Leichenko, R.M. (2001) 'Liechenko_Growth and Change in Cities and Suburbs', 32(May 1999), pp. 1–29. Available at: papers2://publication/uuid/C3D1EFAE-7D20-489A-AF46-E133F8DC05E7.

Lima, L. *et al.* (2024) 'Urban spatial configuration and interactions with retail activities: An approach based on contact', *Cities*, 146(November 2022). doi:10.1016/j.cities.2023.104783.

Mohanty, R.D.D. (2015) 'Affordable Housing in the temple city of "Bhubaneswar"', *National Conference on Sustainable and Smart Cities (SSC-15)*, (April), pp. 165–174.

Murphy, K., Shleifer, A. and Vishny, R. (1989) 'Inc_Dist.Pdf'.

Page, M. *et al.* (2024) 'Density as an indicator of sustainable urban development: insights from Helsinki?', *European Planning Studies*, 0(0), pp. 1–21. doi:10.1080/09654313.2024.2370314.

Pathy, A.C. and Panda, G.K. (2012) 'Modeling Urban Growth in Indian Situation-A Case Study of Bhubaneswar City', *International Journal of Scientific & Engineering Research*, 3(6), pp. 1–7. Available at: http://www.ijser.org.

Porta, S. *et al.* (2009) 'Street centrality and densities of retail and services in Bologna, Italy', *Environment and Planning B: Planning and Design*, 36(3), pp. 450–465. doi:10.1068/b34098.

Pritipadmaja and Garg, R.D. (2022) 'Evaluating the Impact of Climate Change on the Urban Environment Using Geospatial Technologies in Bhubaneswar, India', *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, 48(4/W5-2022), pp. 159–166. doi:10.5194/isprs-archives-XLVIII-4-W5-2022-159-2022.

Roy, S. and Basu, D. (2020) 'Selection of intervention areas for improving travel condition of walk-accessed bus users with a focus on their accessibility: An experience in Bhubaneswar', *Transport Policy*, 96(August 2019), pp. 29–39. doi:10.1016/j.tranpol.2020.06.004.

Schuetz, J. (2015) 'Do rail transit stations encourage neighbourhood retail activity?', *Urban Studies*, 52(14), pp. 2699–2723. doi:10.1177/0042098014549128.

Shen, Y. (2017) 'Understanding Functional Urban Centrality Spatio-Functional Interaction and Its Socio-Economic Impact in Central Shanghai'. Available at: http://discovery.ucl.ac.uk/1559915/18/PhD_Thesis_Final_YS_combined.pdf.

Soltani, S. *et al.* (2022) 'The role of spatial configuration in moderating the relationship between social sustainability and urban density', *Cities*, 121(August 2021), p. 103519. doi:10.1016/j.cities.2021.103519.

Sui, D. (2015) 'The new science of cities , by Michael Batty, Cambridge, MA, The MIT Press, 2013, 496 pp., $45.00/£31.95 (hard cover), ISBN 978-0-262-01952-1 ', *International Journal of Geographical Information Science*, 29(2), pp. 345–347. doi:10.1080/13658816.2014.937717.

Teller, C. and Reutterer, T. (2008) 'The evolving concept of retail attractiveness: What makes retail agglomerations attractive when customers shop at them?', *Journal of Retailing and Consumer Services*, 15(3), pp. 127–143. doi:10.1016/j.jretconser.2007.03.003.

Thornton, L.E. *et al.* (2022) 'Operationalising the 20-minute neighbourhood', *International Journal of Behavioral Nutrition and Physical Activity*, 19(1), pp. 1–18. doi:10.1186/s12966-021-01243-3.

Turhan, G., Akalın, M. and Zehir, C. (2013) 'Literature Review on Selection Criteria of Store Location Based on Performance Measures', *Procedia - Social and Behavioral Sciences*, 99(417), pp. 391–402. doi:10.1016/j.sbspro.2013.10.507.

Wang, T. *et al.* (2018) 'Spatial distribution pattern of the customer count and satisfaction of commercial facilities based on social network review data in Beijing, China', *Computers, Environment and Urban Systems*, 71(June 2017), pp. 88–97. doi:10.1016/j.compenvurbsys.2018.04.005.

Wang, Y. *et al.* (2022) 'Evolution and control of the COVID-19 pandemic: A global perspective', *Cities*, 130(August 2020), p. 103907. doi:10.1016/j.cities.2022.103907.

Wentz, E.A. *et al.* (2006) 'Land use and land cover mapping from diverse data sources for an arid urban environments', *Computers, Environment and Urban Systems*, 30(3), pp. 320–346. doi:10.1016/j.compenvurbsys.2004.07.002.

Xing, H. and Meng, Y. (2020) 'Revealing deep semantic commercial patterns: Insights from urban landscape depiction', *Computers, Environment and Urban Systems*, 79(June 2019), p. 101404. doi:10.1016/j.compenvurbsys.2019.101404.

Yoon, H. (2018) 'Interrelationships between retail clusters in different hierarchies, land value and property development: A panel VAR approach', *Land Use Policy*, 78(July), pp. 245–257. doi:10.1016/j.landusepol.2018.06.032.

Zhong, C. *et al.* (2017) 'Revealing centrality in the spatial structure of cities from human activity patterns', *Urban Studies*, 54(2), pp. 437–455. doi:10.1177/0042098015601599.

Research Paper

Research on the Coupling Coordination Degree of Land Intensive Use and Sustainable Development in Shrinking Cities

A Case Study of Northeast China

Shuai Yu, School of Architecture and Design, Harbin Institute of Technology;Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and TechnologyMinistry of Industry and Information Technology, China

Xiaoxiang Yi(Corresponding author) , School of Architecture and Design, Harbin Institute of Technology;Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and TechnologyMinistry of Industry and Information Technology, China

Haoping Zhang, School of Architecture and Design, Harbin Institute of Technology;Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and TechnologyMinistry of Industry and Information Technology, China

Abstract

In China, the phenomenon of shrinking cities is primarily manifested by the outflow of production factors, including population, capital, and enterprises. Simultaneously, these cities continue to develop according to growth-oriented planning concepts, posing significant challenges to the sustainable and high-quality development of urban density.

This study focuses on Northeast China as an empirical case. First, an evaluation system for the degree of land intensive use is established, utilizing the entropy method to assess the spatial distribution characteristics of land intensive use in shrinking cities. Second, factor analysis is employed to evaluate the sustainable development levels of these cities, as well as their temporal and spatial variations. Finally, the coupling coordination degree model is applied to analyze the temporal and spatial differentiation patterns of the coupling coordination degree between land intensive use and sustainable development in shrinking cities.

The findings indicate a high degree of consistency between the pattern of land intensive use in Northeast China and the spatial distribution of identified shrinking cities. There exists a strong temporal and spatial coupling relationship between land intensive use and sustainable development in these cities, with the overall situation currently positioned in a transitional phase towards coupled coordination.

Keywords

Land intensive use, Sustainable development, Shrinking city, Northeast China

1. Introduction

Urban shrinkage, a growing research focus, has emerged globally with unique characteristics in China. While often driven by globalization, deindustrialization, and suburbanization in Western contexts, China's shrinkage is largely due to resource depletion and industrial restructuring, leading to population and capital outflows. Despite population loss, cities maintain a growth-oriented land expansion model, resulting in inefficient land use and vacancy issues, which challenges sustainable urban density.

Addressing these challenges, China's 2014 Guiding Opinions on Promoting Economical and Intensive Land Use aimed to regulate land use and improve land management quality, making progress (The Ministry of Land and Resources, 2014). However, urban construction land increased by over 26% between 2010 and 2020, with a 14% rise in urbanization (China Urban-Rural Construction Statistical Yearbook, 2020), leaving significant underutilized land, particularly in shrinking cities. Studies show a reciprocal influence between land use intensity and urban economic, social, and environmental systems, significantly impacting sustainable urban development.

This study investigates intensive land use in shrinking cities, focusing on the coupling relationship between land use intensity and sustainable development to illustrate land intensification's role in promoting sustainability and to provide insights for spatial planning and sustainable development strategies in shrinking cities.

2. Literature Review

The concept of sustainable development emerged in 1980 with the World Conservation Strategy (Purvis, Mao, and Robinson, 2019) and was further defined as a city framework where economic growth, quality of life, and ecological sustainability coexist (Zovanyi, 2009). Scholars have since developed multi-dimensional indicators to assess sustainable development at various levels, incorporating factors such as population, resources, economy, and society. For instance, An et al. used 19 ecological and economic indicators to evaluate regional sustainability in China (An et al., 2022); Salvati and Carlucci selected 99 variables for Italian cities (Salvati and Carlucci, 2014); and Strezov et al. used nine global indices (Strezov, Evans, and Evans, 2017). Popular evaluation methods include AHP (Fu, Li, and Li, 2014), Entropy (Wang et al., 2022), and PLS-SEM (Li and Long, 2020).

The concept of intensive land use, originally from agricultural rent theories by Ricardo, has evolved to address urban and industrial land efficiency (Lu et al., 2012). Intensive land use aims for high output on smaller areas using concentrated inputs and advanced management (Genga, Zheng, and Fu, 2017). Research has explored various facets: theoretical models like “compact development” align with China’s land use goals (Burchell, Listokin, and Galley, 2000); evaluation approaches include multi-dimensional systems and models like DEA, SFA, and Neural Networks. Studies also investigate the interaction of land use with urbanization and economic factors (Dai and Sh, 2023; Hoole, Hincks, and Rae, 2019; Zhou and Yao, 2024), though further exploration is needed on its coupling with sustainable development.

3. Research Methods and Data Sources

3.1 Research Methods

(1) Entropy Method

The Entropy Method is a multi-indicator weight calculation method based on information entropy theory, used to determine the importance weight of each indicator in a comprehensive evaluation. The core concept involves calculating the information entropy of each indicator to assess its dispersion level and, accordingly, determine its weight. In this study, the Entropy Method is applied to calculate the weights of various indicators for urban land intensive use and sustainable development. First, the raw data of each indicator (x_{ij}) is normalized using the extreme value method to obtain standardized values (x_{ij}), followed by applying the variation coefficient method from objective weighting methods to determine the weights (Bandt and Pompe, 2002).

Data Standardization: Since the measurement units and directions of the indicators may vary, data standardization is required.

$$x_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} \tag{1}$$

x_{ij}represents the value of sample i under indicator j.

$$P_{ij} = \frac{x_{ij}}{\sum_{j=1}^{m} x_{ij}} \tag{2}$$

P_{ij}represents the value of sample i after normalization under indicator j.

$$e_j = -k \sum_{i=1}^{n} P_{ij} \ln(P_{ij}) \tag{3}$$

$e_j$denotes the information entropy of indicator j, where k is a constant, generally set to $\mathrm{k} = \frac{1}{\ln(\mathrm{n})}$

$$g_j = 1 - e_j \tag{4}$$

The greater the difference in data, the greater the weight of its indicators

$$w_j = \frac{g_j}{\sum_{j=1}^{m} g_j} \tag{5}$$

In the formula, $w_j$represents the weight of indicator j.

(2) Coupling Coordination Degree Model

U_1 represents the degree of intensive land use, U_2 represents the level of sustainable development, C represents the coupling degree between the two, D represents the coupling coordination between the two, and α and β are debugging parameters. This study believes that the level of land intensive use and sustainable development in cities are equally important, therefore both coefficients are set as $\alpha = \beta = 0.5$. According to relevant literature, $(0 \leq \mathrm{C} < 0.3)$ is the low coupling stage, $(0.3 \leq \mathrm{C} < 0.5)$ is the antagonistic stage, $(0.5 \leq \mathrm{C} < 0.8)$ is the break in stage, and$(0.8 \leq \mathrm{C} < 1.0)$ is the high coupling stage (Li et al., 2012).

$$D = \sqrt{C \times T} = \left[U_1 \times U_2 / \left(\frac{U_1 + U_2}{2} \right)^2 \times (\alpha \times U_1 + \beta \times U_2)^{1/2} \right] \tag{6}$$

3.2 Construction of the Evaluation System and Indicator Selection

From the perspective of resource constraints and sustainable development, this study constructs an evaluation indicator system based on the principles of comprehensiveness, scientific rigor, systematicity, and operability. Drawing on existing literature and the "input-output" theoretical framework, the system primarily considers land use intensity, input-output efficiency, and sustainability. The Entropy Method is then applied to conduct a multi-dimensional information integration for a comprehensive assessment of land intensification levels. As shown in Table 1, population density and the proportion of construction land area represent land's population carrying capacity and total usage from different perspectives. Fixed asset investment per unit of land and the employment in secondary and tertiary industries reflect the economic and human resource inputs in land use. GDP per unit of land and general public budget revenue measure urban economic development efficiency and land use efficiency from an output perspective. Per capita park green space and forest coverage indicate ecological protection and landscape benefits of land

development. To ensure data consistency, each indicator is expressed in per capita or per unit land terms to minimize the impact of regional land area differences.

Table 1: Evaluation System for Land Intensive Use Levels. Source: Self Drawing.

Criteria Layer	Indicator Layer	Unit	Indicator Attribute
Land Intensive Use	Population Density	people/km^2	+
	Proportion of Built-Up Land Area	%	+
Land Input Intensity	Fixed Asset Investment per Unit of Land	10,000 CNY/km^2	+
	Labor Input per Unit of Secondary and Tertiary Sectors	people/km^2	+
Land Output Efficiency	GDP per Unit of Land	10,000 CNY/km^2	+
	General Public Budget Revenue	10,000 CNY	+
Land Sustainability Degree	Per Capita Park Green Space Area	m^2/people	+
	Forest Coverage Rate	%	+

Following the principles of authority, universality, reliability, comparability, and operability, this study draws on the SDGs evaluation indicator library, localized SDGs indicators within China, and existing research on urban sustainable development (Godard, 2003). After eliminating duplicate and unreliable indicators, a quantitative multicollinearity test was conducted to prevent redundancy in indicator selection. Ultimately, a framework was constructed around four subsystems—economy, livelihood, resources, and environment—encompassing 11 domains and 11 indicators.

Table 2: Evaluation System for Sustainable Development Levels. Source: Self Drawing.

System	Domain	Specific Indicator	Unit	Corresponding SDG	Attribute
Economic Development	Technological Innovation	Proportion of R&D Expenditure in Public Fiscal Expenditure	%	Goal 9: Innovation	+
	Economic Strength	Per Capita GDP	CNY/person	Goal 8: Economic Growth	+
	Industrial Structure	Tertiary Industry Output as a Proportion of GDP	%	Goal 8: Economic Growth	+

Livelihood and Well-being	Quality of Life	Per Capita Disposable Income	CNY/person	Goal 1: No Poverty	+
	Infrastructure Development	Per Capita Road Area	m^2/person	Goal 9: Resilient Infrastructure for Disaster Response	+
	Population Development	Per Capita Education Expenditure	CNY/person	Goal 4: Quality Education	+
Resource Utilization	Resource Security	Per Capita Daily Water Supply	t/person	Goal 6: Sustainable Water Supply Services	+
	Efficient Resource Use	Energy Output Efficiency	10,000 CNY/t standard coal	Goal 7: Sustainable Modern Energy	+
Environmental Quality	Pollution Control	Environmental Pollution Index		Goal 12: Sustainable Production Patterns	-
	Ecological Status	Green Coverage Rate in Built-up Areas	%	Goal 11: Sustainable Cities	+
	Environmental Management	Safe Disposal Rate of Household Waste	%	Goal 6: Sanitation and Hygiene	+

3.3 Study Area

This study focuses on these three northeastern provinces, excluding the two administrative units of Daxinganling and Yanbian Korean Autonomous Prefecture due to data availability, and involves a study of 34 prefecture-level cities.

In this study, shrinking cities within the three northeastern provinces are defined as administrative units experiencing a decrease in urban population from 2010 to 2020, while others are classified as non-shrinking cities. Population shrinkage rates for each prefecture-level city are calculated based on data from the Chinese Population Census using the following formula:

$$X_i = \frac{(P_{2020} - P_{2010})}{P_{2010}} \times 100\% \tag{7}$$

where P_{2010} represents the urban population from the sixth national population census, P_{2020} represents the urban population from the seventh census, and X_i is the population change rate.

The results indicate that from 2010 to 2020, there were 20 prefecture-level cities in the three northeastern provinces experiencing population shrinkage, accounting for approximately 60% of the region. Among them, the cities of Siping, Yichun, and Baishan had population shrinkage rates exceeding 20%. This demonstrates that population shrinkage in the three northeastern provinces is both widespread and severe in certain cities.

Table 3: List of Shrinking Cities. Source. Self Drawing.

Shrinking Cities	Siping, Yichun, Baishan, Benxi, Qitaihe, Baicheng, Tonghua, Jixi, Hegang, Suihua, Qiqihar, Jilin, Shuangyashan, Mudanjiang, Songyuan, Fushun, Heihe, Liaoyuan
Non-Shrinking Cities	Anshan, Dandong, Liaoyang, Jiamusi, Fuxin, Jinzhou, Harbin, Daqing, Yingkou, Tieling, Panjin, Huludao, Shenyang, Dalian, Chaoyang, Changchun

4. Temporal and Spatial Evolution Characteristics of Land Intensive Use

4.1 Temporal Evolution Characteristics

According to the evaluation methods described above, the levels of land intensive use for the 34 prefecture-level cities in the three northeastern provinces were measured from 2010 to 2020, with the results displayed in the figure below. As shown in Figure X, the temporal evolution of land intensive use levels for these cities initially exhibits an upward trend, followed by a decline. The average level of land intensive use across all cities increased from 0.186 in 2010 to 0.223 in 2013, but fluctuated downward from 2014 to 2020, reaching 0.191. Overall, over the past decade, the region has not experienced significant improvement in land intensive use levels, and issues of extensive land use remain unresolved.Regarding population shrinkage, it is evident that the average land intensive use levels in shrinking cities are significantly lower than those in non-shrinking cities. From 2010 to 2020, the change rate in land intensive use levels for shrinking cities was 0.01%, compared to 0.8% for non-shrinking cities, with instances in which the land intensive use level in 2020 was lower than in 2010. Among the 18 prefecture-level cities experiencing population shrinkage, 10, 12, and 14 cities had land intensive use levels below the overall average in 2010, 2015, and 2020, respectively. This indicates a regressive trend in land intensive use levels over the past decade in shrinking cities. Although land input intensity increased, the efficiency of land output and the sustainability of land use remained suboptimal.

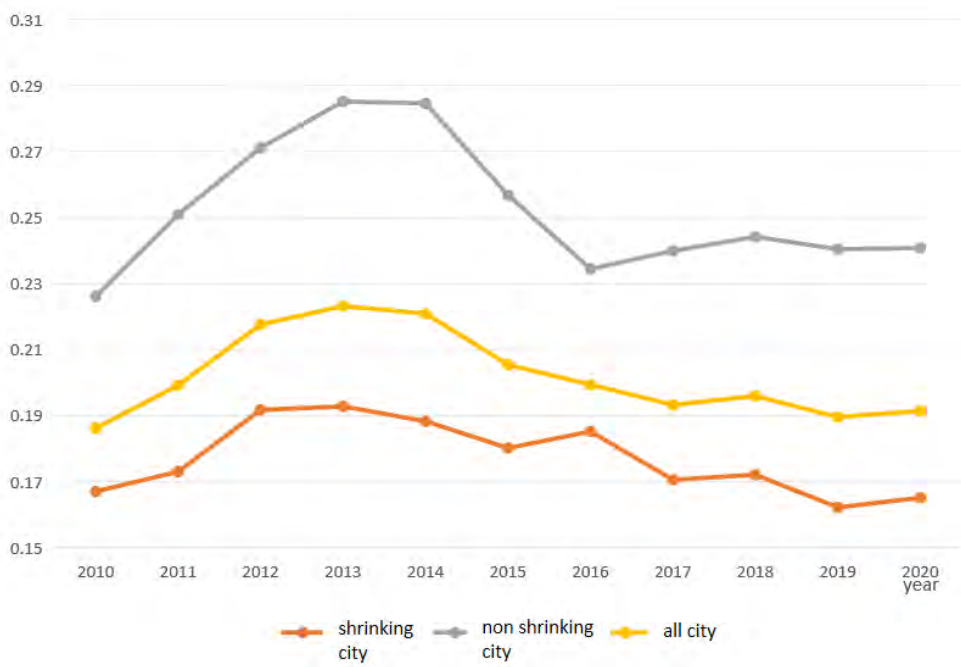


Figure 1: Evaluation Results of Land Intensive Utilization Levels in Northeast China (2010-2020). Source: Self Drawing.

For individual cities, Baicheng, Qiqihar, and Jiamusi are the three cities with the lowest level of land intensive use, with an average of 0.064, 0.075, and 0.076 over the past decade, respectively; Shenyang and Dalian are the two cities with the highest level of land intensive use, with average values of 0.0526 and 0.0532 respectively, far higher than other cities.

4.2 Spatial Evolution Characteristics

To further analyze the spatial differentiation characteristics of land use efficiency in the three provinces of Northeast China, ArcGIS natural break point method was used to classify them into three categories from low to high: low-level zone, general level zone, and high-efficiency zone, and the results were visualized and analyzed. As shown in Figure 2, the areas with high levels of land intensive use in 2010 and 2020 were mainly distributed along the Harbin Dalian axis, exhibiting obvious core periphery characteristics. With the passage of time, the level of intensive land use in the northern border areas has gradually decreased in the region, and has all evolved into low-level areas. In 2020, there was an increase in high-level cities, with three growth poles emerging in Shenyang, Dalian, and Changchun. However, there is a lack of high-level cities in Heilongjiang Province. Overall, the level of land intensive use in the three northeastern provinces shows a phenomenon of high in the south and low in the north, and high in the east and low in the west.

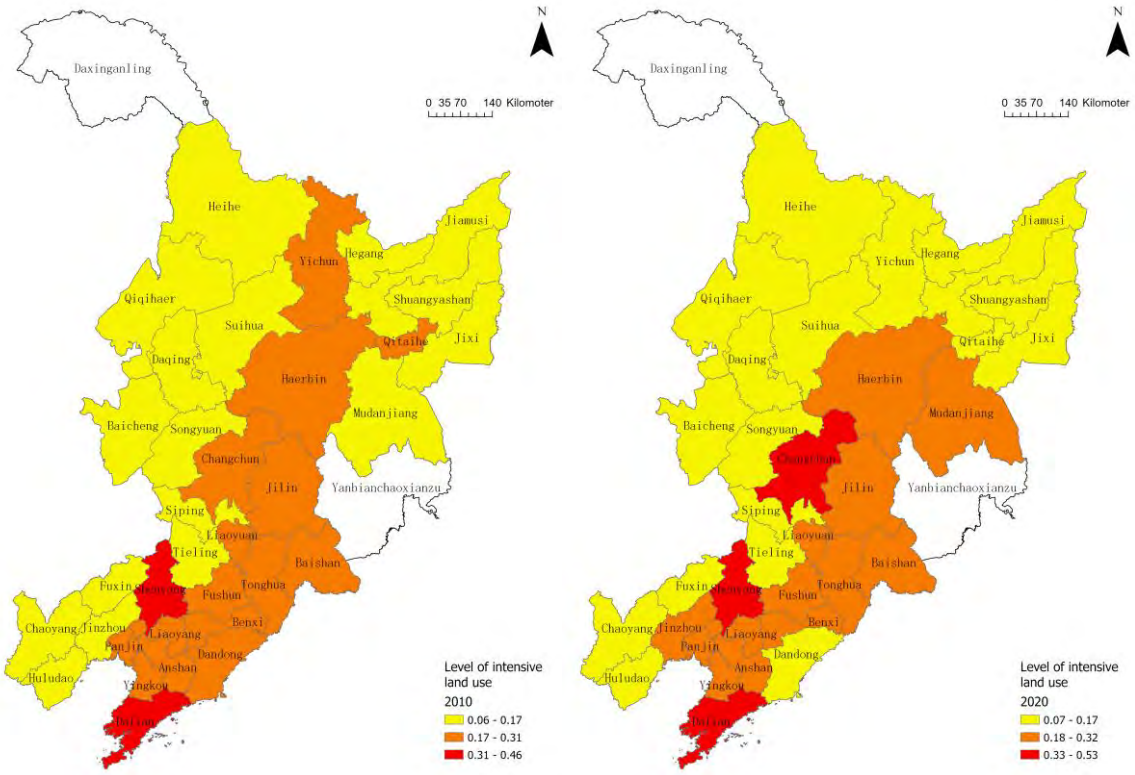


Figure 2: Distribution Pattern of Land Intensive Utilization in Northeast China for the Years 2010, and 2020. Source: Self Drawing.

On the basis of understanding the level of land intensive use in various prefecture level cities, use the "Global Moran's I" in ARCGIS to analyze the global spatial correlation and visualize the results. According to Table 4, the autocorrelation coefficients of land intensive use levels in the three prefecture level cities in Northeast China in 2010, 2015, and 2020 were all positive, and the P-values passed the significance test of 0.5, indicating a significant positive correlation and a significant agglomeration effect in space.

Table 4: Global Spatial Autocorrelation Analysis Results of Land Intensive Utilization in Northeast China. Source: Self Drawing.

Year	Moran's I	z	p
Land Intensive Use Level in 2010	0.305121	3.213665	0.001311
Land Intensive Use Level in 2015	0.276764	2.963194	0.003045
Land Intensive Use Level in 2020	0.212536	2.354618	0.018542

Further analysis of local spatial autocorrelation revealed that the hotspots gradually narrowed in scope, but remained concentrated in the southeastern region of Liaoning Province. The range of cold spots is gradually expanding, forming a "contiguous and extremely impoverished" area in the northeastern border area of Heilongjiang Province, with a few also distributed in Daqing City and Qiqihar City. Overall, the three provinces in Northeast China have formed a spatial pattern of "hot in the south and cold in the north", with hot and cold areas relatively fixed over the past decade.

Shenyang and Dalian occupy prominent central positions within the three northeastern provinces, aggregating resources and development advantages from surrounding cities. As significant growth poles for the region, they exert a strong driving effect, resulting in a marked advantage in the overall allocation and utilization efficiency of land resources in southeastern Liaoning Province. Conversely, the geographical location of the northern border areas is relatively remote. On one hand, an industrial structure primarily based on agriculture and other primary sectors constrains socio-economic development. On the other hand, due to geographical conditions and resource endowments, there is a high proportion of ecological land use, limiting the potential for adequate development and construction. This situation, in turn, hampers the improvement of land intensive use levels.

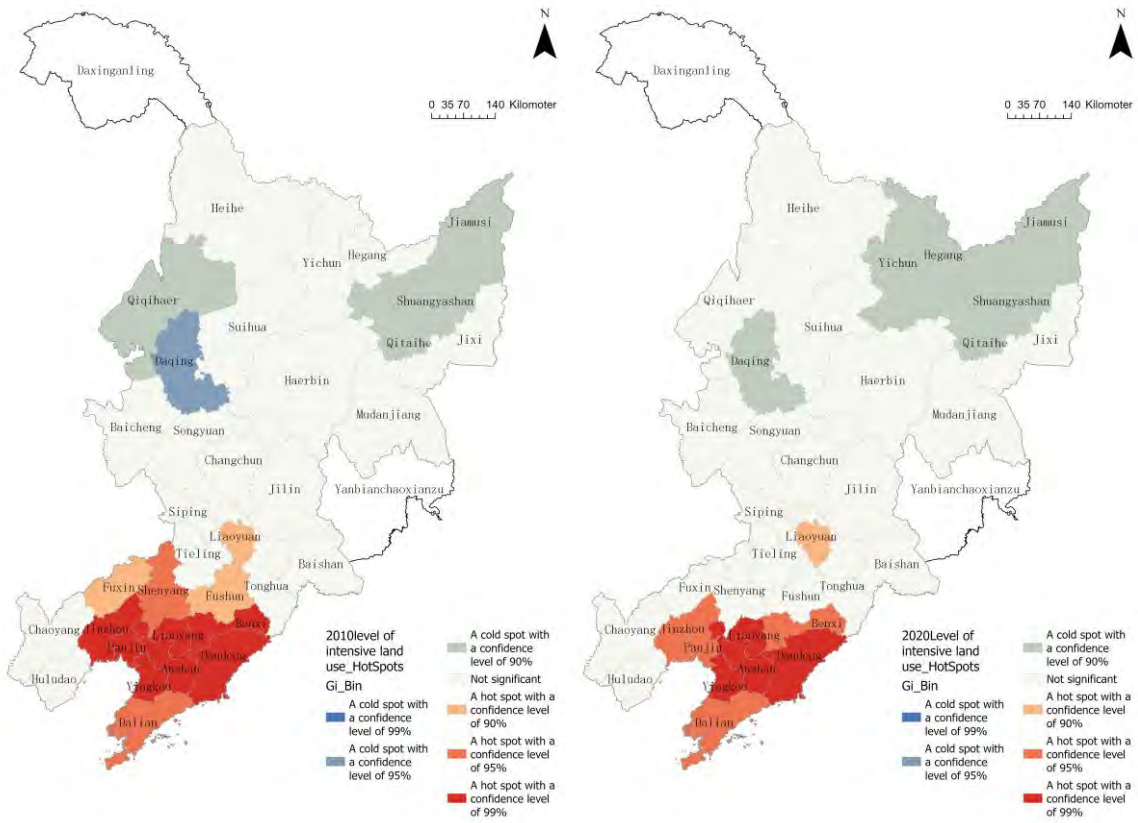


Figure 3: Hotspot Analysis of Land Intensive Utilization in Northeast China for the Years 2010 and 2020. Source: Self Drawing.

5. Temporal and Spatial Evolution Patterns of the Coupling Coordination Degree between Land Intensive Use Level and Sustainable Development

5.1 Temporal Evolution Characteristics

Based on the coupling coordination degree calculation method, this study measures the coupling coordination relationship between land intensive use levels and sustainable development levels in Northeast China from 2010 to 2020.

From a temporal perspective, the coupling coordination degree between land intensive use and sustainable development in Northeast China exhibited fluctuations over the decade, with only a modest increase overall. Between 2010 and 2013, the coupling coordination degree rose from 0.39 to 0.43; however, it declined after 2013, returning to 0.40 in 2020, approximately the same level as in 2010. Over this period, the coupling coordination level remained in the antagonistic stage.The coupling level across prefecture-level cities in Northeast China remained consistently high from 2010 to 2020, sustaining a phase of high coupling. However, coordination was relatively poor, with fluctuations showing an initial increase followed by a decrease, yet consistently remained at a low coordination level. For shrinking cities, the coupling coordination degree was persistently lower than in non-shrinking cities, with fluctuations from 2010 to 2020. During the study period, it increased only slightly from 0.355 to 0.356, with an annual growth rate of merely 0.01%, indicating a low and slow development within the antagonistic stage.Regarding coupling degree, the average value for shrinking cities was 0.973, slightly higher than 0.971 for non-shrinking cities, though the difference was minimal, with both in a high-coupling state. In terms of coordination, shrinking cities had an average of 0.140, significantly lower than the 0.222 average for non-shrinking cities,

demonstrating a more pronounced high-coupling, low-coordination pattern. At the city level, Dalian, Harbin, Shenyang, Yingkou, and Changchun had the highest coupling coordination degrees in 2020, reaching the adjustment phase, and all were non-shrinking cities. In contrast, Baicheng, Chaoyang, Fuxin, Heihe, and Shuangyashan had the lowest coupling coordination levels, remaining in the low-coupling phase and were classified as shrinking cities.

Overall, from 2010 to 2020, the coupling coordination between land intensive use and sustainable development in Northeast China remained at a low level, with slow overall progress and a lack of transition from maladjustment and decline to a coordinated coupling stage. The system's coupling degree was significantly higher than its coordination degree, reflecting a persistent imbalance characterized by high coupling but low coordination. This imbalance was especially pronounced in shrinking cities.

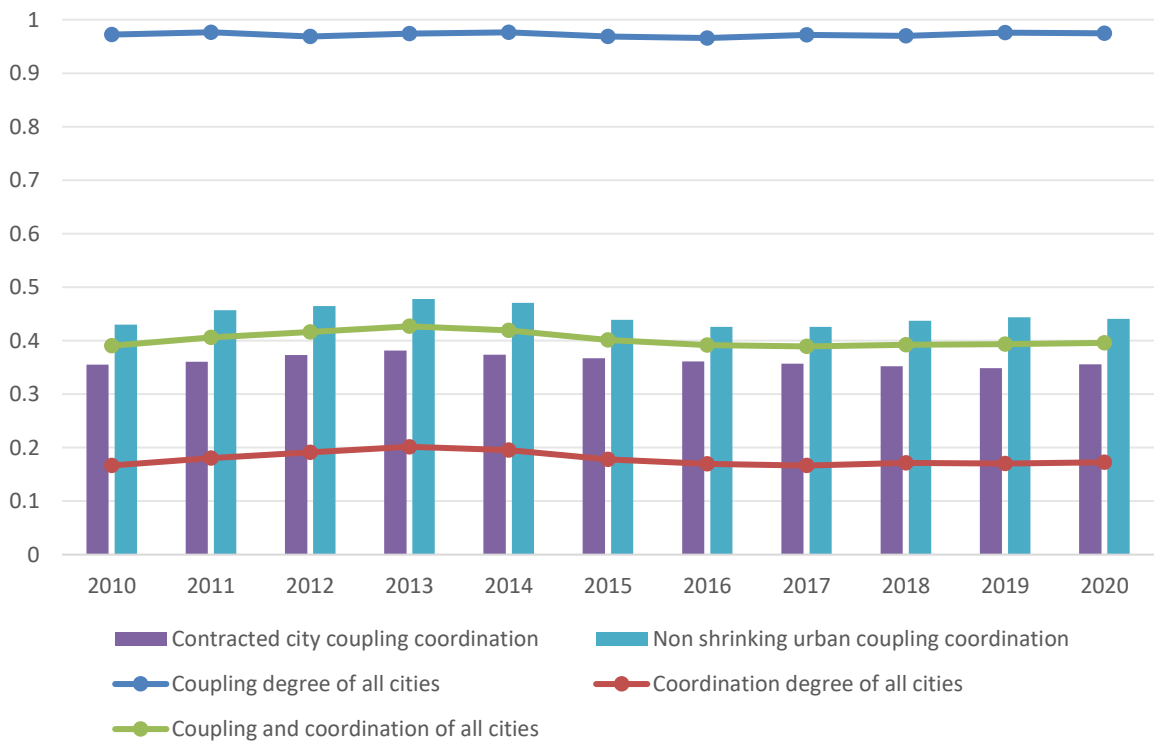


Figure 4: Evaluation Results of Coupling Coordination Degree in Northeast China (2010-2020). Source: Self Drawing.

5.2 Spatial Evolution Characteristics

Based on the coupling coordination degree calculation method, we assessed the coupling coordination relationship between land intensive use levels and sustainable development levels in Northeast China from 2010 to 2020.

As illustrated in the figure, the coupling coordination degree between land intensive use and sustainable development in Northeast China exhibits significant spatial heterogeneity. Cities along the Harbin-Dalian axis generally demonstrate higher coupling coordination degrees, displaying a gradual decrease in coordination levels from the axis towards the east and west, which highlights the prominent "core-periphery" phenomenon. During the study period, the number of cities reaching the coordination stage gradually increased, while the number of cities in the low coupling stage decreased. Notably, the number

of cities in the antagonistic stage was the highest, accounting for 74% in 2020. In 2010 a contiguous low coupling area emerged in the northeastern region of the area. Shenyang, Dalian, Changchun, and Harbin were identified as the four cities with the highest coupling coordination degrees, further emphasizing the structural significance of the Harbin-Dalian axis.

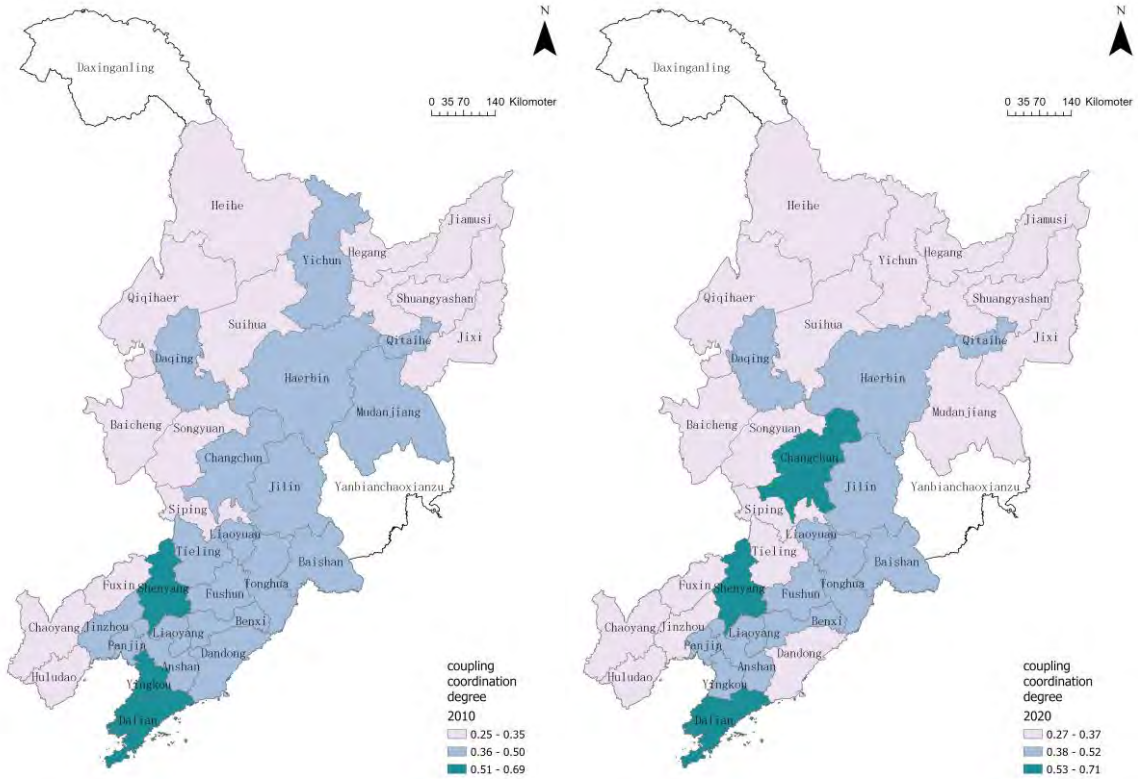


Figure 5: Spatial Patterns of Coupling Coordination Degree in Northeast China for the Years 2010 and 2020. Source: Self Drawing.

Building on the understanding of the coupling coordination degree between land intensive use and sustainable development systems across various prefecture-level cities, we employed the "Global Moran's I" functionality in ArcGIS to analyze global spatial correlations. This analysis was further enhanced by visualizing the local spatial correlation characteristics.

According to Table 5, the autocorrelation coefficients of land intensive use levels in the three prefecture level cities in Northeast China in 2010, 2015, and 2020 were all positive, and the P-values passed the significance test of 0.5, indicating a significant positive correlation in space. The correlation experienced a wave of first increasing and then decreasing, and there was a significant agglomeration effect overall in space.

Table 5: Global Spatial Autocorrelation Analysis Results of Coupling Coordination Degree in Northeast China. Source: Self Drawing.

Year	Moran's I	z	p
Land Intensive Use Level in 2010	0.177413	2.005981	0.044858
Land Intensive Use Level in 2015	0.276764	2.963194	0.003045

Land Intensive Use Level in 2020	0.212536	2.354618	0.018542

Further analysis of local spatial autocorrelation revealed that, similar to the level of land intensive use, the coupling and coordination level between the two systems remained concentrated in the southeastern region of Liaoning Province, with the regional scope gradually shrinking. But over time, the cold spot area has undergone significant changes. In 2010, only Daqing City was a cold spot city, and there were no prominent cold spot cities in 2020. The reason for this may be that the overall coupling and coordination levels in Heilongjiang Province and Jilin Province are relatively low, and the coupling and coordination levels in each prefecture level city are relatively close. Overall, the coupling coordination degree of the three provinces in Northeast China is relatively low and the development is slow. Most cities are still limited by the level of land intensive use and are in a stage of low coupling level.

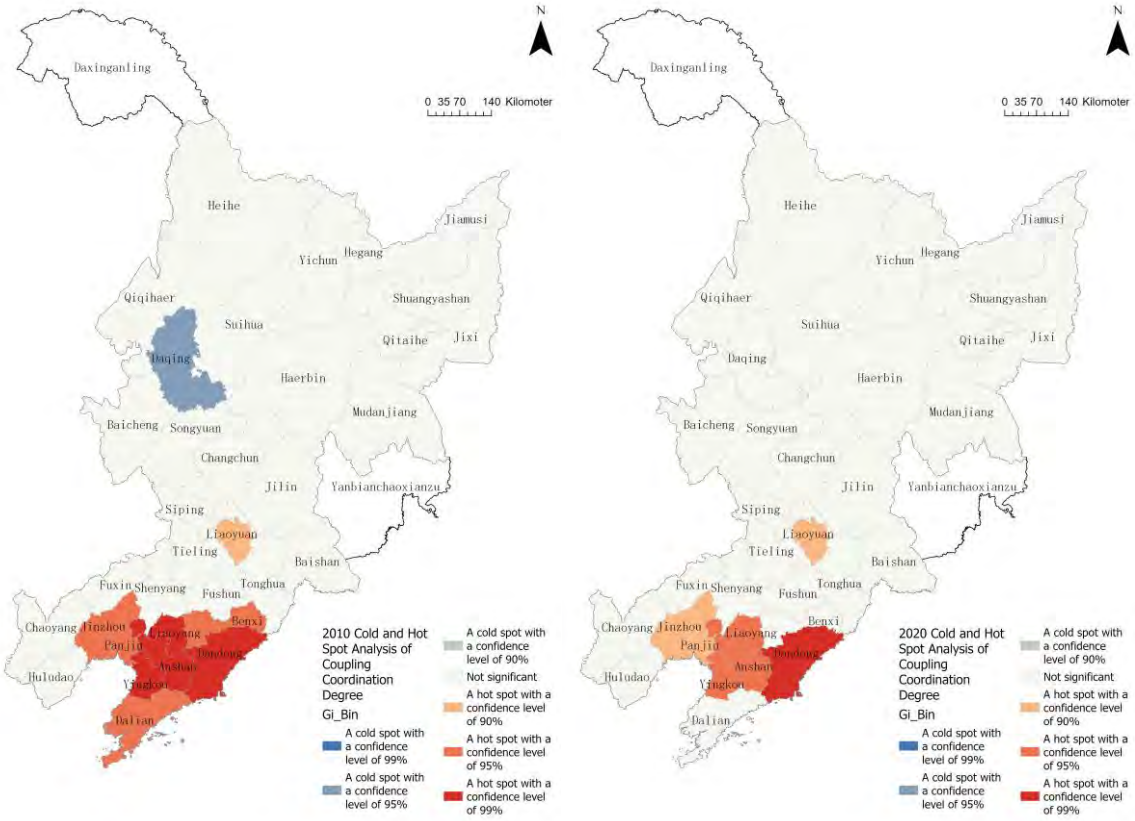


Figure 6: Cold and Hot Spot Analysis of Coupling Coordination Degree in Northeast China for the Years 2010 and 2020. Source: Self Drawing.

6. Conclusions and Discussion

This study first evaluates the land intensive use levels in the prefecture-level cities of Northeast China. Building on this evaluation, we measure the coupling coordination relationship between land intensive use and sustainable development. Empirical analysis is conducted using methods such as the entropy method, coupling coordination degree model, and geographic spatial analysis. The research conclusions are as follows:

(1) Over the past decade, there has been no significant improvement in the land intensive use levels in Northeast China. The patterns of land intensive use closely align with the spatial distribution identified in

urban shrinkage. All cities with low land use intensity are shrinking cities, while cities with higher levels of land intensive use are non-shrinking. Moreover, shrinking cities are experiencing a regression in their land intensive use levels.

(2) There is a significant spatial correlation in the land intensive use levels across Northeast China, exhibiting a pronounced core-periphery characteristic. Regions with higher land intensive use levels are predominantly distributed along the Harbin-Dalian axis, displaying a distribution pattern of higher values in the south and east and lower values in the north and west.

(3) The relationship between land intensive use and sustainable development in Northeast China remains in the antagonistic stage, with overall development progressing slowly. The region has yet to transition from a state of imbalance and decline to one of coupling and coordination. The coupling degree of the systems significantly exceeds the coordination degree, and the interaction between the two maintains a long-term high coupling—low coordination imbalance, particularly pronounced in shrinking cities.

(4) The number of cities in the three northeastern provinces that have reached the stage of integration between intensive land use and sustainable development is gradually increasing, while the number of cities in the low coupling stage is gradually decreasing, and the number of cities in the antagonistic stage is the highest. There is significant spatial heterogeneity, and the coupling and coordination degree of cities distributed along the Harbin Dalian axis is generally high. The spatial characteristics generally show a gradual decrease from the Harbin Dalian axis to the east and west.

7. References

Ahmad, M. et al. (2021) 'Dynamic interactive links among sustainable energy investment, air pollution, and sustainable development in regional China', *Environmental Science and Pollution Research*, 28(2), pp. 1502–1518. doi:10.1007/s11356-020-10239-8.

An, Y. et al. (2022) 'A partitioning approach for regional sustainability based on economic development indicators and ecological values for China', *Journal for Nature Conservation*, 67, p. 126179. doi:10.1016/j.jnc.2022.126179.

Bandt, C. and Pompe, B. (2002) 'Permutation entropy: A natural complexity measure for time series', *Physical Review Letters*, 88(17), p. 174102. doi:10.1103/PhysRevLett.88.174102.

Burchell, R.W., Listokin, D. and Galley, C.C. (2000) 'Smart growth: More than a ghost of urban policy past, less than a bold new horizon', *Housing Policy Debate*, 11(4), pp. 821–879.

Dai, Y. and Sh, Y. (2023) 'Can path dependence explain the evolution of the interaction between industrial structure and urban morphology? A case study of Changsha ancient city, China', in Djokic, V. et al. (eds.) *Praxis of urban morphology, part 2*. Proceedings of the 30th International Seminar on Urban Form Conference (ISUF). Belgrade: University of Belgrade, Faculty of Architecture, pp. 1148–1160.

Fu, P., Li, Y. and Li, X. (2014) 'Evaluation of land sustainable utilization based on analytic hierarchy process', in *2014 International Conference on GIS and Resource Management (ICGRM)*. Lancaster: Destech Publications, Inc., pp. 214–222.

Genga, B., Zheng, X. and Fu, M. (2017) 'Scenario analysis of sustainable intensive land use based on SD model', *Sustainable Cities and Society*, 29, pp. 193–202. doi:10.1016/j.scs.2016.12.013.

Godard, O. (2003) 'Sustainable development and principles of legitimacy', *Social Science Information*, 42(3), pp. 375–402. doi:10.1177/05390184030423004.

Hoole, C., Hincks, S. and Rae, A. (2019) 'The contours of a new urban world? Megacity population growth and density since 1975', *Town Planning Review*, 90(6), pp. 653–678. doi:10.3828/tpr.2019.41.

Jing, Z. and Wang, J. (2020) 'Sustainable development evaluation of the society-economy-environment in a resource-based city of China: A complex network approach', *Journal of Cleaner Production*, 263, p. 121510. doi:10.1016/j.jclepro.2020.121510.

Li, X. and Long, H. (2020) 'Research focus, frontier and knowledge base of green technology in China: Metrological research based on mapping knowledge domains', *Polish Journal of Environmental Studies*, 29(5), pp. 3003–3011. doi:10.15244/pjoes/114500.

Li, Y. et al. (2012) 'Investigation of a coupling model of coordination between urbanization and the environment', *Journal of Environmental Management*, 98, pp. 127–133. doi:10.1016/j.jenvman.2011.12.025.

Liang, R. and Qi, X. (2010) 'Simple analysis based on the ecological footprint of Linyi City for sustainable development', in Zhang, H. and Yu, X.X. (eds.) *Proceedings of symposium from cross-strait environment & resources and 2nd representative conference of Chinese environmental resources & ecological conservation society*. Marrickville: Aussino Academic Publishing House, pp. 171–175.

Lu, Z. et al. (2012) 'Study on the evaluation of urban industrial land intensive use', in Zhang, C. and Lin, P.P. (eds.) *Vibration, structural engineering and measurement II, parts 1-3*. Proceedings of the International Conference on Vibration, Structural Engineering and Measurement (ICVSEM2012). Durnten-Zurich: Trans Tech Publications Ltd., pp. 2442–2447. doi:10.4028/www.scientific.net/AMM.226-228.2442.

Purvis, B., Mao, Y. and Robinson, D. (2019) 'Three pillars of sustainability: In search of conceptual origins', *Sustainability Science*, 14(3), pp. 681–695. doi:10.1007/s11625-018-0627-5.

Salvati, L. and Carlucci, M. (2014) 'A composite index of sustainable development at the local scale: Italy as a case study', *Ecological Indicators*, 43, pp. 162–171. doi:10.1016/j.ecolind.2014.02.021.

Strezov, V., Evans, A. and Evans, T.J. (2017) 'Assessment of the economic, social and environmental dimensions of the indicators for sustainable development', *Sustainable Development*, 25(3), pp. 242–253. doi:10.1002/sd.1649.

Wang, M. et al. (2022) 'Assessing sustainable urban development based on functional spatial differentiation of urban agriculture in Wuhan, China', *Land Use Policy*, 115, p. 105999. doi:10.1016/j.landusepol.2022.105999.

Zhang, Y., Wei, Y. and Zhang, J. (2021) 'Overpopulation and urban sustainable development-population carrying capacity in Shanghai based on probability-satisfaction evaluation method', *Environment, Development and Sustainability*, 23(3), pp. 3318–3337. doi:10.1007/s10668-020-00720-2.

Zhou, Y. and Yao, H. (2024) 'Urban ecological environment space planning strategy considering land use efficiency', *International Journal of Environmental Technology and Management*, 27(4–6). doi:10.1504/IJETM.2024.139992.

Zovanyi, G. (2009) 'Confronting the "sustainable-growth" fallacy impeding the realization of sustainable development and sustainable cities', in Gospodini, A. and Brebbia, C.A. (eds.) *Sustainable city V: Urban regeneration and sustainability*. Proceedings of the 5th International Conference on Urban Regeneration and Sustainability. Southampton: WIT Press, pp. 411–420. doi:10.2495/SC080391.

The Ministry of Land and Resources (2014) *Guiding opinions of the Ministry of Land and Resources on promoting land conservation and intensive utilization*. Available at: https://www.gov.cn/xinwen/2014-09/26/content_2756852.html (Accessed: 30 October 2024).

Ministry of Housing and Urban-Rural Development of the People's Republic of China (2020) *China urban-rural construction statistical yearbook*. Hu, Z. (ed.). Beijing: China Planning Press.

Research Paper

Examining the Land Use and Land Cover Change Using Vegetation Indices in Muğla, Türkiye

Esra Kut Görgün, Ph.D., Independent Researcher, Türkiye

Abstract

Land use and land cover (LULC) changes are influenced by various driving factors over time, with urbanization being a significant contributor among others. Detecting these changes is crucial for effective land planning and management. Vegetation indices play a vital role in defining urban environments and can enhance traditional LULC change analyses. This study aims to determine whether spectral analysis focusing on vegetation indices provides significant insights into detecting LULC changes, thereby complementing conventional methods. Landsat imagery from the years 2013 and 2023 and remote sensing techniques were used to analyze LULC changes. Key vegetation indices used in this study include the Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI), and Green Chlorophyll Index (CL Green). The results indicate that the gradual degradation of natural areas due to urbanization, along with the rapid destruction caused by wildfires, has significantly impacted the natural landscapes of Muğla. While decadal changes in LULC are commonly studied, natural disasters such as forest fires can dramatically alter extensive land cover within a single year. Therefore, there is a need to shift the research focus to monitoring annual changes. Such an approach can improve the accuracy of land planning and support the development of sustainable andgreen climate-resilient cities. This study advocates the incorporation of annual vegetation monitoring and LULC changes into land management practices. Future research should emphasize more short-term monitoring to effectively address the dynamic nature of LULC changes and their environmental impacts.

Keywords

Land use and land cover change (LULCC), land use planning, remote sensing, vegetation indices

1. Introduction

Detecting land use and land cover change is crucial for effective land management, as well as for the promotion of sustainability and the mitigation of climate change. Land use and land cover (LULC) serve as major catalysts for changes in global climate patterns and environmental conditions (Khalid, 2024). These shifts can result in the degradation of natural areas, biodiversity loss, and the disruption of environmental balance. Investigating the dynamic changes in vegetation and the factors that influence them is of significant practical importance for monitoring the quality of regional ecological environments and enhancing the structure and function of ecosystems (Zhang et al., 2023).

Land use and land cover (LULC) changes are growing increasingly complex, driven by multiple factors. LULC change results from the interplay of various factors, including natural elements and political influences (Wu, 2022). Also, socio-economic factors, including population and economic conditions, have played a vital role in the change of LULC (Wang and Yang, 2019). Remote sensing and geographic information systems (GIS) are essential tools for generating maps and for examining land use and land cover change in different scales (Mane et al., 2024). These scales include as the country (Ustaoglu and Aydınoglu, 2019), basin (Berihun et al., 2019; Nyatuame et al., 2020), city (Njoku and Tenenbaum, 2022), peninsula (Krivoguz et al., 2023), and district (Islam and Ul-Zannat, 2023).

Previous studies serve various purposes, including environmental assessment (Berihun et al., 2019; Nyatuame et al., 2020), quantitative assessment (Njoku and Tenenbaum, 2022), LULC modeling (Wang and Maduako, 2018; Gaur and Singh, 2023) using RS and GIS tools. Supervised classification of satellite images is a common method for mapping and evaluating land use changes (Berihun et al., 2019). Also, land change maps should include an accuracy assessment that provides a clear description of the information such as sampling design, an error matrix, and descriptive accuracy metrics such as user's, producer's, and overall accuracy (Olofsson et al., 2013).

Vegetation indices are instrumental in LULC analyses, as they allow for detailed assessments of vegetation health and density, offering deeper insights into the extent and impact of environmental changes. Vegetation indices like NDVI are primarily affected by a range of variances in natural phenomena and anthropogenic activities (Zhang et al., 2023). Normalized Difference Vegetation Index (NDVI) measures the greenness of vegetation, provides insight into vegetation density, and allows for the assessment of changes in plant health (USGS, 2024). The Green Normalized Difference Vegetation Index (GNDVI) method is a vegetation index for estimating photosynthetic activity and the Chlorophyll Index (CL Green) method is a vegetation index for estimating the chlorophyll content in leaves using the ratio of reflectivity in the NIR and green bands (ESRI, 2024). These indices were utilized to enhance the understanding of vegetation dynamics concerning LULC changes.

This study aims to determine whether spectral analysis focusing on vegetation indices provides significant insights into detecting LULC changes, thereby complementing conventional methods. In addition to examining land use and land cover changes, shifts in NDVI, GNDVI, and Chlorophyll indices were also analyzed in Muğla between 2000 and 2023. This integration greatly enhances traditional methods, contributing to more informed and sustainable land use decisions. Muğla was selected for this study as it hosts some of Turkey's most valuable ecosystems, including Mediterranean vegetation. Consequently, this study centers on two primary research questions: How has land use and land cover changed in Muğla from 2013 to 2023? and How have vegetation index values changed in Muğla over the same period?

By addressing these questions, the research aims to deepen our understanding of LULC dynamics and vegetation trends, providing valuable insights for sustainable planning in the region.

2. Data and Methodology

2.1. Case study

Muğla is located in the southwestern part of Türkiye. Muğla is bordered on the western side by the Egean Sea, on the northern by the Aydın province, on the southeast by Antalya, and on the east by Burdur and Denizli. Muğla's population was 1,161,702 in 2023 (TURKSTAT, 2024).

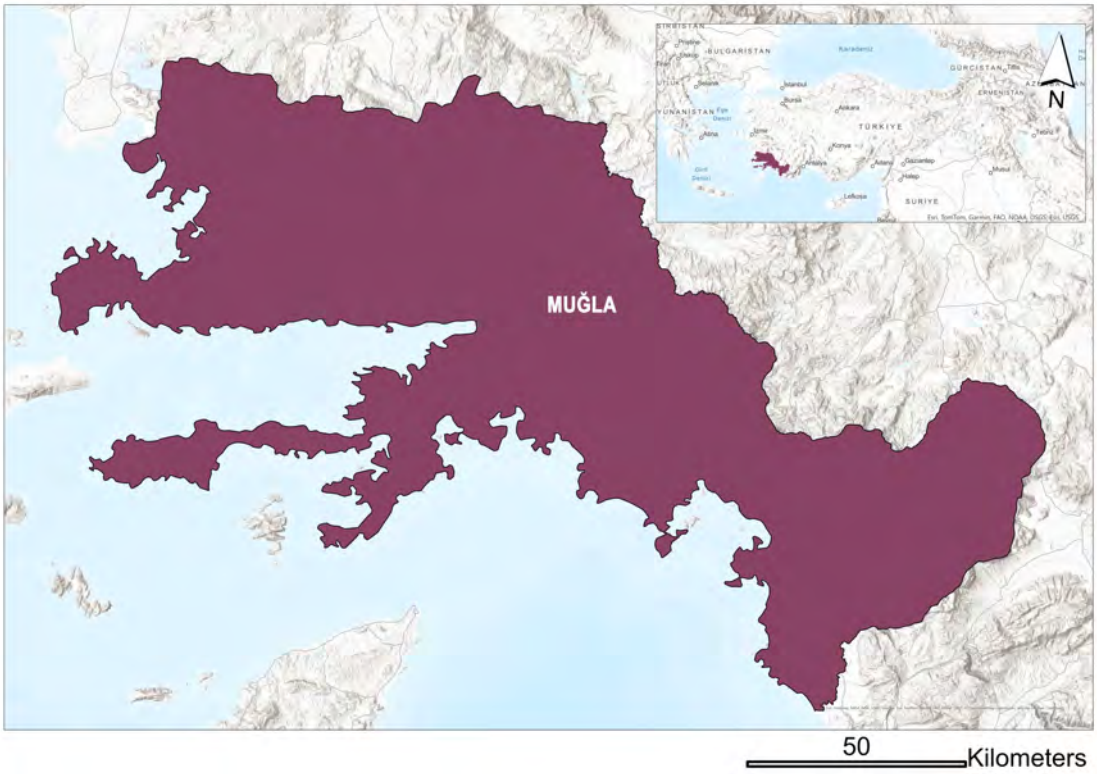


Figure 1. Location of Case Study

2.2. Methodology

In this study, Geographic Information System (GIS) and remote sensing techniques were employed to analyze land use and land cover (LULC) changes in Muğla. Landsat satellite images for the years 2013 and 2023 were obtained from the US Geological Survey (USGS, 2024), with all images captured in July to enhance classification accuracy (Cloete et al. 2024). To ensure a comprehensive representation of the study area, a cloud cover filter was applied, and multiple images from the same year were mosaicked together. This approach facilitated a more accurate and detailed assessment of the LULC dynamics in the Muğla region over the selected periods. The images were then clipped to the province borders, and an infrared composite image was generated for each year.

Following the pre-processing stage, the images were classified into six distinct land use and land cover (LULC) categories: forest, shrubland, agriculture, artificial areas, bare land, and water bodies. An accuracy assessment was conducted for each relevant land cover class, aiming to achieve an acceptable accuracy threshold of 80% or higher (Deng et al., 2009). In the accuracy assessment process, the study adhered to

the "rule of thumb" to commonly accepted guidelines for generating accuracy points (Atay Kaya and Kut Görgün, 2020).

Silva et al. (2020) emphasized that different vegetation indices exhibit varying levels of performance in identifying land cover classes, highlighting the importance of using multiple indices in a comparative approach to improve classification accuracy. Therefore, the use of three different vegetation indices was proposed in this study to enhance the reliability of land cover classification. In addition to the LULC analysis, a comprehensive examination of vegetation cover changes was conducted using the NDVI, GNDVI, and Green Chlorophyll indices in ArcGIS Pro Imagery Indices tools. After completing these steps, a ten-year change detection analysis between 2013 and 2023 was conducted in Muğla.

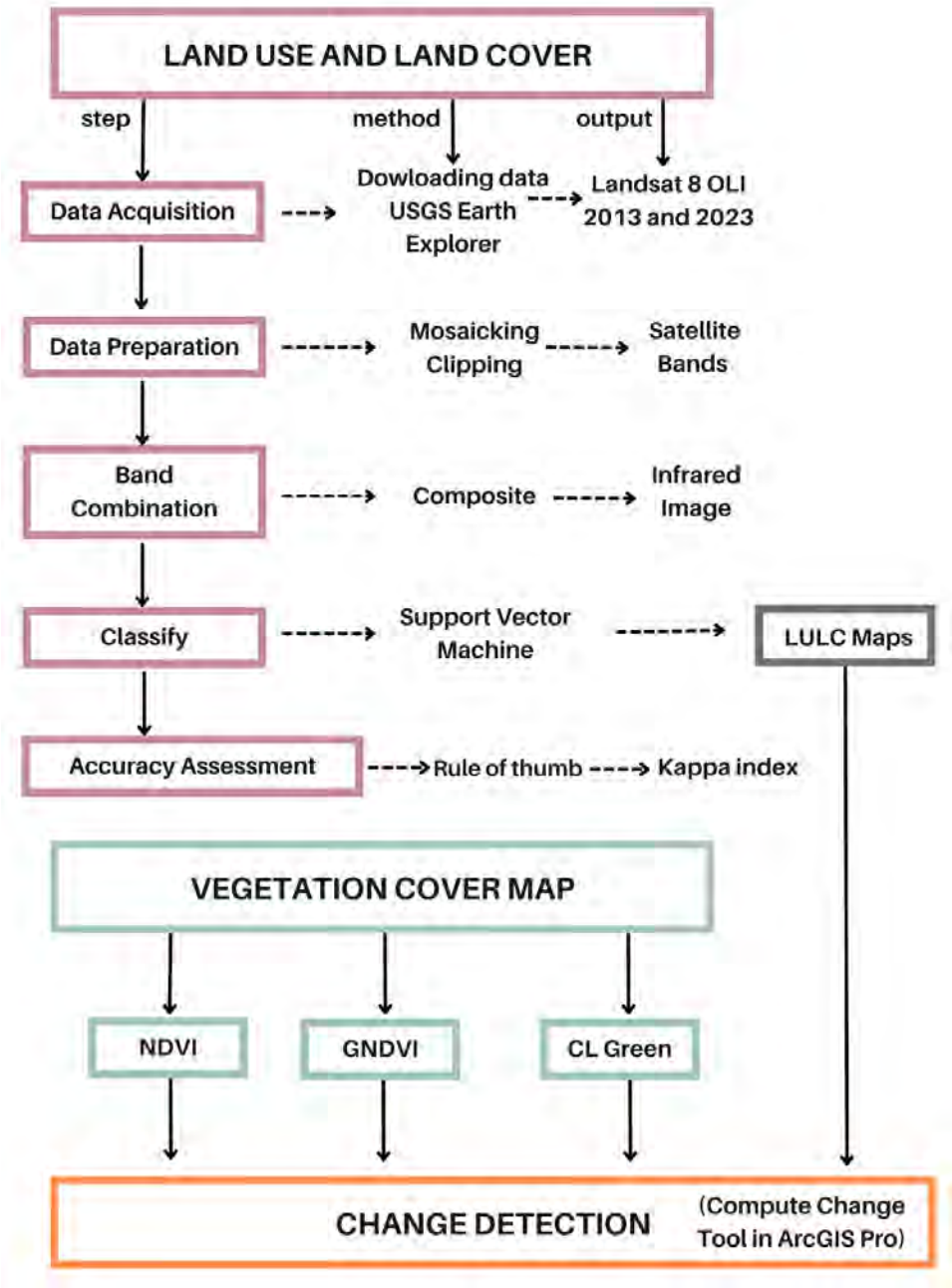


Figure 2. Flowchart

3. Results

3.1. Land use and land cover change

LULC maps were prepared for Muğla in 2013 and 2023 (Figure 3). The results revealed a decrease of 18% in agricultural land, 49% in artificial areas, and 16% in water bodies, while barren land and forest areas increased by 7% and 4%, respectively. It is important to note that "artificial areas" include not only settlements but also other human activities such as mining. Therefore, the decrease in artificial areas does not necessarily indicate a decrease in urbanization activities.

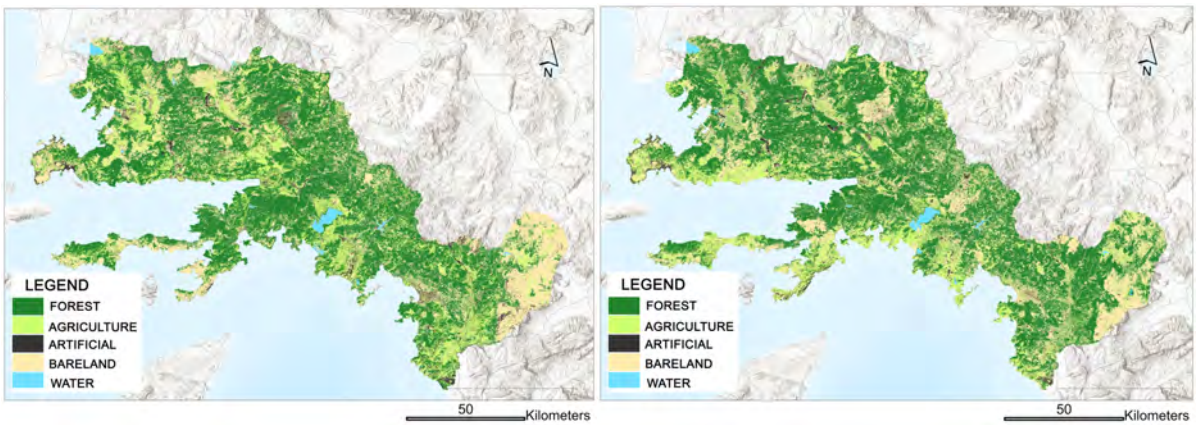
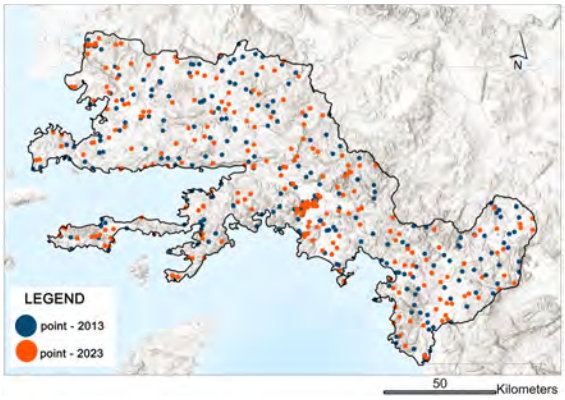


Figure 3. Land use and land cover map in 2013 and 2023

3.2. Accuracy assessment of LULC

The accuracy score and kappa statistic were used to evaluate the performance and reliability of the model. A total of 50 points per class, for a total of 250 points per year, were scored on the card (Figure 4). According to the evaluation results, the model showed that the model achieved an accuracy of 0.85 and a kappa index of 0.82 in 2013, and the accuracy of the model was 0.84 with a kappa index of 0.80 in 2023. Therefore, the results indicate that these values are acceptable, as they exceed the threshold of 0.8.



2013	C_1	C_2	C_3	C_4	C_5	Total	P_Accuracy	Kappa
C_1	50	0	0	0	0	50	1	0
C_2	10	36	0	4	0	50	1	0
C_3	0	2	31	17	0	50	1	0
C_4	1	3	0	46	0	50	1	0
C_5	0	0	0	0	50	50	1	0
Total	61	41	31	67	50	250	0	0
P_Accuracy	0.82	0.88	1.00	0.69	1.00	0.00	0.85	0.00
Kappa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.82

2023	C_1	C_2	C_3	C_4	C_5	Total	P_Accuracy	Kappa
C_1	49	1	0	0	0	50	0.98	0
C_2	11	32	1	6	0	50	0.64	0
C_3	3	4	32	11	0	50	0.64	0
C_4	0	1	0	49	0	50	0.98	0
C_5	1	0	0	1	48	50	0.96	0
Total	64	38	33	67	48	250	0	0
P_Accuracy	0.77	0.84	0.97	0.73	1	0	0.84	0
Kappa	0	0	0	0	0	0	0	0.8

Figure 4. Accuracy assessment points and accuracy matrix

These four major transitions illustrate a dynamic landscape characterized by significant shifts among forest, barren, and agricultural areas. The conversion from forest to barren land (830 km²) is particularly notable, indicating substantial deforestation. Interestingly, an almost equal area of barren land is transitioning back to forest, suggesting efforts toward reforestation or natural regeneration. The transitions from agriculture to barren land (751 km²) and from agriculture to forest (664 km²) also represent substantial land use changes, reflecting possible land abandonment or shifting priorities toward habitat restoration. However, a more detailed analysis of vegetation change using vegetation indices provides additional insights, as shown in the results below (Figure 5).

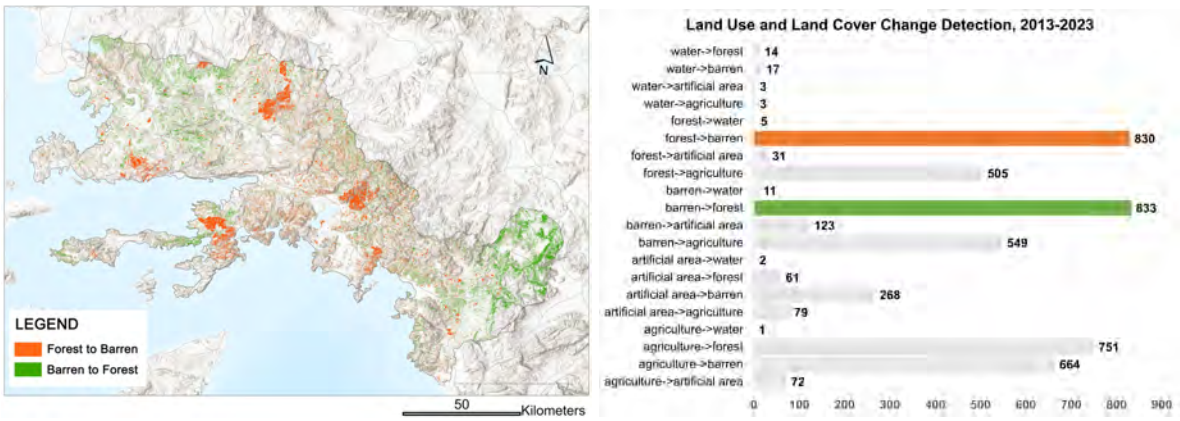


Figure 5. Land use and land cover change from 2013 to 2023 (km²)

3.3. Vegetation cover change

In 2013, the maximum value of the NDVI was 0.534, the mean value was 0.189, and the minimum value was -0.164. The NDVI values for the year 2023 are as follows: a maximum of 0.525, a mean of 0.189, and a minimum of -0.442. The stability of the mean NDVI value indicates a balance in land cover changes, whereby increases in vegetation in some areas may offset declines in others. Nevertheless, the 63% reduction in the minimum NDVI value suggests a notable decline in vegetation health or cover at the local level. In 2013, the GNDVI exhibited a maximum value of 0.488, a mean value of 0.209, and a minimum value of -0.227. By 2023, the maximum GNDVI exhibited a slight decline, reaching 0.476, while the mean value demonstrated a marginal decrease, falling to 0.203. Notably, the minimum value experienced a notable reduction, reaching -0.520. The most notable change is the 56.35% decrease in the minimum GNDVI value. In 2013, the Green CI exhibited a maximum value of 1.905, a mean value of 0.537, and a minimum value of -0.370. By 2023, the maximum Green CI value had decreased slightly to 1.813, the mean value had declined marginally to 0.520, and the minimum value had decreased significantly to -0.685. The most notable change is the 45.99% decrease in the minimum Green CI value, which declined from -0.370 to -0.685.

As a result, the minimum values of the NDVI, GNDVI, and Green CI indices demonstrated a significant decline, indicating a severe deterioration in vegetation health in specific locations. These findings underscore the necessity for a targeted spatial analysis to identify the areas experiencing the most pronounced decline.

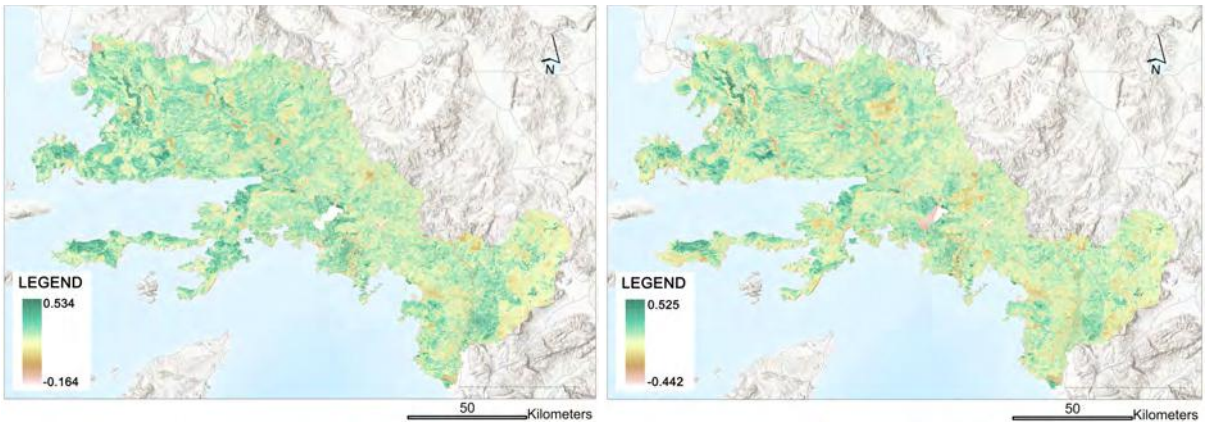


Figure 6. NDVI analysis in 2013 and 2023

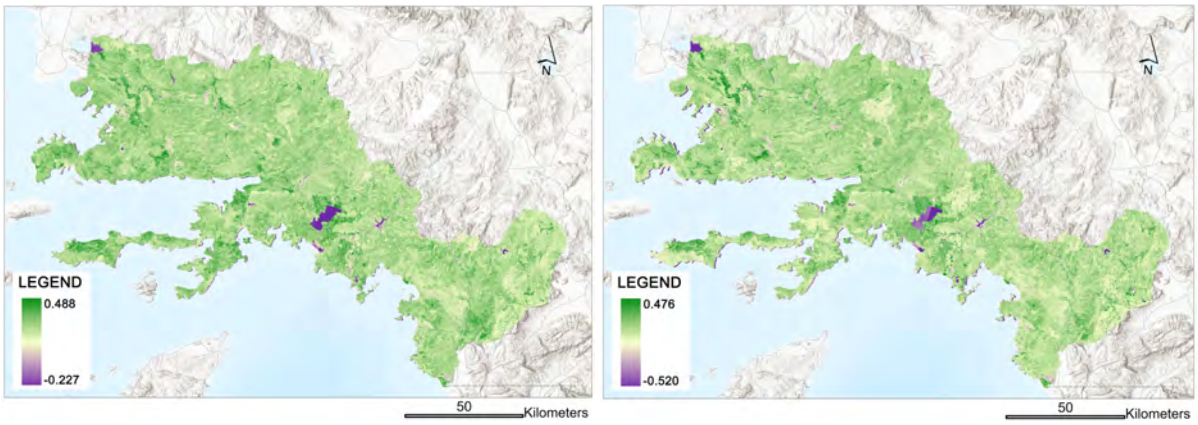


Figure 7. Green NDVI analysis in 2013 and 2023

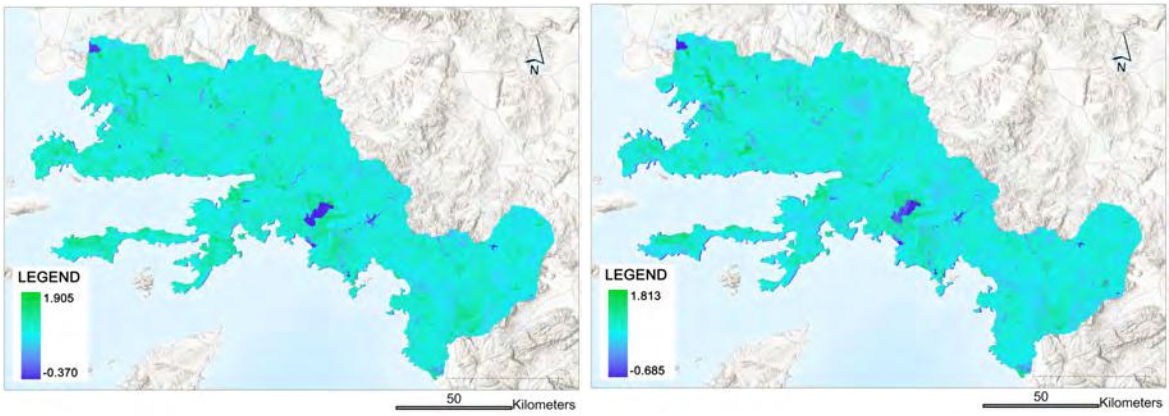


Figure 8. Green Chlorophyll analysis in 2013 and 2023

A comprehensive spatial analysis was conducted to evaluate the interannual variations in index values across all indices (Figure 9-11). Within these change detection analyses, negative values denote a decline in the measured indices from 2013 to 2023. Notably, significant declines were identified in four distinct zones, highlighting that the reductions are not uniformly distributed throughout the entire study area.

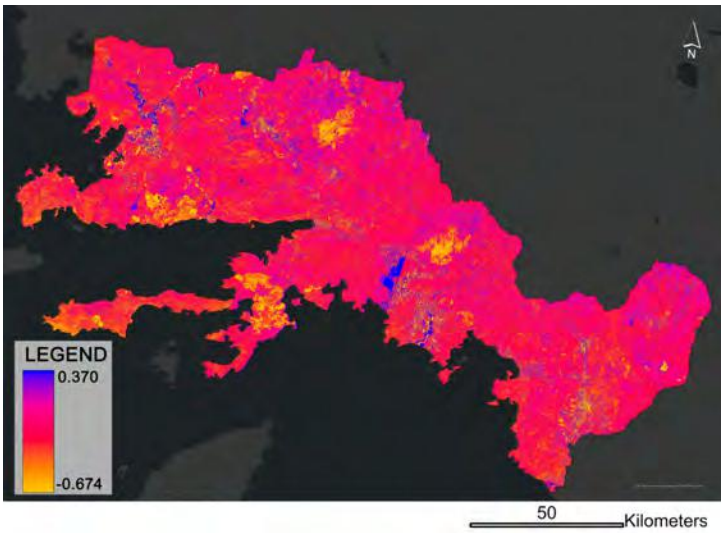


Figure 9. Spatiotemporal Change in Vegetation Cover Based on NDVI (2013–2023)

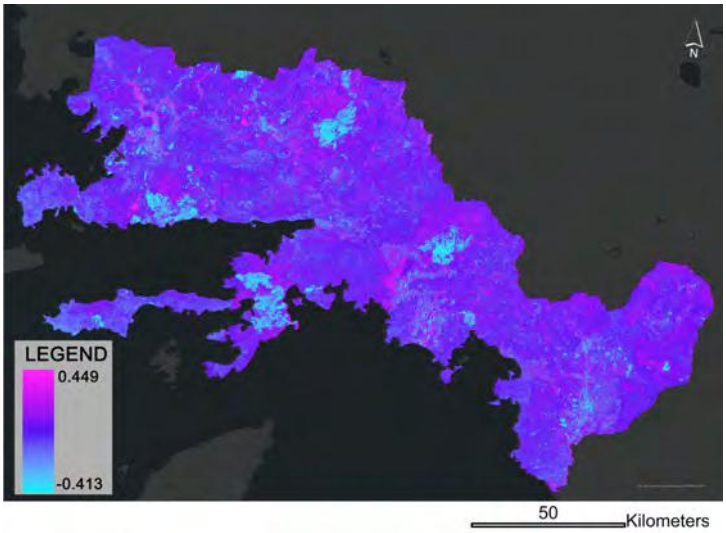


Figure 10. Spatiotemporal Change in Vegetation Cover Based on GNDVI (2013–2023)

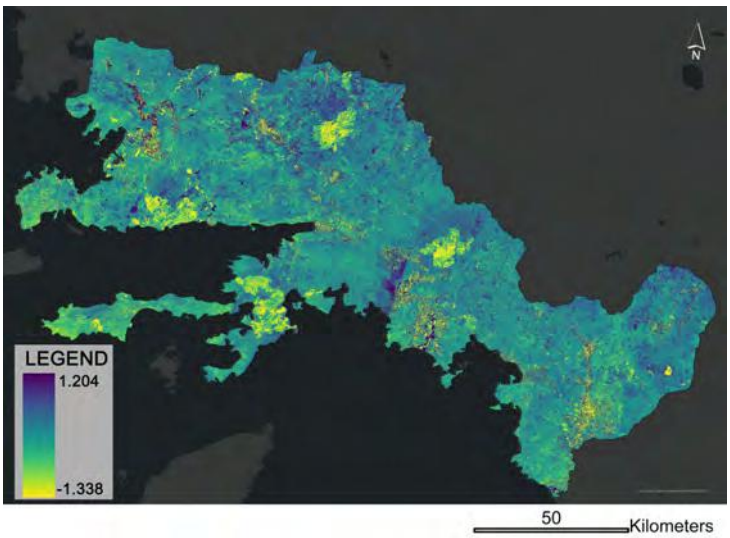


Figure 11. Spatiotemporal Change in Vegetation Cover Based on CL Green (2013–2023)

As demonstrated by the forest cover change analysis presented by Global Land Analysis, these four zones were identified as significant areas of deforestation by 2022 (Figure 12). The marked decline in vegetation cover across these region, evident in areas undergoing a transition from forested ecosystems to barren landscapes, has necessitated an assessment of the potential for wildfires. An examination of data provided by NASA confirmed that wildfire events occurred in this region on August 3, 2021 (Figure 13).

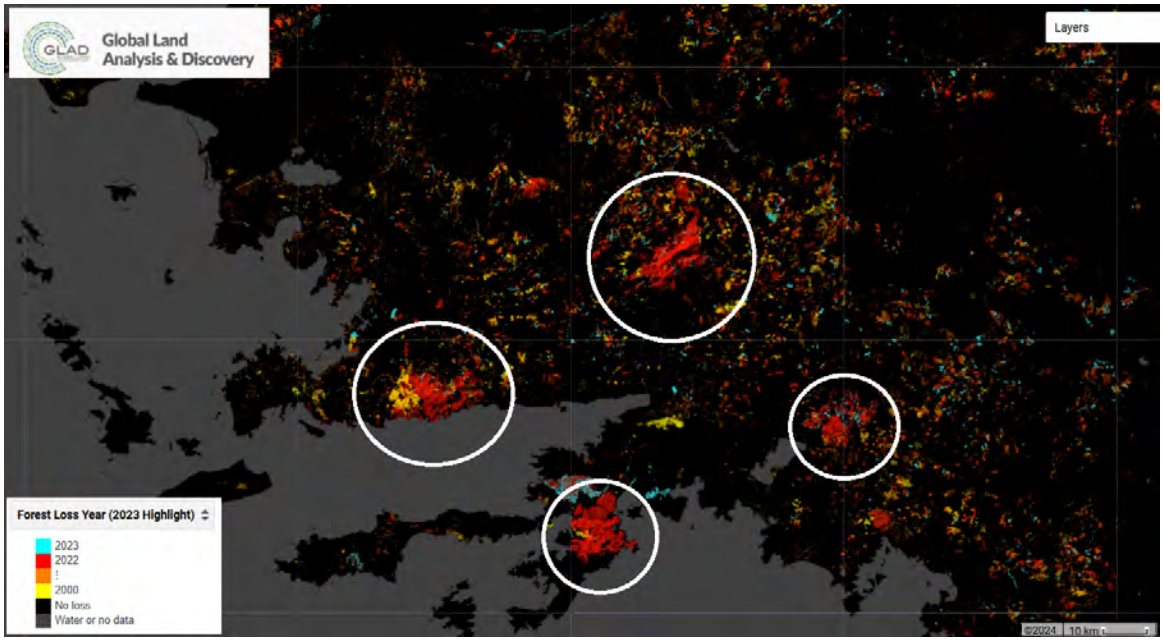


Figure 12. Density of Forest Loss in 2023 in Muğla Province (Global Land Analysis & Discovery, 2024)

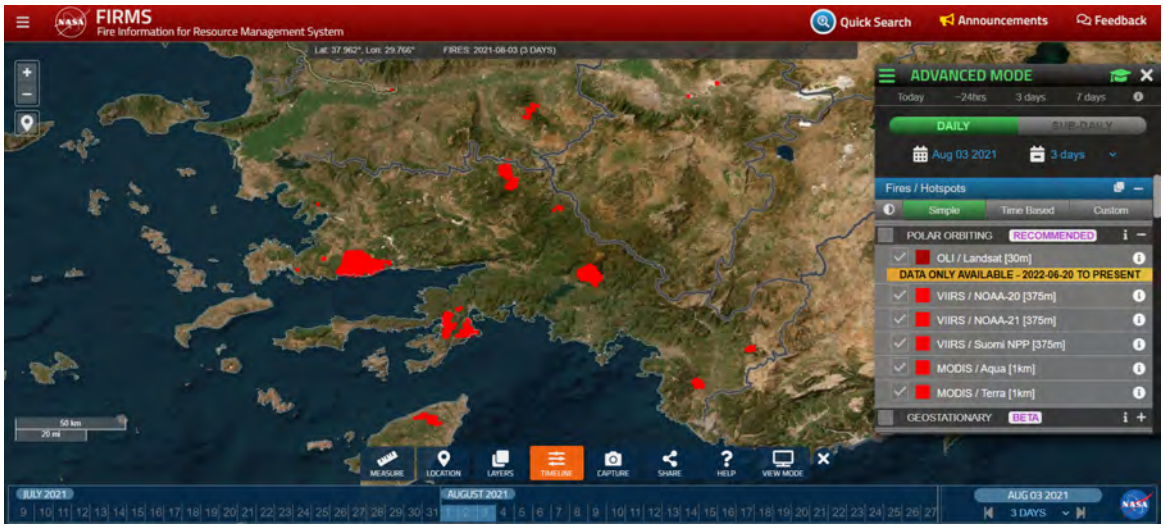


Figure 13. Fire Hotspots Detected in Muğla on 3 August 2021 According to NASA FIRMS Data (2024)

4. Conclusion

In the study, changes in land cover were examined using both LULC dynamics and vegetation indices. Although the areas transitioning from forest to bare land and from bare land to forest are similar in extent, vegetation index analyses reveal significant changes at minimum values. Specifically, four zones represent spatial variability underscoring the necessity for targeted interventions in the most affected regions to address vegetation degradation effectively. When examining the causes of change in these four regions, wildfires were identified as the primary factor. This finding emphasizes that wildfires are significant drivers of land use and land cover (LULC) changes in Muğla. This conclusion aligns with findings by Parente et al. (2023), who also identified wildfires as a key factor in LULC dynamics. However, it is different from earlier studies, such as Sejati et al. (2018), which primarily attributed deforestation to urbanization pressures rather than wildfire activity.

The stability in the mean NDVI, GNDVI, and Green CI indices values hints at a general equilibrium in vegetation cover changes across the studied region. However, the sharp decline in the minimum values underscores the presence of critical areas undergoing substantial vegetation degradation. To address these localized issues effectively, it is essential to conduct detailed spatial analyses to identify and target the most affected regions. The LULC findings supported by vegetation indices have shown considerable significance in this regard. This approach improves the clarity and reliability of LULC assessments and provides a more detailed understanding, thereby enhancing interpretability and insight. Consequently, using vegetation indices reveals critical spatial details about vegetation quality changes that may not be evident in standard LULC analyses.

Wildfires have multifaceted effects on forests, leading to changes in vegetation structure, risks to biodiversity, and the release of greenhouse gases, such as carbon dioxide, which intensify climate change (Gajendiran et al., 2024). Understanding land use and land cover (LULC) changes is essential for guiding sustainable development goals and implementing effective climate change adaptation strategies. Comprehensive knowledge of LULC dynamics promotes sustainable agricultural practices, improved land management, and biodiversity conservation. Additionally, consistent monitoring of land use is crucial for disaster management, enabling the identification of at-risk areas, enhancing disaster preparedness, and mitigating socio-economic impacts. LULC research also addresses environmental justice issues by revealing disparities in resource distribution and exposure to risks. Globally, forests hold the highest carbon stocks, followed by croplands and wetlands, highlighting the importance of conserving these critical ecosystems.

Current regional vegetation degradation assessment methods based on long-term data have key limitations, including low resolution and dependence on complex vegetation indicators (Sun et al., 2019). Looking forward, future research on land change monitoring will increasingly rely on advanced technologies such as remote sensing, machine learning, and big data analytics to achieve high accuracy. While urban expansion remains a significant driver of land change, other factors like wildfires also play a crucial role and must be integrated into monitoring frameworks. Relying solely on decades of land use change data may not provide a comprehensive picture, as it can overlook anomalies and non-linear trends. Future studies should consider different temporal scales, including vegetation cover alongside land use and land cover. By adopting these approaches, stakeholders can better manage land resources, support sustainable development, and enhance resilience against environmental challenges.

5. References

Atay Kaya, I. and Kut Görgün, E., 2020. Land use and land cover change monitoring in Bandırma (Turkey) using remote sensing and geographic information systems. *Environmental Monitoring and Assessment,* 192(7), p.430. https://doi.org/10.1007/s10661-020-08411-1

Berihun, M.L., Tsunekawa, A., Haregeweyn, N., Meshesha, D.T., Adgo, E., Tsubo, M. et al., 2019. Hydrological responses to land use/land cover change and climate variability in contrasting agro-ecological environments of the Upper Blue Nile basin, Ethiopia. *Science of the Total Environment,* 689, pp.347–365. https://doi.org/10.1016/j.scitotenv.2019.06.338

Cloete, D. N., Shoko, C., Dube, T., & Clarke, S. (2024). Remote sensing-based land use land cover classification for the Heuningnes Catchment, Cape Agulhas, South Africa. *Physics and Chemistry of the Earth, Parts A/B/C,* 134, 103559. https://doi.org/10.1016/j.pce.2024.103559

Deng, J.S., Wang, K., Hong, Y. and Qi, J.G., 2009. Spatiotemporal dynamics and evolution of land use change and landscape pattern in response to rapid urbanization. *Landscape and Urban Planning,* 92(3–4), pp.187–198. https://doi.org/10.1016/j.landurbplan.2009.05.001

ESRI, 2024. ArcGIS Pro. [online] Available at: https://pro.arcgis.com/ (Accessed 1 September 2024).

Gajendiran, K., Kandasamy, S. and Narayanan, M., 2024. Influences of wildfire on the forest ecosystem and climate change: A comprehensive study. *Environmental Research,* 240, p.117537. https://doi.org/10.1016/j.envres.2023.117537

Gaur, S. and Singh, R., 2023. A comprehensive review on land use/land cover (LULC) change modeling for urban development: current status and future prospects. *Sustainability,* 15(2), p.903. https://doi.org/10.3390/su15020903

Global Land Analysis & Discovery, 2024. GLAD- Earth Engine App. [online] Available at: https://glad.earthengine.app (Accessed 1 September 2024).

Haldar, S., Mandal, S., Bhattacharya, S. and Paul, S., 2023. Dynamicity of land use/land cover (LULC): An analysis from peri-urban and rural neighbourhoods of Durgapur Municipal Corporation (DMC) in India. *Regional Sustainability, 4*(2), pp.150–172. https://doi.org/10.1016/j.regsus.2023.05.001

Islam, M.R. and Ul-Zannat, E.M., 2023. Remote sensing based investigation of coastal LULC dynamics in the coastal region of Bangladesh. Remote Sensing Applications: *Society and Environment,* 31, p.100982. https://doi.org/10.1016/j.rsase.2023.100982

Khalid, W., Shamim, S.K. and Ahmad, A., 2024. Synergistic approach for land use and land cover dynamics prediction in Uttarakhand using cellular automata and artificial neural network. *Geomatica,* 76(2), p.100017. https://doi.org/10.1016/j.geomat.2024.100017

Krivoguz, D., Chernyi, S.G., Zinchenko, E., Silkin, A. and Zinchenko, A., 2023. Using Landsat-5 for accurate historical LULC classification: A comparison of machine learning models. *Data,* 8(9), p.138. https://doi.org/10.3390/data8090138

Mane, R., Patil, M., Wandre, S. and Dalavi, P., 2024. Preparation of land use land cover (LULC) for Panchganga River Basin using remote sensing and GIS. 17 June 2024, PREPRINT (Version 1) available at Research Square. https://doi.org/10.21203/rs.3.rs-4529737/v1

NASA, 2024. Fire Information for Resource Management System (FIRMS). [online] Available at: https://firms.modaps.eosdis.nasa.gov (Accessed 1 September 2024).

Njoku, E.A. and Tenenbaum, D.E., 2022. Quantitative assessment of the relationship between land use/land cover (LULC), topographic elevation and land surface temperature (LST) in Ilorin, Nigeria. *Remote Sensing Applications: Society and Environment*, 27, p.100780. https://doi.org/10.1016/j.rsase.2022.100780

Nyatuame, M., Amekudzi, L.K. and Agodzo, S.K., 2020. Assessing the land use/land cover and climate change impact on water balance on Tordzie watershed. *Remote Sensing Applications: Society and Environment, 20*, p.100381. https://doi.org/10.1016/j.rsase.2020.100381

Olofsson, P., Foody, G.M., Stehman, S.V. and Woodcock, C.E., 2013. Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation. *Remote Sensing of Environment, 129*, pp.122–131. https://doi.org/10.1016/j.rse.2012.10.031

Parente, J., Tonini, M., Stamou, Z., Koutsias, N. and Pereira, M., 2023. Quantitative assessment of the relationship between land use/land cover changes and wildfires in Southern Europe. *Fire,* 6(5), p.198. https://doi.org/10.3390/fire6050198

Sejati, A.W., Buchori, I. and Rudiarto, I., 2018. The impact of urbanization to forest degradation in Metropolitan Semarang: A preliminary study. *In: IOP Conference Series: Earth and Environmental Science*, Vol. 123, p.012011. doi:10.1088/1755-1315/123/1/012011

Silva, V.S., Salami, G., da Silva, M.I.O., Silva, E.A., Monteiro Junior, J.J. and Alba, E., 2020. Methodological evaluation of vegetation indexes in land use and land cover (LULC) classification. *Geology, Ecology, and Landscapes,* 4(2), pp.159–169. https://doi.org/10.1080/24749508.2019.1608409

Sun, B., Li, Z., Gao, W., Zhang, Y., Gao, Z., Song, Z. et al., 2019. Identification and assessment of the factors driving vegetation degradation/regeneration in drylands using synthetic high spatiotemporal remote sensing data—A case study in Zhenglanqi, Inner Mongolia, China. *Ecological Indicators,* 107, p.105614. https://doi.org/10.1016/j.ecolind.2019.105614

TURKSTAT, 2024. Turkish statistical data. [online] Available at: https://www.tuik.gov.tr (Accessed 1 August 2024).

USGS, 2024. Earth Explorer. [online] Available at: https://earthexplorer.usgs.gov/ (Accessed 1 June 2024).

Ustaoglu, E. and Aydınoglu, A.C., 2019. Regional variations of land-use development and land-use/cover change dynamics: A case study of Turkey. *Remote Sensing,* 11(7), p.885. https://doi.org/10.3390/rs11070885

Wang, J. and Maduako, I.N., 2018. Spatio-temporal urban growth dynamics of Lagos Metropolitan Region of Nigeria based on hybrid methods for LULC modeling and prediction. *European Journal of Remote Sensing,* 51(1), pp.251–265. https://doi.org/10.1080/22797254.2017.1419831

Wang, R. and Yang, Y., 2019. Driving forces of land use/cover change and urban construction land conversion: A case study of Tianjin. *In: IOP Conference Series: Earth and Environmental Science,* Vol. 237, No. 3, p.032040. IOP Publishing. https://doi.org/10.1088/1755-1315/237/3/032040

Wu, F., Mo, C. and Dai, X., 2022. Analysis of the driving force of land use change based on geographic detection and simulation of future land use scenarios. *Sustainability,* 14(9). https://doi.org/10.3390/su14095254

Zhang, Y., Zhang, L., Wang, J., Dong, G. and Wei, Y., 2023. Quantitative analysis of NDVI driving factors based on the geographical detector model in the Chengdu-Chongqing region, China. *Ecological Indicators,* 155, p.110978. https://doi.org/10.1016/j.ecolind.2023.110978

Research Paper

Evaluation of ecological environment quality in Harbin based on Remote Sensing Based Ecological Index

Rong GUO, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Shuo LYU, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China

Chang LIU, Shijiazhuang College of Applied Technology, China

Abstract

Urban ecological environment is the basis of human survival and development, but with the continuous increase of urbanization process, it will inevitably have an impact on ecological environment. In this paper, ecological factors such as greenness, humidity, dryness and temperature were used to build the RSEI model. With Harbin as the research area, Landsat remote sensing data of 2000, 2005, 2010, 2015 and 2020 were selected as the data source to conduct a comprehensive evaluation of the eco-environmental status of Harbin. The results show that: (1) From 2000 to 2020, the mean RSEI in Harbin increased from 0.64 to 0.70, with an increase of 9.38%. (2) From the perspective of spatial distribution, the area of poor and poor RSEI decreased, the area of moderate RSEI increased, and the area of excellent and good RSEI expanded significantly, showing a concentrated contiguity distribution. (3) The northeastern part of Harbin always maintained a high RSEI value, the western part gradually changed to a high RSEI value, and the central part fluctuated greatly. According to the requirements of ecological civilization construction, this paper puts forward countermeasures and suggestions for the improvement of the eco-environmental quality in Harbin.

Keywords

Urban ecology, RSEI, Harbin

1. Introduction

The rapid urbanization of the world has provided various benefits to human society, greatly improving the convenience of life and job opportunities for urban residents. However, the process of urbanization is accompanied by the encroachment of construction land on ecological space, which intensifies the pollution of air, water and soil. These problems affect the ecological quality of the city, and bring potential threats to the health of the residents and the stable development of the social economy. Under the background of rapid urbanization, urban ecological quality has become the focus of people's attention (Folke et al.,2016). In order to better cope with these challenges, quantitative and spatial eco-environmental quality assessment is particularly important. It can help to formulate targeted ecological protection and

restoration strategies, and provide theoretical support and practical guidance for urban planning and management.

The evaluation of ecological quality is an important means to measure the health status of eco-environmental system in a region (Shan et al.,2019). Through this evaluation, we can understand the stability, integrity and function of the ecosystem itself. However, the eco-environmental covers many elements of the natural ecosystem, such as the water, vegetation, and biodiversity. These elements are interrelated and interact with each other to form a complex ecosystem network. Therefore, its quality is difficult to be measured directly, and the eco-environmental quality is obtained indirectly in most studies. At present, most studies evaluate eco-environmental quality by selecting different evaluation index systems, such as index evaluation method and fuzzy discrimination method, to investigate the status quo and change trend of urban ecosystem from multiple dimensions (Bai et al.,2016; Asif 2016; Wu *et al,* 2022).

Some scholars have proposed the Remote Sensing Based Ecological Index (RSEI) (Xu ,2013) based on remote sensing information, which integrates four factors of greenness, humidity, heat and dryness through principal component analysis technology to comprehensively assess the overall status of regional ecological environment. Based on ecosystem classification and extraction of ecological parameters, the model can directly reflect the basic dynamics of ecological environment by evaluating the overall state of regional environment (Yue et al.,2019). RSEI can couple multiple single index comprehensive index evaluation, and can remove redundant information between indexes (Xu et al., 2018). RSEI can reduce the influence of subjective factors caused by artificial weight setting, and has the characteristics of simplicity, fast and objective. Initially, RSEI was mainly used for local or regional scales, and scholars built improved RSEI models according to the characteristics of different regional scales. At present, RSEI model has been widely used in the evaluation of regional ecological environment quality and the exploration of driving factors at different scales such as mining areas, nature reserves, wetlands, cities, regions and river basins (Yuan et al., 2021). For example, Maity (Maity et al.,2022) used RSEI to assess the ecological environment status of Kolkata urban agglomeration from 1990 to 2020, and the results showed that the impact of urbanization on the ecological environment in some areas was mitigated through the implementation of ecological management measures.

Rapid and timely evaluation of the change of ecological environment quality is the premise of realizing the coordinated and sustainable development of ecological environment and economy. In this study, the eco-environmental quality of Harbin was studied in five years: 2000, 2005, 2010, 2015 and 2020. The chosen time span includes the critical periods of urbanization, industrial growth, and the implementation of ecological policies in Harbin. Consequently, it offers robust data support for assessing the long-term trends in ecological quality and lays the foundation for future ecological management and decision-making processes.

2. Method

2.1. The study area

Harbin is located in Heilongjiang Province. It’s temperature shows obvious seasonal changes, the spatio-temporal distribution of precipitation is uneven, and the rain and heat are in the same season. The urban area of Harbin is flat and low-lying, with mountains and hills in the east, branches of Zhangguangcai Mountains in the southeast, and Small Xingan Mountains in the north. The rivers are vertical and horizontal, and the large and small rivers in the territory belong to the Songhua River system, and the change of water volume has obvious seasonal characteristics, with spring and summer two flood seasons. The total land area of Harbin is 53076.4km2, and the black soil is the most widely distributed and the most abundant soil

type. At the end of 2020, Harbin consisted of 9 districts and 9 counties, with a total population amounting to 9.485 million and annual GDP of 518.38 billion yuan. Over the past few years, Harbin's ecosystem has become more susceptible to threats, and there is a risk of continuous degradation of ecological environment quality. Therefore, the eco-environmental quality evaluation can provide strong support for local government and environmental policy formulation and adjustment.

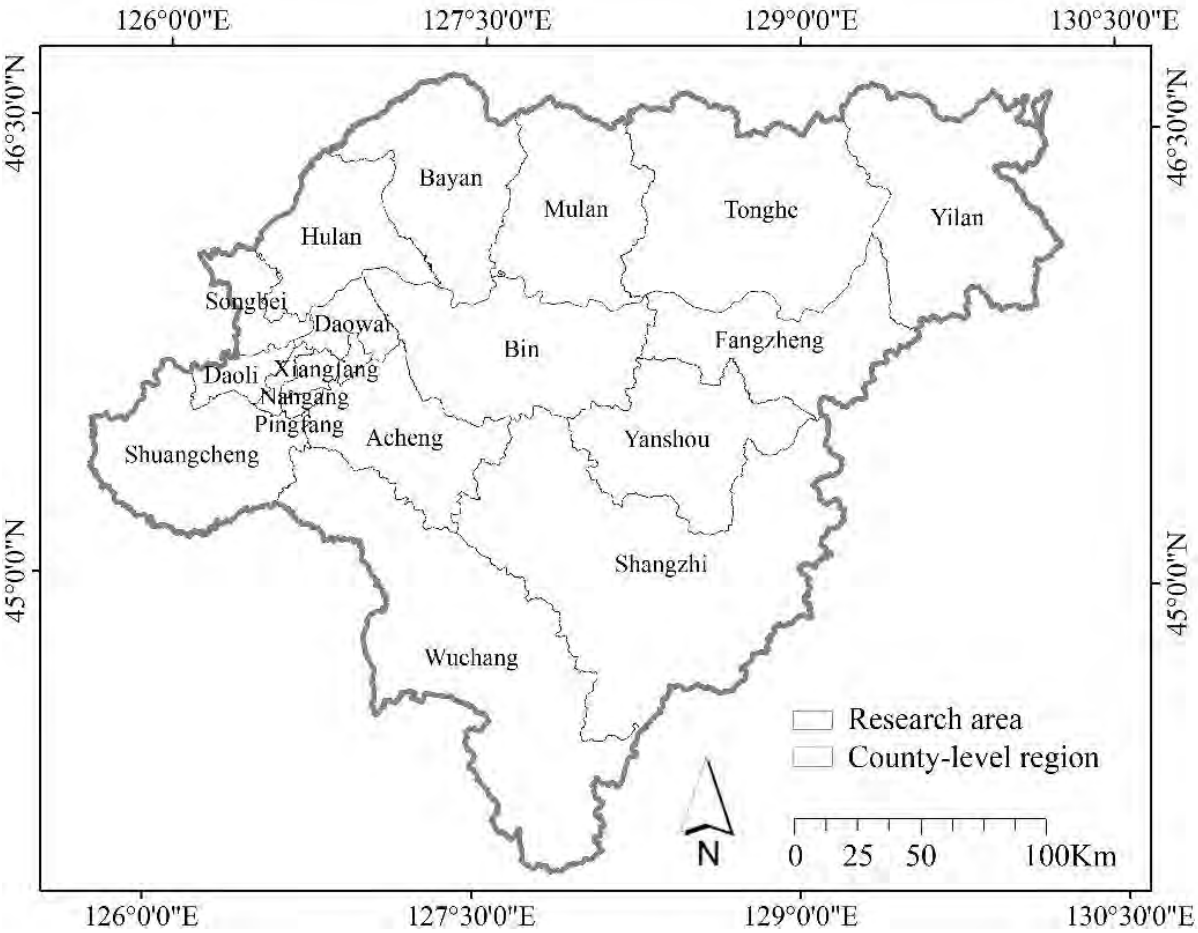


Figure 1. The study area. Source: Author self-painted.

2.2. Data Sources

The remote sensing satellite images were taken from Landsat series images with a resolution of 30m. In addition, to more comprehensively eliminate the seasons and weather as much as possible, the image with the smallest cloud cover in June to September when the plant growth is better was selected as the data.

2.3. Research Methods

RSEI takes into account the plants and the influence of the water, light and heat, which is simple and can comprehensively evaluate the quality of ecosystems by integrating multiple factors. Furthermore, PCA optimizes the evaluation index and summarize it into a comprehensive index that can characterize the ecosystem quality.

Table 1. Index summary table of remote sensing ecological index. Source: Compiled by the author.

Index	Description	Formula
Greenness	NDVI is adopted as the greenness index.	$NDVI = \frac{(\rho_{NIR} - \rho_R)}{(\rho_{NIR} - \rho_R)}$
Wetness	The Wetness Index (WET) derived from remote sensing data through fringe capacity transformation was utilized as a measure of wetness.	$WET = C_1\rho_B + C_2\rho_G + C_3\rho_R + C_4\rho_{NIR} + C_5\rho_{SWIR1} + C_6\rho_{SWIR2}$
Dryness	The surface temperature is calculated by combining brightness temperature and surface specific emissivity correction.	$LST = \frac{T_b}{\left[1 + \left(\frac{\lambda T_b}{\rho}\right)\right]}$
Heat	The IBI and the SI are utilized to quantify heat.	$NDSI = \frac{IBI + SI}{2}$

3. Results

The indexes and RSEI standardized mean values of Harbin in the five periods of 2000, 2005, 2010, 2015 and 2020 are listed in Table 2. From the perspective of time scale, from 2000 to 2020, the average RSEI in Harbin showed a continuous growth trend, from 0.64 to 0.70, with an increase rate of 9.38%. Harbin showed a significant upward trend in the past 20 years.

Greenness has gradually increased from 0.74 in 2000 to 0.82 in 2020. This is due to the development of urban green construction, ecological restoration, vegetation protection and other measures. Humidity fluctuated widely between 2000 and 2020, peaking at 0.83 in 2005, after which it declined slightly. The rise of moisture index indicates that soil moisture content or surface water area has increased, which is closely related to a series of strengthening measures taken by Harbin City in water resources management. The heat also showed a continuous upward trend, rising from 0.33 to 0.43. This reflects the enhanced urban heat island effect, which is related to urban expansion, increased building density, energy consumption and other factors. Dryness also showed an overall upward trend, but the increase was relatively small, from 0.54 to 0.60, indicating a relatively stable dryness in the region. The RSEI value increased steadily from 0.64 in 2000 to 0.70 in 2020, indicating that the ecological environment of Harbin has improved on the whole.

Table 2. Four indicators and RSEI mean value of Harbin from 2000 to 2020. Source: Compiled by the author.

Year	Greenness	Wetness	Dryness	Heat	RSEI
2000	0.74	0.70	0.33	0.54	0.64
2005	0.75	0.83	0.35	0.61	0.66
2010	0.78	0.74	0.38	0.52	0.67
2015	0.81	0.84	0.42	0.59	0.69
2020	0.82	0.78	0.43	0.60	0.70

To more comprehensively evaluate the eco-environmental quality of Harbin, we divided the RSEI value of each year into 5 grades, which successively represented 5 grades of poor, poor, medium, good and excellent quality.

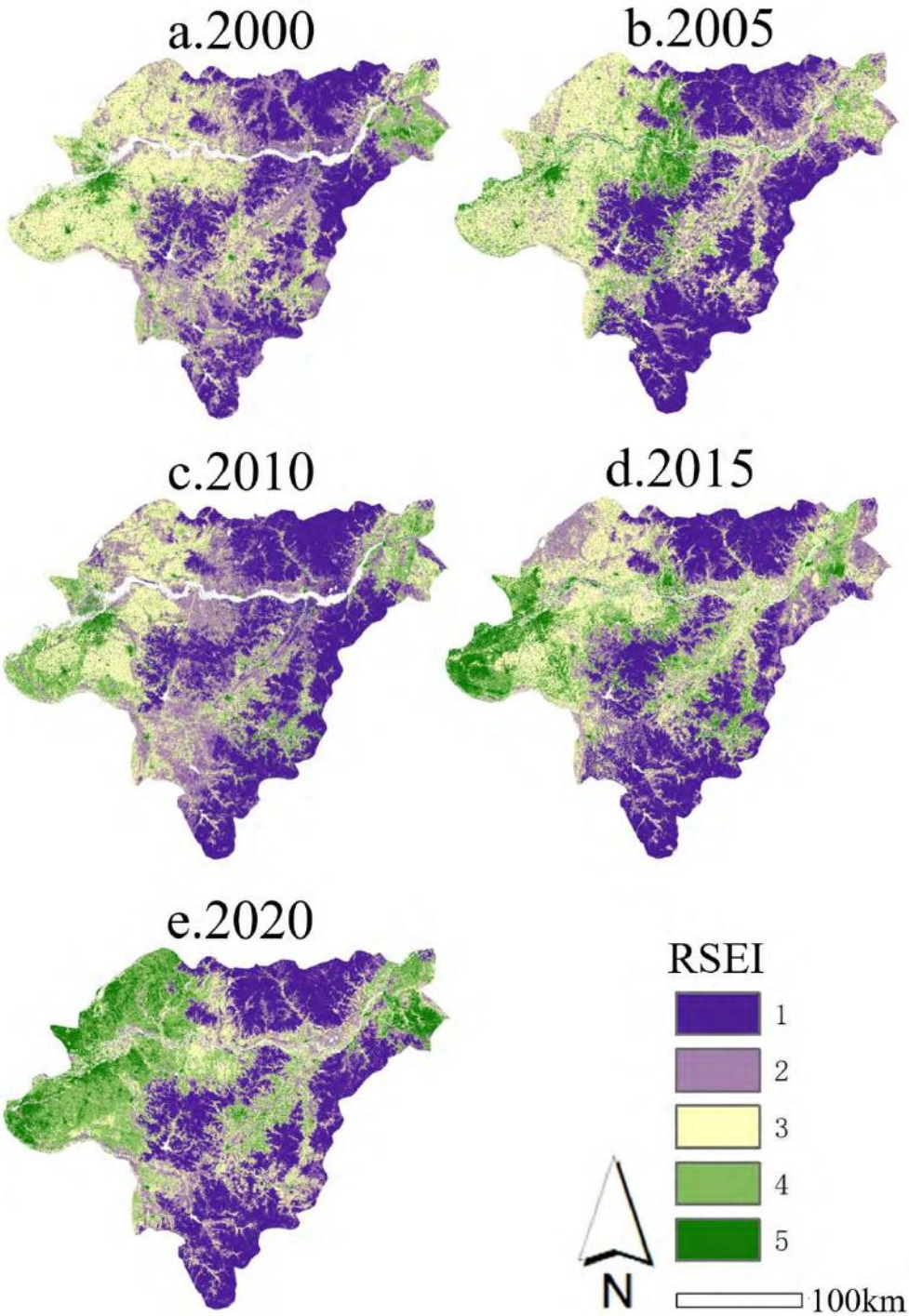


Figure 2. Spatial pattern of RSEI in Harbin from 2000 to 2020. Source: Author self-painted.

From the perspective of spatial distribution, the area of low RSEI value in 2000 was large, concentrated in tonghe, shangzhi and wuchang. The region with medium RSEI is the second, and the area with excellent RSEI and good RSEI is small. On the whole, RSEI in Harbin in 2000 was general and showed obvious spatial differentiation. Among them, the development of resources such as sand and gravel in Tonghe may lead

to ecological degradation, while the expansion of agricultural activities in Shangzhi and Wuchang may cause pressure on the ecosystem. Compared with 2000, the area of low RSEI decreased in 2005, while the area of middle RSEI increased and became more concentrated. The area of RSEI good also increased, but the area of RSEI good changed relatively little. This may be because the best areas are usually located in nature reserves or ecological core areas with less variability. In 2010 and 2015, the area of low-value RSEI decreased significantly, while the area of high-value RSEI expanded significantly. There were fewer RSEI medium regions in 2015 compared to 2010. In 2020, the high-value RSEI area expands significantly and presents a concentrated contiguity of distribution characteristics, while the low-value and medium-value RSEI areas further shrink, indicating that the ecological quality continues to improve and the health and stability of the ecosystem has been significantly improved.

During 2000-2020, the overall trend of RSEI in Harbin is good, but the spatial differentiation was still obvious. The northeast always maintained a high RSEI value, the western region gradually changed to a high RSEI value, and the central region fluctuated greatly, and the overall spatial pattern changed significantly. The RSEI level showed an obvious upward trend, the low and medium RSEI areas gradually decreased, while the high RSEI areas gradually expanded. This indicates that the ecological environment indicators such as vegetation cover and humidity in Harbin have been improved, which is related to the implementation of local environmental management measures.

Table 3 lists the areas and proportions of each level of ecological quality in Harbin. The area of RSEI of different grades in Harbin changed significantly from 2000 to 2020, and the area proportion of low-value areas continued to decline from 2000 to 2010, but the decline narrowed from 2010, and even rebounded in 2015. The area shared of the middle class declined between 2000 and 2010, but rebounded after 2010. The proportion of high-value areas continues to rise, which reflects that Harbin has achieved remarkable results in improving the ecological environment.

Table 3. Statistical table of the percentage of RSEI value of each grade in Harbin from 2000 to 2020.

Source: Compiled by the author.

RSEI	2000		2005		2010		2015		2020	
	area/ km^2	percent /%	area /km^2	percent /%	area /km^2	percent /%	area /km^2	percent /%	area /km^2	percent /%
very poor	14657	28	17885	34	17638	33	15976	30	17340	33
poor	14559	27	13761	26	10087	19	11301	21	9261	17
medium	16378	31	12462	23	15713	30	13586	26	9576	18
good	4681	9	5772	11	7131	13	8234	16	11871	22
excellent	1714	3	2109	4	2531	5	4002	8	5052	10

4. Conclusion

Taking 2000-2020 as the research period, this study quantified key ecological indicators through the construction of RSEI model, systematically analyzed the characteristics of Harbin's eco-environmental quality, and drew the following conclusions.

(1) From 2000 to 2020, the average RSEI in Harbin showed a continuous increasing trend, rising from 0.64 to 0.70, with an increase of 9.38%. This shows that the ecological quality of Harbin has improved.

(2) From 2000 to 2020, the greenness gradually increased from 0.74 to 0.82, indicating that the vegetation cover of Harbin has shown a significant improvement trend in the past 20 years. Humidity peaked at 0.83 in 2005. The increase of moisture index indicates that the soil moisture content or surface water area has increased. The heat increased from 0.33 to 0.43, reflecting the enhanced urban heat island effect. The dryness increased from 0.54 to 0.60, indicating a relatively stable dryness in the region.

(3) From 2000 to 2020, the area of coastal RSEI with low value is larger, followed by the area with medium value, and the area with high value is smaller. On the whole, the area of low-value RSEI decreased, the area of medium-value RSEI increased, and the area of high-value RSEI expanded significantly, showing the characteristics of centralized and contiguity distribution.

(4) From 2000 to 2020, the overall spatial differentiation of RSEI in Harbin is obvious. The northeast always maintains a high RSEI value, and the ecological quality is good and stable. The western region gradually changes to a high RSEI value, and the central region fluctuates greatly.

5. Countermeasures and suggestions

In the past 20 years, Harbin has made progress in actively implementing green development, ecological protection and restoration. Combined with the status quo of eco-environmental quality in Harbin, efforts should still be made in ecological protection and environmental governance.

(1) We will control new construction land, and avoid blind expansion. Priority should be given to the development of green Spaces such as parks, ecological corridors and wetlands to form a coherent ecological network. This can not only effectively improve the ecological environment of Harbin, but also improve the overall landscape quality of the city and the living comfort of residents.

(2) Increase vegetation coverage and improve ecological service functions. Actively expand urban green areas and improve vegetation coverage. Different types of vegetation have different contributions to air quality, soil and water conservation, biodiversity and so on. According to the natural conditions of different regions, suitable vegetation types should be selected, and the conservation and management of existing green space should be strengthened to improve its ecological service function.

(3) Improve the green land rate of built-up areas, create a comfortable environment, improve the environment of community public areas. This can not only beautify the urban landscape, but also improve the urban microclimate.

(4) While accelerating economic development, we ought to focus on ecological protection and strengthen the positive interaction between resource development and environmental protection in Harbin. We will strengthen the protection of forest lands, cultivated land and water areas, protect forest vegetation and biodiversity, and reduce soil erosion.

(5) The seasonal variation of annual precipitation in Harbin city is large, which is easy to cause regional urban flood disasters, protect the surface ecological environment and alleviate flood disasters, purify

harmful substances in the environment, conserve water sources, and provide conditions for the development of biodiversity.

6. References

Asif M. (2016) 'Growth and Sustainability Trends in the Buildings Sector in the GCC Region with Particular Reference to the KSA and UAE', *Renewable and Sustainable Energy Reviews,* 55, pp.1267-1273.

Bai Y., Jiang B., Wang M., et al. (2016) 'New Ecological Redline Policy (ERP) to Secure Ecosystem Services in China', *Land Use Policy,* 55, pp.348-351.

Boori M.S., Choudhary K., Paringer R., et al. (2021) 'Spatiotemporal ecological vulnerability analysis with statistical correlation based on satellite remote sensing in Samara, Russia'. *Journal Environmental Management,* 285, pp.112138.

Folke C., Biggs R., Norström A.V., et al. (2016) 'Social-Ecological Resilience and Biosphere-Based Sustainability Science', *Ecology and Society,* 21(3), p.41.

Karimi F. M., Fathololoumi S., Kiavarz M., et al. (2021) 'Land Surface Ecological Status Composition Index (LSESCI): A novel remote sensing-based technique for modeling land surface ecological status'. *Ecological Indicators,* 123, pp.107375.

Liu H., Jiang Y., Misa R., et al. (2021) 'Ecological environment changes of mining areas around Nansi lake with remote sensing monitoring', *Environmental Science and Pollution research*, 28(32), pp.44152-44164

Maity S., Das S., Pattanayak J.M., et al. (2022) 'Assessment of ecological environment quality in Kolkata urban agglomeration, India', *Urban Ecosystems*, 25(4), pp.1137-1154.

Shan W., Jin X., Ren J., et al. (2019) 'Ecological environment quality assessment based on remote sensing data for land consolidation', *Journal of Cleaner Production,* 239, pp.118126.

Wen X., Ming Y., Gao Y., et al. (2020) 'Dynamic monitoring and analysis of ecological quality of pingtan comprehensive experimental zone, a new type of sea island city, based on RSEI'. *Sustainability,* 12(1), p.21.

Wu S., Gao X., Lei, J. et al. (2022) 'Ecological environment quality evaluation of the Sahel region in Africa based on remote sensing ecological index'. *Journal of Arid Land,* 14(1), pp.14-33.

Xiong Y., Xu W., Lu N., et al. (2021) 'Assessment of Spatial–Temporal Changes of Ecological Environment Quality Based on RSEI and GEE: A Case Study in Erhai Lake Basin, Yunnan Province, China'. *Ecological Indicators*, 125, p.107518.

Xu H. (2013) 'A remote sensing index for assessment of regional ecological changes', *China Environmental Science,* 33(5), pp.889-897.

Xu H., Wang M., Shi T., et al. (2018) 'Prediction of ecological effects of potential population and impervious surface increases using a remote sensing based ecological index (RSEI)', *Ecological Indicators,* 93, pp.730–740.

Yang X.Y., Meng F., Fu P.J., et al. (2021) 'Spatiotemporal change and driving factors of the Eco-Environment quality in the Yangtze River Basin from 2001 to 2019', *Ecological Indicators*, 131, p.108214

Yuan B.D., Fu L.N., Zou Y., et al. (2021) 'Spatiotemporal change detection of ecological quality and the associated affecting factors in Dongting Lake Basin, based on RSEI', *Journal of Cleaner Production*, 302, p.126995

Yue H., Liu Y., Li Y., et al. (2019) 'Eco-Environmental Quality Assessment in China's 35 Major Cities Based on Remote Sensing Ecological Index', *IEEE Access,* 7, pp.51295-51311.

Zhang X., Fan H., Zhou C., et al. (2023) 'Spatiotemporal Change in Ecological Quality and Its Influencing Factors in the Dongjiangyuan Region, China'. *Environmental Science and Pollution research,* 30(26), pp.69533–69549.

Zheng Z.H., Wu Z.F., Chen Y.B., et al. (2020) 'Marinello Exploration of eco-environment and urbanization changes in coastal zones: A case study in China over the past 20 years', *Ecological Indicators*, 119, p.106847

Zhou Z., Du J., Liu Y. (2020) 'Evolution development and evaluation of eco-transportation in Guangdong-Hong Kong-Macao Greater Bay Area'. *Systems Science & Control Engineering*, 8(1), pp.97-107.

Zhu D.Y., Chen T., Niu R.Q., et al. (2021) 'Analyzing the Ecological Environment of Mining Area by Using Moving Window Remote Sensing Ecological Index'. *Geomatics and Information Science of Wuhan University*, 46(3), pp.341-347.

Research Paper

Study on the correlation between pm2.5 and urban vitality in megacities in china over the past 20 years

a case study of beijing

Juan GUAN, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, CHINA
Shan WANG, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, CHINA
Jiujiu GUO, Shanghai Tongji Urban Planning & Design Institute Co., Ltd, CHINA

Abstract

Since 2007, the concept of "ecological civilization" has been incorporated into China's strategic system, with sustainable development emerging as a core question in urban development in China. Megacities, as the primary spatial carriers of population aggregation, economic vitality, and material exchange, play a crucial role in achieving sustainable development.
Beijing is a mega - city in China facing both economic and environmental challenges. This paper takes Beijing as a case study, collecting PM2.5 data and statistical yearbook data from 2000 - 2020. Using SPSS and ArcGIS, it analyzes the correlation between PM2.5 and urban vitality factors like population, economy, ecology and transportation.
Results indicate a close correlation between PM2.5 and urban vitality. PM2.5 not only affects environmental quality and health, but also reduces city vitality and attractiveness. To maintain Beijing's vitality, this paper suggests measures like functional decentralization, ecological restoration and improving road networks to reduce PM2.5 concentration and explore sustainable development paths for Chinese mega - cities.

Keywords

PM2.5, Urban vitality, Correlation, BEIJING

1. Research Basis

1.1. Research Background

In recent years, the issue of global air quality has become increasingly severe, posing a significant constraint on the economic and social development of major cities(Dockery, 1993; Pope, 1995; Klein, 2003; Hao, 2012). China has undergone an extensive process of energy consumption to propel economic growth, during which its natural environment has suffered varying degrees of impact. Environmental pollution, with air pollution being the foremost, has gradually emerged as one of the major obstacles limiting the sustainable development of cities.

PM2.5 represents one of the foremost air pollution sources currently facing China. According to the "China Ecological Environment Bulletin," in 2020, PM2.5 was the primary pollutant for more than 51% of the days when air pollution exceeded standards in China. Air pollution dominated by PM2.5 has severely hampered the current urban development in the country. Existing methodologies, such as Environmental Impact Assessment (EIA), have commenced analyzing air pollution from the perspective of urban planning. However, research into the impact mechanism between urban vitality and PM2.5 remains somewhat

limited, with even fewer studies incorporating the application of megacity planning and management. (Holling, 1995; Brenkert, 2005; Gallopín, 2006).

1.2. Research Objectives

As a representative factor currently constraining urban development in China, the impact of atmospheric pollution, with PM2.5 as the primary culprit, is progressively intensifying. In response to the conflict between the environmental and health damages caused by PM2.5 and the socio-economic development of cities, it is crucial to ascertain the changes in PM2.5 concentrations in megacities over the past two decades and analyze the mechanism through which PM2.5 affects urban vitality. Based on these insights, targeted planning measures can be proposed.

1.3. Research Objects and Methods

Beijing serves as the capital of China, a hub for politics and culture, and a center for scientific and technological innovation. This study selected remote sensing data spanning (2000 to 2020) to conduct multi-seasonal simulations of PM2.5 concentrations across 16 district- and county-level administrative units within the Beijing municipality, covering a total area of 16,410 square kilometers.

Firstly, this paper employs a method combining remote sensing inversion with machine learning, utilizing software such as Python and ENVI, to simulate the spatiotemporal distribution scenarios of PM2.5 in Beijing(Shepard, 1968; Zurflueh, 1967; Hoek, 2008; Liu, 2017). Secondly, several indicators are selected across dimensions such as ecological environment, development conditions, and public service facilities to construct an evaluation system for the urban vitality index, with weight allocation conducted through the Analytic Hierarchy Process (AHP). Thirdly, SPSS is utilized to analyze the relationship between PM2.5 air pollution concentrations and various urban vitality indices. Finally, corresponding planning strategies are proposed from various dimensions of urban vitality to mitigate the constraints imposed by PM2.5 concentration pollution on urban development.

2. Spatial-Temporal Simulation and Distribution Characteristics of PM2.5 in Beijing

2.1. Simulation Method for PM2.5

This study selects the remote sensing retrieval method to conduct spatiotemporal simulation of PM2.5 in Beijing. Compared to numerical simulations and statistical models, remote sensing retrieval technology offers advantages such as a broad spatiotemporal scope, accurate data acquisition, and relatively low computational complexity, and has been widely applied(Kaufman, 1997; Liu, 2005; Bilal, 2014; Shi, 2017;). For data, MODIS data sourced from NASA's official website (https://ladsweb.modaps.eosdis.nasa.gov/) is chosen, which boasts extensive coverage, high accuracy, and easy accessibility(Holben, 1992; Hsu, 2013; Sayer, 2014; Zhang,2015).

2.2. Spatial-Temporal Distribution Characteristics of PM2.5 in Beijing

China's Ambient Air Quality Standards set the primary limit for daily PM2.5 concentration at 35μg/m³ and the secondary limit at 75μg/m³(Neng, 2013; Lin, 2015). Analysis of daily PM2.5 trends in Beijing reveals:

In 2000, PM2.5 exceeded the primary limit for 320 days (87.67% of the year) and the secondary limit for 231 days (63.29% of the year).

In 2005, it exceeded the primary limit for 299 days (81.92%) and the secondary limit for 182 days (49.86%).

In 2010, the figures were 311 days (85.21%) and 155 days (42.47%).

In 2015, 286 days (78.36%) and 157 days (43.01%).

In 2020, 189 days (51.78%) and 35 days (9.59%).

Overall, Beijing's annual PM2.5 pollution days have declined annually. Additionally, PM2.5 pollution exhibits a "clustering" pattern, occurring intensely over periods.

To further analyze monthly PM2.5 concentration variations, this paper analyzes monthly PM2.5 distribution. Monthly mean PM2.5 concentrations fluctuate significantly, peaking in January and gradually declining to a minimum in September, then rising again. Seasonal patterns show winter > autumn > spring > summer, with winter's high coal consumption for heating contributing to significant soot and dust emissions.

Table 1. Statistical Seasonal Average PM2.5 Values in Beijing in 2020. Source: Authors. Data Source: China Meteorological Data Network (https://data.cma.cn)

Season	Minimum Value	Maximum Value	Seasonal Average	Standard Deviation
spring	23.14564	28.3558	25.05525	1.116289
summer	28.1785	36.47148	31.96882	1.344884
autumn	30.31466	36.23782	33.25706	1.499505
winter	42.26843	58.41939	48.96263	4.223031

Taking the seasonal spatial distribution of PM2.5 in Beijing in 2000, 2005, 2010, 2015, and 2020 (Figures 1-5) as examples, the following observations can be made:

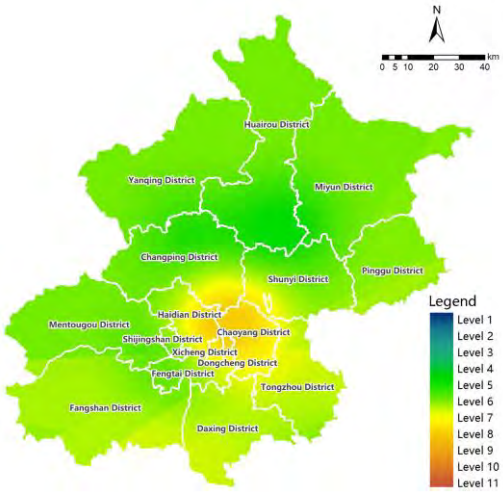
In spring, high PM2.5 concentrations are mainly found in the southeastern plains, with little spatial variation, while low concentrations are in the northern and western mountainous regions, exhibiting some spatial differences. PM2.5 concentrations gradually increase towards the plains, showing a "low on the edges, high in the center" distribution.

In summer, PM2.5 concentrations are generally low, with high values concentrated in the central city and southern plains. The spatial distribution of high PM2.5 concentrations varies significantly, showing a pattern of decreasing from the center towards the east and west.

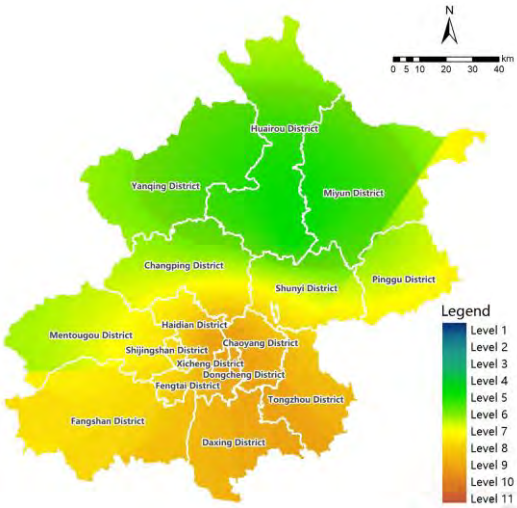
In autumn, the spatial distribution of PM2.5 concentrations resembles that of spring, with high values in the southeastern plains. However, the spatial differences in high-value areas are more pronounced in autumn, with concentrations increasing towards the southern edge.

Winter sees the most severe pollution, with higher concentrations compared to other seasons. High-value areas are found in the central and southwestern plains, with some spatial variation, and pollution is more severe in the south than in the center.

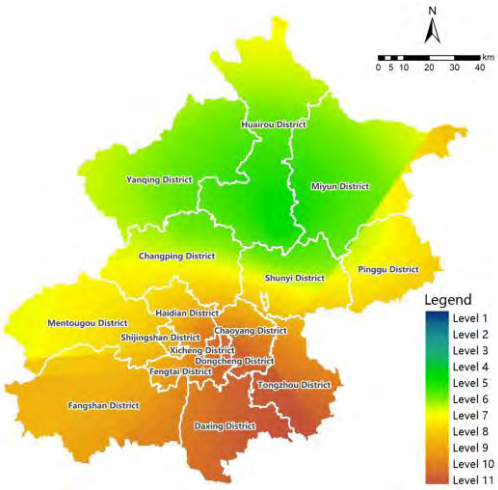
a. Spatial Distribution of PM2.5 in Spring



b. Spatial Distribution of PM2.5 in Summer

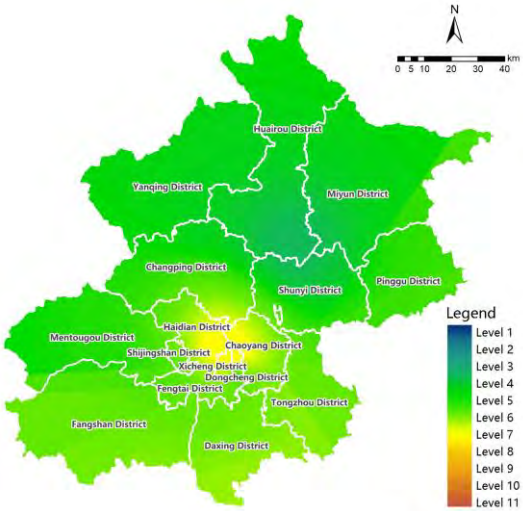


c. Spatial Distribution of PM2.5 in Autumn



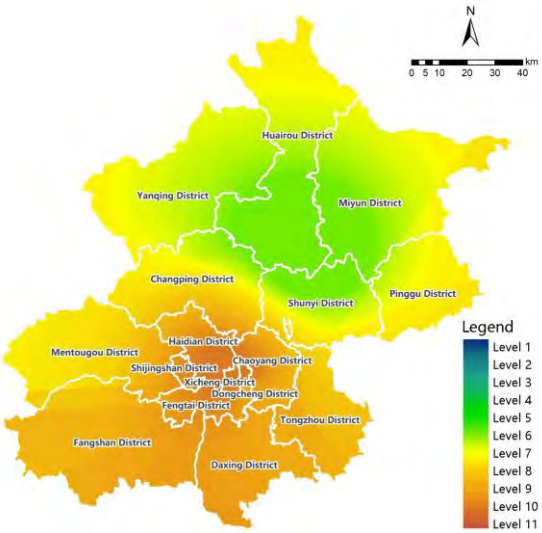
d. Spatial Distribution of PM2.5 in Winter

Figure 1. Seasonal Distribution of PM2.5 in Beijing in 2000. Source: Authors.

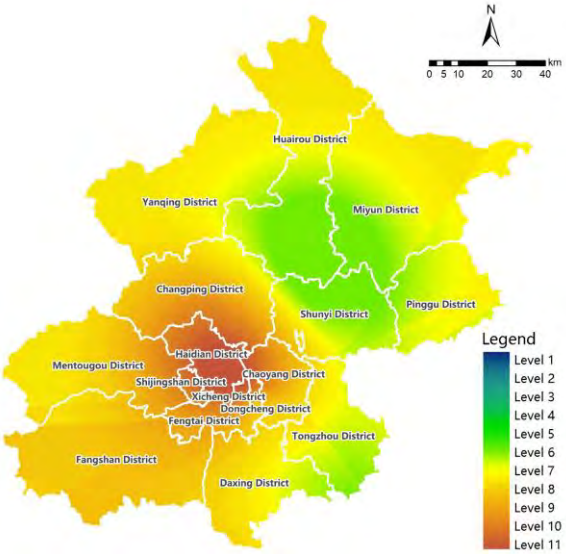


a. Spatial Distribution of PM2.5 in Spring

b. Spatial Distribution of PM2.5 in Summer

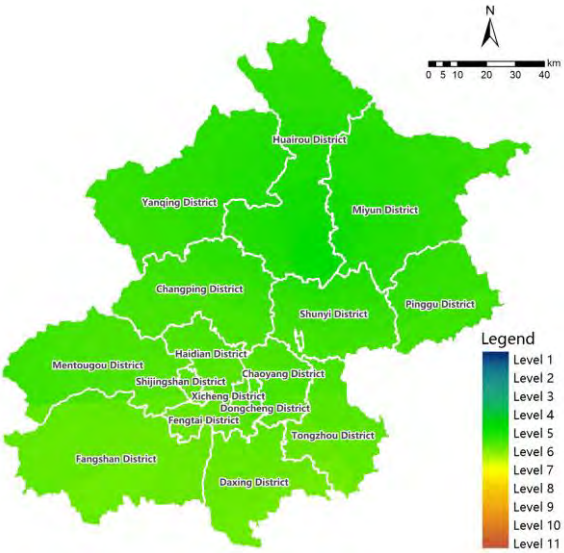


c. Spatial Distribution of PM2.5 in Autumn



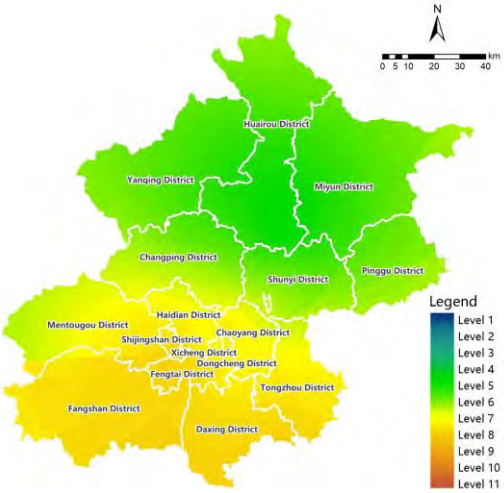
d. Spatial Distribution of PM2.5 in Winter

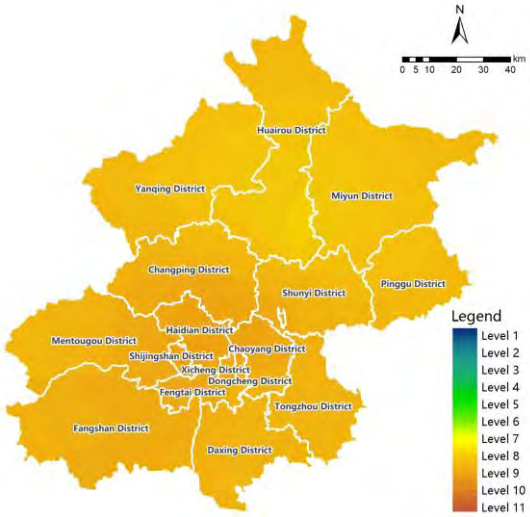
Figure 2. Seasonal Distribution of PM2.5 in Beijing in 2005. Source: Authors.



a. Spatial Distribution of PM2.5 in Spring

b. Spatial Distribution of PM2.5 in Summer

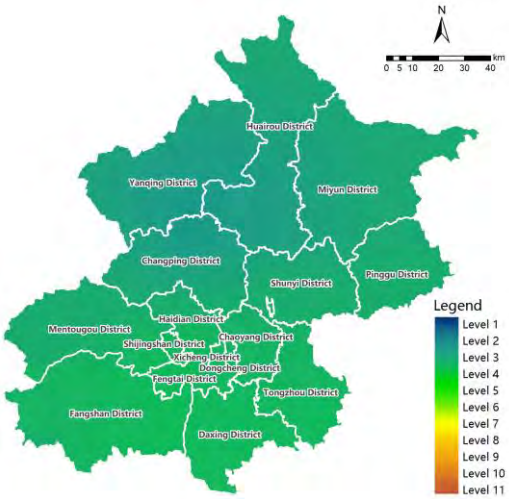




c. Spatial Distribution of PM2.5 in Autumn d. Spatial Distribution of PM2.5 in Winter

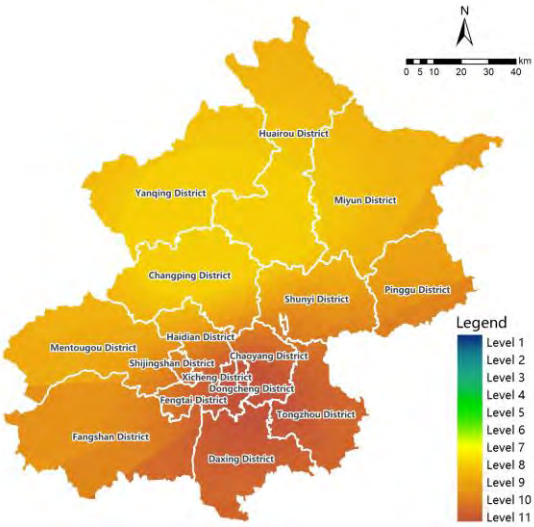
Figure 3. Seasonal Distribution of PM2.5 in Beijing in 2010. Source: Authors.

a. Spatial Distribution of PM2.5 in Spring



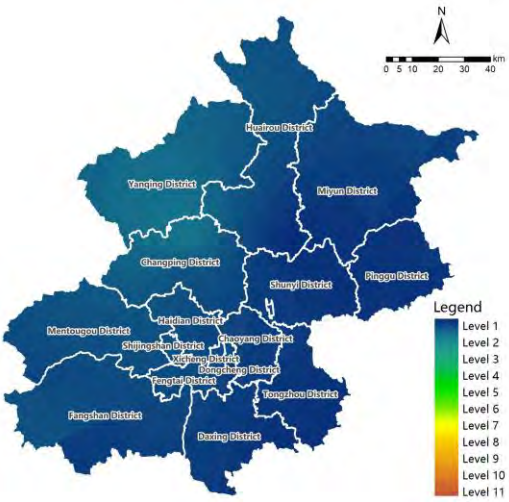
b. Spatial Distribution of PM2.5 in Summer

c. Spatial Distribution of PM2.5 in Autumn

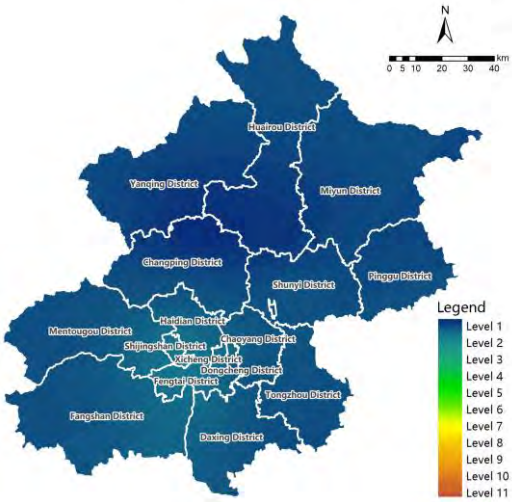


d. Spatial Distribution of PM2.5 in Winter

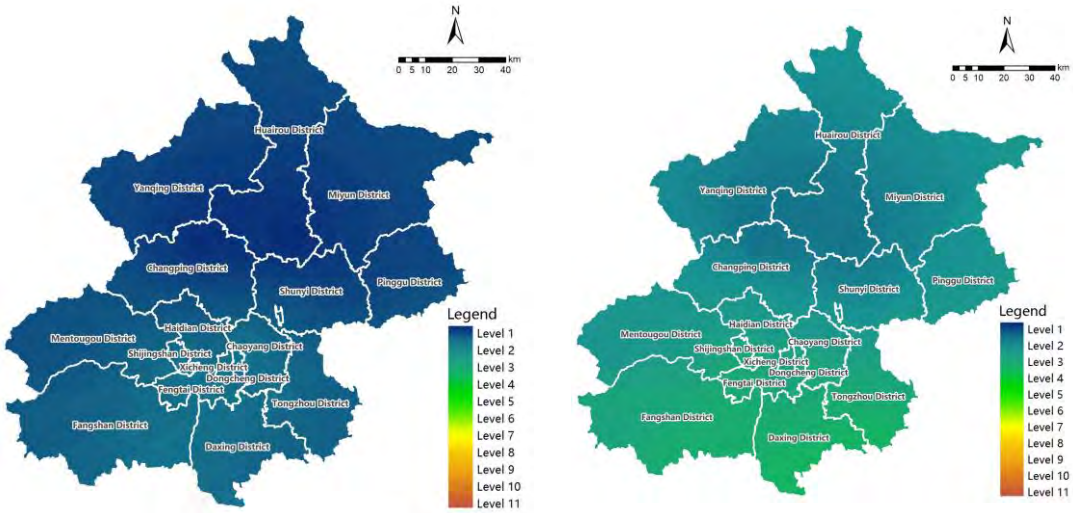
Figure 4. Seasonal Distribution of PM2.5 in Beijing in 2015. Source: Authors.



a. Spatial Distribution of PM2.5 in Spring



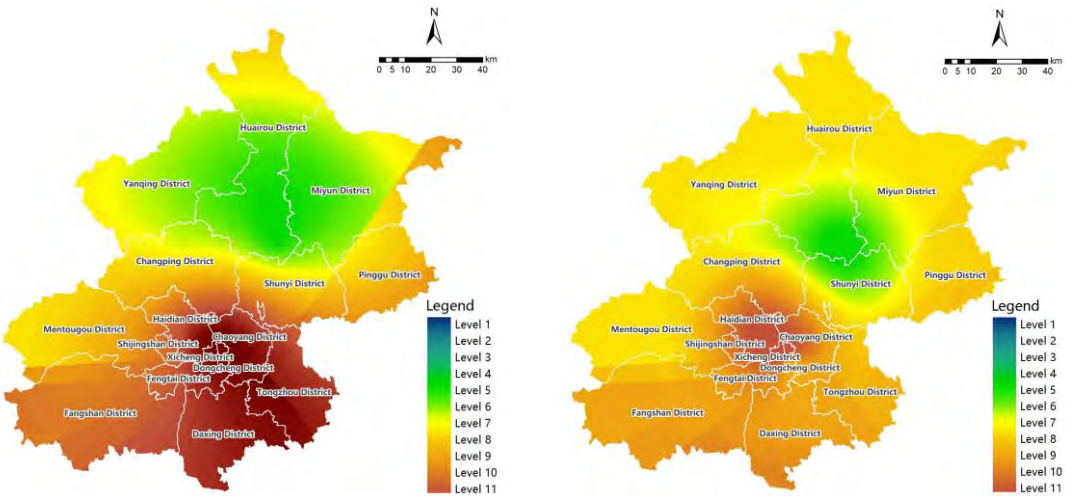
b. Spatial Distribution of PM2.5 in Summer



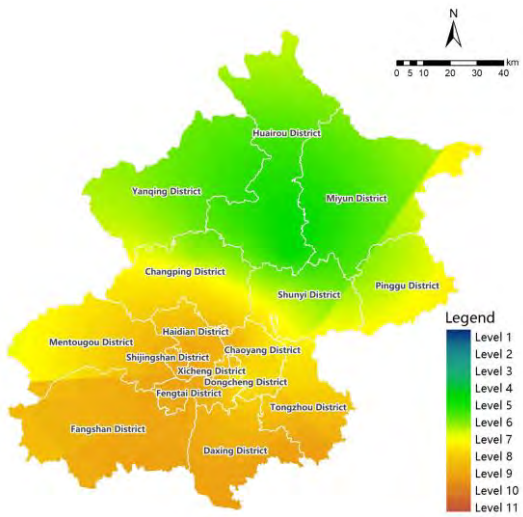
c. Spatial Distribution of PM2.5 in Autumn d. Spatial Distribution of PM2.5 in Winter

Figure 5. Seasonal Distribution of PM2.5 in Beijing in 2020. Source: Authors.

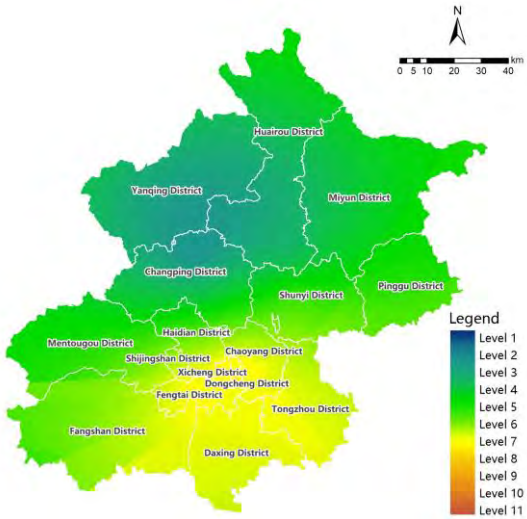
The spatial distribution of PM2.5 concentrations in Beijing exhibits a pattern of "higher in the southeast and lower in the northwest," with notable regional and seasonal variations. Peak PM2.5 concentrations occur in winter, while they are lower in summer. Over the years, PM2.5 concentrations in Beijing have shown a trend of initial stable increase, followed by a plateau and then a rapid decrease. Between 2000 and 2005, both the maximum and seasonal average PM2.5 concentrations rose slightly. Around 2010, PM2.5 levels remained comparable to those in 2000, indicating insufficient attention to air pollution control. In recent years, with the relocation of industries from central urban areas and heightened environmental awareness, PM2.5 concentrations in Beijing have decreased significantly.



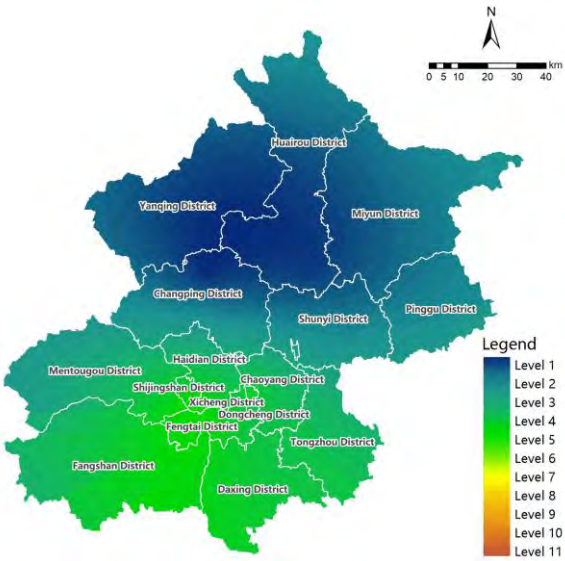
a. Spatial Distribution of PM2.5 in the Year 2000 b. Spatial Distribution of PM2.5 in the Year 2005



c. Spatial Distribution of PM2.5 in the Year 2010



d. Spatial Distribution of PM2.5 in the Year 2015



e. Spatial Distribution of PM2.5 in the Year 2020

Figure 6. Annual PM2.5 Distribution in Beijing in the Years 2000, 2005, 2010, 2015, and 2020. Source: Authors.

Table 2. Annual Average PM2.5 Statistical Values in Beijing for the Years 2000, 2005, 2010, 2015, and 2020. Source: Authors. Data Source: China Meteorological Data Network (https://data.cma.cn)

Year	Minimum Value	Maximum Value	Seasonal Average	Standard Deviation
2000	69.2855453	104.0763779	83.6626129	9.366407
2005	67.2185974	106.9986649	85.9641266	5.8196664
2010	72.7635727	94.2926331	83.0442734	5.9829316
2015	66.9684296	86.4423904	77.298233	5.3552365
2020	32.9322662	40.9922981	36.6725502	2.3184595

3. Comprehensive Evaluation and Changes of Urban Vitality in Beijing

3.1. Construction of an Urban Vitality Evaluation Model

Urban vitality refers to the degree of support provided within cities for activities such as life trajectories, ecological and environmental protection, and socio-economic development. Greater vitality implies stronger support, serving as a crucial indicator for promoting high-quality urban development.

Globally, cities with high levels of urban vitality often exhibit the following characteristics: superior natural conditions, rational population distribution, and a highly developed economy. Based on this, this paper evaluates the vitality index of cities from four dimensions: ecological energy, economic consumption, public service investment, and population development.

3.2. Selection of Evaluation Factors for Urban Vitality

In accordance with the aforementioned content, the urban vitality evaluation factors of this study mainly cover the following four aspects:

Ecological Energy: The utilization of various resources by the city can reflect the ecological foundation level of the city. It includes three factors: urban greening coverage rate, total energy consumption, and per capita park green area.

Economic Consumption: The consumption level of residents indicates the economic situation of the city. It includes three factors: consumer price index of residents, per capita consumption expenditure of residents in the city, and total import and export value of the city.

Public Service Investment: The financial investment in public service facilities, which is the livability of the city. It includes four factors: public transport passenger volume, road network density, personnel of medical and health institutions, and actual number of hospital beds.

Population Development: The population growth of the city indirectly reflects the labor base and innovation level of the city. It includes three factors: number of employees at the end of the year, population concentration degree, and number of domestic tourists.

For the specific interpretation of the indicators, please refer to Table 3.

In addition, before evaluating urban vitality, it is necessary to standardize each evaluation factor to eliminate the dimensional differences. The specific formula is as follows:

$$X' = (X - X_{\min}) \ / (X_{\max} - X_{\min})$$

Source: Normalization equation,Ye, H.M., Rong, M.T., and Deng, X.D. (2011)

The Analytic Hierarchy Process (AHP) involves inviting experts to assess the relative importance of each pair of indicators and construct a judgment matrix. It is a method for determining weights that combines qualitative and quantitative approaches, offering the advantages of simplicity in operation and intuitive results. The specific formula is as follows:

$$V_i = \sqrt[n]{\prod_{j=1}^{n} a_{ij}}, i = 1, 2, \cdots n$$

Source: Analytic Hierarchy Process, Thomas L. Saaty (1970)

In the equation, Vi represents the weight of indicator i, n denotes the total number of indicators, and aij signifies the proportion of influence that evaluation indicators i and j have on the target. The final weights obtained are presented in the table below.

Table 3. 1Explanation of Data Interpretations for Various Urban Vitality Indicators. Source: Authors.

Primary Indicators	Weight	Secondary Indicators	Weight	Interpretation
Ecological Energy	0.25	Urban Green Coverage Rate	0.25	Total green covered area within the city/Total area of the region
		Total Energy Consumption	0.25	Sum of energy consumed by various industries and residents'lives
		Per Capita Park Green Area	0.5	Total park green area within the region/Region's population
Economic Consumption	0.25	Consumer Price Index	0.25	Relative change over time in the level of consumer goods and services
		Per Capita Consumption Expenditure of Residents in the City	0.5	Average expenditure per resident for daily consumption over a certain period
		Total Import and Export Value of the City	0.25	Total value of actual imports and exports of goods over a certain period
Public Service Investment	0.25	Public Transport Passenger Volume	0.17	Actual number of passengers transported by the public transport system over a certain period
		Road Network Density	0.33	Total mileage of roads within a certain region/Area of the region
		Personnel in Medical and Health Institutions	0.33	Relevant professional and technical personnel in medical and health institutions
		Actual Number of Hospital Beds	0.17	Fixed and actual number of beds available for patients in medical institutions
Population Development	0.25	Number of Employees at the End of the Year	0.2	Total number of personnel working in enterprises and institutions
		Population Concentration	0.4	Difference between the resident population at the end of the period and at the beginning of the period
		Number of Domestic Tourists	0.4	Total scale of domestic tourists

3.3. Comprehensive Evaluation of Urban Vitality in Beijing

Based on the corresponding weights, the factors were integrated to obtain the evaluation results of Beijing's urban vitality index (2000 - 2020), as shown in the following table:

Table 4. Evaluation Results of Urban Vitality Index in Beijing from 2000 to 2020. Source: Authors.

Year	Type				Urban Vitality Index
	Ecological Energy	Economic Consumption	Public Service Investment	Population Development	
2000	0.02	0.06	0.01	0.03	0.12
2005	0.09	0.04	0.04	0.06	0.23
2010	0.19	0.14	0.13	0.10	0.56
2015	0.24	0.17	0.21	0.17	0.78
2020	0.25	0.19	0.17	0.20	0.81

According to Table 4, Beijing's urban vitality index exhibited a steady upward trend from 2000 to 2020. Specifically, the ecological energy dimension saw rapid growth initially, followed by stability. Economic consumption declined slightly in the early period but rose steadily later. Public service investment showed slight growth initially, rapid increase in the middle period, and a slight decline later, attributed to fluctuations in public transport passenger volume due to the increasing popularity of private cars. Population development maintained a stable upward trend throughout the period.

3.4. Analysis of the Correlation and Interaction between PM2.5 and Urban Vitality

Pearson's correlation coefficient is a method for correlation analysis. It is generally used to measure the interaction between multiple variables conforming to normal distribution and quantify the degree of correlation between two elements. This paper employs the Correlation package in Rstudio to calculate the correlation coefficient between the urban vitality index and PM2.5, imports the results into IBM SPSS for testing, and finally conducts visual expression. If a significant test ($p<0.05$) is passed and the Pearson's correlation coefficient is positive, it indicates a synergistic relationship between the pair; otherwise, it indicates a trade-off relationship. Based on relevant research, this paper classifies the correlation coefficients as follows: strong correlation ($|r| \geqslant 0.5$), moderate correlation ($0.3 \leqslant |r| < 0.5$), and weak correlation ($0.1 \leqslant |r| < 0.3$).

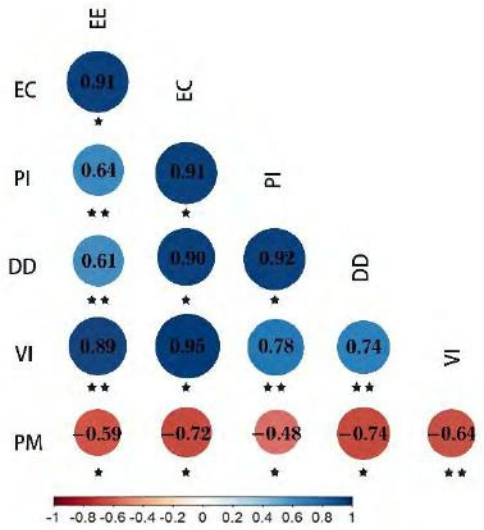


Figure 7. Correlation Analysis between PM2.5 and Urban Vitality Index in Beijing. Source: Authors.

According to the analysis results, PM2.5 exhibits a moderate negative correlation with ecological energy (EE) ($r=-0.59$, $p<0.05$), a strong negative correlation with economic consumption (EC) ($r=-0.72$, $p<0.05$), a moderate negative correlation with public service investment (PI) ($r=-0.48$, $p<0.05$), a strong negative correlation with population development (DD) ($r=-0.74$, $p<0.05$), and a strong negative correlation with the urban vitality index (VI) ($r=-0.64$, $p<0.01$). Overall, PM2.5 demonstrates negative correlations with all dimensions of the urban vitality index, and all correlations have passed significance tests. The study indicates a trade-off relationship between PM2.5 and urban vitality, with PM2.5 exerting a certain inhibitory effect on urban development.

4. Planning Response Strategies to Address the Impact of PM2.5 on Urban Vitality

4.1. Relocate some industries and optimize the energy structure

Relocation of Heavy Industries and Reduction of High-Pollution Energy Dependence

To mitigate pollution, heavy industries are relocated to sub-central cities, encouraging enterprises and residents to adopt clean energy, thereby reducing energy consumption and pollutant emissions. Additionally, there is a gradual reduction in the reliance on traditional high-pollution energy sources such as coal, with increased development and utilization of clean energy.

4.2. Promote ecological restoration and increase urban greening

Enhancing Vegetation Coverage: By increasing vegetation cover in urban and surrounding areas, trees and plants can adsorb particulate matter in the air, thereby purifying it. Rational planning of parks, green spaces, and other green areas can provide residents with leisure and sports venues.

4.3. Strengthen investment in public services, taking into account the impact of population aggregation

Optimizing Population Distribution: Reducing environmental pressure caused by excessive population concentration involves strengthening environmental governance and constructing public service facilities at the community level to improve residents' quality of life and happiness.

4.4. Promote the improvement of road networks and advocate for a green lifestyle

Promoting New Energy Vehicles: Efforts should be intensified to promote new energy vehicles, improve fuel quality and vehicle emission standards, and encourage public transportation and green travel modes such as walking, cycling, and using public transport.

5. Conclusion

This article simulates 20 - year PM2.5 changes in Beijing, evaluates urban vitality from four aspects, verifies its correlation with PM2.5, and proposes strategies for Beijing's future.

6. References

Bilal, M., Nichol, J.E. and Chan, P.W. 'Validation and accuracy assessment of a simplified aerosol retrieval algorithm (sara) over Beijing under low and high aerosol loadings and dust storms', *Remote Sensing of Environment,* 153, p50-60.

Brenkert, A.L., Malone, E.L. 'Modeling vulnerability and resilience to climate change: a case study of India and Indian states', *Climatic Change,* 72(1), p57-102.

Dockery, D.W. *et al*. 'An association between air pollution and mortality in six us cities', *New England Journal of Medicine,* 1993, 329(24), p1753-1759.

Gallopín, G. 'Linkages between vulnerability, resilience, and adaptive capacity', *Global Environmental Change,* 2006, 16(3), p293-303.

Hao J. Air 'Quality management in China: issues, challenges, and options', Journal of *Environmental Sciences,* 2012(1),p12.

Hoek, G. *et al*. 'A review of land-use regression models to assess spatial variation of outdoor air pollution', *Atmospheric Environment,* 2008, 42(33), p7561-7578.

Holben, B. *et al*. 'Aerosol retrieval over land from avhrr data application for atmospheric correction', *Ieee Trans. Grs,* 1992, 30(2), p212-222.

Holling, C.S., Gunderson, L. and Light, S. 'Barriers and bridges to the renewal of ecosystems', *New York: Columbia University Press. Cap,* 1995, 10, p428-460.

Hsu, N. *et al*. 'Enhanced deep blue aerosol retrieval algorithm: the second generation', *Journal of Geophysical Research: Atmospheres,* 118(16), p9296-9315.

Kaufman, Y.J. *et al*. 'Operational remote sensing of tropospheric aerosol over land from eos moderate resolution imaging spectroradiometer', *Journal of Geophysical Research Atmospheres*, 1997, 102(D14), p17-51.

Klein, R., Nicholls, R.J. and Thomalla, F. 'Resilience to natural hazards: how useful is this concept?', *Global Environmental Change Part B Environmental Hazards,* 2003, 5(1), p35-45.

Lin, C. *et al*. 'Using satellite remote sensing data to estimate the high resolution distribution of ground-level Pm2.5', *Remote Sensing of Environment,* 2015, 156, p117-128.

Liu, Y. *et al*. 'Estimating ground-level Pm2.5 in the eastern United States using satellite remote sensing', *Environmental Science & Technology,* 2005, 39(9), p78-3269.

Liu, Z. *et al*. 'GIS-based analysis of population exposure to Pm2.5 air pollution—a case study of Beijing', *Journal of Environmental Sciences,* 2017, 59(9), p48-53.

Neng, H. *et al*. 'Interpreting aerosol lidar profiles to better estimate surface Pm2.5 for molumnar aod measurements', *Atmospheric Environment,* 2013, 79(Nov.), p172-187.

Pope, C.A. *et al*. 'Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults', *Am J Respir Crit Care Med,* 1995, 151(3), p669-674.

Sayer, A.M. *et al*. 'Modis collection 6 aerosol products: comparison between aqua's e–deep blue, dark target, and "merged" data sets, and usage recommendations', *Journal of Geophysical Research: Atmospheres,* 2014, 119(24).

Shepard, D.A. 'Two-dimensional interpolation function for computer mapping of irregularly spaced data: harvard papers in theoretical geography', *Geography and Properties of Surfaces Series,* 1968(15), p19.

Shi, Q. *et al*. 'Improving fmask cloud and cloud shadow detection in mountainous area for Landsats 4–8 images', *Remote Sensing of Environment,* 2017, 199, p107-119.

Ye, H.M., Rong, M.T. and Deng, X.D. 'A hybrid algorithm for normalized waveform matching based on absolute value difference', *Information Technology*, 2011(8), p89-93.(Chinese)

Zhang, Y., Li, Z. 'Remote sensing of atmospheric fine particulate matter (Pm2.5) mass concentration near the ground from satellite observation', *Remote Sensing of Environment,* 2015, 160, p252-262.

Zurflueh., Ernst, G. 'Applications of two-dimensional linear wavelength filtering', *Geophysics,* 1967, 32(6), p1015.

Research Paper

The Impact of Spatial Density on Residents' Perception in Residence-Dominated Metro Station Areas

Taking the Red Line of Harbin Metro in China as an Example

Qiu, Zhiyong. School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China.

Duan, Mengyao. School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China.

Dai, Jian. School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of National Territory Spatial Planning and Ecological Restoration in Cold Regions, Ministry of Natural Resources, China.

Yang, Ling. Architecture Design and Research Institute of HIT, China.

Abstract

As the city's "essence of the resource chain" and the "new skeleton" of the city's expansion, the rail transit line carries diversified functional elements. The high-density spatial form constituted by the aggregation and composite of these elements can directly affect the residents' psychological perception. This study takes residential-dominated stations in Harbin Metro Line 1 as an example. Based on the service range of 800m, we construct a spatial density model of the metro station areas at the meso-micro scale in three dimensions, namely, building types, land use function, and street system to measure the distribution characteristics and spatial patterns of the elements. The results show that: (1) the overall spatial density elements show "central city clustering hot spots, and dispersed cold spots at the edges of built-up areas". (2) The elements of POI facilities' concentration, functional mixing, and building height are all strong influence factors that have a significant impact on residents' perception. (3) The interaction effect of each factor is mostly a synergistic enhancement. This study can provide a reference for the resource allocation of spatial elements in the metro station areas, to dissolve the negative impacts of spatial creation on the residents under the control of pure indexes, and to promote the sustainable development of the urban space.

Keywords

High-density, Residential-dominated metro station areas, Spatial density, Resident perception, Geo-detector

1. Introduction

According to the survey report of UN-HABITAT, by 2030, more than 60% of the global population will live in cities, and the number of cities with a concentration of more than 10 million people will increase to 43, of which the number of cities in China is about 1/5. Under the double constraints of population pressure and land resource scarcity, the development of urban densification has become an inevitable trend to

cope with the spatial and functional needs, and is regarded as an important part of the sustainable urban development strategy in the 21st century.

As a fundamental support for the development of urban densification, rail transit line makes the time distance of the city in different directions shorten dramatically, promotes the high concentration of urban elements such as residential population and resources, and becomes the main axis leading the development of the city. With the development of rail transit in China, by the end of 2023, a total of 55 cities have opened 306 rail transit lines, with a total length of 10,165.7 kilometers. Rail transit lines change the original urban spatial structure, further catalyze the agglomeration of people and functions, and the space around the stations becomes the most dynamic place in the city. Metro Line 1, as the city's “essence of the resource chain” and the “new skeleton” of the city's expansion, carries the key role of linking the old city with the new district, connecting the subway stations, work and residential space and other aspects of the environment with people, their daily lives and urban development, making the residents of the old city have a strong sense of humor and a strong sense of responsibility. It makes the residents of the old city district have a strong dependence on it. Among them, the residence-dominated stations not only take on the node function of transportation, but also carry more diversified life scenes and functional elements such as residence, consumption, entertainment, etc., realizing the multiple coupling of rail transit and residents' life and urban functions, and further developing into the integrated “rail + life” comprehensive development mode, which is a combination of “station”, city, production and humanities. development mode. However, the excessive concentration of elements makes the development of urban space around the station more and more three-dimensional, emphasizing the quantitative growth, ignoring the quality of social, ecological and other multi-dimensional guarantee. Such a control approach focusing on the measurement of a single indicator makes the station space face many problems such as overloaded infrastructure, lack of open space, crowded population, and tight housing (Figure 1). Therefore, the key issue is to improve the match between station areas and residents' behavioral and psychological needs by means of deploying built environment elements in residential-dominated stations in order to eliminate the negative perception of high density and concentration of elements in station areas.

Figure 1. Advantages and potential problems of urban densification. Source: Self-drawn by the author, 2024.

This study focuses on the residential- dominated subway stations in the old city district, and uses Geodetectors to explore the characteristics of the circled spatial patterns formed by the radiation and attraction of the stations to the surrounding spatial elements after implantation, as well as the evolution of the city's own morphology, in an attempt to reduce the negative perception of spatial density from the perspective of the residents' perceptions. Therefore, this study determines the spatial density elements from the perspective of Urban Morphology, detects the influence of each dimension of spatial density

elements on the residents' perception, and identifies the main spatial density elements that affect the residents' perception, so as to better realize the good experience of the residents in the “last kilometer”.

2. Materials and Methods

2.1. Overview

With the transformation of the core value of urban design from “object-centered” to “human-centered”, people's perception of the environment has become the main research object and target. Research shows that among the many factors affecting residents' psychological perception, environmental factors account for 40%-50%, and the rapid growth of urban “volume” gradually reveals the negative marginal effect. However, there are fewer studies on agglomeration diseconomies, and the direction of the impact of spatial density on residents' perceptions has not yet been a more consistent conclusion. Most studies generally agree that higher building densities are more unpleasant and lead to negative perceptions. In contrast, an imagery study conducted in Oslo reported that if the environment is safe and free of noise, high building density may promote social relationships to improve resident perceptions. This suggests that the positivity of high building density on residents' perceptions is conditional and the key lies in the coordination with other environmental elements. With the transformation of the core value of urban design from “object-centered” to “human-centered”, people's perception of the environment has become the main research object and target. Research shows that among the many factors affecting residents' psychological perception, environmental factors account for 40%-50%, and the rapid growth of urban “volume” gradually reveals the negative marginal effect. However, there are fewer studies on agglomeration diseconomies, and the direction of the impact of spatial density on residents' perceptions has not yet been a more consistent conclusion. Most studies generally agree that higher building densities are more unpleasant and lead to negative perceptions. In contrast, an imagery study conducted in Oslo reported that if the environment is safe and free of noise, high building density may promote social relationships to improve resident perceptions. This suggests that the positivity of high building density on residents' perceptions is conditional and the key lies in the coordination with other environmental elements.

Current research on the spatial density elements affecting residents' perceptions mostly focuses on the objective level of physical spatial form. In recent years, scholars at home and abroad have proposed that spatial density elements such as building density, floor area ratio, open space rate, facility agglomeration, land use mixing, openness of street space, and interface coverage have a significant impact on residents' perception. Among them, the intensity of positive perception is significantly higher in neighborhoods dominated by multi-story buildings, large avenues, and neighborhoods with dense road networks than in other types of neighborhoods. With the research on spatial form gradually shifting to the human scale, the related research on density perception has also begun to focus on the design elements at the micro level, with particular attention to the positive impact of specific space types such as street space, green space, etc., on the psychological perception of residents. Quantitative analysis of the impact of green visibility, street aspect ratio, interface density, sky visibility, etc. on the perception of residents, and further use of computer scenario modeling methods to explore when the street interface transparency threshold of 40% of the human visual perception of the highest degree of comfort, a better guide to the creation of space . It can be seen that focusing on the coordination and threshold between spatial density elements in the control can significantly improve the livability satisfaction of residents to the current spatial environment.

2.2. Research Subjects and Methods

Residents' perception of spatial density is the complexity and diversity of the spatial form composed of density elements, which is the result of the interaction between human psychology and spatial

environment. The metro station areas as a special public space environment, the radiation attraction of the station makes the space carry diverse life scenes and agglomeration of functions, and the agglomeration and conformity of functions make the station space form present differentiated characteristics, and also make the mismatch between the residents' perception and behavioral needs and the spatial environment.

Based on this, this study starts from the perspective of Urban Morphology and draws on the planar pattern analysis theory of Conzeen's Urban Morphology to measure the image factors and influence mechanisms that have a significant effect on residents' perception from three aspects: building types, land use function, and street systems. Figure 2 shows the overall idea of this study, firstly, from the functional point of view, ten residential-dominated stations in Harbin Metro Line 1 are selected, and the organizational structure and organizational relationship of spatial density elements in the station areas are measured by ArcGIS and Depthmap, and all kinds of influence factors are visualized and analyzed. Secondly, based on the identified influence factors, a questionnaire survey is used to measure the perception status of residents on the density elements, and further analyze the impact of different factors on the perception of residents. Thirdly, based on the identified influencing factors, a questionnaire survey was used to measure the residents' perception of the density elements, and further analyze the perception characteristics of the residents in different stations. Finally, Geodetector were used to detect the single and interactive synergistic effects of the factors, and to analyze the differences in the effects of the density factors and the degree of influence in the station space.

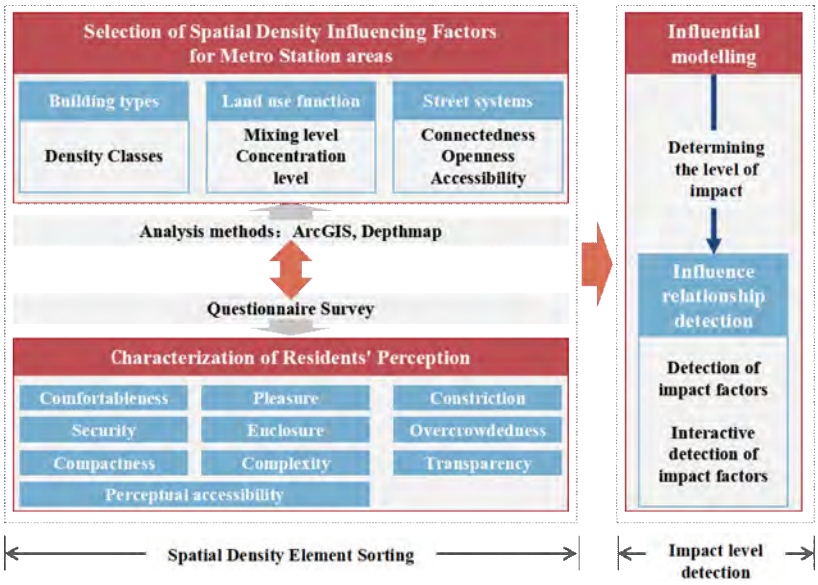


Figure 2. Research ideas. Source: Self-drawn by the author, 2024.

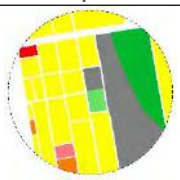
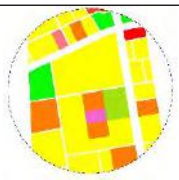
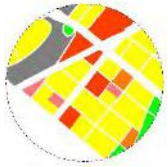
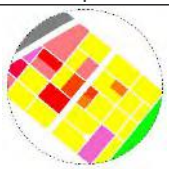
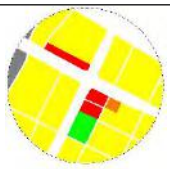
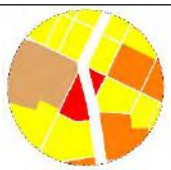
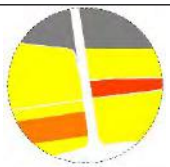
2.2.1. Research Areas

In the process of selecting and establishing metro stations, they are affected by multiple factors such as urban functions, spatial patterns and land properties, forming different spatial functional characteristics, and the differentiated spatial densities and functional fitnesses make the station areas present different spatial characteristics. Among them, the residential-dominated stations, as the most numerous and widely distributed stations, have complex spatial patterns composed of spatial densities that directly affect the quality of life of the residents and the spatial vitality of the station areas, which are closely related to the daily lives of the residents. Therefore, this study starts from the function orientation, and investigates the land use functions in the station areas according to《the Urban Land Use Classification and Planning and Construction Standards》, in which the residence- dominated stations should meet the land use functions in the station area with residence as the main function and the proportion of land ≥

40%. Based on this, this study takes the residential- dominated stations in Harbin Metro Line 1 as the research object, and selects a total of 10 samples such as Harbin East Station, Tobacco Factory, West Bridge, and Hexing Road (Table 1).

The delineation of the subway station area is not a fixed value in the related research, and the station area is mostly determined in a circle within a certain range accessible on foot centered on the subway station. According to the TOD model advocated by Peter Calthorpe and the research on TOD development at home and abroad by scholars such as Pan Haixiao and Ding Chuan, the radial influence of the metro station is mostly limited to the range of 500-1,000m; it is defined as a 15-minute walk from the station within the range of 500-800m in 《the Guidelines for Planning and Designing of Areas Along Urban Railways》 issued by the Ministry of Housing and Construction. Area. Therefore, taking into account the spatial characteristics of the metro station area and the walking ability of people of all ages, this study selects the station as the core and the area with a radius of 800m as the research scale of the spatial density of the metro area.

Table 1. Residential-led Metro Station Site Characteristics. Source: Self-drawn by the author, 2024.

	Harbin East Railway Station	Huashu Street	School of Transportation	Taipingqiao Bridge	Tobacco Factory
Site Characteristics					
Planar Texture					
	Medical University First Hospital	West Bridge	Hexing Road	Xuefu Road	Harbin South Railway Station
Site Characteristics					
Planar Texture					
Scale and North					

2.2.2. Research Methodology

2.2.2.1. Optimal Parameters-based Geographical Detector

Geodetector, as a statistical tool for detecting spatially stratified heterogeneity and the driving forces behind it, can detect the influential relationship between one-factor and two-factor interactions on the dependent variable, respectively, so as to explain the driving effect and degree of the independent

variable on the dependent variable. In the analysis, discretization of spatial data and spatial scale effects are key issues. The Optimal Parameter Geodetector model based on the GD package of R language adopts a variety of classification methods such as equal intervals, natural discontinuities, quartiles, geometric intervals, standard deviations, etc., and determines the optimal parameters by comprehensively considering various combinations of the discretization methods and the number of interval categories, and then further calculates q-values of each continuous variable related to the geospatial data, so as to select the parameter combination that produces the highest q-value as the optimal parameter combination. discretization method, effectively reducing the interference of subjective selection of discretization methods in traditional research.

In the research of detecting the differences in the spatial distribution of independent variables and dependent variables, it is generally based on four modules: factor detection, ecological detection, interaction detection and risk detection Therefore, this study takes the residents' perception as the dependent variable and the spatial density elements of each level as the independent variables, and utilizes factor detection and interaction detection to explore the main driving factors and driving mechanisms of the spatial density of metro station areas on the residents' perception under the effect of a single factor and a double factor, respectively. The factor detector measures the degree of influence of spatial density elements on residents' perceptions by q-value.

2.2.2.2. Space Syntax

Spatial Syntax, as one of the methods of quantitative analysis of spatial morphology, can quantitatively react to the accessibility or connectivity of spatial environmental structure by analyzing the spatial layout of cities or buildings, thus explaining the intrinsic mechanism of spatial morphology evolution, and thus has been widely used in the fields of urban morphology and urban spatial structure. The commonly used analytical models include visual field model, convex space model, axis model and line segment model, in which the axis model is based on the true distance of the road and the turning angle of the road as the main calculation factors, which has a higher credibility in calculating the radius of the road at different distances. Therefore, the axial model is chosen in this study to analyze the accessibility of the street system. In terms of analyzing parameters, the three influencing factors of Integration, Choice and Connectivity are chosen to calculate the openness of station space based on the viewpoint model, which is characterized by the viewpoint Integration.

2.2.3. Data Sources

This study mainly uses several vector data containing road network data, building data, POI data land use data within the study area. On this basis, the road data are simplified into a network composed of road centerlines through screening, topology checking, and modification; the building data are calculated according to the principle of 3m/floor for their building heights; the POI data are reclassified; and the land use functions in the master plan are corrected based on the urban land use functions shown in Baidu Maps, so that the spatial density of the subway station area can be visualized.

2.3. Selection of Indicators

2.3.1. Selection of Spatial Density Indicator Factors for Metro Station Areas

Spatial density reflects the objective distribution of various urban components (including social groups, physical facilities, economic activities, etc.) at the spatial scale. Therefore, the spatial density in this study focuses more on the meso-micro spatial patterns constituted by the combination of physical spatial forms. The meso-morphology mainly refers to the topology of the road network and the planar morphology of the facility layout in the station area, while the micro-morphology focuses on the three-dimensional geometric morphology of the buildings and street space in the station area. Therefore, when

selecting the spatial density elements affecting residents' perception, on the one hand, taking the previous research as the benchmark, and on the other hand, drawing on the planar pattern analysis theory of Conzeen's urban morphology, the urban morphology and spatial density are divided into three dimensions: the building types (including the buildings and plots), the land use function, and the street system.

Table 2. Index system of spatial density elements in residential dominated subway station areas. Source: Self-drawn by the author.

Dimension	First Indicators	Secondary Indicators	
Building Types	Density Classes	Building density（X_1）	
		Floor area ratio（X_2）	
		Height（X_3）	
Land use Function	Mixing Level	Land use mixing（X_4）	
	Concentration Level	Density of POI facilities（X_5）	
		POI facility agglomeration kernel density（X_6）	
Street Systems	Connectedness	Road network density（X_7）	
	Openness	Openness of the sky（X_8）	
		Closeness（X_9）	
	Accessibility	Integration	Global integration（X_{10}）
			Local integration（X_{11}）
		Choice	Global choice（X_{12}）
			Local choice（X_{13}）
		Connectivity（X_{14}）	

Based on this comprehensive consideration, the spatial density index factor of metro station area including three dimensions of building types, land use function and street systems, six elements of density classes, mixing level, concentration level, connectedness, openness and accessibility and corresponding 14 factors were finally constructed (Table 2), in order to study the differential impact of the uneven characteristics of the spatial density of metro station area on the perception of residents.

2.3.2. Measurement of Residents' Perceived Characteristics

Perception, as a bridge and a continuous inward channel for the built environment to interact with the human psyche, is the main way for people to evaluate their surroundings. This study focuses on residents' perception of spatial layout patterns and planar texture patterns composed of density elements, including two-dimensional and three-dimensional spatial features. Therefore, it is mainly based on the five dimensions of imagery, enclosure, human scale, transparency, and richness proposed by Ewing , and on this basis, the perceptual results of tension, security, and crowding brought about by complex urban spatial organization are derived. The questionnaire was used to describe the residents' perceptions of comfort, pleasure, enclosure, security, constriction, crowding, compactness and transparency created by the spatial density elements from multiple perspectives.

The questionnaire includes two parts: (1) the basic attributes of the respondents, including gender, age, occupation, cultural level, place of residence, etc.; (2) the respondents' perceptions of the spatial density of the residence-led station area, which is characterized by 10 indicators, including comfortableness, pleasure, constriction, security, enclosure, overcrowdedness, compactness, complexity, transparency, and perceptual accessibility, to describe the residents' perceptions of the spatial characteristics of the station area. To describe the results of residents' perception of the spatial characteristics of the station area and the distribution of density elements, a five-point Likert scale is used, with “5, 4, 3, 2, 1” assigned to “very satisfied”, “satisfied”, “average”, “dissatisfied” and “very dissatisfied”, so that the residents' scores reflect the perceived spatial density of the metro station area.

3. Result Analysis

3.1. Distribution of Influencing Factors of Spatial Density in Metro Station Area

Calculate the 14 key factors of the six levels identified in Table 3, characterize the spatial density level of the station with the mean value of each influence factor, and visualize and compare the analysis of some of the factors (Figure 3).

(1) From the perspective of the density class hierarchy(Figure 3a,3b,3c), the spatial pattern of the construction intensity of each site is characterized by diversity due to differences in location. The overall situation of “local aggregation, high center site and low edge site” is presented, and there are fewer high-intensity development sites. The principle of graded density advocated by TOD theory has not yet been realized, and the central city site is relatively mature.

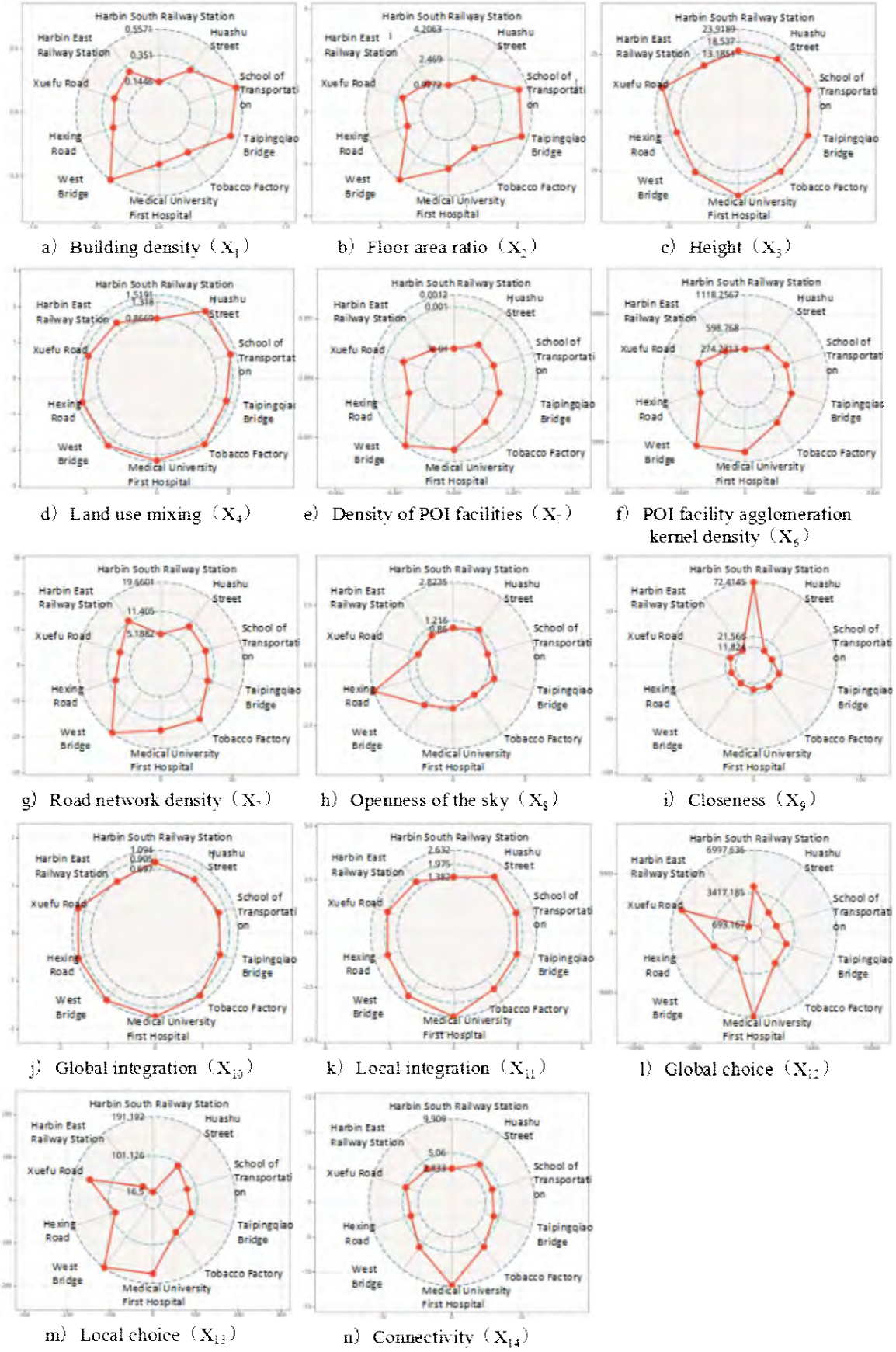
(2) From the viewpoint of mixing degree level (Figure 3d), the overall mixing degree presents high mixing characteristics with balanced distribution, a few sites have functional monotonous development, and the spatial distribution of high and low values shows a certain clustering trend. The residential function of the residential-led stations attracts related supporting functions to form a “functional core” around the stations, which greatly improves the land intensification and spatial vitality in the station space.

(3) From the perspective of concentration level (Figure 3e,3f), the spatial concentration of POI facilities in the station space is relatively strong, and all of them have formed point-like cores in the station space, with relatively complete public service facilities. Among them, the high value area of concentration within each station area mostly overlaps with the station location, but there also exists a certain divergence phenomenon, and the synergy between POI facilities and subway stations is poor. And the unevenness of the spatial development of each station area, the central city station's facility concentration characteristics are more significant, indicating that the location and the concentration of facilities on the station's service capacity is still a major limitation.

(4) From the viewpoint of connectivity level(Figure 3g), there are differences in the connectivity of roads in the station space, the density of the road network of the stations in the center of the city is significantly higher than that of the stations located at the end of Line 1, and the shape of the road network has more obvious grid characteristics, so that the street system has better connectivity. The road network density of the stations at the edge of the built-up area is lower, and the radiation influence of the stations is relatively weak.

(5) From the perspective of openness hierarchy (Figure 3h,3i), the openness in the station space shows a balanced high openness pattern. And there is a certain similarity between the distribution of street enclosure and sky openness, mostly distributed along the streets. This is also flanked by the lack of open spaces such as parks and squares in the current station.

(6) From the viewpoint of accessibility hierarchy (Figure 3j,3k,3l,3m,3n), there is a center-edge feature in the accessibility degree of station space. From the figure, it can be seen that the areas with higher degree of integration and connection of the street system in each station area basically coincide with the entrance and exit space of the subway station, indicating that the road connectivity in the station area is high, and it has better accessibility and spatial vitality. In terms of selectivity, the distribution within the station space is basically consistent, the overall synergy of the street network is stronger, and the local spatial network is integrated with the global spatial network, which has higher accessibility and greater commercial potential. On the other hand, the accessibility of some stations is low, and the lack of intertwined road connections between different neighborhoods leads to obstacles in walking through the area, resulting in uneven spatial development as a whole.



a) Building density (X_1)
b) Floor area ratio (X_2)
c) Height (X_3)
d) Land use mixing (X_4)
e) Density of POI facilities (X_5)
f) POI facility agglomeration kernel density (X_6)
g) Road network density (X_7)
h) Openness of the sky (X_8)
i) Closeness (X_9)
j) Global integration (X_{10})
k) Local integration (X_{11})
l) Global choice (X_{12})
m) Local choice (X_{13})
n) Connectivity (X_{14})

Figure 3. Calculation results and statistics of spatial density elements in residential dominated subway station areas. Source: Self-drawn by the author, 2024.

3.2. Characterization of Residents' Perception

The time of this research is April-May 2024, the object is to live in the scope of the station residents, the questionnaire distribution time as far as possible involving rest days and working days in the morning, afternoon and evening three hours, a total of 300 questionnaires recovered, to get a valid questionnaire 285, the validity rate is 95%. Based on the obtained questionnaire results were tested for reliability and validity using SPSS. The results showed (Table 3) that the overall reliability (Cronbach's α) coefficient value of the questionnaire was 0.871 (reference value > 0.7), and the overall results had a high level of confidence and reliability. The validity was further verified using KMO and Bartlett's test, and the KMO value of 0.825 was (reference value > 0.7), indicating that the validity of the data was very good. And the significance of Bartlett's test of sphericity was (P < 0,001), indicating structural validity among the factors.

Table 3. Reliability and validity test results. Source: Self-drawn by the author.

Cronbach's α coefficient value		0.871
KMO		0.825
Bartlett's test of sphericity	Approximate chi-square	629.678
	Number of degrees of freedom	136
	Significance	0.000

Among the respondents, 53.7% were male and 46.3% were female, and in order to explore the spatial heterogeneity of residents' perceptions in different sites, we evaluated the residents' perceptions based on a five-level Likert scale with 10 levels of comfort, pleasure, crowding, and compactness, and calculated the perceptual scores of each dimension by averaging the scores, which characterize the level of residents' perceptions of the site. level, where a higher score represents a stronger perception of residents.

Overall (Figure 4), the residents' perception of the spatial density level of the station area within each site shows that there is no obvious difference between the dimensions, but the overall difference in the level of perception is significant. Among them, the overall perception level of Hexing Road and Harbin East Station is low, attributed to the road division space and strong mobility within the station area, which reduces the residents' safety perception; while Xuefu Road and other stations have a higher perception level due to the presence of large-scale commercial or cultural facilities within the station area space, which matches the residents' psychological feelings and behavioral needs better. From the perspective of perception dimensions, the higher level of comfort and accessibility to the station space indicates that residents have a stronger perception of the comfort and accessibility of the space created by the current density elements. At the same time, the level of crowdedness and compactness is lower, indicating that the current layout of station space density elements is more compact.

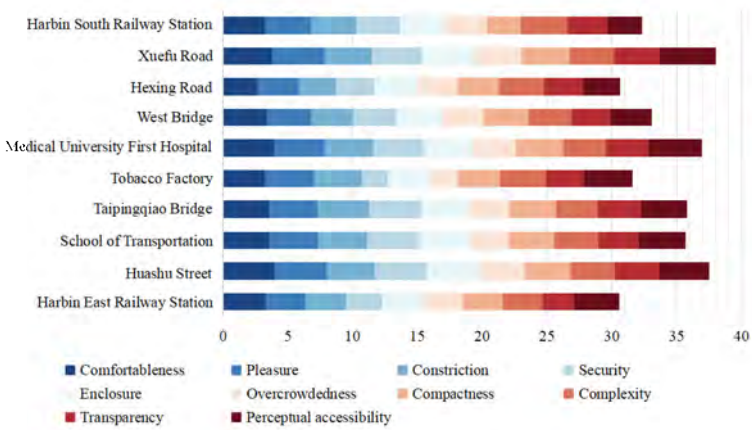


Figure 4. Perception results of residents in the subway station area space. Source: Self-drawn by the author, 2024.

3.3. Detection of Influence Factors on Residents' Perception

In order to explore the influence factors of the spatial density of the metro station domain on residents' perception and the degree of their influence, the Geodetector model based on the optimal parameters is calculated, and the results show (Table 4) that, except for the density of POI facility agglomeration kernel (X_6), the openness of the sky (X_8), the degree of global integration (X_{10}), and the degree of local integration (X_{11}), whose influence on residents' perception is insignificant, the rest of the factors pass the significance test . Comparison of q-values reveals that the effect of each density factor on residents' perception is smooth and higher than 0.5. Among them, the degree of connectivity (X_{14}) has a highly significant effect on residents' perceptions (with an explanatory power of 0.7492), and the degree of connectivity of the street system plays an important role in influencing residents' perceptions of spatial densities in the station area. Volume ratio (X_2) and enclosure (X_9) also have a significant effect on residents' perceptions, but the explanatory power is relatively weak.

Overall, except for the elements that do not have a significant effect, the rest of the spatial density elements in the residential-dominated stations have a strong influence on the perception results, and more attention should be paid to the configuration of the overall density elements within the station space.

Table 4. Detection results of influencing factors perceived by residents. Source: Self-drawn by the author.

Impact factor	q-value	p-value	impact factor	q-value	p-value
Building density（X_1）	0.5693	0.0426**	Openness of the sky（X_8）	0.1703	0.6231
Floor area ratio（X_2）	0.6843	0.0071**	Closeness（X_9）	0.6837	0.0121**
Height（X_3）	0.5327	0.0404**	Global integration（X_{10}）	0.3070	0.3475
Land use mixing（X_4）	0.4920	0.0230**	Local integration（X_{11}）	0.3677	0.1267
Density of POI facilities（X_5）	0.5186	0.0257**	Global choice（X_{12}）	0.5814	0.0398**
POI facility agglomeration kernel density（X_6）	0.4068	0.1631	Local choice（X_{13}）	0.5633	0.0078**
Road network density（X_7）	0.5492	0.0465**	Connectivity（X_{14}）	0.7492	0.0001***

3.4. Interaction Detection of Influencing Factors on Residents' Perception

Through geographic interaction detection, it is possible to more accurately explain what kind of elemental factors play an enhancing role in the degree of influence on residents' perceptions, so as to determine the short-board factors that affect residents' perceptions. The results show that there is an interaction between the influence of each factor on residents' perception, which is manifested as Enhance, nonlinear, Enhance, bi- and Weaken, nonlinear (Figure 5), reflecting the fact that residents' density perception in the station space is affected by a variety of factors together.

Among them, the ones with the highest explanatory power are building density (X_1) ∩ height (X_3), POI facility density (X_5) ∩ enclosure (X_9), road network density (X_7) ∩ connectivity (X_{14}), etc., among which building density, road network density, enclosure and other elements show enhancement when interacting with other elements, and have a dominant enhancement in influencing the perception of residents' density, which suggests that station space has a strong relationship with the above elements due to its own radiation attraction. This indicates that the station space, due to its own radiation attraction, will have a large marginal effect when combined with the above elements, which is a key role in influencing residents' perception. On the other hand, local choice (X_{13}) and connectivity (X_{14}) show a non-linear weakening effect when interacting with individual elements, indicating that there may be a certain threshold effect of the influence of these elements on the residents' perception, and that attention should be paid to the reasonable configuration of these elements in the creation of the station area space to realize the coordination of the overall spatial form, so as to give the residents a positive perception of the density.

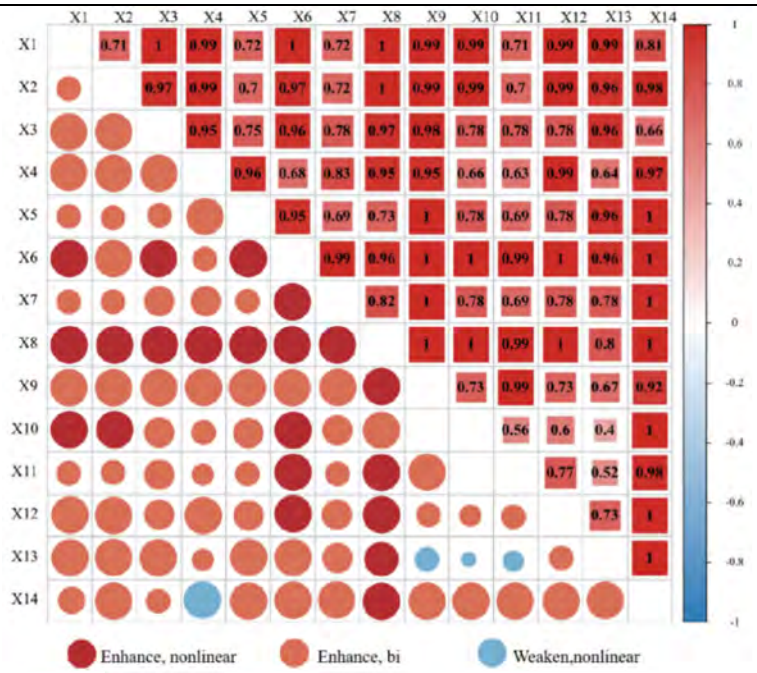


Figure 5. Interaction detection results of influencing factors. Source: Self-drawn by the author, 2024.

4. Conclusion and Discussion

Starting from the theory of Conzeen's urban morphology, this study, based on the three dimensions of building types, land use function, and street system, synthesizes related studies and constructs a spatial density index system including three dimensions, six elements, and corresponding 14 factors, so as to conduct an in-depth analysis of the organizational characteristics of the spatial density of the residence-dominated station area and its degree of influence on the residents' perception. Firstly, the spatial density of residential-dominated station areas is quantitatively visualized through ArcGIS and spatial syntax; secondly, the main driving factors affecting residents' perception are explored based on the optimal parameter Geodetector model.

The main conclusions are as follows: (1) The spatial densities of the three dimensions of residential-led stations are characterized by differentiation, and the overall situation of “concentrated hotspots in the central city, dispersed in multiple cores, and dispersed coldspots at the edges of built-up areas” is presented. (2) The results of factor detection show that the level of residents' perception is characterized by composite nature and influenced by a variety of factors. However, the impact of each density factor on residents' perception is relatively robust, in which the degree of connectivity has a highly significant impact on residents' perception, and the volume ratio and enclosure degree also have a significant impact on residents' perception, but the explanatory power is relatively weak, which is a secondary impact factor, reflecting that the degree of access to the street system and the 3D spatial pattern play an important role in dissolving the residents' negative perceptions. And the effect of POI facilities agglomeration kernel density, sky openness, and integration degree on residents' perceptions is not significant. (3) Through the analysis of interaction factor detection, it is found that the influence of each factor on residents' perception has interaction effects, and the results show that the elements of building density, road network density, and degree of enclosure show enhancement when interacting with other elements, and have a dominant enhancement effect in influencing residents' density perception, indicating that the station area space, due to its own radial attraction, has a large marginal effect when combined with the above elements. On the other hand, local selectivity and

connectivity are nonlinearly weakened when interacting with individual elements, showing a certain threshold effect.

The purpose of this study is to explore the influence mechanism of spatial density elements in residential-dominated metro station areas, with a view to forming a sustainable spatial density configuration model based on perception, in order to eliminate the negative impacts of spatial creation on residents under the control of pure indexes, and to promote the sustainable development of urban space. However, there are some limitations in this study: there is some subjectivity in the investigation of residents' perceived characteristics, and there are some limitations in the representativeness of the spatial density factor selection, and the direction of the influence on residents' perception still needs further research. In the future, the residents' perception and influence factors can be identified more accurately through VR simulation, skin electric detection and other methods

5. References

Zheng Yi and Yang Junyan. (2022) 'Reflection and Exploration of High Density Urban Design Methods from the Perspective of 'Pan Health', *Research on Urban Development*, 29(9): 23-32+2.

Zhang Qiumeng, Teng Li, Chen Xinyu, Lin Yangle and Zhang Jianing. (2023) 'Analysis of Spatial Function Differentiation and Typical Station Structure Characteristics of TOD Station Area in Guangzhou Metro'. *City Observation*, (04): 63-79+161-162.

CHEN C, LI H, LUO W et al. (2022) 'Predicting the effect of street environment on residents' mood states in large urban areas using machine learning and street view images', *Science of The Total Environment*, 816: 151605.

Lv Fei, Han Bingbing and Wang Bo. (2018) 'Research on the Impact of Built Environment in Cold Residential Areas on the Emotional Health of Elderly People Based on Principal Component Analysis', *City Building*, (24):47-50.

Liu Minghao, Li Kun and Li Chenhui. (2023) 'Research on the Relationship between Resident Emotions and Built Environment Based on Weibo Big Data: A Case Study of Wuhan City', *Journal of Western Human Settlements and Environment*, 38(2): 24-29.

Wang Xinyu and Li Fangzheng. (2023) 'Research on the Impact of High Density Block Built Environment on Residents' Positive Emotions: A Case Study of Beijing', *Research on Urban Development*, 30(06): 89-96+140.

Yuanyuan M, Yunzi Y and Hongzan J. (2021) 'Exploring the Impact of Urban Built Environment on Public Emotions Based on Social Media Data: A Case Study of Wuhan', *Land*, 10(9): 986-986.

LIN Y, WOOD S A and LAWLER J J. (2022) 'The relationship between natural environments and subjective well-being as measured by sentiment expressed on Twitter', *Landscape and Urban Planning*, 227: 104539.

Fang Zhiguo, Wang Ranran and Liu Cong et al. (2023) 'Research on the Impact of Street Environment on Individual Sense of Security Based on Multi source Data', *Shanghai Urban Planning*, (02): 109-115.

Fu Yao, Wang Shuwen and Liu Yutong et al. (2022) 'Quantitative study on visual perception measurement of the lower level street facing surface of commercial streets in cold regions', *Xi'an University of Architecture and Technology*, 54(3): 364-375.

Zhu Zhilin and Tian Yinsheng. (2022) 'Exploration of the Application of Quantitative Analysis Methods in the Urban Morphology of Kangze En: A Case Study of Traditional Street Blocks in Guangzhou', *Southern architecture*, (09): 8-18.

Xu Yijuan, Gu Dazhi and Meng Qinghe. (2022) 'Research on Quantifying and Enhancing the Spatial Vitality of Rail Transit Stations from the Perspective of Big Data: A Case Study of Hefei Rail Transit Line 2', *Journal of Qingdao University of Technology*, 43(05): 48-58.

Pan Haixiao, Sun Song and Zhu Qianyun. (2022) 'Practice of Urban Rail Transit and TOD Construction in China', *Architectural Practice*, (9): 178-187.

Zhou Yan, Shao Haiyan and Jin Cheng. (2024) 'The impact of Xiamen Island's built environment on the distribution of shared bicycle starting and ending points based on big data', *Journal of Nanjing Normal University (Natural Science Edition)*, 47(01): 21-29.

Song Y, Wang J, Ge Y and Xu C. (2020) 'An optimal parameters-based geographical detector model enhances geographic characteristics of explanatory variables for spatial heterogeneity analysis: Cases with different types of spatial data', *GIScience & Remote Sensing,* 57(5): 593-610.

Rapporteurs:

- ***Jolanta Zarzycka**, Just Consultancy, Belgium*
- ***Eleni Stefania Kalapoda**, Director, Embeded Climates, USA*
- ***Süleyman Adahi Şahin**, Sakarya University of Applied Sciences, Turkey*

1. Introduction

The 60th ISOCARP World Planning Congress, held in Siena, explored innovative urban strategies under the theme "Reinventing the (In) Visible Cities: From Heritage to Innovation, Forging Pathways to Resilience." Drawing from Siena's rich heritage, the congress emphasized sustainable development, resilience, and environmental stewardship. Track 5, Circular Urbanity, focused on enhancing resource efficiency and minimizing waste in urban planning. Cities, as dynamic centers of activity, face increasing challenges in optimizing resource use while reducing environmental impacts. By integrating advanced technologies, traditional practices, and community-driven solutions, urban planners can address these challenges effectively. This report synthesizes global insights and practices that emphasize circular economy principles, adaptive reuse, and waste reduction strategies. By leveraging innovative tools and fostering international collaboration, Track 5 provides actionable pathways for creating resilient, sustainable urban systems that prioritize long-term environmental health.

2. Core Objectives

Track 5 focuses on three primary objectives that are crucial to the future evolution of urban spaces:

1. **Promoting Circular Economy Principles in Urban Planning:** Encourage the integration of circular economy models to reduce waste, optimize resource use, and minimize the environmental footprint of urban development.
2. **Fostering Sustainable Resource Management:** Develop strategies to enhance the efficiency of material, energy, and water use in cities, supporting systems that prioritize reuse, recycling, and regeneration over linear consumption patterns.
3. **Encouraging Innovation and Collaboration**

for Resilient Cities: Support technological innovations, policy frameworks, and community-driven initiatives that address waste reduction and resource efficiency while enhancing the resilience of urban environments against climate and ecological challenges.

3. Sub-Themes

To better manage these objectives and contextualise concepts and case-studies, two sub-themes have been defined:

1. **Practical Applications of Urban Circularity**
   This subtheme focuses on implementing circular economy principles in real-world urban contexts. It emphasizes how cities can integrate resource-efficient systems, such as waste-to-energy solutions, water reuse technologies, and material recovery strategies, to create self-sustaining urban environments. Examples include the adaptive reuse of buildings, designing closed-loop waste management systems, and promoting shared resource economies. These practical applications aim to showcase how circularity can be seamlessly integrated into urban planning and operations, ensuring sustainability at a systemic level.
2. **Uncovering Circularity Perspectives Across Urban Sectors**
   This subtheme explores how circular economy principles can be applied across different urban sectors, including housing, transportation, energy, and industry. It investigates sector-specific challenges and opportunities, such as transitioning to renewable energy, designing green infrastructure for mobility, and creating circular supply chains in urban industries. By identifying synergies and interdependencies between sectors, this subtheme aims to uncover innovative solutions that amplify the benefits of circularity, ultimately contributing to holistic and resilient urban development.

4. Data Summary

Track 5: Circular Urbanity sessions featured 11 presenters six countries: Austria, China, Egypt, Italy, Romania, and Turkey. Spanning two focused sessions, the discussions highlighted diverse perspectives and innovative approaches to integrating circular economy principles into urban planning and development, showcasing international collaboration and expertise.

5. Key Findings

Identified findings from Track 5: Circular Urbanity highlighted circularity as a versatile and cross-sectoral approach to addressing urban challenges with efficiency and co-benefits. Discussions explored diverse strategies, including innovative water management systems, the reuse of sustainable materials like timber, and urban designs that promote ventilation and adaptability. Circular urbanization models demonstrated integrated solutions for regeneration and reuse, with a strong emphasis on energy efficiency and renewable energy sources. These approaches collectively aim to create livable, climate-resilient cities while minimizing environmental impact.

- **Circularity as a Cross-Sectoral Approach:** Discussions emphasized circularity's ability to address urban challenges efficiently while creating co-benefits across multiple sectors.
- **Resourceful Water Management:** Innovative methods for recycling and conserving water were highlighted to support

sustainable urban water systems.

- **Reuse of Timber in Building Structures:** Demonstrated how repurposing natural materials can reduce construction waste and lower carbon emissions.
- **Road Layouts Enabling Ventilation:** Showcased urban design strategies aimed at improving air quality and thermal comfort within cities.
- **Self-Standing, Multi-Purpose Modular Forms:** Explored flexible and adaptable architectural designs that reduce resource consumption and cater to diverse urban needs.
- **Circular Urbanization Models:** Introduced integrated strategies for reuse, regeneration, and sustainable urban planning.
- **Energy Efficiency and Renewable Energy Sources (RES):** Highlighted as a common platform, these approaches aim to mitigate climate change while enhancing urban livability and resilience.

6. Identified Challenges

The discussions within Track 5: Circular Urbanity brought to light several challenges associated with implementing circularity in urban planning and development:

- **Practical Applications of Circularity:** Despite its potential, the practical application of circular economy principles in urban planning remains a significant challenge. Translating theoretical concepts into actionable and scalable solutions often encounters barriers related to feasibility, resource allocation, and stakeholder engagement.
- **Complexity of Urban Circularity:** The inherently cross-sectoral nature of urban circularity adds layers of complexity. Effective integration requires coordination across multiple sectors, such as housing, transportation, and energy, often hindered by differing priorities, regulations, and resource management practices.
- **Fragmented Approaches:** Current strategies for circular urban development are frequently fragmented, leading to inefficiencies and a lack of cohesive outcomes. The absence of unified frameworks and collaboration among stakeholders impedes the creation of comprehensive and sustainable urban circularity models.

7. Recommendations

- **Harness the Potential for Innovation:** Circularity offers significant opportunities for innovation in urban planning and development. Encouraging research and experimentation can lead to transformative solutions that enhance resource efficiency and sustainability.
- **Develop Methods and Practical Applications:** Further development of methods and actionable strategies is essential to boost urban circularity. Practical recommendations, tailored to diverse urban contexts, should be prioritized to ensure scalability and impact.
- **Engage Stakeholders Effectively:** Active involvement of stakeholders, including governments, private sector actors, communities, and researchers, is critical. Collaborative approaches help define effective solutions and are a key factor in successfully implementing circularity in urban environments.

8. Conclusion

Track 2 The discussions and insights from Track 5: Circular Urbanity underscore the transformative potential of circular economy principles in urban planning. By addressing challenges such as the complexity of cross-sectoral integration, practical application barriers, and fragmented approaches, circularity emerges as a vital framework for fostering resource efficiency, sustainability, and resilience. Innovative practices, stakeholder collaboration, and the integration of advanced technologies with traditional methods provide actionable pathways for creating climate-resilient, livable cities. By embracing these strategies, urban planners and stakeholders can redefine urban systems to not only meet contemporary challenges but also build a sustainable legacy for future generations.

Research Paper

Research on Campus Environmental Space Configuration under the Perspective of Supply and Demand--Taking Harbin Institute of Technology as an Example

Tianxiao Huang, Corresponding author, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Ming Lu, School of Architecture and Design, Harbin Institute of Technology; Key Laboratory of Cold Region Urban and Rural Human Settlement Environment Science and Technology, Ministry of Industry and Information Technology, China

Abstract

Under the background of low-carbon development, building a green and low-carbon campus has become the responsibility and mission of colleges and universities. As the main body of energy consumption on university campuses, students' daily environmental protection behaviours impact campus carbon emissions. Environmental protection space refers to the space for recycling resources on campus, and whether the configuration of campus environmental protection space is reasonable or not has an important impact on enhancing students' recycling initiative and reducing carbon emissions. Taking Harbin Institute of Technology as an example, this study constructs an evaluation index system based on the perspective of supply-demand balance and researches the supply-demand relationship between the configuration of campus environmental protection space and users' behavioural needs. It is found that the configuration of environmental space on campus does not present the desired compatible relationship with user needs. Finally, we propose optimization ideas for different types of environmental protection space. The study aids in guiding campus students to be proactive in environmental protection and in creating a low-carbon and efficient environmental space on campus.

Keywords

University campus, Environmental protection space, Low-carbon behavior

1. Introduction

In the context of low-carbon development, the reduction of low-carbon emissions on university campuses is of great significance to the construction of low-carbon cities, and the construction of green low-carbon campuses has become the responsibility and mission of universities (Tan, 2022). There is a close relationship between the built environment of university campuses and carbon emissions. Optimizing the university campus's built environment can reduce the campus's carbon emissions by 20%-30% (Zou, Zhang, Fang, 2017). Environmental protection space refers to the space for recycling resources

on campus (Wu, Qiu, Liu, 2023), which is the material carrier that assists students in low-carbon environmental protection behaviour and is an important part of a low-carbon campus. The population density of university campuses is large, and students are the main energy consumption of university campuses, which is the main producer of campus waste. Students' low-carbon environmental protection behaviour also affects the carbon emission intensity on campus (Wu, Zhang, Cui, 2022; Tan, Xu, Song, 2019). Optimizing the design of environmental protection space can promote students' active occurrence of low-carbon behaviour and improve the efficiency of carbon emission reduction on campus (Zhao, Qiu, Xu, 2020; Jiang, Chen, Xu, 2013). The existing research on campus low-carbon mainly focuses on campus buildings' low-carbon design, the campus's overall spatial form design, and students' daily behaviour. Studies on students' low-carbon behaviour mainly focus on "sports activities" (Baller, Stephanie, Peachey, 2015; Horacek, Yildirim, Seidman,2019; De Lauer, Hayes, Haluch, 2022), "commuting" (Yang, Liang, Cao, 2020), "energy use" (Busaeri, Hiron, 2021; Hacımurat, 2024), etc. There are few studies on students' behaviour-based carbon reduction and environmental protection space. Whether the current campus environmental space configuration can meet the needs of students' environmental behaviour needs to be researched. The focus of this study is how to scientifically and reasonably allocate the campus environmental protection facilities so that they can play a full role in maximum efficiency. The research analyses the supply of campus environmental protection facilities and students' environmental protection behaviour and studies the balance between supply and demand. It will help guide campus students to take the initiative to protect the environment and create a low-carbon and efficient campus environmental protection space.

2. Methodology

2.1. Overview of the study area

The study was carried out on the main campus of Harbin Institute of Technology, and the selected campus covers the teaching area, dormitory area, office area, sports area, cafeteria area and landscape area with about 15,000 students. As shown in Figure 1, the scope has a complete function of the campus, between the various functional areas of the longest time of 15 min on foot, reflect comprehensively the campus environmental behaviour, environmental space configuration is more traditional, students environmental awareness is higher, can represent the traditional campus to carry out the research. According to the actual situation of the campus, the campus environmental protection space is divided into four categories: garbage collection space, express carton recycling space, old clothing recycling space and old book recycling space. Garbage collection space refers to the general garbage collection space containing garbage bins on the campus. As the pre-survey results show, the areas with the largest garbage are the dormitory and the teaching areas. These two areas are also the areas where students spend the most time daily. The setting of environmental protection space in these two regions has a greater impact on carbon emission reduction than other regions, so the following paper mainly discusses these two regions. Both garbage collection spaces are small, and the dormitory area is mainly located in the public hygiene room or corner space on each floor of the dormitory building and in front of the dormitory building. The garbage generated by students mainly consists of takeout plastic packaging, food scraps, plastic water bottles, express cartons and express plastic packaging. The teaching area is mainly located in the classrooms and public toilets on each floor, and the waste generated by students is mainly used paper and plastic water bottles. The teaching area is close to the cafeteria, producing less food debris and takeout plastic packaging. The express packaging recycling space refers to the space for students to unpack and recycle the express packaging, generally located at the gate of the express station

on campus. There are two stations within the sample campus, one of which is a large express station with a paper packaging recycling space, including an express unpacking area and an outer packaging recycling box, and the other is a small express station with only a recycling box and no other space. The clothing recycling space used on the sample campus is mainly located in the common lobby at the entrance of the first floor of each residence hall. There is a recycling space for used books in the sample campus in the form of a second-hand trading booth.

Figure 1. Overview of the scope of the study

2.2. Method of measurement

The study measures the matching level of supply and demand relationship of environmental protection space by its availability level. Through the correlation analysis of each index in the availability and the implementation level of students' environmental behaviour, the strong correlation factors affecting the availability of environmental protection space are obtained. Finally, we propose an optimization method of environmental space design based on the availability of environmental space, the results of students' environmental behaviour demand and the results of correlation analysis.

In supply and demand relationship research, spatial availability is usually measured by the Gaussian two-step mobile search method (Zhang, Dou, Qin, 2024). However, when using the Gauss two-step mobile search method, the effective service radius of facilities is a difficult factor to determine (Tao, Cheng, 2016), and this method is mostly used to study the supply and demand relationship between large-scale public facilities and community residents in large cities. However, the scale of campus environmental protection space is small, the types are diverse, the service radius is small and different, and the users' daily activities are regular and concentrated. Hence, this research method is not applicable. Therefore, this study builds an evaluation index system based on relevant literature and samples for campus environmental protection space availability. The specific index system is shown in Table 1. In the first part of the questionnaire, the evaluation questions are set according to the indicators and the overall availability of various environmental protection spaces. The Likert scale scoring method of 1-5 points is adopted. The scale consists of statements, such as "I think the garbage classification method of the garbage collection space in the public toilet of the dormitory building is very reasonable." For each statement, there are five answers: "strongly agree," "agree," "not necessarily," "disagree," and "strongly disagree," which are recorded as 5, 4, 3, 2, and 1. The average result of the overall score was used to evaluate the level of each indicator. 1-3 was classified as poor level, 3-4 as good level, and 4-5 as

excellent level. In the second part of the questionnaire, questions are set for students' daily environmental behaviour, and the scoring method is also adopted. The scale is also a set of statements, such as "I will conduct environmental behavior of garbage classification in the garbage collection space in the public bathroom of the dormitory building." Finally, the Pearson correlation analysis method was used to obtain the strong spatial correlation factors affecting environmental protection behaviour. The third part of the questionnaire is about the personal attributes of the respondents. The questionnaire was randomly sampled and distributed to students in the sample campus. Finally, 325 valid questionnaires were collected.

Table 1. Evaluation index and scoring method of campus environmental protection space availability

Number	Types	Evaluation index	Number	Types	Evaluation index
1	Garbage collection space	·Garbage sorting method ·Size of bin recycling space ·Convenient bin location ·Number of Dustbins ·Garbage collection management ·Dumpster marking	3	Old clothes recycling space	·Spatial position ·Space quantity ·Space size ·Spatial identification ·Space management
2	Express packaging recycling space	·Express packaging unpacking processing space position ·Express package unpacking processing space ·Express packaging processing space identification ·Quantity of express packaging handling space ·Recyclable bin location ·Recyclable bin size ·Number of recyclable bins ·Recovery management	4	Recycling space for old books	·Spatial position ·Space quantity ·Space size ·Spatial identification ·Space management

3. Results

3.1. Analysis of availability of campus environmental protection space

Among the availability of the four types of environmentally friendly space on campus, only the used clothing recycling space has a good overall score, while the other three types of space have a low score, which indicates that the configuration of environmentally friendly space on campus does not meet the needs of users.

The evaluation results of garbage collection space showed that the overall availability of environmentally friendly space in the dormitory area was poor (score=2.5), while the teaching area was relatively good (score=3.6). The environmental protection space in the dormitory area mainly includes the garbage dumping space on each floor and the centralized garbage disposal space in front of the dormitory building. The low score (score < 3.0) was mainly for the rationality of garbage classification, the size of trash recycling space and the clarity of trash identification. The study found that each level of the public

waste bin is a large bin, in the form of mixed treatment, without waste separation, resulting in a loss of carbon reduction in recyclable waste such as plastic water bottles and delivery boxes, resulting in at least 24.0% of excess carbon emissions (Li, Tan, 2015). In addition, there are more students in the dormitory building, and students stay in the dormitory building for a long time, resulting in a large amount of garbage generation in the dormitory building; the current size of garbage recycling space and recycling management level can not match the needs of garbage delivery, and the garbage bin in the public toilet will still overflow. Female students have a higher demand for environmentally friendly space in dormitory buildings because of their higher shopping frequency than male students. The central garbage disposal space in front of the dormitory building contains garbage bins classified as recyclable and non-recyclable. However, the volume of garbage bins is too small, and recyclable garbage, such as large cardboard boxes, cannot be put into them. Most students put garbage in the dormitory in the garbage bin in the public bathroom rather than outside of the building, which results in the low recycling rate of garbage bins in front of the building. The score of the teaching area is low (score < 3.0), mainly for the rationality of garbage classification. The investigation found that the garbage bin in the classroom was a large bucket, also in the form of mixed treatment, and there was no garbage classification. Although the types of waste generated in the classroom are relatively simple, most are recyclables such as paper and plastic bottles, which will still cause carbon emission reduction losses.

The availability of express packaging recycling space was generally poor (score=2.9), and the rationality of the size of express packaging opening processing space, the adequacy of the quantity of express packaging processing space, and the rationality of the location of recyclable boxes scored low (score < 3.0). According to the analysis, the processing time of students' delivery boxes mainly depends on the delivery size and the material of the goods. Usually, the small parcel express will open and put the outer package into the recycling box on the spot after receiving the express, which requires higher space for packaging, unpacking and processing at the express pick-up point. Large express or fragile express students usually get into the dormitory first. Then, there is packaging, which requires a higher position for the recycling box of express packaging, and most people want to be able to put it nearby.

The availability of used clothing recycling space was generally good (score=3.7), and the rationality score of space size was low (score < 3.0). This is because the sample school is located in a cold region of China, the old clothes contain a large number of thicker winter clothes, the old clothes recycling box can only withstand the thicker coat within 10 pieces for the number of old clothes of students in an apartment building, the box capacity is not enough, need to be adjusted.

The availability of recycled space for old books was generally poor (score=2.8), and the scores of space sufficiency and timeliness of space management were low (score < 3.0). Donation or exchange of old books is a common form of resource reuse on university campuses. However, the current recycling space of old books exists in second-hand trading booths, and there is only one place, which leads to resource replacement only through a third party, resulting in poor information and poor resource utilization effect. Although the book donation activity is held during the graduation season every year, the effect is not ideal, and the management of the activity needs to be improved.

3.2. Analysis of strong correlation spatial factors of campus environmental protection behaviour

The environmental spatial factors that are linearly positively correlated with the implementation level of students' environmental protection behaviour were identified through Pearson correlation analysis. As shown in Table 2, the correlation coefficient R-value above 0.8 and P-value below 0.05 were judged to be

strongly correlated factors, indicating that increasing the value can directly promote students' environmental protection behaviour. In addition to the above factors that need to be improved, the express packaging recycling space can promote students' environmental behaviour by optimizing the convenience of the spatial location of the express packaging unpacking and the rationality of the number of recyclable boxes. Recycling space for old books can promote students' environmental behaviour by optimizing the convenience of spatial location.

Table 2. Campus environmental protection space strong correlation factors

Types of environmental protection space	Garbage collection space			Express packaging recycling space		Recycling space for old books
	Dustbin in dormitory building	Centralize garbage in front of dormitory building	Dustbin in teaching building			
Correlation factor	Garbage sorting method	Size of bin recycling space	Garbage sorting method	Express packaging unpacking processing space position	Number of recyclable bins	Spatial position
Correlation coefficient	0.904**	0.848**	0.842**	0.812**	0.843**	0.803**

Where ** indicates P<0.01 and * indicates P<0.05.

4. Conclusion

In this study, the matching relationship between the four types of campus environmental protection space configuration and user behavior needs was obtained by constructing the campus environmental protection space evaluation index system and the evaluation and correlation analysis of indicators. The results show that, on the whole, there is no ideal relationship between campus environmental space configuration and user needs. According to the research results, different types of environmental protection space optimization methods are proposed. The idea of space allocation proposed in this study provides a certain reference significance for transforming traditional material space planning into a concept centered on people's needs. It plays a positive role in promoting the construction of low-carbon campuses in colleges and universities. In the future, the research will combine more theories and methods to deepen this part of the research more scientifically and rationally.

5. References

Baller, Stephanie, L., Peachey, Andrew, A., (2015). 'Perceived built environment characteristics of on-campus and off-campus neighborhoods associated with physical activity of college students'. *Journal of American college health*, 63(5), pp.37-42.

Busaeri, N., Hiron, N., (2021). 'Green Campus Establishment Through Carbon Emission and Energy Efficiency Control'. *International conference on smart-green technology in electrical and information systems*, pp.106-111.

De Lauer, V., Hayes, T., Haluch, A. (eds.). (2022). 'The Impact of Natural Environments and Biophilic Design as Supportive and Nurturing Spaces on a Residential College Campus'. *Cogent social sciences*, 8(1), p.2000570.

Hacımurat, D., (2024), 'Design and optimization of hybrid renewable energy systems for hydrogen production at Aksaray University campus'. *Process Safety and Environmental Protection*, 192, pp.543-556,

Horacek, T.M., Yildirim, E.D., Seidman, D. (eds.) (2019). ' Redesign, Field-Testing, and Validation of the Physical Activity Campus Environmental Supports (PACES) Audit'. *Journal of environmental and public health*, 5, p.5819752.

Jiang, P., Chen, Y. H., Xu, B., Dong, W. , Kennedy, E., (2013). ' Building low carbon communities in China: The role of individual's behaviour change and engagement'. *Energy Policy*, 60, pp.611-620.

Li, X. , Tan, H. , Rackes, A., (2015). 'Carbon footprint analysis of student behavior for a sustainable university campus in china'. *Journal of Cleaner Production*, 106(nov.1), pp. 97-108.

Tan, H.W., (2022). 'New exploration of the sustainable development path of university campus under the goal of carbon neutralit'. *Energy Environmental Protection*, 36(5), pp.1-12.

Tao, Z. L., Cheng, Y., (2016). 'Research progress of the two-step floating catchment area method and extensions'. *Progress in Geography*, 35(5), pp. 589-599.

Wu, J.X., Zhang, M.Y., Cui, J.T., Xin, Z.Y., (2022). 'Research on the Relationship Between Campus 0utdoor Space Desicn and Students'Use Behaviors'. *Urbanism and Architecture*, 19(5),pp.133-137.

Wu, Y., Qiu, H.F., Liu, X.Y., Yuan, Y., (2023). 'A study on the correlation between campus space and students' carbon emission behavior'. *China Annual Urban Planning Conference*, 19, pp.290-302

Yang, W.Y., Liang, F.W., Cao, X.S., (2020). 'Examining the effects of the multi-scale built environment on residents'CO2 emissions from commuting'. *Geographical Research*, 39(7), pp.1625-1639.

Zhang, L., Dou, W.S., Qin, B., (2024). 'Study on spatial allocation of public sports facilities in Beijing at residential communities scale'. *Journal of Geo-information Science*, 26(2), pp.381-392.

Zhao, X.L., Qiu, X., Xu, J.G., Hou, Y.J., (2020). 'Review of Research Methods for Green Spatial Behavioral Activities and Environmental Cognition'. *Landscape Architecture*, 27(03), pp.56-62.

Zou, R., Zhang, C.Y., Fang, T.,Wang, C.J., (2017). 'Research on low-carbon construction strategy of campus in cold area based on carbon balance accounting'. *Chinese Journal of Population Resources and Environment*, 27(4), pp.144-150.

Research Paper

Timber Buildings and the Environmental Benefits of Cascading: LCA Application to Circular Practices in the Wood Value Chain

Anna RUINI, *Ecodynamics Group, Department of Physical Sciences, Earth and Environment, University of Siena, Italy and Department of Science, Technology and Society, University School for Advanced Studies IUSS Pavia, Pavia, Italy*

Fabio SPORCHIA, *Ecodynamics Group, Department of Physical Sciences, Earth and Environment, University of Siena, Italy and Department of Science, Technology and Society, University School for Advanced Studies IUSS Pavia, Pavia, Italy*

Alessia LE ROSE, *Ecodynamics Group, Department of Physical Sciences, Earth and Environment, University of Siena, Italy*

Carmela GIOIA, *Ecodynamics Group, Department of Physical Sciences, Earth and Environment, University of Siena, Italy*

Nicoletta PATRIZI, *Ecodynamics Group, Department of Physical Sciences, Earth and Environment, University of Siena, Italy*

Simone BASTIANONI, *Ecodynamics Group, Department of Physical Sciences, Earth and Environment, University of Siena, Italy*

Abstract

The construction industry is a significant resource consumer and a key contributor to greenhouse gas emissions worldwide. Timber buildings in general, and particularly those using mass timber construction products, have the capacity to change the current carbon emission trend in the construction sector and instead act as a net carbon sink. However, the current timber value chain remains linear, prioritizing energy recovery over reuse due to insufficient standards and low demand for recovered materials.

This study compares the environmental benefits of reusing mass timber elements designed for deconstruction versus the current practice of energy recovery. The findings highlight that extending the value chain by retaining timber's structural function is more environmentally advantageous than downgrading or direct energy production. These results underscore the need for regulatory changes to promote timber reuse and a circular timber economy.

Keywords

Engineered timber, timber building, LCA, end-of-life, reuse, Design for Deconstruction and Reuse

1. Introduction

1.1. Study Background

The population increase combined with transformation in social processes like population aging, increased affluence, and global warming is contributing to an increased need for shelter and infrastructure. (EEA,

2024). As a result, the construction industry is a major contributor to socio-economic development, and, at the same time, it is the most environmentally impactful sector in the EU, accounting for over 30% of the EU's environmental footprint. (EEA, 2024). A significant portion of these impacts is embedded in the materials used for construction (IPCC, 2023), making material selection crucial for reducing the sector's environmental impacts (Hu, 2023; Pomponi et al., 2020). Against this background, mass timber construction products such as cross-laminated timber (CLT) and glued laminated timber (glulam) have gained increasing attention: on one hand, they have lower global warming potential and life cycle primary energy than those built from concrete or steel (Duan et al., 2022). On the other they have the potential to transform the construction sector from a carbon emitter to a net carbon sink (Churkina et al., 2020): buildings made using mass timber construction products materials are able to store carbon over their lifespan, acting as "second forests" by sequestering carbon while real forests absorb new CO2 (Amiri et al., 2020; Arehart et al., 2021; Garcia et al., 2020).

Nevertheless, CLT and glulam are manufactured using smaller-diameter trees and wood by-products, yet offer high strength and durability, becoming a good material for circular practices, as they are durable, lightweight, and easy to disassemble through dry connections (Klinge et al., 2019; Munaro et al., 2022), they result suited for Design for Deconstruction and Reuse (Cristescu et al., 2020; Klinge et al., 2019), allowing the reuse with their original function, extending their lifecycle and reducing waste.

Although the benefits of cascading applied to wood products have been acknowledged (Arias et al., 2025, Niu et al., 2021; Thonemann and Schumann, 2018), research specifically addressing the reuse of structural timber components is limited (Niu et al., 2021; Vis et al., 2016). Moreover, a lack of European standards and regulations for wood recovery, along with low demand for recovered materials (Cristescu et al., 2020), results in a predominately linear timber value chain, with energy recovery often prioritized (Niu et al., 2021). The linear approach amper the expression of the environmental advantages of extending the lifecycle through cascading.

1.2. Aim of the Study

This study quantitively evaluates the environmental benefits of reusing mass timber elements within a multi-stage cascading system, maintaining their structural function across multiple lifecycles. Life Cycle Assessment (LCA) is applied to a five-story timber building designed for multi-stage cascading. The study assesses and compares the environmental benefits of reusing mass timber elements designed for deconstruction versus the current practice of energy recovery. It aims to emphasize the importance of incorporating cascading use into end-of-life modeling for timber buildings.

2. Material and methods

2.1. Case Study

The subject of the study is a five-story commercial timber building with an area of 7,290 m² and a height of 20 meters. The building presents prefabricated elements, a post-and-beam system, and a non-structural façade. Core components such as reinforced concrete foundations, glulam beams, CLT slabs, and laminated veneer lumber (LVL) façades were included in the assessment, while interior finishes and non-structural elements were excluded. Approximately 55% of the building's weight consists of concrete, adhering to Danish standards (Danish Ministry of Economic and Business Affairs, Danish Enterprise and Construction Authority, 2010. The Building Regulations 2010). The building's Reference Service Life (RSL) is set at 50 years, in line with ISO 15686-1: 2011) and BS EN 1990 requirements.)

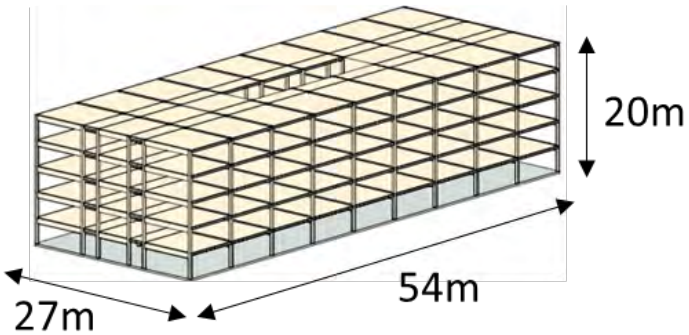


Figure 2.1 The case study examined: structural frame of a five-story commercial timber building with an area of 7,290 m² and a height of 20 meters.

The study aims to evaluate the environmental impact of reusing mass timber elements designed for deconstruction versus the current practice of energy recovery. In order to do so, two different scenarios are hypnotized: Extended Lifespan scenario and Conventional Disposal scenario.

In the Extended Lifespan scenario, Figure 2.2, timber components—such as glulam beams, CLT slabs, and LVL façade elements— are dismantled and reused for the same function after the building's 50-year lifecycle. Approximately 98% of the timber is reused and it is assumed to maintain its integrity and meet required standards, allowing it to serve the same role in the new building. While the scraps are incinerated. After the second building lifecycle, timber is cascaded into Particle Board (PB) and then incinerated. The PB obtained from dismantling the 2nd building is 2,199 m3, a technical loss of 5% due to transport and production processes was included in the PB calculation (Hoglmeier et al., 2015).

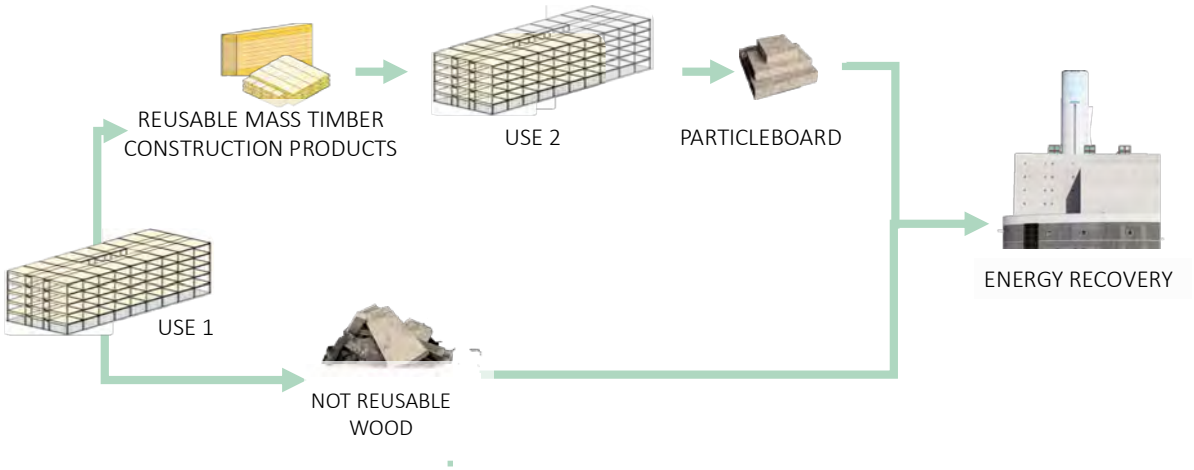


Figure 2.2 Extended Lifespan Scenario, at the end of the building's 50-year reference service life, the structural components are dismantled and reused in new construction for an additional 50 years. Wood scraps generated during disassembly incinerated, with virgin materials replacing any portion that cannot be reused.

In the conventional Disposal scenario, Figure 2.3, although the structural components in this scenario are also designed to be dismantled and reused, they are not reused. After 50 years, the building is demolished, and all wood elements, including (reusable) glulam beams, CLT slabs, and LVL façades, are incinerated in line with the EN 15804:2012+A2:2019.

Figure 2.3 Conventional Disposal Scenario, at the end of the building's 50-year reference service life (RSL), the structural components are incinerated, with no reuse of materials.

2.2. Use of the paragraphs

The LCA follows ISO 14040:2006 and 14044:2020 standards, and is implemented to compare the Extended Lifespan and Conventional Disposal scenarios. To allow comparison, the commercial service provided by the building's structure over 100 years is set as the functional unit (see Figure 2.4). This results in different reference flows for the two scenarios.

In the Extended Lifespan scenario, the reference flow is two buildings and particleboard: the first building is made from virgin wood. The second uses wood from the deconstruction of the first, with some virgin wood added, each lasting 50 years for a total of 100 years. The particle board, 2199 m^3, is made of post-consumer wood from recycling the wood from the second building. In the Conventional Disposal Scenario, the reference flow is two buildings built using virgin wood, each lasting 50 years for a total of 100 years, and particle board, 2199 m^3, from pre-consumer scrap external sources. It was necessary to add PB from external sources in the Conventional Disposal Scenario in order to have the same output for both scenarios to ensure comparability.

The temporal system boundary is 100 years and the geographical scope is limited to European countries.

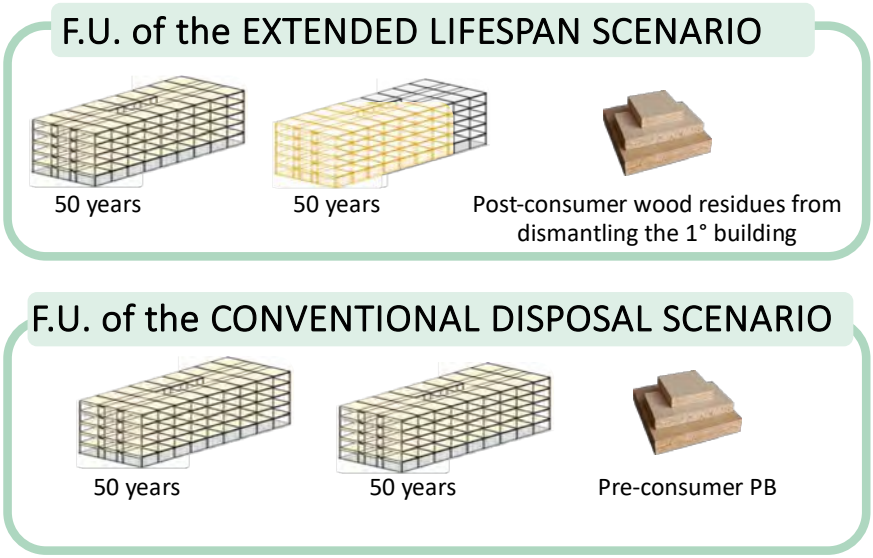


Figure 2.4 The figure describes the functional unit for each scenario. In the Conventional Disposal Scenario, two 5-story timber buildings are built using virgin wood, each lasting 50 years for a total of 100 years. The wood comes from virgin sources, and at their end of life, the buildings are demolished and the wood is incinerated. In the Extended Lifespan Scenario, the first building is made from virgin wood, but the second uses wood from the deconstruction of the first, with some virgin wood added after 50 years, the wood from the second building is recycled into particle board, using post-consumer wood from both buildings.

Foreground data for the building's composition—including the list of structural components and their quantities—was collected and used for the Life Cycle Inventory (Table 2.1).

Table 2.1 Life Cycle Inventory of the timber building.

	Scenario	*Conventional Disposal Scenario*	*Extended Lifespan Scenario*
Component	Material	Amount (kg)	Amount (kg)
Groundwork	Sand	393,660	393,660
	Gravel	415,530	415,530
	Concrete	729,000	729,000
	Reinforcement steel	11,868	11,868
	XPS	46,656	46,656
	PVC	2,916	2,916
Foundation	Concrete	1,140,000	1,140,000
	Steel	42,750	42,750
Framework	Glulam (columns)	48,384	968
	Brackets (columns)	750	750
	Glulam (beams)	125,355	2,507
	Brackets (beams)	1,125	1,125
	Concrete (stairs)	31,250	31,250
	Steel (stairs)	3,000	3,000

Floors	CLT	595,350	11,907
	Concrete	992,250	992,250
	Rockwool	33,750	33,750
	Gypsum board	182,250	182,250
Internal walls	CLT	221,466	4,429
	Steel	1,200	1,200
Envelope	Steel plates	48,600	48,600
	Windbreaker	38,880	38,880
	Wood skeleton (LVL)	30,618	612
	Mineral wool	29,160	29,160
	Plasterboard	87,480	87,480
	Plaster	24,300	24,300
	Paint	1,118	1,118
Roof	Mineral wool	510	510
	PVC	2.92	2.92
	Bituminous film	7.29	7.29

The LCA analysis was conducted using SimaPro v.9.0 software.

Background data were obtained from the Ecoinvent 3.6 database, covering most materials' upstream production and raw material extraction for timber elements (glulam, CLT, LVL). Primary data for timber manufacturing were gathered from industry sources, supplemented by literature (Rüter, 2012), while for other materials, production data were derived from Environmental Product Declarations (EPDs). The transportation of materials was modeled over a 100 km distance (Höglmeier et al., 2015), using 16-32 metric ton trucks adhering to Euro V emission standards. Energy demand during the construction phase was based on diesel and electricity consumption reported in EPDs. In the Extended Lifespan Scenario, disassembly energy was assumed to be equal to the energy required for assembly, while fuel consumption for demolition in the Conventional Disposal Scenario was estimated using the model provided by Ivanica et al. (2022). Waste treatment for steel and concrete was modeled using European waste treatment statistics, while for other materials, statistics from EPDs were used. The Life Cycle Impact Assessment was conducted using the EF 3.0 method (Eurostat, 2018; Fazio et al., 2018), in accordance with EN 15804:2019. The selected impact indicators included Climate Change, Ozone Depletion, Acidification, Freshwater Eutrophication, Tropospheric Ozone Formation, and Abiotic Depletion for both fossil and non-fossil resources. In line with standard LCA practices, biogenic CO_2 uptake during forest growth and emissions at the end of life were not accounted for. A conservative approach was also taken by excluding credits for avoided impacts, such as energy recovery from wood combustion. Therefore, "incineration" will be used instead of "energy recovery" when describing the end-of-life treatment for wood components.

3. Results

The Extended Lifespan Scenario showed a 13% reduction in Global Warming Potential compared to the Conventional Disposal Scenario (3,283 t CO2 eq vs. 3,788 t CO2 eq). This was mainly due to a 28% decrease

in emissions from the second building materials. Additionally, PB production saw a 20% reduction in emissions and lower timber incineration impacts (Figure 3.1).

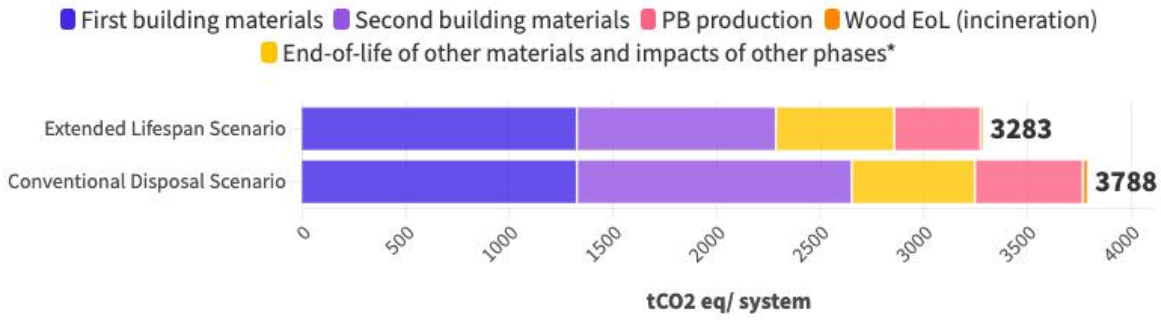


Figure 3.1 Comparison of Global Warming Potential for Extended Lifespan vs Conventional Disposal scenario. The chart illustrates the contribution of different lifecycle stages to the total GWP (t CO_2 eq) for each scenario. The Extended Lifespan scenario shows reduced emissions, particularly from the second building materials and particle board production phases. Note that Timber EoL is set to zero since no biogenic carbon is accounted for such process

As shown in Table 3.1, Ozone Depletion Potential was reduced by 20%, Photochemical Ozone Formation by 24%, Acidification Potential by 16%, and Eutrophication by 24%. Resource Use for Fossil Energy decreased by 16%, though Resource Use for Minerals and Metals showed only a 1% reduction.

Table 3.1 Comparison of the results of Life Cycle Impact Assessment of both scenarios. The indicators selected were: Climate Change, Depletion Potential of the stratospheric Ozone layer, Acidification Potential, Eutrophication Potential freshwater (EP-freshwater), formation potential of tropospheric ozone, Abiotic Depletion Potential for non-fossil resources, and Abiotic Depletion Potential for fossil resources.

Scenario	Climate change	Ozone depletion	Photochemical ozone	Acidification	Eutrophication, freshwater	Resource use, fossils	Resource use, minerals and metals
	t CO_2 eq	g CFC11 eq	t NMVOC eq	kmol H+ eq	kg P eq	GJ	g Sb eq
Conventional Disposal	3,788	450	19	20	165	58,183	41,200
Extended Lifespan Scenario	3,283	360	14	17	125	48,657	40,700
	-13%	-20%	-24%	-16%	-24%	-16%	-1%

4. Results

The results of this study add to the expanding body of research on timber reuse and cascading principles (Cordier et al., 2022; Duan et al., 2022; Szichta et al., 2022; Thonemann and Schumann, 2018). While prior studies have highlighted the potential of mass timber products like CLT and glulam to reduce emissions in the construction sector (Churkina et al., 2020; Duan et al., 2022), few have explored the environmental advantages of designing timber buildings for reuse at the end of their lifecycle. Most research either overlooks this reuse potential or discusses timber in the context of recycling for lower-grade applications or energy recovery, with Niu et al. (2021) being an exception. By adopting an ex-ante design for disassembly and reuse, this study shows how timber can retain its high-value structural role, thereby extending its

lifecycle and avoiding downgrading. It fills a critical gap by providing quantitative assessments of the environmental benefits of timber reuse, in contrast to previous speculative discussions.

The reuse strategy presented in the Extended Lifespan Scenario results in emissions reductions compared to the Conventional Disposal Scenario. Although our analysis focuses on a commercial building, the reuse strategy can be adapted to various building types, including residential structures. The combined use of post-and-beam system and reusable timber components, makes the benefits of reuse applicable across different architectural designs. This versatility provides policymakers and urban planners with a scalable solution for reducing urban carbon emissions.

However, the full environmental potential of timber reuse is restricted by current international standards, like EN 16485:2014, that do not set reused as a possible end of life. Our study demonstrates that timber can be dismantled and reused, effectively doubling its service life. Revising standards to formally recognize timber reuse with the same function as a legitimate end-of-life scenario in Life Cycle Assessments would broaden system boundaries and functional units, fully capturing the environmental advantages of timber reuse and supporting the shift toward circular economy practices in the construction sector.

5. Conclusion

Embracing circular economy practices can lead to drastically decrease resource and emissions levels in the construction industry. Timber, a renewable and abundant material, offers a unique advantage over fossil-based options like concrete and steel thanks to its high potential for reuse and recycling. Even minimal reuse of engineered timber can can have a significant positive impact on the environment.

Our research marks an important step towards quantifying the environmental advantages of wood multiple cascading, focusing on the reuse with the same function. It addresses existing knowledge gaps and highlights the shortcomings of current regulations, calling fora revision of circular economy practices and LCA standards (Malabi Eberhardt et al., 2021).

It proposed a shift from the traditional building-focused perspective to a a systematic outlookthat includes the entire value chain and encompass both reuse and recycling stages. Such an approach amplifies environmental and socio-economic benefits, engaging a range of stakeholders in the process (Bastianoni et al., 2023). As a matter of fact, reusing engineered timber components for the same purpose aligns with the goals of the Circular Economy Action Plan to increase circularity in the construction sector and addresses two out of three UNEP's (2023) critical paths for decarbonizing the industry.

Designing timber buildings for easy deconstruction and maximizing the recovery of timber elements is essential for unlocking a new economic sector. Currently, this potential is hindered by the lack of reusable engineered timber and insufficient regulations. The regulatory framework must be updated to fully harness engineered timber's advantages. Specifically, EN 16485:2014 should be revised to formally recognize timber reuse for the same function as a possible end-of-life scenario in Life Cycle Assessments. Extending the lifespan of timber products and enhancing biogenic CO2 storage through cascading reuse also supports the goals of the EU Green Deal (Sikkema et al., 2023). Although this study did not address biogenic carbon accounting or the benefits of temporary carbon storage, these aspects must be considered to fully realize the environmental benefits of timber in construction and cascading reuse practices.

Acknowledgments

The results of this paper are outcomes of the Build-in-Wood project, a European-funded Horizon 2020 project (number 962820 funded within the H2020-RUR-2019-1 call. Topic LC-RUR-11-2019-2020 “Sustainable wood value chains”).

This paper and related research have been conducted during and with the support of the Italian national inter-university PhD course in Sustainable Development and Climate change.

During the preparation of this work the authors used the Grammarly software (preminum verison) and ChatGPT (4o mini version) in order to spell and grammar check the article and make the test as fluent as possible . After using this tool/service, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

References

Amiri, A., Ottelin, J., Sorvari, J. and Junnila, S., 2020. Cities as carbon sinks—classification of wooden buildings. *Environmental Research Letters*, 15(9), p.094076. https://doi.org/10.1088/1748-9326/aba134

Arehart, J.H., Hart, J., Pomponi, F. and D’Amico, B., 2021. Carbon sequestration and storage in the built environment. *Sustainable Production and Consumption*, 27, pp.1047–1063. https://doi.org/10.1016/j.spc.2021.02.028

Arias, A., Feijoo, G., Moreira, M.T., Tukker, A. and Cucurachi, S., 2025. Advancing waste valorization and end-of-life strategies in the bioeconomy through multi-criteria approaches and the safe and sustainable by design framework. *Renewable and Sustainable Energy Reviews*, 207, p.114907. https://doi.org/10.1016/j.rser.2024.114907

Basquill, S., Neily, P., Quigley, E., Stewart, B. and Keys, K., 2011. *Nova Scotia Department of Natural Resources Renewable Resources Branch: Report For 2011-1*.

Bastianoni, S., Goffetti, G., Neri, E., Patrizi, N., Ruini, A., Sporchia, F. and Pulselli, F.M., 2023. LCA based circularity indices of systems at different scales: a holistic approach. *Science of The Total Environment*, 897, p.165245. https://doi.org/10.1016/j.scitotenv.2023.165245

BS EN 15804:2012+A2:2019, 2019. *Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products*. Brussels: British Standards Institute.

BSN Eurocode, 2002. *BS EN 1990:2002 + A1:2005 - Basis of structural design*. Brussels: British Standards Institute.

Churkina, G., Organschi, A., Reyer, C.P.O., Ruff, A., Vinke, K., Liu, Z., Reck, B.K., Graedel, T.E. and Schellnhuber, H.J., 2020. Buildings as a global carbon sink. *Nature Sustainability*, 3, pp.269–276. https://doi.org/10.1038/s41893-019-0462-4

Cordier, S., Blanchet, P., Robichaud, F. and Amor, B., 2022. Dynamic LCA of the increased use of wood in buildings and its consequences: Integration of CO2 sequestration and material substitutions. *Building and Environment*, 226, p.109695. https://doi.org/10.1016/j.buildenv.2022.109695

Cristescu, C. et al., 2020. *InFutURe Wood Report 1: Design for deconstruction and reuse of timber structures – state of the art review*. https://doi.org/10.23699/bh1w-zn97

Duan, Z., Huang, Q. and Zhang, Q., 2022. Life cycle assessment of mass timber construction: A review. *Building and Environment*, 221, p.109320. https://doi.org/10.1016/j.buildenv.2022.109320

European Committee for Standardization, 2019. *EN 15804:2012+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products*.

European Committee for Standardization, 2014. *EN 16485:2014. Round and Sawn Timber, Environmental Product Declarations, Product Category Rules for Wood and Wood-Based Products for Use in Construction*.

European Environment Agency, 2024. *Addressing the environmental and climate footprint of buildings*. https://doi.org/10.2800/1800539

Eurostat, 2018. *Circular economy indicators - Recovery rate of construction and demolition waste*.

Fazio, S. et al., 2018. *JRC Technical Reports: Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment method: New models and differences with ILCD*. Ispra: Joint Research Centre, European Commission.

Garcia, R., Alvarenga, R.A.F., Huysveld, S., Dewulf, J. and Allacker, K., 2020. Accounting for biogenic carbon and end-of-life allocation in life cycle assessment of multi-output wood cascade systems. *Journal of Cleaner Production*, 275, p.122795. https://doi.org/10.1016/j.jclepro.2020.122795

Höglmeier, K., Steubing, B., Weber-Blaschke, G. and Richter, K., 2015. LCA-based optimization of wood utilization under special consideration of a cascading use of wood. *Journal of Environmental Management*, 152, pp.158–170. https://doi.org/10.1016/j.jenvman.2015.01.018

Hu, M., 2023. A look at residential building stock in the United States - mapping life cycle embodied carbon emissions and other environmental impact. *Sustainable Cities and Society*, 89, p.104333. https://doi.org/10.1016/j.scs.2022.104333

International Standard Organization, 2011. *ISO 15686-1:2011. Buildings and constructed assets — Service life planning — Part 1: General principles and framework*. Geneva: ISO.

IPCC, 2023. Buildings. In: IPCC, *Climate Change 2022: Mitigation of Climate Change. Working Group III Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press, pp.953–1048. https://doi.org/10.1017/9781009157926.011

Ivanica, R., Risse, M., Weber-Blaschke, G. and Richter, K., 2022. Development of a life cycle inventory database and life cycle impact assessment of the building demolition stage: A case study in Germany. *Journal of Cleaner Production*, 338, p.130631. https://doi.org/10.1016/j.jclepro.2022.130631

Klinge, A., Roswag-Klinge, E., Radeljic, L. and Lehmann, M., 2019. Strategies for circular, prefab buildings from waste wood. *IOP Conference Series: Earth and Environmental Science*, 225, p.012052. https://doi.org/10.1088/1755-1315/225/1/012052

Malabi Eberhardt, L.C., van Stijn, A., Kristensen Stranddorf, L., Birkved, M. and Birgisdottir, H., 2021. Environmental Design Guidelines for Circular Building Components: The Case of the Circular Building Structure. *Sustainability*, 13(10), p.5621. https://doi.org/10.3390/su13105621

Munaro, M.R., Tavares, S.F. and Bragança, L., 2022. The ecodesign methodologies to achieve buildings' deconstruction: A review and framework. *Sustainable Production and Consumption*, 30, pp.566–583. https://doi.org/10.1016/j.spc.2021.12.032

Niu, Y., Rasi, K., Hughes, M., Halme, M. and Fink, G., 2021. Prolonging life cycles of construction materials and combating climate change by cascading: The case of reusing timber in Finland. *Resources, Conservation and Recycling*, 170, p.105555. https://doi.org/10.1016/j.resconrec.2021.105555

Pomponi, F., Hart, J., Arehart, J.H. and D'Amico, B., 2020. Buildings as a Global Carbon Sink? A Reality Check on Feasibility Limits. *One Earth*, 3(2), pp.157–161. https://doi.org/10.1016/j.oneear.2020.07.018

Rüter, S., 2012. *Ökobilanz-Basisdaten für Bauprodukte aus Holz*. Braunschweig: Johann Heinrich von Thünen-Institut.

Sikkema, R., Styles, D., Jonsson, R., Tobin, B. and Byrne, K.A., 2023. A market inventory of construction wood for residential building in Europe – in the light of the Green Deal and new circular economy ambitions. *Sustainable Cities and Society*, 90, p.104370. https://doi.org/10.1016/j.scs.2022.104370

Szichta, P., Risse, M., Weber-Blaschke, G. and Richter, K., 2022. Potentials for wood cascading: A model for the prediction of the recovery of timber in Germany. *Resources, Conservation and Recycling*, 178, p.106101. https://doi.org/10.1016/j.resconrec.2021.106101

Thonemann, N. and Schumann, M., 2018. Environmental impacts of wood-based products under consideration of cascade utilization: A systematic literature review. *Journal of Cleaner Production*, 172, pp.4181–4188. https://doi.org/10.1016/j.jclepro.2016.12.069

United Nations Environment Programme (UNEP), 2023. *Building Materials and the Climate: Constructing a New Future*.

United Nations Environment Programme (UNEP), 2021. *2021 Global Status Report for Buildings and Construction: Towards a Zero Emission, Efficient and Resilient Buildings and Construction Sector*. Nairobi: UNEP.

Vis, M., Mantau, U. and Allen, B., 2016. *CASCADES: Study on the Optimised Cascading use of Wood*. Luxembourg: Publications Office of the European Union.

Wernet, G., Bauer, C., Steubing, B., Reinhard, J., Moreno-Ruiz, E. and Weidema, B., 2016. The ecoinvent database version 3 (part I): overview and methodology. *International Journal of Life Cycle Assessment*, 21, pp.1218–1230. https://doi.org/10.1007/s11367-016-1087-8

Case Study Report

Circular Urbanity: Innovations and Insights for Sustainable Urban Development

Mingyi Shi, Shanghai Tongji Urban Planning & Design Institute Co.,ltd., China

Abstract

In the context of global urbanization, where resource consumption and environmental pollution issues are becoming increasingly prominent, the traditional linear economic development model faces severe challenges. Circular cities achieve sustainable urban development by integrating circular economy principles into urban planning. This case study explores the pioneering efforts made by Amsterdam, Malmö, Yokohama and Copenhagen in circular cities, providing development ideas for sustainable urban transformation. The De Ceuvel project in Amsterdam emphasizes the importance of community participation and sustainable practices in urban reconstruction by adaptively reusing former industrial land into sustainable communities. Malmö's West Harbor sets a benchmark for large-scale sustainable urban reconstruction by transforming industrial areas into vibrant, environmentally friendly communities. Yokohama's G30 plan provides a template for urban waste management by implementing a comprehensive recycling program. Copenhagen adopts a diversified energy strategy to support low-carbon urban development while maintaining economic growth, providing important reference and practical experience for sustainable urban development. The study shows that policy support, technological innovation, cross-border cooperation and public participation are key factors for the success of circular urbanization. The innovative practices of these cities not only achieve environmental benefits but also create economic and social value, providing actionable insights and strategies for other cities around the world to transform into circular urbanization.

Keywords

Circular urbanization, sustainable development, waste management, urban innovation, resource efficiency

1. introduction

1.1. Research Background

With the rapid development of global urbanization, resource and environmental issues are becoming increasingly prominent. At present, cities gather more than half of the world's population. Cities are not only the engine of economic development, but also the center of resource consumption and environmental pollution. Cities consume most of the world's primary energy, emit a large amount of greenhouse gases, and make a great contribution to the global economy. Under the constraints of resources and the environment, the traditional "acquisition-manufacturing-disposal" linear development model urgently needs to be transformed. Circular urbanization provides a feasible solution to this situation through innovative technologies and management methods, so that effective resource utilization and economic development can be carried out simultaneously.

1.2.Research Objectives and Significance

This study investigates the circular urbanization practices of four cities around the world: Amsterdam, Malmö, Yokohama and Copenhagen. By analyzing their innovative initiatives in resource utilization, waste management and urban planning, the study identifies the implementation strategies and success factors for circular urbanization, provides valuable references for urban decision makers and planners, and builds a theoretical framework and feasible solutions for cities at different stages of development.

2. Research Methodology

2.1. Multiple Case Comparative Analysis

Case studies in four cities, including Amsterdam, Malmö, Yokohama and Copenhagen, were selected as research objects. Through horizontal comparison and vertical analysis, the effectiveness of each case in circular urbanization was systematically evaluated.

2.2. Quantitative Analysis Methods

(1) Multi-dimensional Benefit Assessment

Establish an evaluation index system covering environmental, economic and social dimensions:

Environment: carbon emission reduction, resource recovery rate, energy efficiency.

Economy: project investment, employment growth rate, number of patents.

Society: citizen participation, GDP contribution rate, landfill volume.

(2) Heat Map Analysis

Use heat maps to analyze the resource recycling efficiency of each city from 2018 to 2022, and perform visual analysis from the horizontal, vertical and resource type dimensions.

(3) Investment-Benefit Correlation Analysis

The bubble chart is used to analyze the input-output relationship of projects in the circular city, and the investment benefits are evaluated through indicators such as investment scale, CO_2 emission reduction, and energy saving rate.

2.3. Research Framework

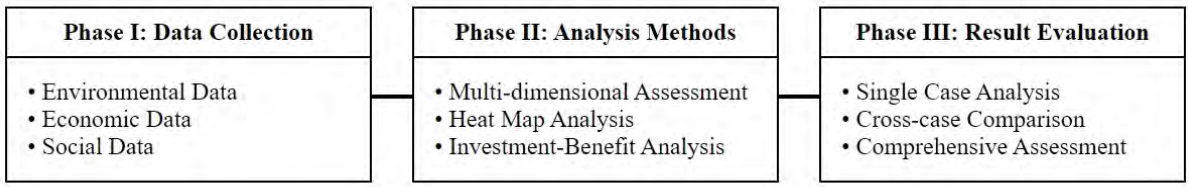


Figure 1. Research Framework for Circular Economy Development Assessment. Source: Author's compilation

2.4. Case Selection

This study needs to select research objects from cities with mature circular city transformation, mainly through three aspects: first, the selected cities have systematic circular economy policy documents and

public implementation data; second, ensure regional diversity and cover cities in different regions; third, select cities with relatively mature development. The final selected cities are: Amsterdam, Malmö, Yokohama and Copenhagen, each of which is representative: Amsterdam has performed well in the sharing economy, Malmö has performed well in industrial symbiosis and clean energy transformation, Yokohama represents Asian cities' innovation in waste management, and Copenhagen demonstrates the integration of circular economy and urban planning. The diverse experiences of these cities provide a multi-dimensional reference for circular urbanization.

3. Case Study

3.1. Amsterdam's De Ceuvel Project: A Model of Circular Urbanization

The De Ceuvel project demonstrates Amsterdam's innovative attempt to redevelop abandoned industrial land. In 2012, the Amsterdam municipality launched this 10-year temporary development experiment at an abandoned shipyard in the north of Amsterdam. This decision reflects the city's forward-looking thinking in the face of environmental issues, and has opened up a new path for urban sustainable development by combining environmental governance with community building.

The project uses a series of innovative environmental governance solutions. In terms of soil remediation, the team chose low-disturbance plant remediation technology, which creates a green landscape while purifying the soil to solve environmental problems by planting carefully selected plants. In terms of energy systems, the project integrates a variety of renewable energy technologies such as solar power generation and biomass energy utilization to establish a complete clean energy supply system. In terms of water resource management, the efficiency of water resource utilization has been greatly improved by combining rainwater collection, sewage treatment and ecological toilets. In terms of space transformation, the design team cleverly used abandoned barges and transformed them into unique office spaces. All buildings are modularly designed, which not only ensures the functionality of use, but also enables them to be moved as a whole after the lease ends, fully reflecting the concept of sustainable resource utilization. Through these innovative means, the project successfully transformed a piece of wasteland into a vibrant ecological creative space.

The success of De Ceuvel is not only reflected in the construction of space, but more importantly, it has developed into a vibrant ecological community. The project has attracted many creative enterprises and entrepreneurial teams to settle in, and has gradually developed into a sustainable development demonstration community integrating work, leisure and education. The community has promoted the public's in-depth understanding of the circular economy while spreading environmental protection concepts through regular workshop visits.

As an important part of Amsterdam's circular city strategy, the De Ceuvel project has been widely recognized. Its success proves that through innovative planning and design and effective community participation, the city's environmental problems and development needs can be effectively solved. This development model that combines environmental restoration, resource recycling and community construction provides a template for the sustainable development of global cities.

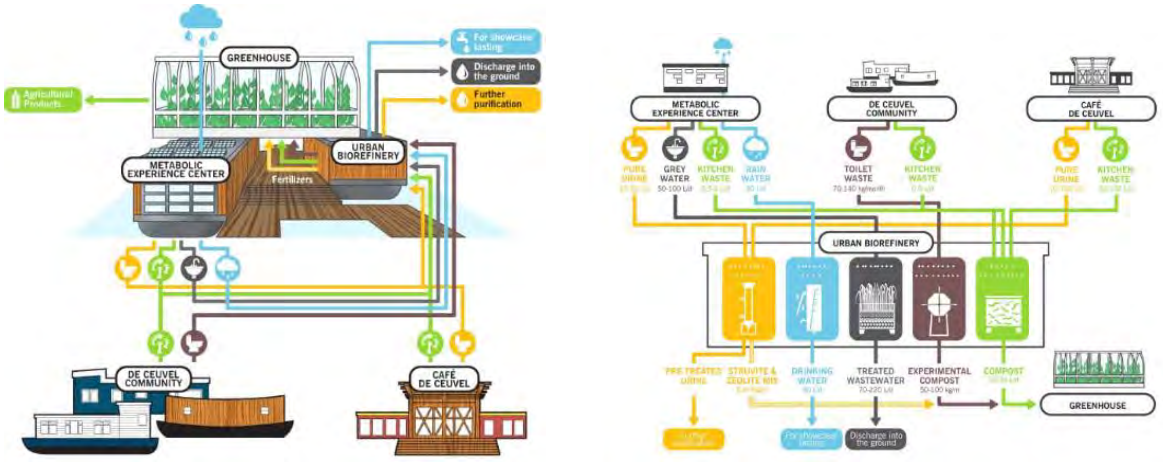


Figure 2. Comprehensive urban ecological cycle system. Source:https://www-metabolic-nl.translate.goog/?_x_tr_sl=zh-TW&_x_tr_tl=zh-CN&_x_tr_hl=zh-CN&_x_tr_pto=sc

3.2. Western Harbor, Malmö: From Industrial Site to Eco-Exemplar

The transformation of Malmö West Harbor began in the late 1990s. The shipbuilding industrial base was facing multiple challenges such as environmental pollution and economic recession. With the decline of traditional industries, the transformation of the industrial land has become an urgent problem for urban development.

The launch of the project coincided with the historical opportunity of Sweden's accession to the European Union in 1995. As a member of the European Union, Sweden not only received support from the EU structural funds, but also benefited from the EU's policy guidance and technical exchanges in the field of sustainable development. Against this background, the Malmö Municipal Government proposed a strategic concept to plan the 175-hectare abandoned shipyard as an ecological demonstration area, and set a development goal of accommodating 25,000 residents and creating 25,000 jobs by 2031. The project implementation adopted an innovative development model, and a strict quality management system was established through close cooperation between the government and the developer. The project pays special attention to energy innovation and has formulated strict building standards, with an annual energy consumption of no more than 105 degrees per square meter. Through a diversified energy combination such as solar energy, wind energy, geothermal energy and seawater heat pumps, supplemented by a smart grid system, the goal of 100% renewable energy supply has been achieved.

The project embodies a comprehensive sustainable concept in planning and design. More than 50% of the area is planned as green space and water, emphasizing the importance of ecological space. Through multifunctional design, residential, office, educational and leisure spaces are organically integrated. At the same time, a green transportation system is built to create a green and livable community. The transformation of Malmö's West Port has had a wide impact internationally and has become a model for sustainable urban development, providing valuable experience for the ecological transformation of industrial land around the world.

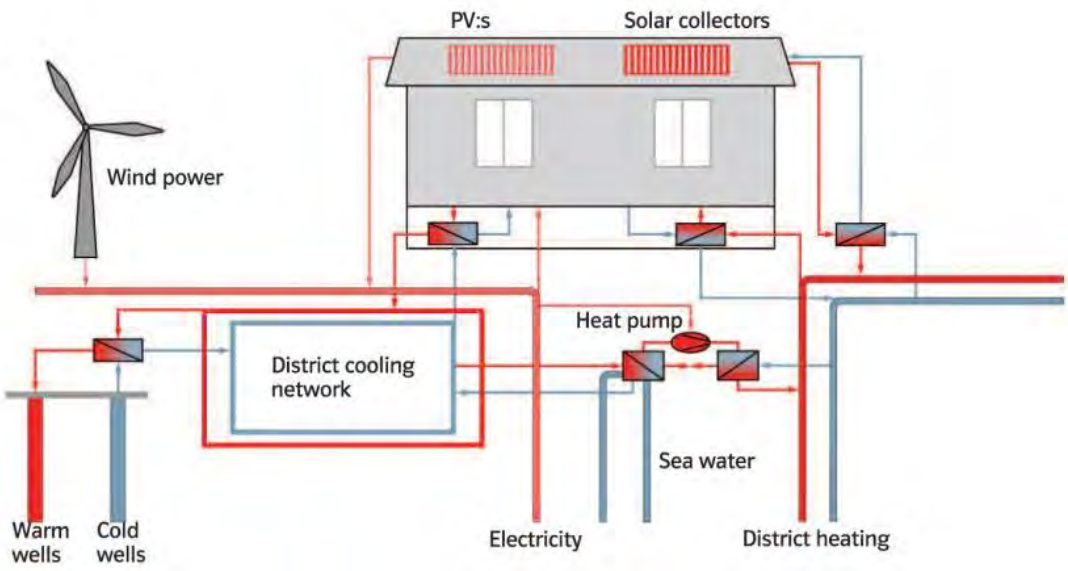


Figure 3. 100 % locally renewable energy. Source: E.ON Värme Sverige.

3.3. Yokohama G30 Plan:A Model for Sustainable Urban Waste Management

In 2003, Yokohama faced a major waste management challenge, with 1.6 million tons of waste generated annually and only 10% recycled. The Yokohama City Government implemented the "G30" program, which aimed to reduce waste to 30% by 2010 through a model of government guidance, corporate support, and citizen participation.

The program expanded waste classification from 5 to 15 categories and established a comprehensive resource recovery system. Yokohama held more than 11,000 public seminars and worked with 3,900 companies to ensure effective implementation of the program.

By 2010, the results of the program exceeded expectations: total waste was reduced by 43.5%, per capita daily waste decreased from 1,033 grams to 608 grams, and the recycling rate increased to 30%. As a result of the successful implementation of the program, two waste incinerators were closed, saving an additional 1.7 billion yen per year and reducing carbon dioxide emissions by 840,000 tons.

The Yokohama experience shows that through systematic planning and sustained efforts, cities can significantly reduce waste and use resources efficiently. While setting clear goals and conducting scientific monitoring, it also focuses on public participation and emphasizes multi-party cooperation, providing a successful model for waste management in cities around the world.

Figure 4. Municipal Solid Waste Management Process Flow. Source: Author's own elaboration.

3.4. Copenhagen: A Global Model for Sustainable Urban Development

In the context of global climate response, Copenhagen has proposed a successful model for sustainable urban development. Between 2005 and 2015, the city reduced carbon emissions by 33% while its population grew by 18% and its economy continued to develop.

Copenhagen has adopted a diversified energy strategy, developing solar and offshore wind power, establishing a regional heating system, and promoting cogeneration. The city has also transformed its public transportation into electrification and hybrid power to support the city's low-carbon development.

In terms of resource recycling, Copenhagen has planned resource recycling projects such as CopenHill to convert waste into energy, utilize biomass, and treat it comprehensively. In terms of smart cities, Copenhagen has improved the efficiency of urban operations through bicycle-friendly planning, flexible heating system planning, and integrated urban utility planning.

Copenhagen's practice has proved that through innovative planning concepts, advanced technology applications, and systematic implementation plans, cities can maintain economic growth and social development while achieving environmental protection goals. This balanced development model provides important reference and practical experience for the sustainable development of global cities.

4. Multi-dimensional Impact Analysis

4.1. Key Performance Indicator Analysis

The study analyzed data from four cities on recycling rates, material use, employment, innovation, and energy efficiency. All four cities have made significant progress in implementing the circular economy. Copenhagen leads with a 55% recycling rate; Amsterdam has made significant achievements in circular material use; Yokohama excels in innovation capacity; and Malmö excels in energy efficiency. Overall, these cities have achieved environmental benefits through the circular urbanization transformation.

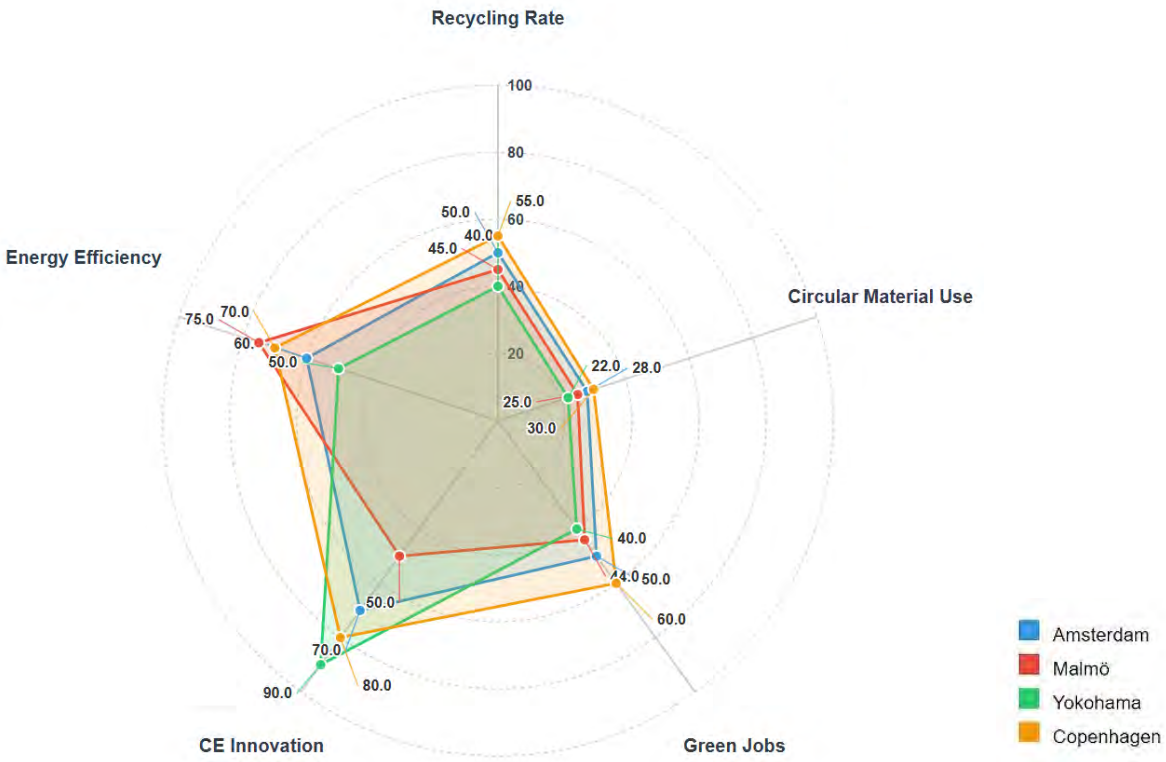


Figure 5. Urban Circular Economy Indicators Radar Chart. Data Source: EU Circular Economy Monitoring Framework (2022) & City Sustainability Reports (2021-2022)

4.2. Resource Recovery Efficiency Assessment

By studying data from 2018 to 2022, it was found that the average resource recycling rate of each city increased by 12%, among which plastic recycling had the highest increase, reaching 18%, and landfill waste decreased by 22%.

	Paper	Plastic	Glass	Metal	Organic
Amsterdam	85%	30%	80%	85%	60%
Malmö	82%	35%	75%	80%	65%
Yokohama	80%	28%	72%	78%	70%
Copenhagen	88%	38%	78%	88%	68%

0% - 20%
20% - 40%
40% - 60%
60% - 80%
80% - 100%

Figure 6. Resource Recovery Rate Heatmap. Data Source: European Environment Agency Urban Waste Management Report (2023), City Waste Management Annual Reports (2018-2022)

4.3. Project Investment Benefit Analysis

With a total investment of €350 million, the four cities achieved 11.5 million tonnes of CO2 reduction and 12.75% average energy savings. Yokohama (€120M investment) reduced CO2 by 4 million tonnes with 13% energy savings. Malmö achieved the highest efficiency, using €50M to reach 2.5 million tonnes reduction

and 15% energy savings. Amsterdam (€90M) and Copenhagen (€80M) reduced CO2 by 2.8 and 2.2 million tonnes respectively, with energy savings of 12% and 11%. These results demonstrate that project success depends on both investment scale and implementation efficiency.

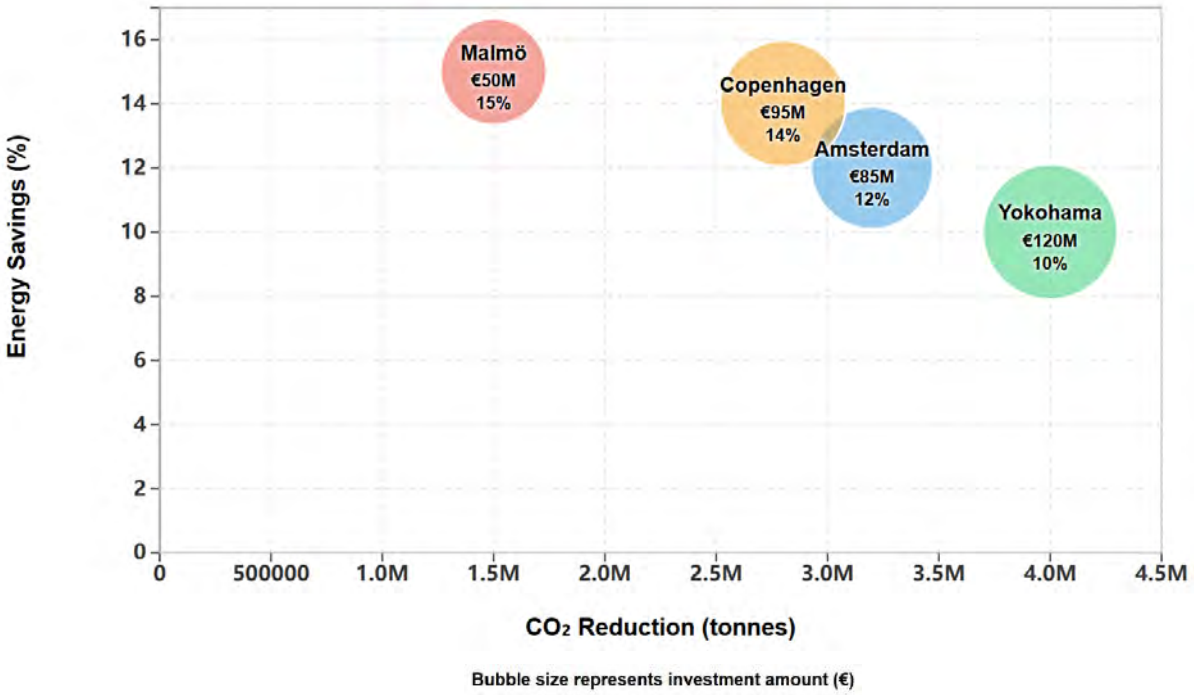


Figure 7. Circular Economy Project Impact (2018-2022). Data Source: C40 Cities Climate Leadership Group (2022), City Climate Action Plans & Municipal Financial Reports (2018-2022)

5.Experience and inspiration

5.1. Success Factors

The study shows that the key factors for the success of circular city practices in the four cases include:

1. Strong government support and a comprehensive policy framework;

2. Innovative technology applications, especially the organic combination of smart city technology and circular economy principles;

3. Multi-level participation mechanism involving government, enterprises and the public;

4. Scientific project planning and efficient execution capabilities.

5.2. Implementation Challenges

Although the cities in these cases have achieved positive results, there are still many challenges in achieving circular city transformation:

1. The huge initial investment requires innovative financing models;

2. Traditional infrastructure upgrades face major challenges;

3. Establishing a cross-departmental collaboration mechanism requires breaking through existing institutional constraints;

4. The breadth and depth of public participation need to be improved.

These challenges have both common characteristics and unique features in different cities, requiring localized responses.

5.3. Promotion Recommendations

Based on the case study analysis, it is recommended that other cities that need to transform into circular cities:

1. Formulate a clear development roadmap and feasible phased goals;

2. Establish a supporting policy system and improve regulations and standards;

3. Strengthen technological innovation and demonstration projects to accumulate practical experience;

4. Strengthen international cooperation and experience exchange;

5. Establish a dynamic evaluation mechanism to summarize experiences and lessons in a timely manner to ensure the sustainability of the project.

6. Conclusions

Circular urbanization provides a viable path for sustainable urban development, achieving a balance between economic growth and environmental protection. The successful cases of cities such as Amsterdam, Malmö, Yokohama and Copenhagen provide valuable experience for cities around the world, especially for developing countries with rapid urbanization. Circular urbanization will play a key role in future urban development and promote the realization of sustainable development goals.

7. References

Anderberg, S. (2015) 'Western Harbor in Malmö', ISOCARP Review, 11, pp. 210-227.

Carbon Neutral Cities Alliance (2024) Copenhagen [online]. Available at: https://carbonneutralcities.org/cities/copenhagen/ (Accessed: 25 September 2024).

City of Amsterdam (2020) Amsterdam Circular 2020-2025 Strategy. Amsterdam: City of Amsterdam, in collaboration with Circle Economy.

City of Copenhagen (2014) Copenhagen: Solutions for Sustainable Cities. 3rd edn. Copenhagen: City of Copenhagen.

City of Malmö (2021) Voluntary Local Review: City of Malmö 2021. Malmö: City of Malmö.

City of Yokohama (2023a) G30 Plan [online]. Available at: https://www.city.yokohama.lg.jp/city-info/yokohamashi/org/shigen/sonota/hoshin/g30/g30.html (Accessed: 20 September 2024).

City of Yokohama (2023b) Yokohama City SDGs Future City Plan (2022-2025). Yokohama: City of Yokohama.

Edo, M. (2021) Waste-to-Energy and Social Acceptance: Copenhill WtE plant in Copenhagen. IEA Bioenergy Task 36.

Energy Institute (2024) Statistical Review of World Energy 2024. London: Energy Institute Publishing.

Greenroofs.com (2022) 'Featured Project: CopenHill, Denmark', Greenroofs.com, 8 January [online]. Available at: https://www.greenroofs.com/2022/01/08/featured-project-copenhill-denmark/ (Accessed: 25 September 2024).

GuidebookSweden (2023) 'Västra Hamnen - Innovative district in Malmö', GuidebookSweden [online]. Available at: https://www.guidebook-sweden.com/en/guidebook/destination/vaestra-hamnen-innovative-district-in-malmoe (Accessed: 20 September 2024).

ICLEI East Asia Secretariat (2020) 'International Zero-Waste City Series ② | The Netherlands: Central Government Leadership and Local Implementation', ICLEI East Asia Secretariat, 22 September [online]. Available at: https://eastasia.iclei.org/zh-hans/zero-waste-city-series-2-the-netherlands/ (Accessed: 25 September 2024).

Kirchherr, J., Reike, D. and Hekkert, M. (2017) 'Conceptualizing the circular economy: An analysis of 114 definitions', Resources, Conservation and Recycling, 127, pp. 221-232.

Li, P. and Liu, J. (2015) 'City Event as an Opportunity for Transformation and Redevelopment of Former Industrial Site: A Case Study on House Fair, Malmo, Sweden', Urban Planning International, 30(2), pp. 87-94.

Malmö stad (2014) Utvecklingsplan Varvsstaden. Malmö: Stadsbyggnadskontoret.

Metabolic (2024) 'Designing De Ceuvel: From polluted land to a cleantech playground', Metabolic Projects [online]. Available at: https://www.metabolic.nl/projects/de-ceuvel/ (Accessed: 25 September 2024).

Prendeville, S., Cherim, E. and Bocken, N. (2018) 'Circular cities: mapping six cities in transition', Environmental Innovation and Societal Transitions, 26, pp. 171-194.

UN-Habitat (2021) Future Cities and New Economy: Carbon Neutrality Driven by Green Innovations. Nairobi: UN-Habitat.

UN-Habitat (2023) Unlocking the Potential of Cities: Financing Sustainable Urban Development. Nairobi: United Nations Human Settlements Programme.

UN-Habitat (2024) 'Urban Energy', UN-Habitat [online]. Available at: https://unhabitat.org/topic/urban-energy (Accessed: 20 September 2024).

Williams, J. (2019) 'Circular cities: Challenges to implementing looping actions', Sustainability, 11(2), p. 423.

World Bank (2023) 'Urban Development Overview', World Bank [online]. Available at: https://www.worldbank.org/en/topic/urbandevelopment/overview (Accessed: 20 September 2024).

World Economic Forum (2024) The Global Risks Report 2024. Geneva: World Economic Forum.

Research Paper

Floating Futures:
Redefining Water Management through Sustainable Landscape Interventions in South Boston

Yiqun WANG*, University of Innsbruck, Austria & Harvard Graduate School of Design, United States

*Corresponding author: Yiqun WANG, yiqunwang24@gmail.com

Abstract

This Floating Futures project uses decentralized, community-centered landscape interventions to present a sustainable water management strategy for South Boston. This concept addresses water scarcity, lowers costs, and improves environmental resilience by reinventing home backyards as floating water landscapes that include sustainable planting and wastewater treatment. The floating landscapes provide shared public-private spaces that encourage community interaction while treating and reusing local wastewater through the use of a phytoremediation technology. Pilot projects demonstrate a 27.5% decrease in infrastructure and water expenditures, along with notable environmental advantages like enhanced resilience and better microclimates. For other cities dealing with comparable issues, this flexible model offers a reproducible method of managing urban water resources that fosters social justice and climate adaption.

Keywords

Decentralized Water Management, Sustainable Landscape Design, Landscape Cyborg, Community Engagement, Climate Resilience, Urban Water Infrastructure

1. Introduction

1.1. Background of Water Scarcity

A pressing worldwide issue that affects both urban and rural regions is brought to light by the decrease of drinking water brought on by climate change and made worse by inadequate water management. According to research, increasing global temperatures are speeding up the melting of glaciers and decreasing snowpack, which would drastically reduce the natural freshwater reservoirs that many areas depend on (Bates et al., 2008). "Megadrought" circumstances, which are characterized by severe and prolonged water shortages, are becoming more prevalent in places like Los Angeles and Santiago. As a result, dramatic measures like emergency water rationing plans and restrictions on outdoor watering have been implemented (Cook et al., 2015). In order to solve current and upcoming shortages, prompt action and long-term solutions are required due to the significant and frequently irreversible depletion of these water resources.

In addition to the diminishing supply, this challenge involves questions of access, distribution, and sustainable management. Gleick (2014) claims that "peak water" is a paradigm where water scarcity is

governed by social, economic, and ecological factors rather than merely supply and demand. In order to overcome water scarcity, traditional infrastructure must be rethought, and decentralized water management solutions that are adaptable to changing conditions must be adopted. Localized and community-based solutions including rainwater collecting, greywater recycling, and wastewater treatment through landscape interventions can help achieve sustainable water usage and conservation (Brown & Farrelly, 2009).

Furthermore, modern urban environments have special chances to develop hybrid ecosystems that combine technology and organic water management techniques. In the face of climate change, these systems improve water resilience and offer ecological, social, and aesthetic advantages, making cities more livable (Benedict & McMahon, 2006). A more robust framework that can handle present and future water difficulties can be created by combining natural and artificial water management techniques.

1.2. Landscape Cyborg as Cure

A theoretical framework for comprehending and resolving this environmental issue through hybridized landscapes is offered by Elizabeth Meyer's "Landscape Cyborg" idea. In Meyer's ground-breaking book *The Expanded Field of Landscape Architecture*, she called for a traditional classification such as nature-culture, and human - nature fall short of capturing the intricate connections between biological processes and human endeavors. Therefore, by fusing aesthetics, physics, and ethics, she makes the case for a more integrated approach to landscape design. It seeks to develop environments that are both culturally and environmentally appropriate while embracing the complexity of the ecosystem (Meyer, 1997).

One of the basic examples Meyer mentions is the design of Boston's Emerald Necklace Park system by the Olmsted firm in the late 19th century. This seven-mile circle links a range of Boston landscapes, from Franklin Park and the Arnold Arboretum to the Fens and into the city via Commonwealth Avenue to the Public Garden and the Common. It encompasses New England's diverse habitats, such as upland forests and tidal estuaries. Meyer describes this alignment as a collection of objects integrated within an urban park system that functions as a "hybrid of natural and cultural systems." Fens, freshwater streams, and other natural features are examples of these artifacts. This project's primary objective was to restore a tidal marsh in order to improve water quality and lessen floods brought on by urbanization in the Back Bay area. The Emerald Necklace's design combines man-made and natural components to produce a system where mechanical parts and biological ecosystems coexist together (Meyer, 1997).

This technique, which reflects Meyer's idea of the landscape as a connected system of organic and inorganic materials, creates sustainable metropolitan regions by combining the beauty of both natural and artificial features. Meyer states in "Sustaining Beauty": Musings on a Manifesto that the aim of landscape design should be to create landscapes that are informative, practical, and representative of contemporary environmental ideas. Her essays on appearance performance and other subjects are in line with this. Although her theories do not particularly address "landscape cyborgs," they do advocate for the integration of natural and artificial systems to enhance ecological resilience and societal relevance (Meyer, 2008; Meyer, 2015).

For projects like the planned water reconstruction in South Boston, Meyer's viewpoint on the landscape cyborg provides a foundation for reassessing urban water management. Designers may manage water shortages, involve communities, and enhance environmental sustainability by considering the landscape as a system that seamlessly integrates ecological and infrastructure components. Meyer's four main ideas—functional sustainability, aesthetic integration, cultural relevance, and ecological responsiveness—offer helpful guidance for implementing the landscape cyborg concept in light of contemporary urban concerns.Hybrid horticulture challenges the status quo by fusing natural and artificial ingredients. Formal

and Functional Juxtaposition combines ecological and recreational areas to encourage shared responsibility.

By putting people in close proximity to nature, Constructing Experiences encourages designs that inspire environmental responsibility. Last but not least, Enduring and Dynamic Design values resilience by shifting away from static beauty and toward adaptable landscapes that thrive in the face of change, thereby fostering a sustainable, regenerative relationship between humans and the environment (Meyer, 2008).

1.3. Project Position and Significance

In order to solve the pressing issue of water scarcity, this project looks into innovative, community-centered approaches to municipal wastewater management using South Boston, Massachusetts, as a model. It accomplishes this by using a "landscape cyborg" intervention to redefine urban water infrastructure. The project aims to establish a decentralized water management system by integrating wastewater treatment and landscape design into a floating water landscape using a phytoremediation method. This intervention reorganizes South Boston's limited water supply in ways that are sustainable from an economic, social, and environmental perspective. The primary goal is to create a strong framework for water management that addresses water scarcity and helps local communities adapt to climate change. This study's primary focus is on how to rebuild water infrastructure in a way that will increase environmental resilience, save costs, and encourage community involvement in water management. By promoting bottom-up participation, the project seeks to transform backyards into practical, sustainable spaces that promote community resilience and the efficient use of natural resources.

2. Research Context and Analysis

2.1. Potable Water System Challenges in South Boston

Due to several operational and infrastructure issues, South Boston's current potable water supply is expensive and environmentally burdensome. Three major reservoirs—the Quabbin Reservoir, the Wachusett Reservoir, and the Ware River—about 72 kilometers from South Boston provide water for this system, which is a component of a larger network. Residents eventually pay hefty monthly water bills as a result of the substantial financial costs associated with the development and upkeep of this vast infrastructure. The top-down, centralized structure of this water infrastructure restricts citizen participation by keeping them out of important decision-making processes pertaining to infrastructure planning, management, and water use.

This system's enormous energy demand—up to 128,716,000 kWh annually needed to pump water into South Boston—is one of its main problems. A significant obstacle to sustainability is that, despite efforts to integrate renewable energy sources, about 84% of this energy still comes from non-renewable power plants (Gleick, 2010). Water distribution to urban dwellers has a significant carbon footprint, which is made worse by the dependence on far-off water sources and energy-intensive transportation. As metropolitan areas deal with expanding demands and depleting resources, the necessity for local, decentralized solutions that lessen reliance on massive infrastructure becomes more evident (Brown et al., 2009; Figure 1).

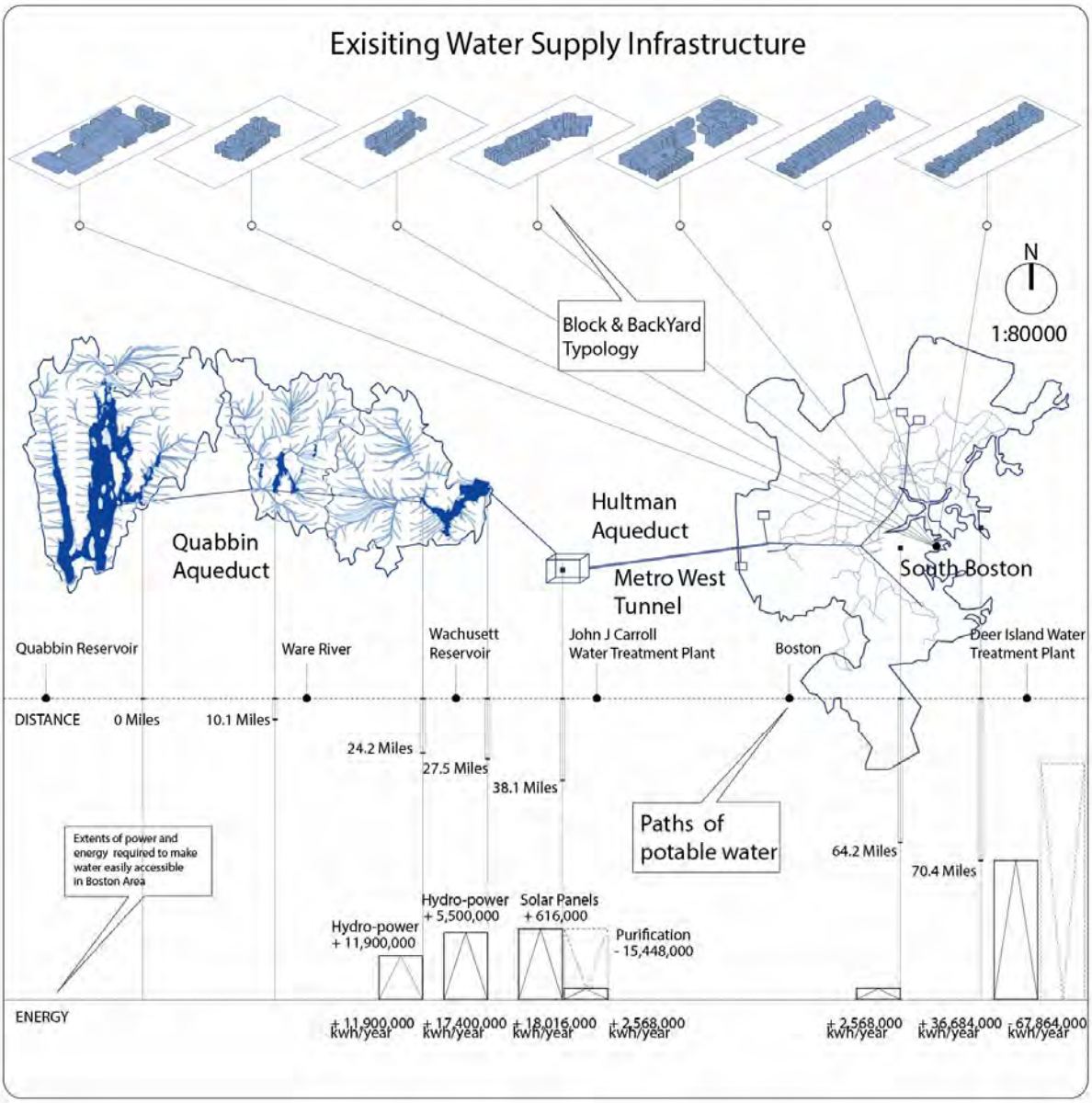


Figure 1. Exisiting Water Supply Infrastructure. Source: Author.

2.2. Sewer and Stormwater System Challenges in South Boston

Additional difficulties arise in the post-use phase of water management, which includes stormwater and sewer systems, primarily because of inefficiency and the negative environmental effects of antiquated infrastructure. Wastewater and storm runoff are channeled by South Boston's combined sewer and stormwater overflow systems, which frequently produce excess flow during major storm events. Since stormwater collecting systems only occupy 15.5% of the city's land surface, mostly in the form of catch basins and backyard soils, they are extremely vulnerable to overflow, which frequently results in flooding and sewage discharge into nearby natural rivers (Benedict & McMahon, 2006).

Untreated wastewater is frequently released directly into Massachusetts Bay or other rivers when storm events overwhelm the infrastructure, which has serious negative effects on the environment. This includes detrimental effects on marine habitats, water body pollution, and bacterial blooms. The energy cost is

further increased by the requirement to transport wastewater over long distances to the Deer Island treatment plant, which is around 80 miles away. In addition to raising energy demand and contributing to secondary pollution from fossil fuel-driven power sources, this prolonged conveyance procedure uses more resources.

Additionally, combined sewer overflow (CSO) incidents affect public health and water quality by releasing contaminants and untreated sewage into public waterways. A shift to decentralized, community-managed systems that provide more flexibility, resilience, and sustainability is required since urban water systems that depend on centralized sewage and treatment facilities are particularly susceptible to these problems (Marlow et al., 2013). By encouraging ecologically friendly wastewater management techniques, decreasing reliance on energy-intensive transportation, and allowing citizens to take a more active role in managing local water resources, decentralized systems can help strengthen communities.

3. Proposed Intervention

3.1. Decentralized Water Management Model

In reaction to the expensive and centralized water infrastructure in South Boston, this initiative suggests a community-based, decentralized water management paradigm. Residents are currently burdened with expensive water bills as a result of the city's top-down infrastructure, which demands large financial and energy investments. Decentralized systems, on the other hand, promote local involvement and allow citizens to take an active role in water management. Moving toward decentralized models improves flexibility, strengthens communities, and tackles governance issues related to conventional water systems, as noted by Biswas and Tortajada (2010) (Figure 2).

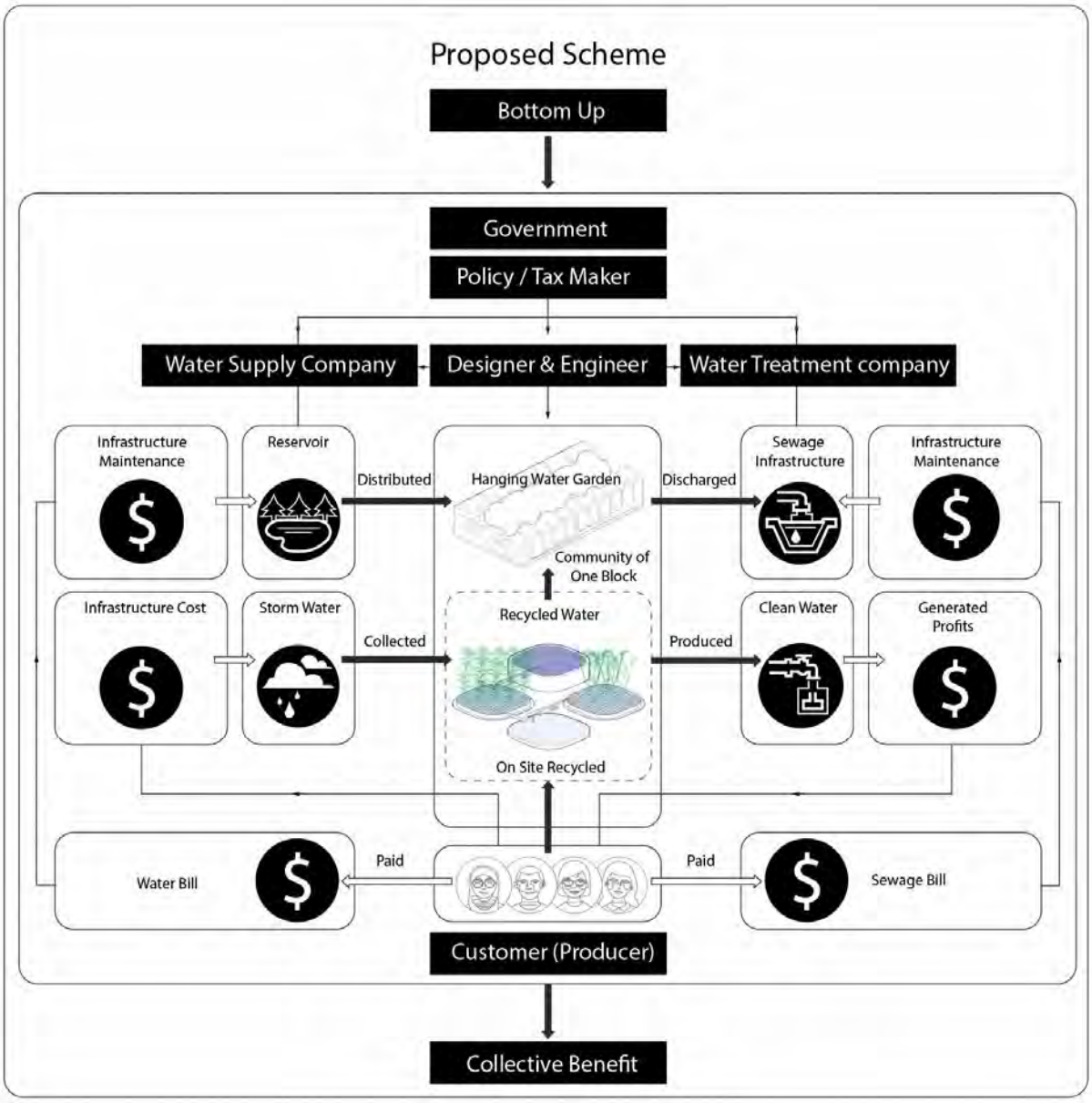


Figure 2. Decentralized Water Management Model. Source: Author.

This suggested intervention uses macrophytes and phytoremediation to create a localized floating water infrastructure landscape in backyards of homes. There are 77 residences in the pilot study close to Dorchester Heights, and each one produces roughly 4608.9 gallons of wastewater every day. 2613.1 gallons are cleaned and recycled locally through on-site treatment, while 1346.2 gallons are sold to neighboring communities, bringing in extra money for locals. This configuration demonstrates the economic feasibility

of decentralized systems by potentially lowering home water bills and infrastructure maintenance expenses by 27.5% (Novotny et al., 2010; Wong & Brown, 2009; Figure 3).

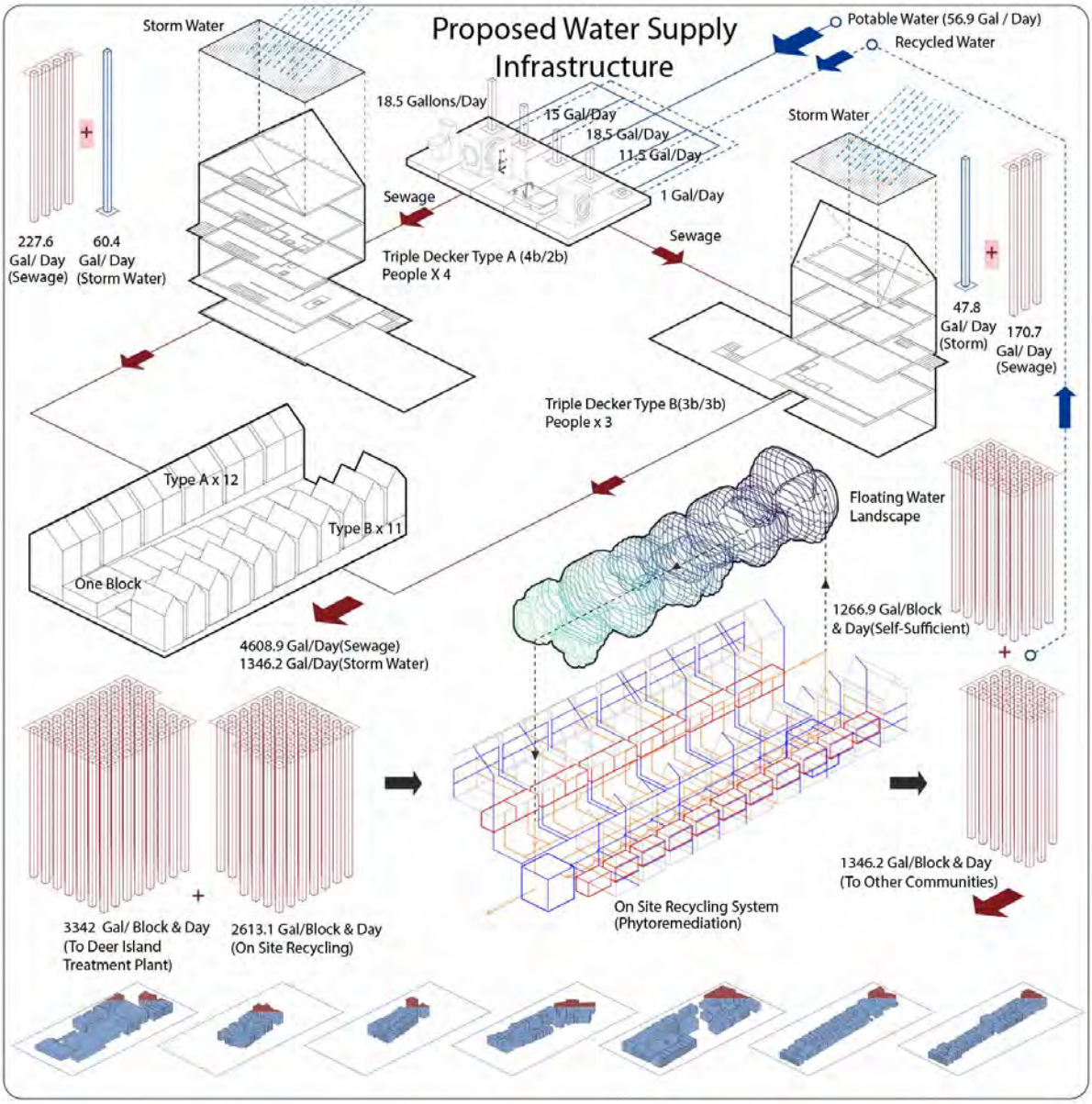


Figure 3. Proposed Water Supply Infrastructure. Source: Author.

By including locals in decision-making, decentralized systems also promote social fairness by converting water management from a city-controlled utility to a resource driven by the community. Due to the fact that locals benefit economically and environmentally, this strategy is consistent with Dunn's (2010) analysis of the social justice advantages of green infrastructure. Additionally, this system's decentralization of wastewater treatment lowers energy requirements related to water transportation and conforms to water-sensitive design principles, strengthening community resilience to the effects of climate change. (Pinkham, 2002; Roy et al., 2008).

3.2. Design and Implementation of Floating Water Landscape

The step-like design of the floating water landscape, which supports gravity-fed, multi-level water filtration, makes use of South Boston's geology. Based on Ferguson's (1998) ideas on simulating natural hydrology, this design enables wastewater to pass through many filtering stages, with distinct macrophytes placed at each stage to maximize purification. In addition to improving treatment efficiency, this tiered system integrates easily with subterranean and rooftop water systems to provide a unified water circulation network that adapts dynamically to local environmental circumstances (UNESCO, 2020).

Prefabricated from lightweight, transparent materials like organic glass, the filtration units are inexpensive and adjustable to various backyard sizes, allowing for modular deployments in various communities. This adaptability is necessary to make sure the system can grow or change to meet the evolving requirements of the community. By grouping these units together across property lines, a shared, semi-public area is created, encouraging social connection and resulting in an urban environment that strikes a balance between social interaction and ecological functionality (Fletcher et al., 2013).

Reconnecting this small water system with larger Boston metropolitan networks also makes the area more resilient to the effects of climate change. Complex urban water regimes require decentralized and adaptive systems, as highlighted by Pahl-Wostl et al. (2010). As a model for comparable urban settings, this floating water landscape offers adaptable and scalable solutions for sustainable water management in a variety of urban contexts (Figure 4).

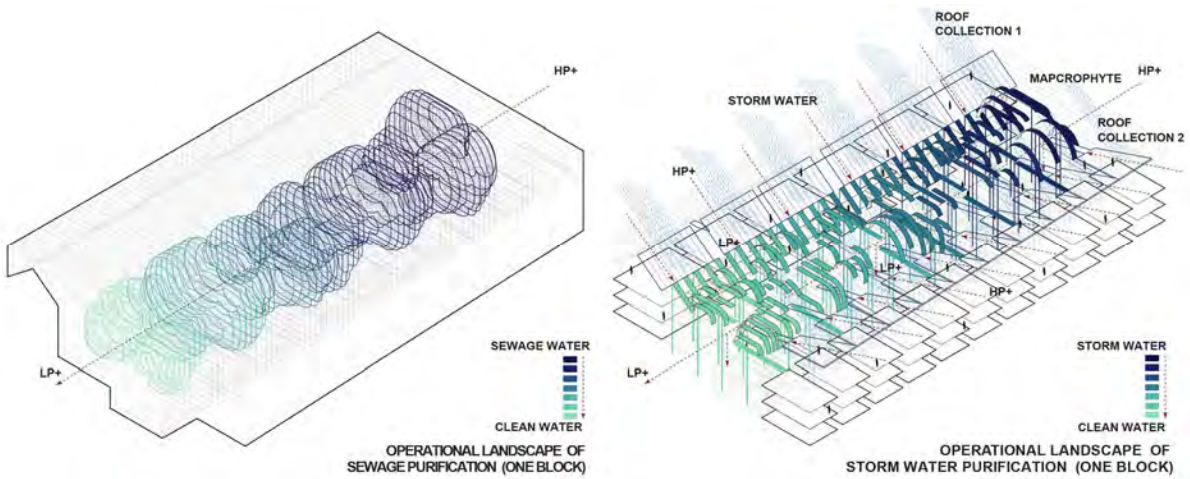


Figure 4. Prototype Study. Source: Author.

3.3. Spatial and Aesthetic Qualities

Aquatic plants are placed in gradients within the floating water landscape's phytoremediation system to optimize the effectiveness of water filtering. Greywater passes through several stages of treatment thanks to these plants' progressive purifying process. The addition of "bubble clusters," which are pliable, tubular components intended to provide light, airflow, and room for flora, improves the system's usability and appearance. This method, which was influenced by Gorgolewski et al. (2016), produces a design that blends in well with the urban setting and is both aesthetically pleasing and functional. By integrating rooftop and subterranean water systems, the system's step-like design maximizes water flow and treatment by using gravity to provide natural, multi-tiered filtering. By reducing heat and promoting ecological balance, this design enhances the local microclimate and adheres to the water-sensitive urban design principles proposed by Wong and Brown (2009). Additionally, semi-public areas are created by floating water clusters across backyard boundaries, which obfuscate the distinction between private and public places and

promote closer community connections. Additionally, mock-up models of triple-decker buildings are used to illustrate the system's adaptability and scalability. These models allow for customization in a variety of building and landscape configurations by displaying potential connections to flow equalization tanks and rooftop sprinkler systems. Benedict and McMahon's (2006) demand for ecologically friendly infrastructure alternatives that complement metropolitan environments is supported by this adaptability. An inventive approach to sustainable urban water management that blends environmental resilience, community engagement, and aesthetic appeal is the floating water landscape.

3.4. Broader Project Impact and Future Development

In order to alleviate the world's water shortage and foster environmental resilience while lowering reliance on massive infrastructure, the Floating Water Landscape project uses creative ideas. Decentralized treatment systems are used to filter wastewater from nearby homes. Residents save money on maintenance and water costs when this system is put into place. By actively involving communities in water reuse projects, the project promotes social justice. Local communities can become more climate resilient with the aid of its scalable and flexible architecture. It could be replicated in other water-limited regions across the globe. Future research will focus on preventing water from freezing in the winter and removing social obstacles that prevent different people from adopting sewage-based aesthetics.

Acknowledgments

The author wish to acknowledge the use of artificial intelligence (AI) applications, including Grammarly and ChatGPT, during the writing process of this paper. Grammarly was employed for stylistic and grammatical corrections, ensuring clarity and accuracy, while ChatGPT provided iterative suggestions that enhanced the coherence and structural framework of the content.

The author would also like to express gratitude to Professor Belinda Tato, Associate Professor in Practice of Landscape Architecture at Harvard University Graduate School of Design (GSD), for providing invaluable guidance on this project through the Landscape Architecture IV Studio, Spring 2022.

4. References

Bates, B.C., Kundzewicz, Z.W., Wu, S. and Palutikof, J.P. (2008) *Climate change and water*. Technical Paper VI of the Intergovernmental Panel on Climate Change. Geneva: IPCC Secretariat [e-book]. Available at: https://archive.ipcc.ch/pdf/technical-papers/climate-change-water-en.pdf (Accessed: 27 October 2024).

Benedict, M.A. and McMahon, E.T. (2006) *Green infrastructure: linking landscapes and communities*. Washington, DC: Island Press.

Biswas, A.K. and Tortajada, C. (2010) 'Future water governance: problems and perspectives', *International Journal of Water Resources Development*, 26(2) [online], pp. 129–139. Available at: https://doi.org/10.1080/07900627.2010.488853 (Accessed: 27 October 2024).

Brown, R.R. and Farrelly, M.A. (2009) 'Delivering sustainable urban water management: a review of the hurdles we face', *Water Science and Technology*, 59(5) [online], pp. 839–846. Available at: https://doi.org/10.2166/wst.2009.028 (Accessed: 27 October 2024).

Brown, R.R., Keath, N. and Wong, T.H.F. (2009) 'Urban water management in cities: historical, current and future regimes', *Water Science and Technology*, 59(5) [online], pp. 847–855. Available at: https://doi.org/10.2166/wst.2009.029 (Accessed: 27 October 2024).

Cook, B.I., Ault, T.R. and Smerdon, J.E. (2015) 'Unprecedented 21st century drought risk in the American Southwest and Central Plains', *Science Advances*, 1 [online], p. e1400082. Available at: https://doi.org/10.1126/sciadv.1400082 (Accessed: 27 October 2024).

Dunn, A.D. (2010) 'Siting green infrastructure: legal and policy solutions to alleviate urban poverty and promote healthy communities', *Boston College Environmental Affairs Law Review*, 37 [online], pp. 1–34. Available at: https://ssrn.com/abstract=1517909 (Accessed: 27 October 2024).

Ferguson, B.K. (1998) *Introduction to stormwater: concept, purpose, design*. New York: John Wiley & Sons.

Fletcher, T.D., Andrieu, H. and Hamel, P. (2012) 'Understanding, management and modelling of urban hydrology and its consequences for receiving waters: a state of the art', *Advances in Water Resources*, 51 [online], pp. 261–279. Available at: https://doi.org/10.1016/j.advwatres.2012.09.001 (Accessed: 27 October 2024).

Gleick, P.H. (2010) *Bottled and sold: the story behind our obsession with bottled water*. Washington, DC: Island Press.

Gleick, P.H. (2014) 'Water, drought, climate change, and conflict in Syria', *Weather, Climate, and Society*, 6(3) [online], pp. 331–340. Available at: https://doi.org/10.1175/WCAS-D-13-00059.1 (Accessed: 27 October 2024).

Gorgolewski, M., Komisar, J. and Nasr, J. (2016) *Carrot city: creating places for urban agriculture*. New York: Monacelli Press.

Grammarly (2025) *Grammarly* [AI software]. Available at: https://www.grammarly.com (Accessed: 18 January 2025).

Marlow, D.R., Moglia, M., Cook, S. and Beale, D.J. (2013) 'Towards sustainable urban water management: a critical reassessment', *Water Research*, 47(20) [online], pp. 7150–7161. Available at: https://doi.org/10.1016/j.watres.2013.07.046 (Accessed: 27 October 2024).

Meyer, E.K. (1997) 'The expanded field of landscape architecture', in Thompson, G.E. and Steiner, F.R. (eds.) *Ecological design and planning*. New York: John Wiley & Sons, pp. 45–79.

Meyer, E.K. (2008) 'Sustaining beauty: the performance of appearance', *Journal of Landscape Architecture*, 3 [online], pp. 6–23. Available at: https://doi.org/10.1080/18626033.2008.9723392 (Accessed: 27 October 2024).

Meyer, E.K. (2015) 'Beyond "sustaining beauty": musings on a manifesto', in *Values in landscape architecture and environmental design*. United States: LSU Press, pp. 30–53.

Novotny, V., Ahern, J. and Brown, P. (2010) 'Water centric sustainable communities: planning, retrofitting, and building the next urban environment', in *Water centric sustainable communities: planning, retrofitting, and building the next urban environment* [online], pp. 539–593. Available at: https://doi.org/10.1002/9780470949962.ch11 (Accessed: 27 October 2024).

OpenAI (2025) *ChatGPT (Jan 2025 version)* [AI software]. Available at: https://www.openai.com (Accessed: 18 January 2025).

Pahl-Wostl, C., Holtz, G., Kastens, B. and Knieper, C. (2010) 'Analyzing complex water governance regimes: the management and transition framework', *Environmental Science & Policy*, 13(7) [online], pp. 571–581. Available at: https://doi.org/10.1016/j.envsci.2010.08.006 (Accessed: 27 October 2024).

Pinkham, R.D. (2002) *Daylighting: new life for buried streams*. Washington, DC: American Rivers and Trout Unlimited.

Roy, A.H., Wenger, S.J., Fletcher, T.D., Walsh, C.J., Ladson, A.R., Shuster, W.D., Thurston, H.W. and Brown, R.R. (2008) 'Impediments and solutions to sustainable, watershed-scale urban stormwater management: lessons from Australia and the United States', *Environmental Management*, 42(2) [online], pp. 344–359. Available at: https://doi.org/10.1007/s00267-008-9119-1 (Accessed: 27 October 2024).

UNESCO (2020) *The United Nations World Water Development Report 2020: water and climate change*. Paris: UNESCO [e-book]. Available at: https://unesdoc.unesco.org/ark:/48223/pf0000372985 (Accessed: 27 October 2024).

Wong, T.H.F. and Brown, R.R. (2009) 'The water sensitive city: principles for practice', *Water Science and Technology*, 60(3) [online], pp. 673–682. Available at: https://doi.org/10.2166/wst.2009.436 (Accessed: 27 October 2024).

Research Paper

Transforming public spaces towards user-friendly, climate resilient and energy producing spaces

The BARTLETT

Alfred Willinger, Architekten Tillner & Willinger, Austria
Marianne Bügelmayer-Blaschek, Austian Institute of Technology, Austria
Silja Tillner, Architekten Tillner & Willinger, Austria
Karl Grimm, Karl Grimm Landschaftsarchitekten, Austria
Irene Zluwa, Grün statt Grau, Austria
Elia Stefan, WienNeu+, Austria
Rita Ebner, Tanja Tötzer, Martin Jung, Martin Schneider, Romana Berg, Karl Berger

Abstract

Urban areas are severely affected by climate change, as the associated increase in temperature and precipitation intensity are further exacerbated by the prevailing morphology of densely built areas and the prevalence of sealed surfaces. Especially heat has been recognised as an increasing risk and therefore, appropriate adaptation measures such as nature-based solutions (NbS) have been studied extensively.
Space is scarce and valuable in cities and the usability of urban spaces has gained a growing attention in the last years – not only in the sense of climate adaptation but also for climate protection, as the energy transition calls for the implementation of renewable energy sources, where public spaces offer great potential for PV-suitable areas. In addition, an increasing number of people living in cities demand more living space and put even more pressure on available public spaces.
These three aspects form the basis of the presented study, where a highly frequented public space, the Volkertplatz in Vienna is chosen to be transformed into a climate-resilient, user-friendly and energy-generating space. To achieve this, the following steps are necessary: (i) analysis of the current and future local climate conditions, (ii) incorporating and understanding the needs of the local users, (iii) design of the BARTLETT (Blue-green energy-generating canopied seating and communication facility and (iv) implementation of an appropriate process of involvement of the local authorities.
The analyses show that the current design of the space prevents the infiltration of rainwater, intensifies the prevailing heat load in summer and mainly meets the needs of male users. Therefore, the transformed space needs to reduce the identified barriers in order to improve the quality of the Volkertplatz. A key element is the BARTLETT, a construction that improves the local microclimate, collects rainwater for irrigation of the plants and produces energy through the installed PV collectors. Furthermore, its design enhances its usability of the square by different groups, providing both open and more hidden spaces. To ensure the acceptance of local citizens, their needs have been identified, their behaviour observed, and their opinions incorporated through workshops. As important as the local support, is the timely involvement of relevant political stakeholders, which is ensured by the project partners and collected in a handbook to allow transferability to other public spaces.

Keywords

Sustainable urban design, Climate change, Water management, Renewable energies

1. STATUS QUO, ANALYSIS, DEMAND

The last few years have been marked by the COVID-19 pandemic and related actions and consequences, the extreme impact of climate change on people and infrastructure, and, since February 2022, the Ukraine war. This human tragedy has also shed light on the dependence on Russian fossil fuels and the need to switch to renewable energy sources, which is also crucial for climate mitigation. These global developments are also being felt in Austria's cities.

All these challenges result in changing demands on the available (public) space:

- good quality of stay without consumption and car dominance
- Adaptation to climate change (heat and heavy precipitation)
- Infrastructure/space for renewable energy sources in the city and implementation of climate mitigation measures.

This tension is also noticeable at Volkertplatz in Vienna's 2nd district, which is located within a highly heated area due to a dense residential development, the dominance of sealed surfaces and very little greening. To address the mentioned aspects the research focuses on making the Volkertplatz and Volkertmarkt a climate-resilient place with a high quality of stay.

To do this, the following goals have been identified:

1. holistic water management
2. climate change adaptation and climate mitigation
3. increasing usability for all

As evidence based solution for the findings of the analysis and the questionnaires of the users, regarding their age and gender as well as their preferred kind of usage and the time they use it where.
As a connecting, innovative element, the BARTLETT (Blue Green Photovoltaic Shading Element) is being developed. It contributes to water management (higher drainage level, which drains precipitation water without coming into contact with the contaminated ground surface in the market area, into the surrounding green areas without the use of pumps), climate change adaptation (greening) and climate protection (PV panels), as well as usability for all (weather protection and electricity).
It is developed as a modular construction that can be used in different urban situations.

To ensure a sustainable transformation of the square and market, the project builds on an inter- and transdisciplinary team and methods: quantitative models, measurements and participatory processes are combined. The findings regarding legal and implementation-relevant aspects for a successful redesign are summarized in a guideline to ensure transferability to other (Viennese) squares and markets.

Intensive dissemination shall trigger the applicability of the findings in other locations and urban contexts.

To address the findings of the analysis and the project goals a differentiated and inclusive public urban space for any user group at any different time is developed.

The Project objectives to be solved should be achieved with evidence and nature based solutions.

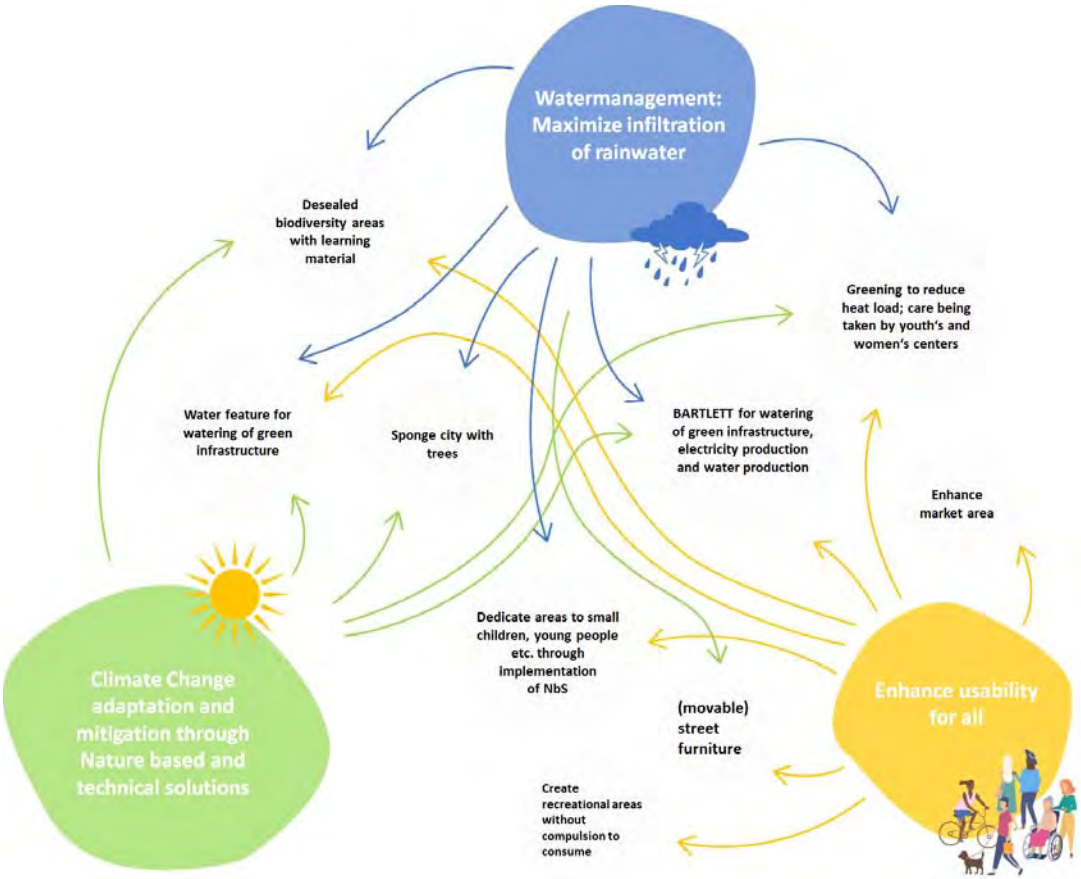


Figure 1. Project Objectives, Source: AIT

Figure 2. Photos of the existing situation, Source: Aerial GOOGLE EARTH, ARCHITEKTEN TILLNER & WILLINGER

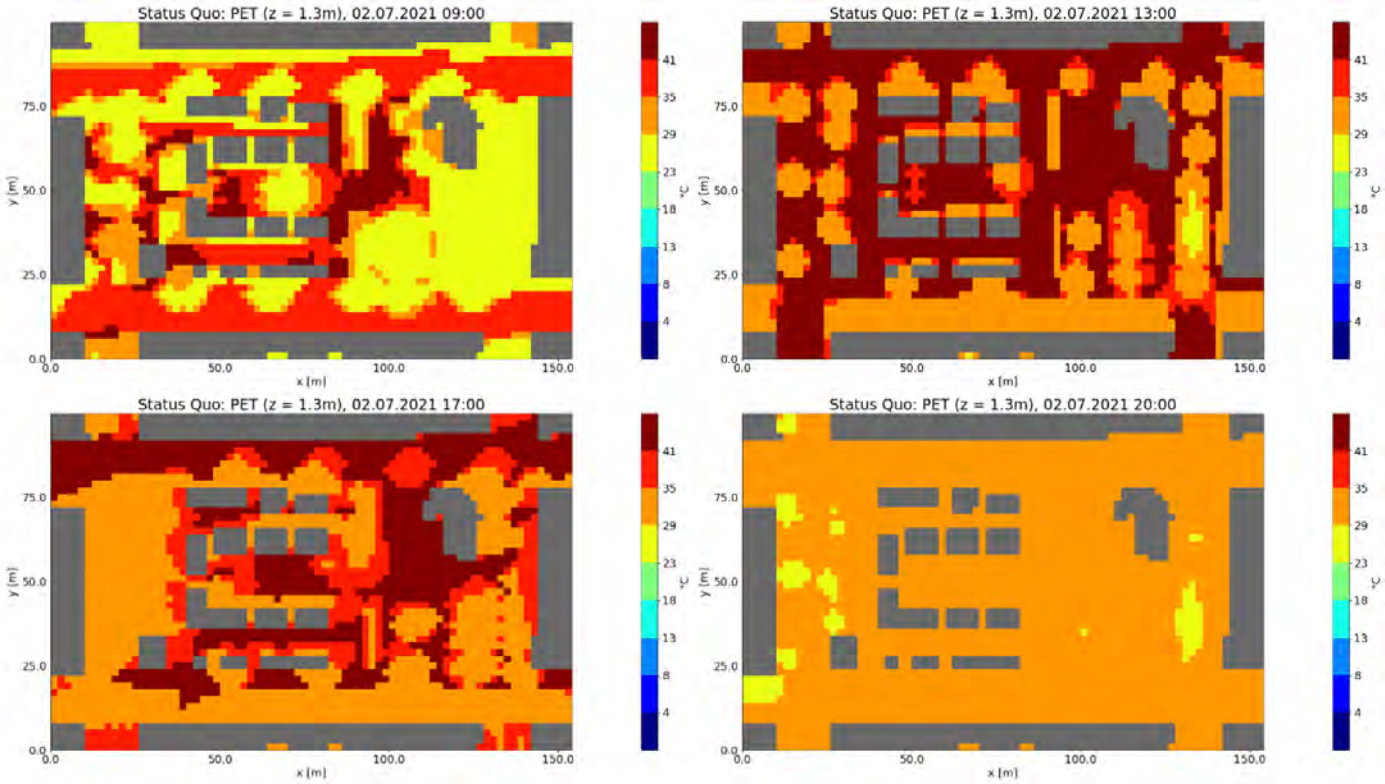


Figure 3. Heat Simulation Volkertplatz and Volkertmarkt, Source: AIT

The heat map of the Volkertplatz Square as well as of the Market Area shows the need for shading but on the other hand also the high potential for photovoltaics.

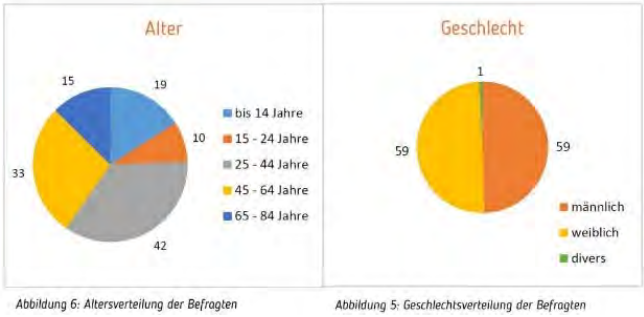


Figure 4. Age and Gender Inquiry, Source: DISTRICT MANAGEMENT*

An intense analysis of the users and the usage now and desired was made to have an evidence base for the planned measures. Questionnaires, direct consultation and observation of the users on site show a clear and differentiated picture of the user groups and when they use the square how, also their wishes for a future improvement show a clear scope of desired measures.

Figure 5. Time of usage and age of the users Source: DISTRICT MANAGEMENT*

Figure 6. Kind of usage by age of users Source: DISTRICT MANAGEMENT*

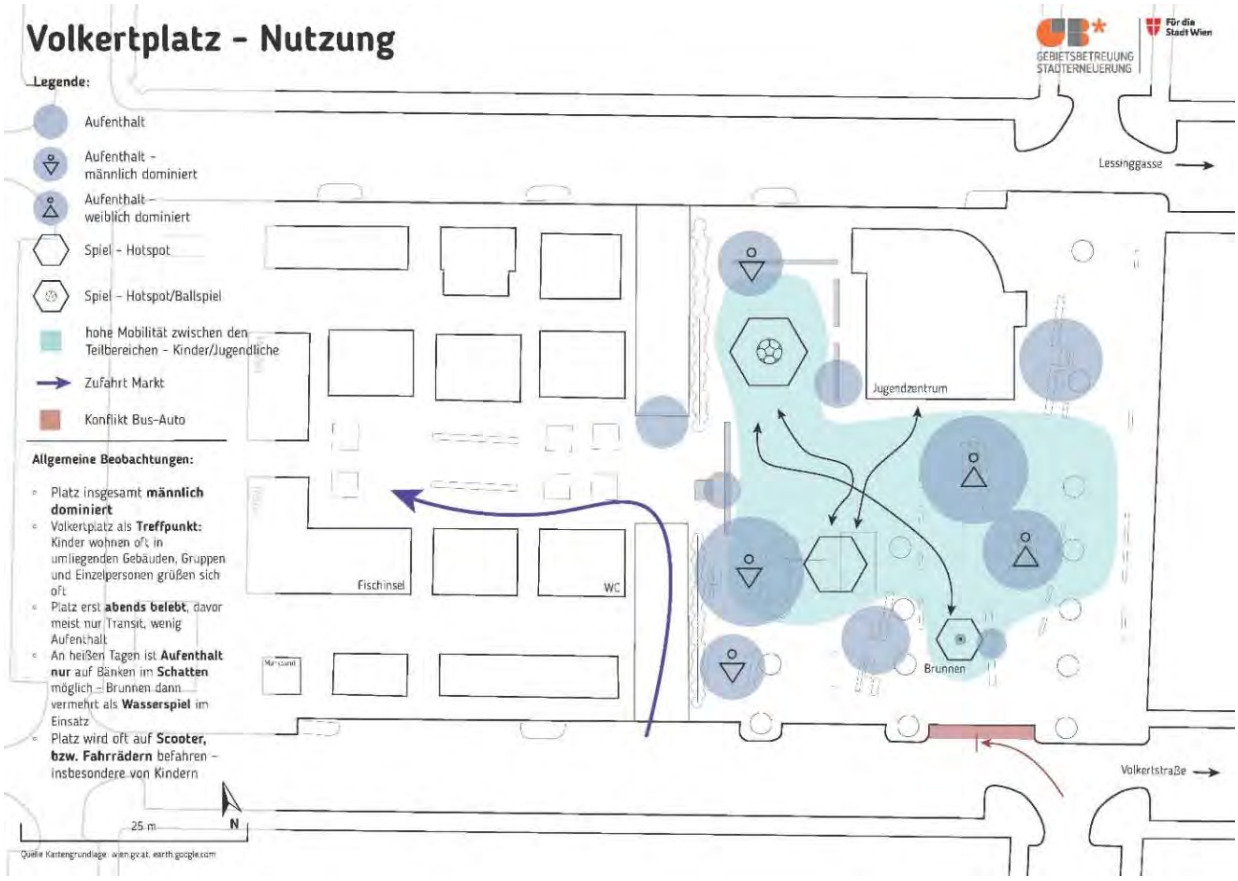


Figure 7. Diagram of usage and movement, Source: DISTRICT MANAGEMENT*

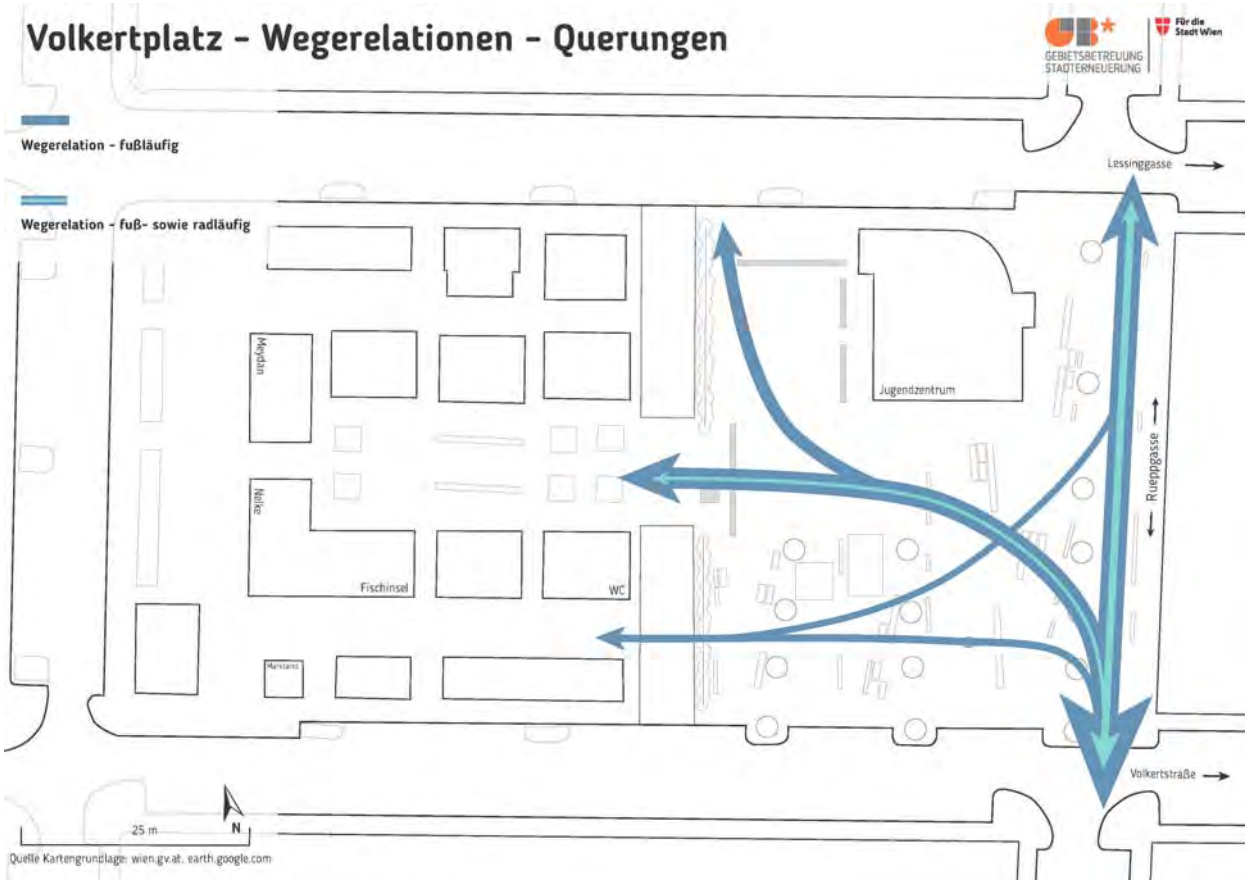


Figure 8. Way relations and crossings, Source: DISTRICT MANAGEMENT*

2. DESIGN BARTLETT

2.1. Modular Layers

The design of the BARTLETT shows a modular Construction of different elements respectively layers that can be added or reduced and chosen for a specific task at hand.

3 Modules are to be built and then the effect measured and observed to obtain detailed data for further improvement and basic data for other realizations, that is publicized with the research findings.

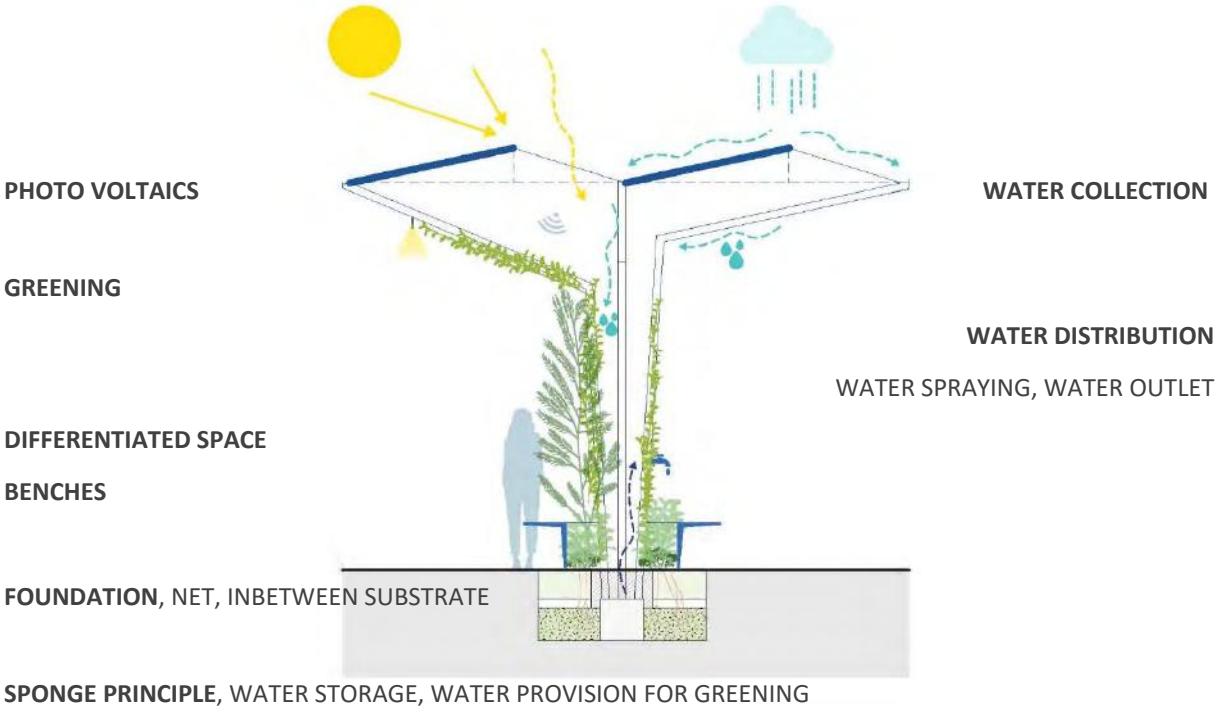


Figure 9. Section of the BARTLETT Blue Green Photovoltaic Shading Element, Source: ARCHITEKTEN TILLNER & WILLINGER

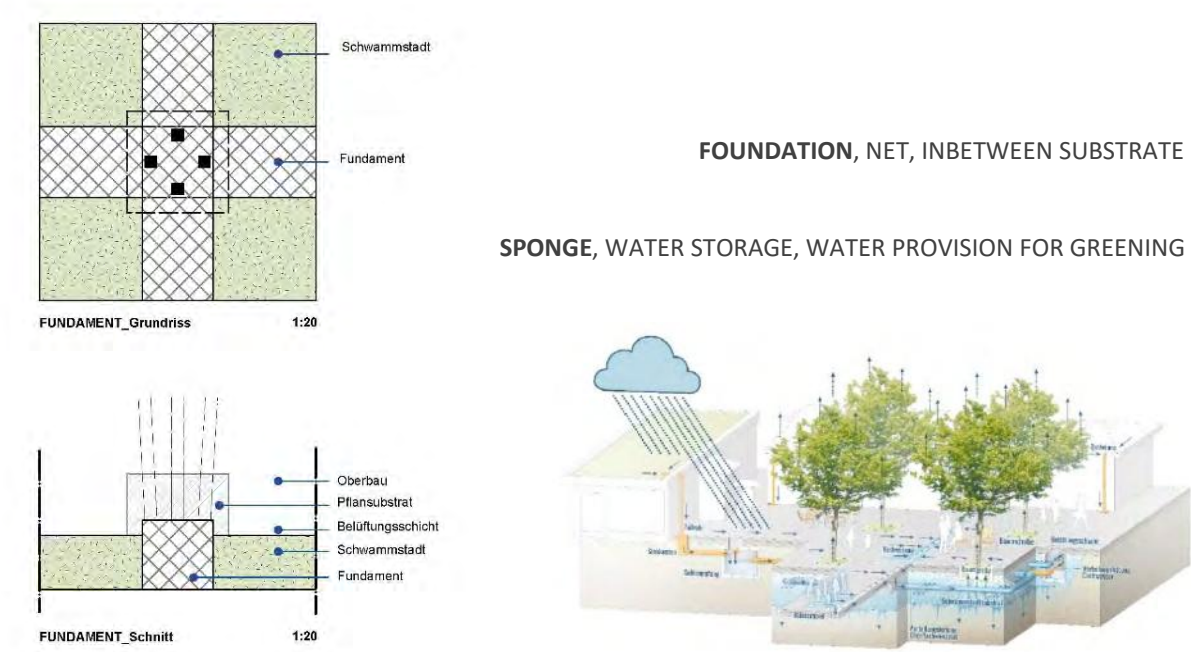


Figure 10. Netlike Foundation Concept, Source: ARCHITEKTEN TILLNER & WILLINGER, Sponge City Concept Axonometric, Source: Karl GRIMM

2.1. Modular Assembly

The modular elements grouped around a central connection to the sponge can be organic shaped and configured for a perfect fit at any given space.

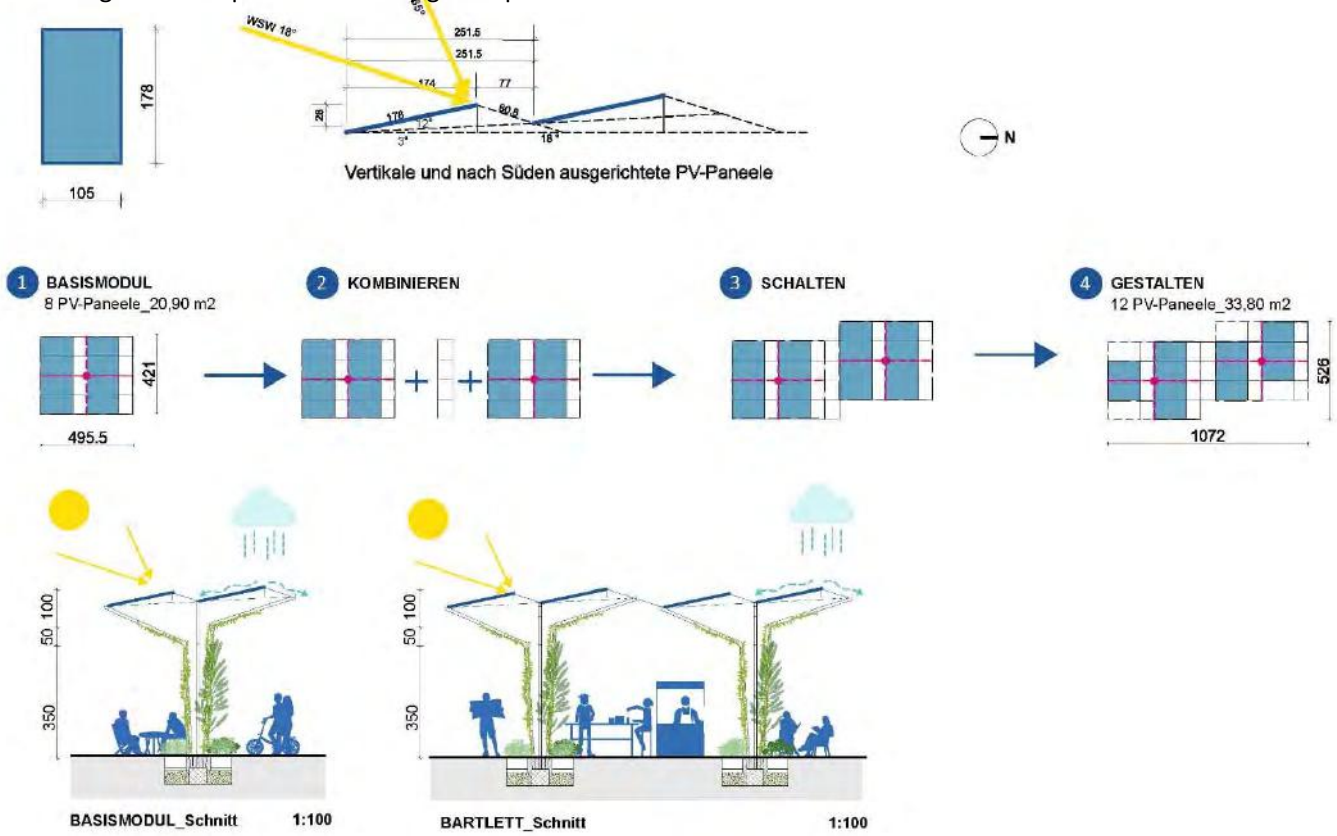


Figure 11. Modular Structure and Combination Principle of the BARTLETT modules,

Source: ARCHITEKTEN TILLNER & WILLINGER

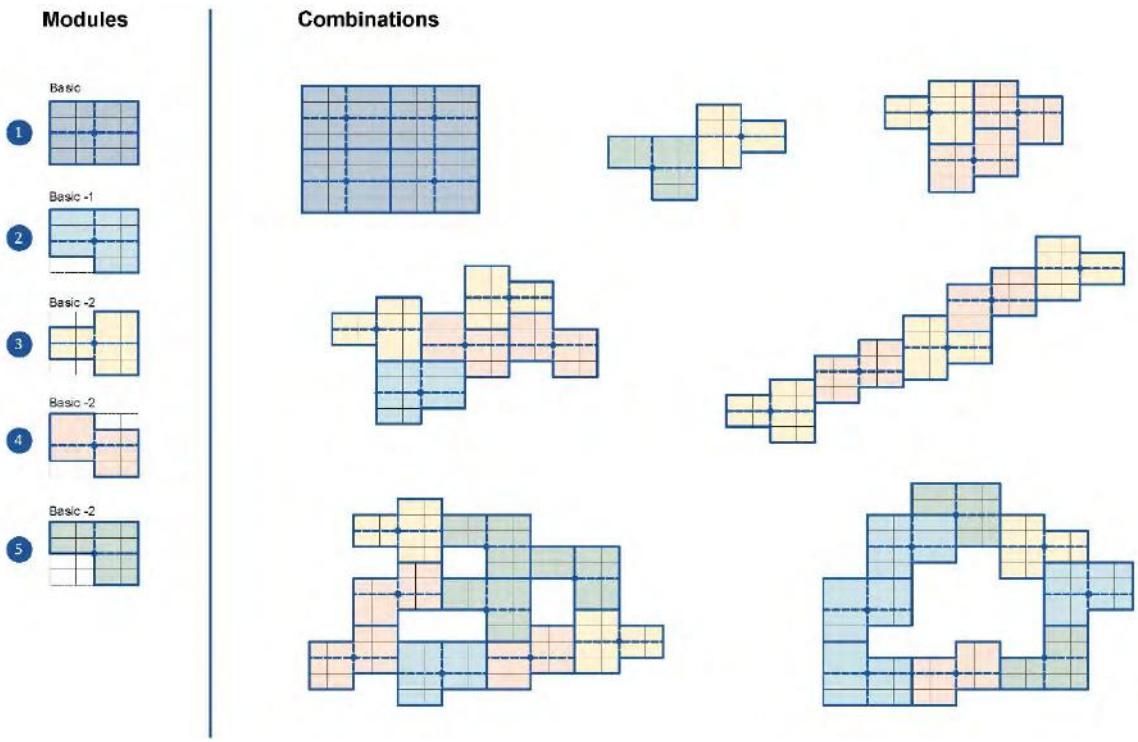


Figure 12. Different Combinations of Modules, Source: ARCHITEKTEN TILLNER & WILLINGER

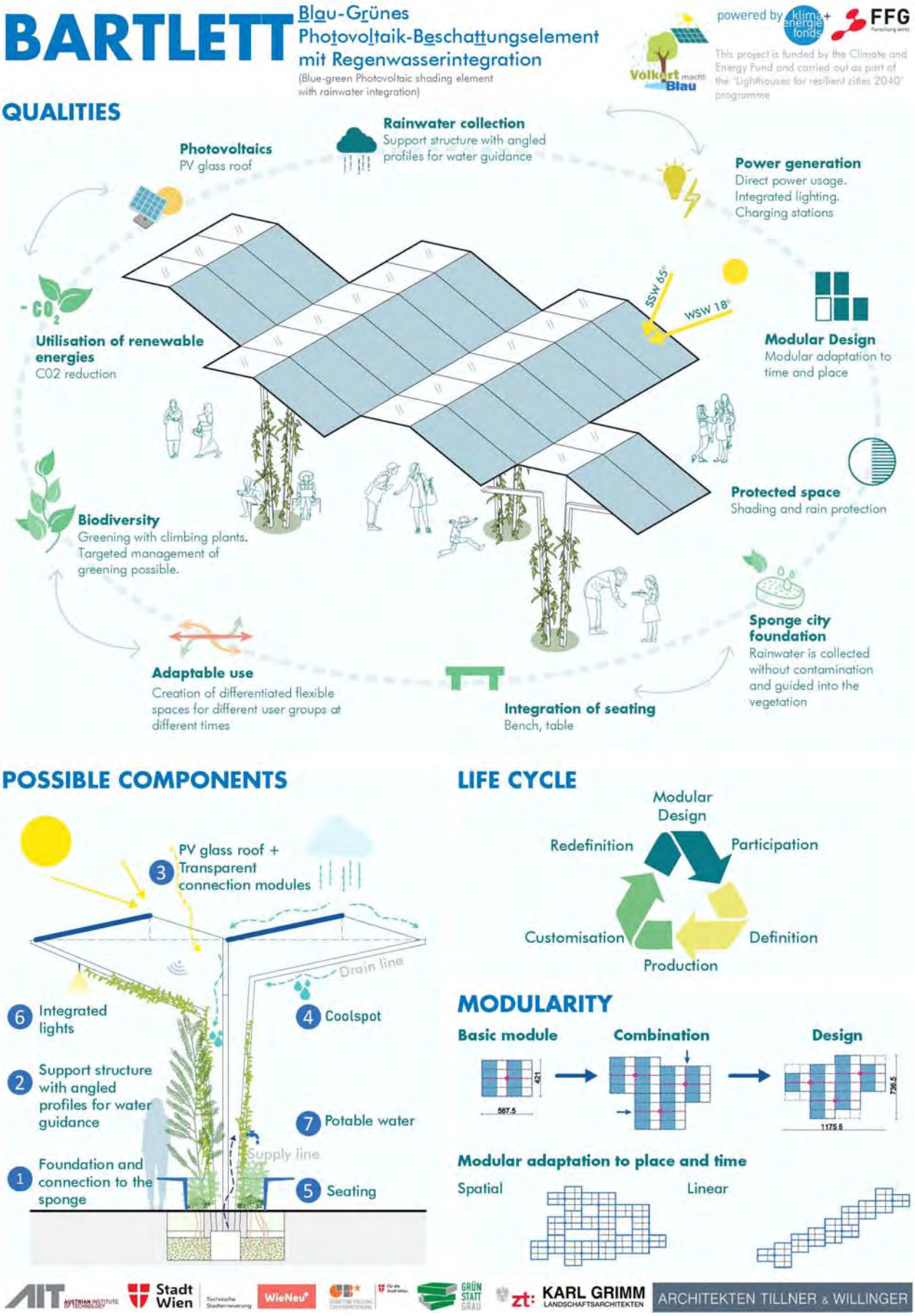


Figure 13. One pager for information and dissemination, Source: ARCHITEKTEN TILLNER & WILLINGER

3. DESIGN VOLKERTPLATZ SQUARE

The urban space is identified as including the Square, the Market and the street space up to the surrounding buildings to holistically enhance the public space. The realisation is planned in 3 phases. The BARTLET first, then Volkertplatz Square and on long term the street space.

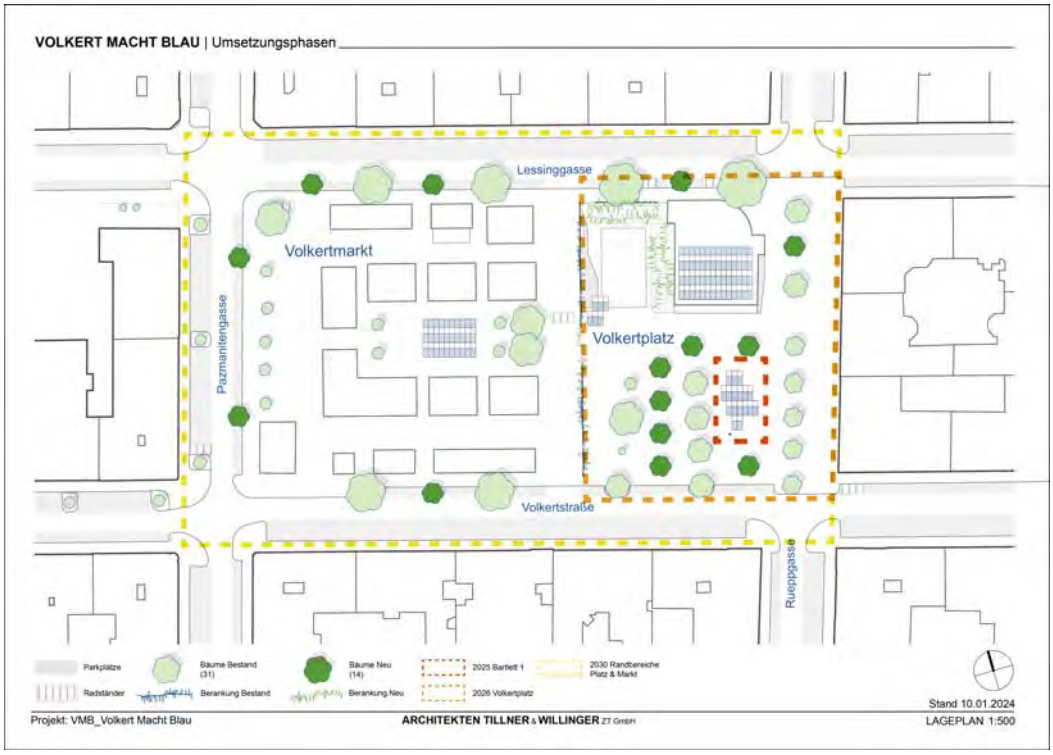


Figure 14. Realization in PHASES, Source: ARCHITEKTEN TILLNER & WILLINGER

Zones of the design differentiated by the intensity of use and communication potential, extraverted, introverted movement space and green space.

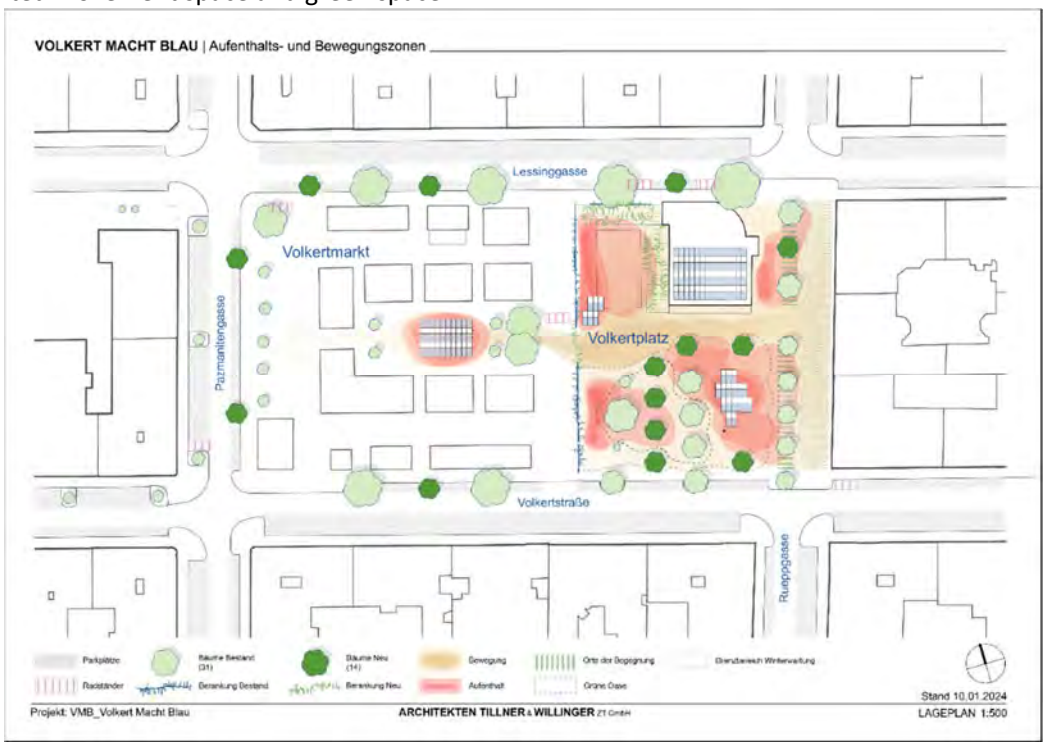


Figure 15. Zones, Source: ARCHITEKTEN TILLNER & WILLINGER

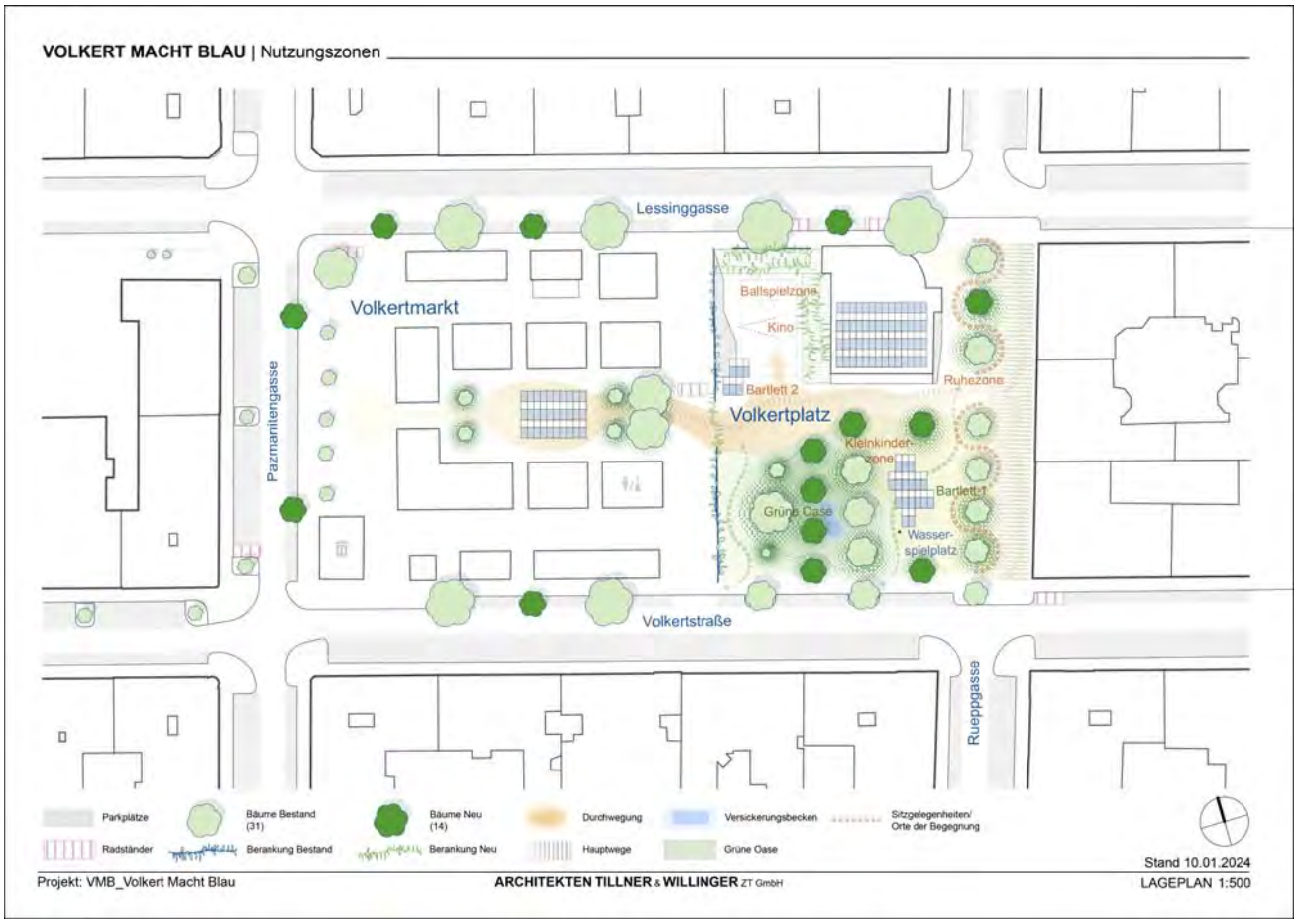


Figure 16. Final Design of the Square, fluid spaces, Source: ARCHITEKTEN TILLNER & WILLINGER

Figure 17. Visualisation of the realisation, Source: ARCHITEKTEN TILLNER & WILLINGER

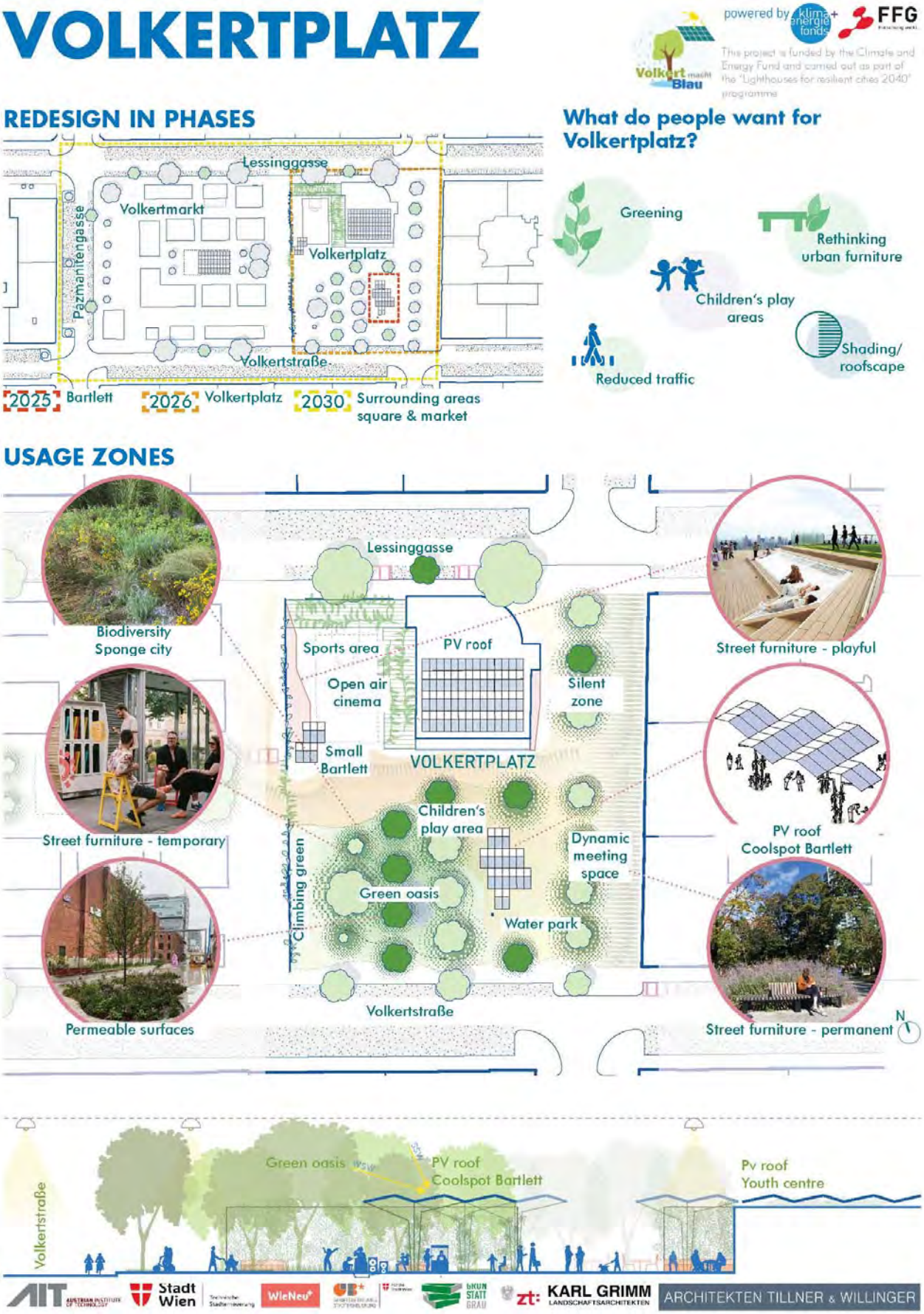


Figure 18. One pager square design Volkertplatz, Source: ARCHITEKTEN TILLNER & WILLINGER

4. References

Cadot, E., Rodwin, V.G. & Spira, A. (2007). In the Heat of the Summer. J Urban Health 84, 466–468

AIT, Austrian Institute of Technology (2023) Heat Simulation Volkertplatz and Market, Vienna

District Management* (2023) Report of the consultation and observation of the users of Volkertplatz and Market, Vienna

Architekten Tillner & Willinger (2024) Design plans BARTLETT, Square Design, Vienna

Research Paper

Response to "Dual-Carbon" Objective in Comprehensive Territorial Spatial Planning of Resource-Based Cities: A Case Study of Fujin city

Zesen FAN, Harbin Institute of Technology, China

Yibo LIU, Harbin Institute of Technology, China

Jun XING, Harbin Institute of Technology, China

Lei XIA, Harbin Institute of Technology, China

Abstract

The "Dual-Carbon" objectives in China mark a historic shift in carbon emission reduction and pose new requirements for comprehensive territorial spatial planning. Comprehensive territorial spatial planning is the fundamental basis of a spatial blueprint for sustainable development and various development, protection, and construction activities. It views space as a product, asset, and factor, enabling rational planning and layout. Its core purpose is highly consistent with the "Dual-Carbon" objective and provides a realistic pathway for the realization of the "Dual-Carbon" objective. Global resource-based cities account for 75% of carbon emissions, and such cities in China need to shift from resource dependence to high-quality development. This paper focuses on the connotation of the "dual-carbon" objective and the uniqueness of resource-based cities, and establishes a linkage mechanism between the "dual-carbon" objective and comprehensive territorial spatial planning of resource-based cities. Aiming at the dilemmas faced by comprehensive territorial spatial planning of resource-based cities, the response pathways of comprehensive territorial spatial planning of resource-based cities under the "dual-carbon" objective is explored and verified with the example of comprehensive territorial spatial planning of Fujin City. It guides traditional resource-based cities towards low-carbon transformation and sustainable development from a multidisciplinary perspective, thereby achieving a win-win for both the economy and environmental protection.

Keywords

"Dual-carbon" objective, Resource-based cities, Comprehensive territorial spatial planning, Carbon emission reduction, Increasing carbon sink

1. Introduction

The excessive emission of greenhouse gases, specifically carbon dioxide, is contributing to the gradual rise in global temperatures, resulting in important alterations to the climate system, such as rising sea levels, which threaten global ecosystems [1]. During the General Debate of the 75th Session of the United Nations General Assembly, President Xi Jinping announced China's commitment to peak carbon dioxide emissions before 2030 and achieve carbon neutrality by 2060 [2]. To realize the 'dual-carbon' objective, China has introduced a comprehensive set of policies aimed at promoting a green transformation in both economic and social development. The country calls for the integration of carbon peaking and neutrality targets into the medium and long-term planning frameworks for economic and social development, ensuring strong

support from national development planning, territorial spatial planning, sectoral planning, regional planning and local planning at all levels.

Comprehensive territorial spatial planning, an important component of the territorial planning system, offers a systematic and scientific pathway to achieving the 'dual-carbon' objective through a multidisciplinary and integrated approach. It focuses on using spatial design to unify critical sectors such as industry, livelihoods, ecology, transportation, and land use. Techniques such as 'dual evaluation' and the delineation of the three lines effectively enhance constraints on resource and environmental thresholds, promoting low-carbon transformation and promoting green, high-quality development within resource-based cities [3].

Resource-based cities play an important role in the transformation and development of urban areas in China. Historically, these cities have depended on abundant natural resources to drive economic growth; however, with the nation's shift towards high-quality development, the previous extensive urban development model is no longer viable. The heavy reliance of these cities on resource industries has led to an increase in carbon emissions, obstructing industrial innovation and transformation while increasing carbon intensity. Worldwide, resource-based cities are responsible for 75% of carbon emissions [4], with a notably higher contribution from Chinese cities. Consequently, the formulation of comprehensive territorial spatial planning for resource-based cities, considering the imperatives of carbon reduction and increasing carbon sinks, is critical for achieving the 'dual-carbon' goals.

2. The correlation mechanism between the "dual-carbon" objective and comprehensive territorial spatial planning of resource-based cities

2.1. The connotation of "dual-carbon" objective

The "dual-carbon" objective encompasses two primary milestones: reaching a peak in carbon dioxide emissions prior to 2030, followed by achieving carbon neutrality before 2060. Carbon peaking refers to the critical point at which total carbon emissions reach a maximum and then begin to decline. Carbon neutrality signifies a state in which human-generated carbon emissions are balanced by carbon absorption and the environment reaches net-zero emissions. Reaching the carbon peaking is the key to achieving carbon neutrality, and the timing and extent of the peak will influence the achieving of this goal [5].

In order to achieve the 'dual-carbon' goal, China has mainly adopted two strategies: emission reduction and carbon sinks enhancement. China advocates the green and low-carbon principle and encourages green technology innovation to promote emissions reduction. The key is promoting industrial transformation and developing low-carbon industries, including clean energy and efficient transportation system. In the enhancing carbon sinks, the collaboration between human and nature has been strengthened through the restoration of forests, wetlands and other ecosystems to increase carbon absorption and storage capacities. Achieving the 'dual-carbon' objective is important for economic development and ecological protection, helping to mitigate the adverse impact of global climate change.

2.2. The specificity of resource-based cities

Resource-based cities refer to urban areas primarily focused on the exploitation, processing and export of natural resources such as oil, coal and agriculture. These cities are important energy supply and security bases in China [6][7]. Resource-based cities exhibit the following characteristics: (1) They are sensitive to changes in external market demand, so fluctuations in resource prices can have an important impact on the local economy. (2) Due to their reliance on natural resource extraction and processing, resource-based

cities often possess a single-industry structure and lack high-tech industries, leading to difficulties in economic structural transformation. (3) The unique industrial structure of resource-based cities contributes to severe environmental pollution and ecological degradation. It negatively impacts the quality of living environments and ecosystems. (4) Resource-rich areas experience relative prosperity, while surrounding regions face resource and infrastructure deficiencies, leading to imbalanced urban development.

2.3. The relationship between comprehensive territorial spatial planning of resource-based cities and the "dual-carbon" objective

The comprehensive territorial spatial planning of resource-based cities plays an important role in achieving the 'dual-carbon' objective [8]. Under the framework of the "dual-carbon" goal, comprehensive territorial spatial planning takes into account multiple factors such as economy, society, environment and culture. It places special emphasis on the control of carbon emissions, optimising energy utilization and protection of ecological environment [9] while optimising the factors layout and configuration. The comprehensive territorial spatial planning promotes the low-carbon development and efficient resource use, which provides a realistic path for the achievement of the 'dual-carbon' goal.

2.3.1. Comprehensive territorial spatial planning of resource-based cities provides pathways for carbon emission reduction

The main industries of resource-based cities are concentrated in the energy, minerals and agriculture sectors, characterised by high energy consumption and high carbon emissions. In order to reduce carbon emissions, the comprehensive territorial spatial planning generally includes the following measures:(1) rational allocation of industrial, ecological and construction land within resource-based cities to achieve optimal layout and allocation of the resources;(2) effective land allocation through controlling multiple factors such as the scale of construction land and the spatial mix of the city to ensure the efficient resources use and the environmental protection;(3) rational planning of industrial areas, residential areas , facility zones and green areas, and supplementing high energy consumption and high carbon emission industries with low carbon industries to achieve optimal allocation of resources. Scientific planning of transport networks and optimisation of public transport routes are also important considerations [10].

2.3.2. Comprehensive territorial spatial planning of resource-based cities provides pathways for increasing carbon sink

Resource-based cities have rich natural resources and space resources, which can effectively solve the problem of increasing carbon sink through land consolidation and ecological layout. Specific measures include:(1) Rectification of illegally occupied land and reclamation of abandoned mines to restore the ecological function of the land. This not only improves land utilization efficiency but also increases carbon sink. (2) Delineating ecological protection redlines and establishing a comprehensive green space system to increase vegetation coverage and enhance carbon absorption and fixation capabilities. (3) Controlling the utilities of different types of land to minimize unnecessary land development and construction. It improves the utilization efficiency of land resource to provide more space for increasing carbon sinks.

3. Response of comprehensive territorial spatial planning of resource-based cities under the "dual-carbon" objective

3.1. Dilemmas facing comprehensive territorial spatial planning of resource-based cities

Although comprehensive territorial spatial planning of resource-based cities has shifted from single-factor control to comprehensive control encompassing all areas, all elements, and the entire process, it still faces numerous challenges in achieving the "dual-carbon" objective. Resource-based cities rely on high-energy-consuming resource development, lack of industrial diversification, and have a singular development path, which hinders low-carbon transition. Planning in the past is disconnected from the "dual-carbon" concept, focusing on resource development while neglecting environmental factors. The "dual-carbon" concept is often only stated at the conceptual level, lacking specific implementation details. There is a lack of carbon emission monitoring and assessment. As a result, planning decisions lack data support and carbon emissions cannot be effectively controlled.

3.2. Response of comprehensive territorial spatial planning of resource-based cities

The "dual-carbon" objective of comprehensive territorial spatial planning of resource-based cities need to be achieved through strengthened support and guarantees from systems such as comprehensive territorial spatial planning and special planning. It is necessary to establish a planning, construction, and management mechanism that is guided by green and low-carbon principles. Based on the characteristics of resource-based cities, such as abundant natural resources and a relatively single industrial structure, comprehensive territorial spatial planning should be used as an effective tool [11] to coordinate the planning of various elements, including land, industry, and ecology. This will promote low-carbon planning and green governance in urban, agricultural and ecological spaces, aiming to create compact and low-carbon urban spaces, promote the building of increasing carbon sink in agricultural and ecological spaces, implement the plan of the "dual-carbon" objective, and form a sustainable territorial spatial pattern.

3.2.1. Efficient site structure

3.2.1.1 Optimization of comprehensive territorial spatial pattern

By constructing a multi-centred, clustered, and intensive comprehensive territorial spatial pattern [12], adjusting the spatial layout and growth mode of urban areas, and promoting the transition of traditional lifestyles towards green and low-carbon directions. It is necessary to build a multi-level urban spatial system that encompasses the entire region, urban-rural areas, and central urban areas. This will promote the two-way flow of resource elements and scientifically plans the layout of eco-agricultural development. It should Strengthen ecological protection and bottom-line constraints, and emphasise ecological features and values to guide sustainable agricultural development.

3.2.1.2 Integration of "three lines" delineation and control

The planning should scientifically draw redlines for protecting the ecosystems, designate permanent basic cropland and delineate boundaries for urban development, and establish a policy system for pollution reduction and carbon mitigation in urban, agricultural, and ecological spaces [13]. The key is to strengthen the control and management of ecological environments zoning. It should keep consistent with the requirements of use control and territorial planning zoning. The requirements of carbon peaking and carbon neutrality should be incorporated into the zoning and control system of the "three lines one permit" to guide industrial structure adjustments and optimize spatial layouts.

3.2.1.3 Optimization of land structure for construction

The planning aims to break the traditional single-centre urban system pattern of resource-based cities, and achieve the intensive utilization of land resources through measures such as land scale control and structural optimization. It is important to abandon the drawbacks of single-function development in cities, where work, residence, and daily life are segregated. Emphasis should be placed on the multifunctional and compound development of urban land, and the rationality of land use planning, leading to a spatial layout of land resource utilization that is multi-centred and intensive [14]. Optimizing land conversion is a important step towards achieving sustainable development. When agricultural land is converted into urban land, priority should be given to protecting high-quality agricultural land to ensure the sustainability of food production and reserves. A portion of agricultural land should be preserved as urban green space or converted to ecological agricultural purposes to increase carbon sink and ecological sustainability in cities.

3.2.2. Systematic ecological protection and restoration

3.2.2.1 Strengthening the protection and utilization of resource elements

The planning adheres to the system governance of mountains, rivers, forests, farmlands, lakes, and grasslands, and constructs a large-scale and large-region ecological network structure system [15]. This approach aims to protect natural spaces and achieve network connectivity, stimulating the increasing carbon sink function of agricultural and ecological spaces, and forming an ecological foundation of urban ecological purification. In terms of ecology, the development of natural protected area systems such as national parks are being advanced, integrating protected areas to build an ecological network structure system. This connects protected areas and ecological nodes, forming ecological corridors and ecological linkages, thereby enhancing the stability of ecosystems. In agriculture, there is a focus on strengthening farmland management, improving soil carbon storage capacity, promoting circular agriculture, constructing agroforestry systems, and implementing farmland ecological projects to enhance carbon sequestration capabilities.

3.2.2.2 Ecological restoration and comprehensive land consolidation

We need to strengthen the protection and restoration, and reduce carbon emissions and enhance carbon sinks to promote continuous ecological improvement and low-carbon development [16]. It is necessary to implement a negative list for natural ecological protection and restoration activities, standardize restoration practices, strengthen law enforcement and supervision, reduce non-construction land use, and prevent over-exploitation of land resources and increased carbon emissions. A comprehensive framework for land space remediation and restoration should be established to repair damaged ecosystems and remediate illegal land occupation and reclaim abandoned mines in order to improve the sustainable use of land and soil carbon sequestration capacity. Priority should be given to ecological protection and restoration within ecological protection red lines and key ecological functional areas, focusing mainly on natural recovery supplemented by artificial restoration. Ecosystem protection of the water environment, wetlands, soil and other ecosystems will be strengthened to improve ecosystem stability and carbon sequestration capacity.

3.2.3. Low-carbon layout patterns

3.2.3.1 Industrial spatial layout adjustment

The planning aims to steer resource-based cities towards a high-end, intelligent, green, and service-oriented industrial model through policy guidance and technological innovation [17]. In the primary industry,

it promotes green and ecological farming, enhancing production efficiency and resource use while reducing chemical inputs and agricultural greenhouse gas emissions. In the secondary industry, it encourages green manufacturing and renewable energy, adopting clean production methods to decrease non-renewable resource consumption and waste emissions. In the tertiary industry, it promotes the development of green industries like electronic information, builds blockchain and industry chains, and uses "Internet of Things +" technology for smart city construction, enhancing urban management and services, and reducing carbon emissions from transportation and industries.

3.2.3.2 Optimization of the layout of the central urban area

Resource-based cities, with primary and secondary industries as their main focus, face important transportation challenges. To address this issue, the following measures can be implemented: advocating for the "public transportation priority" and Transit-Oriented Development (TOD) concept, an integrated public transportation system should be established with rail transit as the backbone and conventional buses as the main component. This system should provide multi-level public transportation connections, linking various service centres in the city and offering convenient public transportation services to reduce transportation energy consumption and carbon emissions. Establishing a "narrow roads, dense road network" transportation network can expand the coverage of the public transportation system and optimize traffic flow [18], reducing unnecessary transportation-related carbon emissions. Using big data and smart city platforms, a "blockchain + internet" intelligent transportation management system and smart parking facilities should be developed to enhance the operational efficiency of the transportation system [19]. It will help ease traffic congestion and reduce high carbon emissions by providing intelligent support.

Promoting the concept of "low-carbon living" can contribute to carbon emission reduction in various ways, such as resource utilisation, community green commuting and green buildings [20]. Through implementing measures including waste separation and recycling, organic waste composting and water recycling, establishing a community resource recycling system can reduce the demand for natural resources to contribute to reduce greenhouse gas emissions from landfills and incineration. The key is encouraging green commuting within the community to reduce vehicle gas emissions, such as building infrastructure, providing a convenient public transport system and promoting clean energy transport options. Incorporating greening and landscaping into community planning can help mitigate the urban heat island effect and improve air quality, including increasing green space and vegetation cover into community.

Through adopting green building material, optimising spatial layout and implementing low carbon and energy efficient technologies, it will reduce carbon emissions from constructions to improve the sustainability [21]. Utilising renewable green building materials can help reduce carbon footprint and environmental impact, and promote the development of the green building material industries. Using natural lighting and ventilation through thoughtful spatial layout can reduce the reliance on artificial lighting and energy to reduce carbon emissions at source. The adoption of low-carbon and energy-saving designs and technologies will allow for detailed control of building space, which sets carbon emission limits and assesses the science of spatial planning.

4. Implementation and application of comprehensive territorial spatial planning for resource-based cities under the "dual-carbon" objective: a case study of fujin city

4.1. Overview of the situation in fujin

Fujin City, a county-level city under the jurisdiction of Heilongjiang Province, is located in the northeastern part of the province and is primarily agricultural. It has abundant ecological resources. Nowadays, it faces some challenges: a monocentric spatial structure that restricts urban development, an imbalanced land use structure in the old urban area with mixed industrial and residential zones affecting the living environment. The economy is relatively underdeveloped with a singular industry, and the level of urbanization is low. Infrastructure such as water supply, sanitation, and transportation systems are inadequate. The economy development has led to a decline of ecological quality and scarcity of water resource. The distribution of green spaces is uneven, and the green space system is incomplete. The outflow of young people leads to sustainable development problem.

4.2. Technological route

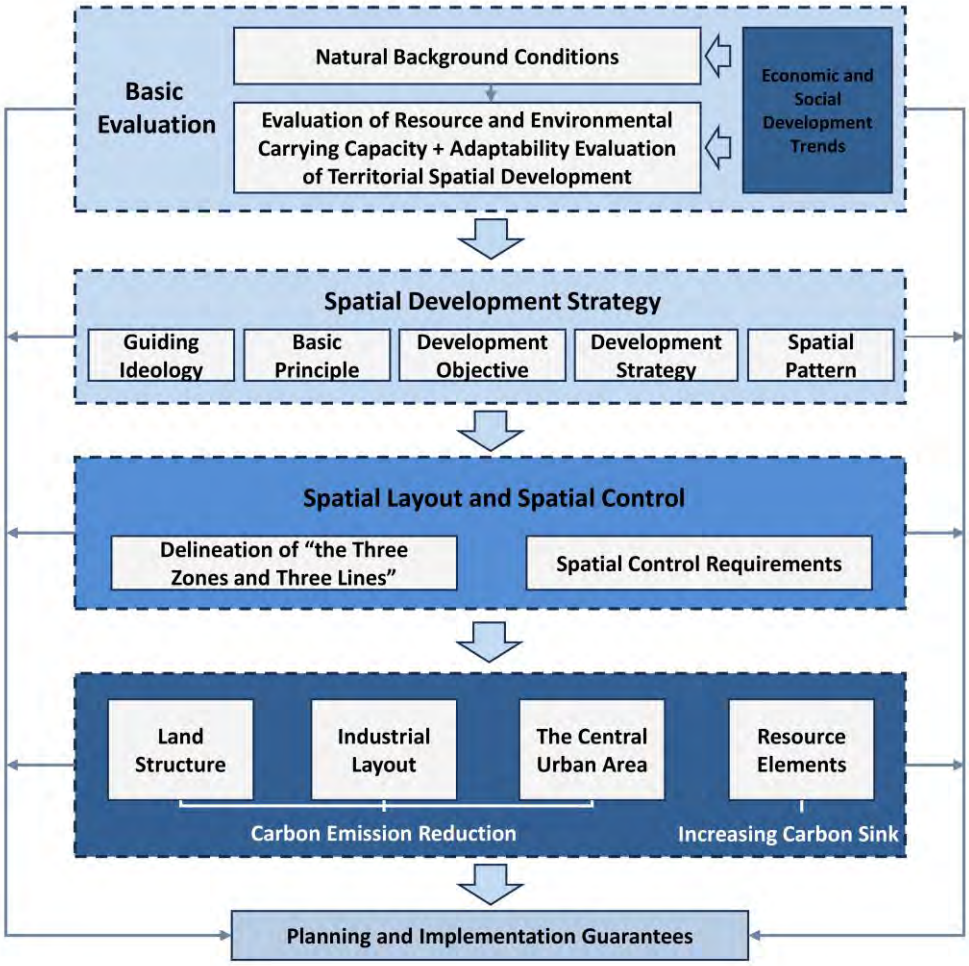


Figure 1. Technical Roadmap for the Comprehensive Territorial Spatial Planning of Fujin City. Source: Self-drawn by the author.

The Comprehensive territorial spatial planning of Fujin City is based on "three investigations" data, combined with natural background conditions such as land and water resources, and ecology. Five individual evaluations are conducted for natural background conditions, water resources, and other indicators. Based on this, an integrated evaluation of resource and environmental carrying capacity is carried out, which comprehensively identifies the strength and weakness levels of carrying capacity. Quantitative analysis is primarily employed, supplemented by qualitative analysis, to conduct individual evaluations of potential for back-up suitable lands and disaster risks, and integrated evaluations of ecological suitability, urban function suitability, agricultural function suitability, and other factors. Based on the adaptability evaluation of territorial spatial development, in combination with higher-level planning and spatial development strategic planning, the spatial pattern and spatial control are determined. In order to coordinate the rational utilization of resources, we need to delineate urban development boundaries, permanent basic farmland redlines and ecological protection redlines, and determinate spatial control requirements for ecological, agricultural, and urban spaces. In response to the "dual- carbon" objective, comprehensive territorial spatial planning of Fujin City provides various implementation paths in terms of land use, industries, resources, and the central urban area. This aims to promote green economic transformation, ecological protection, and utilization, in order to promote carbon emission reduction and increase carbon sink (refer to Figure 1).

4.3. Implementation pathway

4.3.1. Efficient site structure

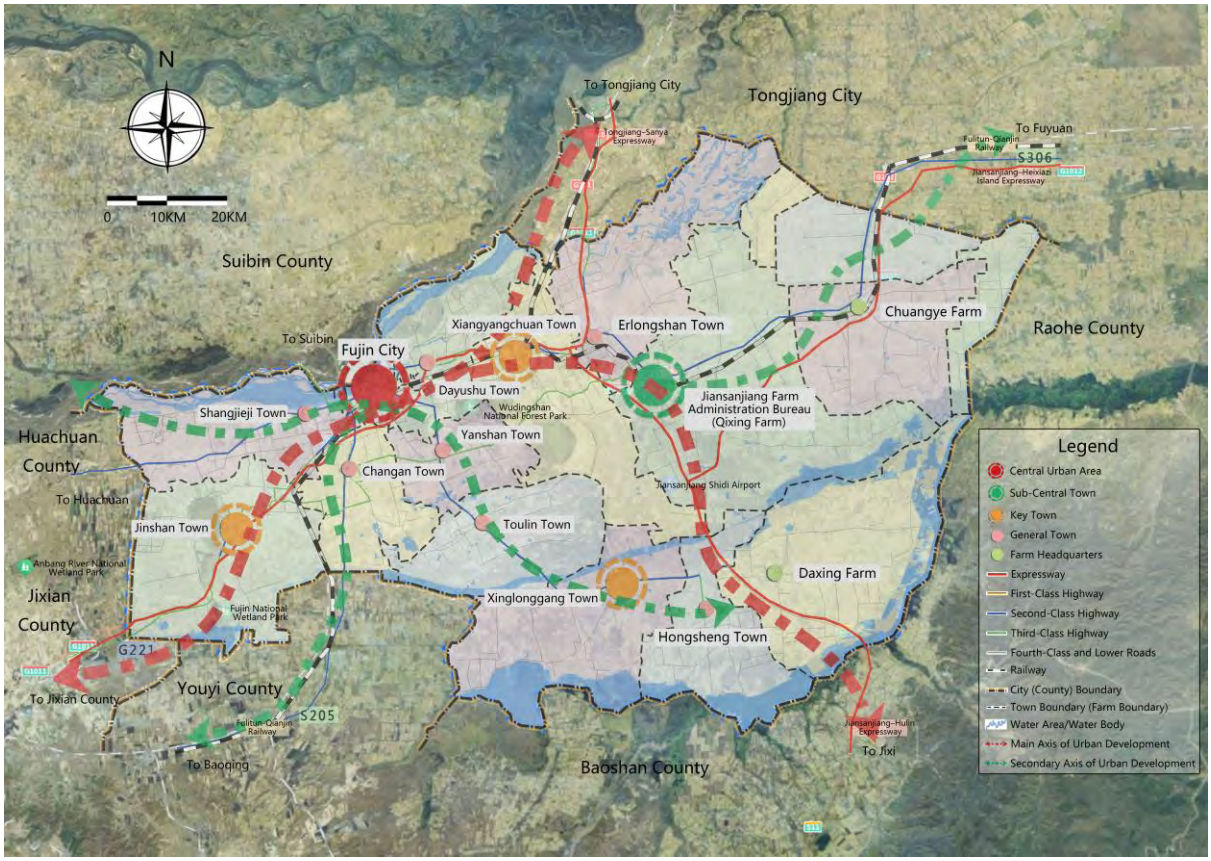


Figure 2. Spatial Structure Plan of Fujin City. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

In spatial structure planning, to strengthen the connection between industries and urban zones, promote the linkage of various transportation modes, and promote the development of eco-agricultural towns, Fujin City's spatial development pattern has shifted from the previous single-centre development model to a "dual-core driving, dual-axis traction" development pattern (refer to Figure 2). The "dual-core driving" approach refers to using the central urban area of Fujin and the sub-centre as engines to drive the overall economic and social development of the city. These two central urban areas primarily focus on the development of secondary and tertiary industries, promoting the concentration of production factors and population in the two core zones within the city. The "dual-axis traction" relies on the road system to form the main and secondary axes for urban development. These two axes unify various townships into a cohesive whole and play a role of spatial traction to realize the transformation of the overall spatial pattern. It effectively alleviates the problems of traffic congestion and carbon emissions brought about by the single-centre city development pattern. Through the shortening of commuting distance and time and providing diversified travelling options, it promotes the development of public transport and non-motorised transport to reduces transport energy consumption and carbon emissions.

4.3.2. Adjustment of industrial spatial layout

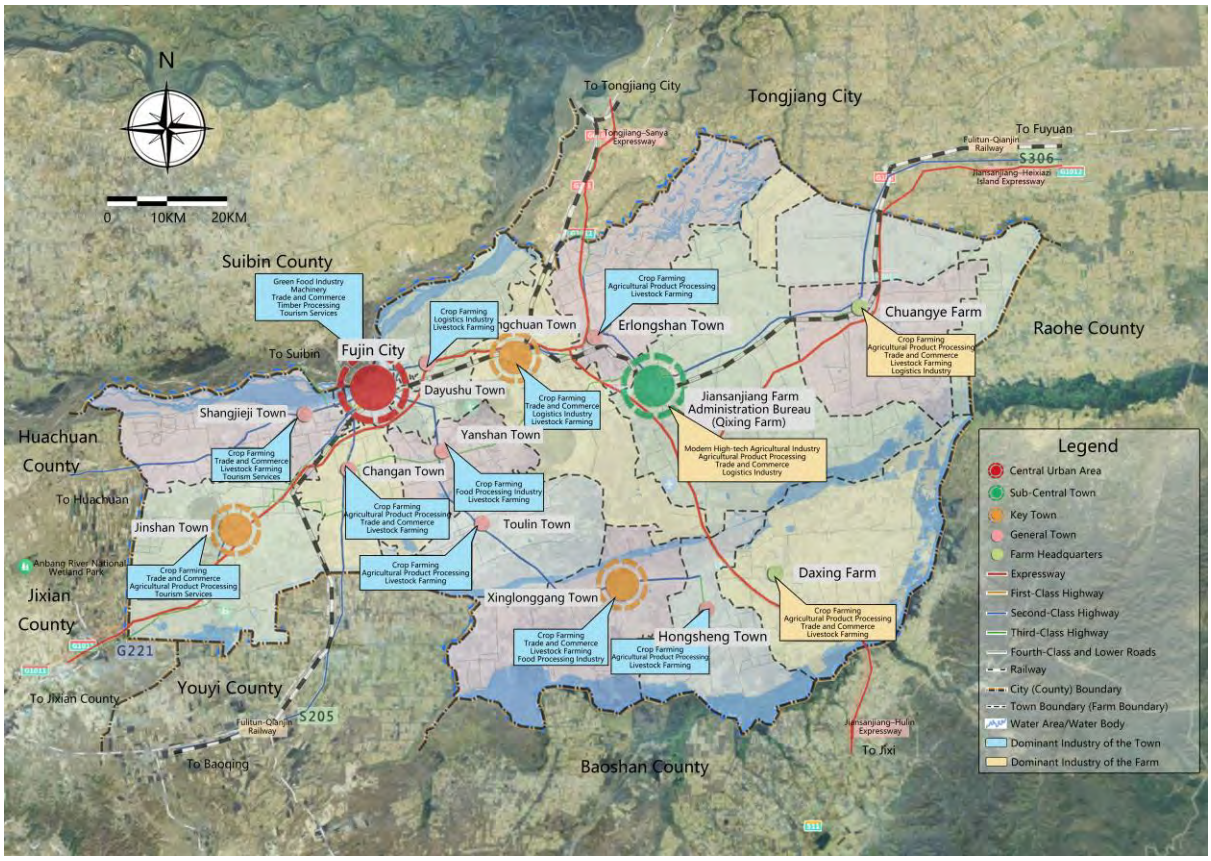


Figure 3. Industrial layout plan of Fujin City. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

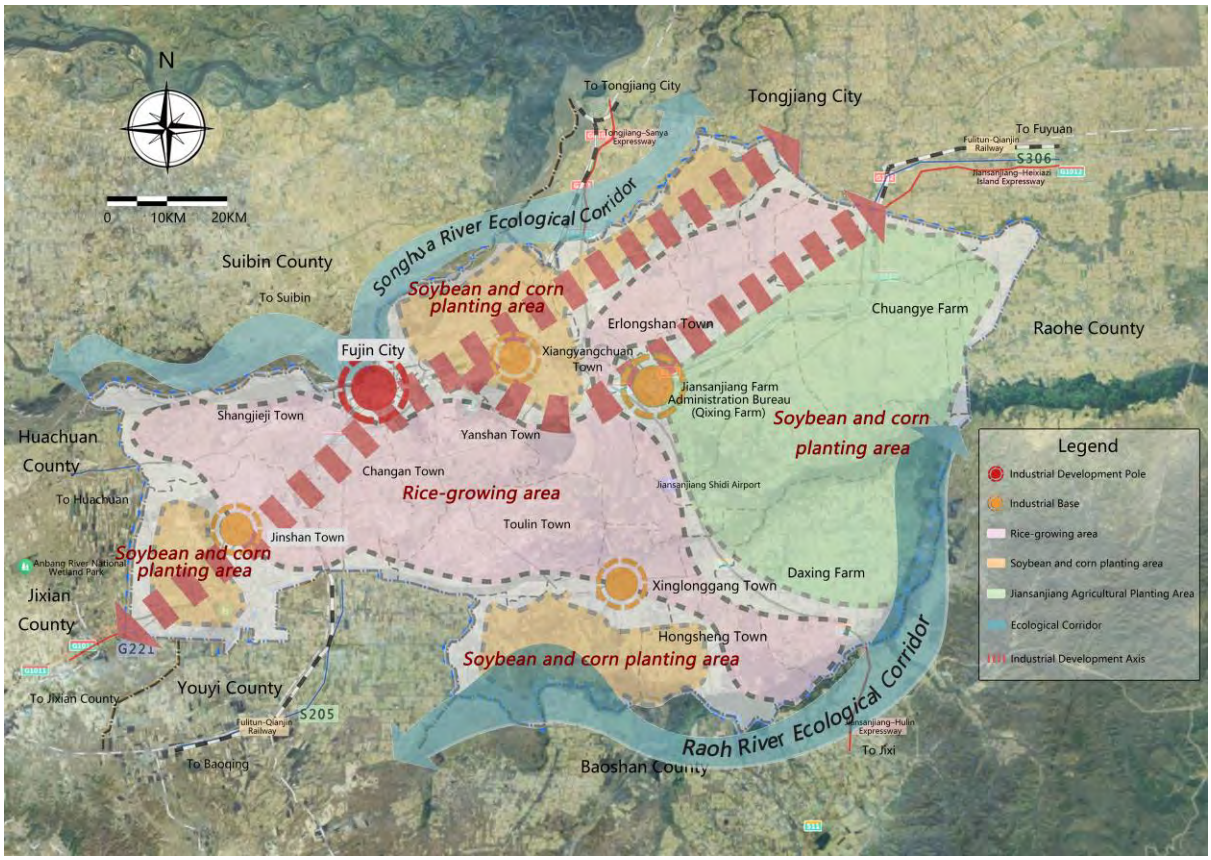


Figure 4. Agricultural layout plan of Fujin City. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

Based on the resources and industrial advantages of Fujin City, the industrial development strategy aims to create a strategic pattern of "one core, two bases, one axis, two corridors, multiple districts and multiple nodes" (refer to Figure 3). "One core" refers to the core area of industrial development in the downtown area of Fujin. It integrates the production and related service functions, commercial and residential functions, and modern port logistics functions of the green food industrial park to realize the multi-functional and integrated connection between the port, industry and city. We can promote the coordinated industrial development to improve resource utilisation efficiency and reduce carbon emissions. The "two bases" feature agricultural resources to form a special agricultural industrial base and a cultural tourism industrial base integrating grain planting, production, processing and sales. In terms of agriculture (refer to Figure 4), the focus is on shifting from traditional inefficient agriculture to seven modern, industrialised and ecological agricultural development models, including high-tech facility agriculture, recycled agriculture and leisure and tourism agriculture. Using of agro-ecological resources to promote the development of rural tourism and service industry as part of the tertiary sector aims to achieve mutual promotion and large-scale development of the industries. In the secondary industry, information technology is used to drive industrialisation and industrialisation is used to promote information technology. We can accelerate the emerging industries development and promote the optimisation and upgrading of industrial structure. Through the development of green technology and circular economy, it reduces dependence on traditional fossil fuels to provide more choices and possibilities for carbon emission reduction.

4.3.3. Enhancing the protection and utilization of resource elements

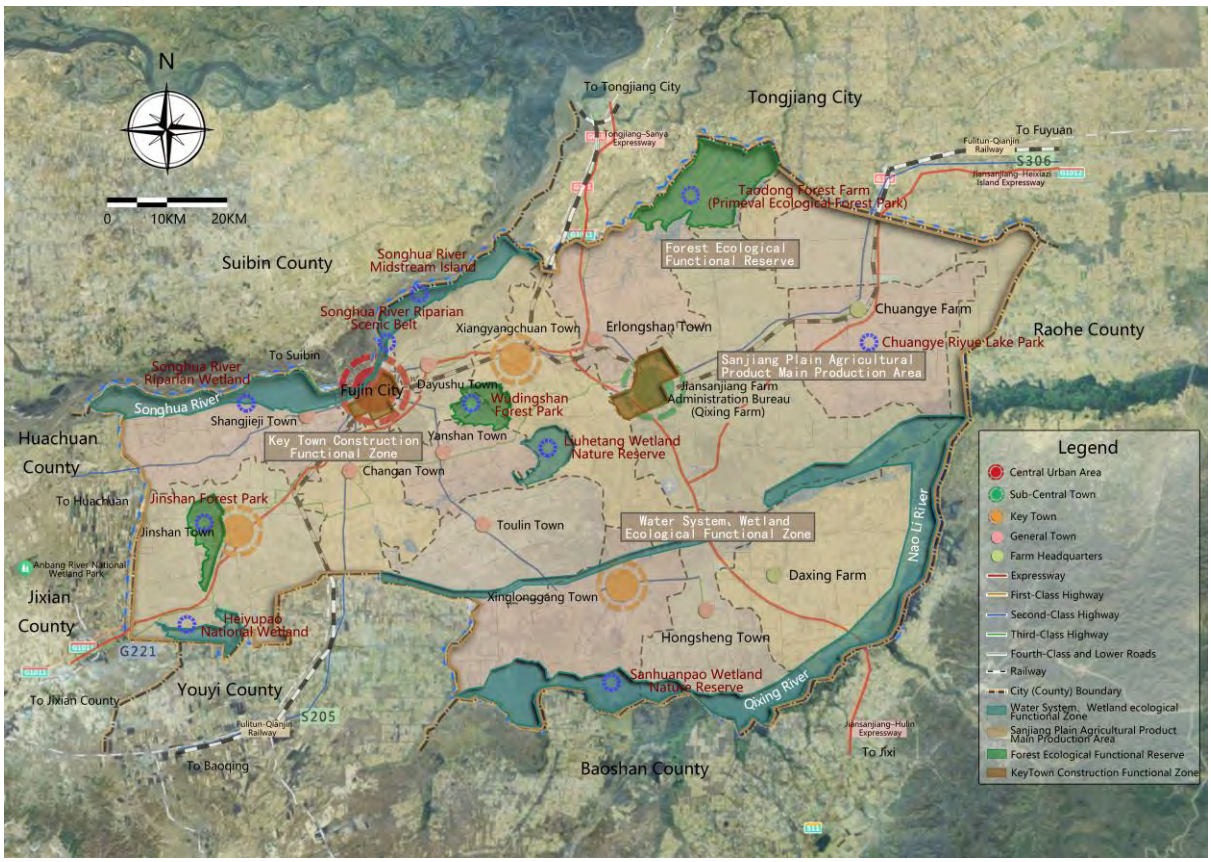


Figure 5. Ecological Resources Layout Plan of Fujin City. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

Based on the land use function and ecological characteristics of Fujin City, the city is divided into four ecological environment function zones: key urban construction function zone, primary agricultural production function zone, water wetland ecological function zone and forest ecological function protection zone (refer to Figure 5). Each zone implements different development and conservation strategies. In the key urban construction function zone, the key is environmental protection, soil and water conversation, and improvement of the living environment to minimize the impact of human activities on the ecological environment. In the primary agricultural production function zone, development and construction activities will be strictly controlled, which creates ecological, green and high-yield agricultural production areas. The water wetland ecological zone focuses on safeguarding the grassland ecosystem and ensuring the stability of the grassland wetland environment. The multi-functionalities of wetlands are used effectively to promote tourism development. In the forest ecological function protection zone, all construction and development activities are strictly prohibited to protect the original forest ecosystem and maintain surface vegetation diversity. Based on the ecological functional zoning, an ecological security pattern of "two mountains, one river, four rivers, and multiple points" is established. Various nature reserves are scientifically established, and different ecological protection mechanisms are put in place. This approach is adaptable to local conditions and maximizes the carbon capture and regulatory capacity of the ecosystem.

4.3.4. Optimization of the layout of the central urban area

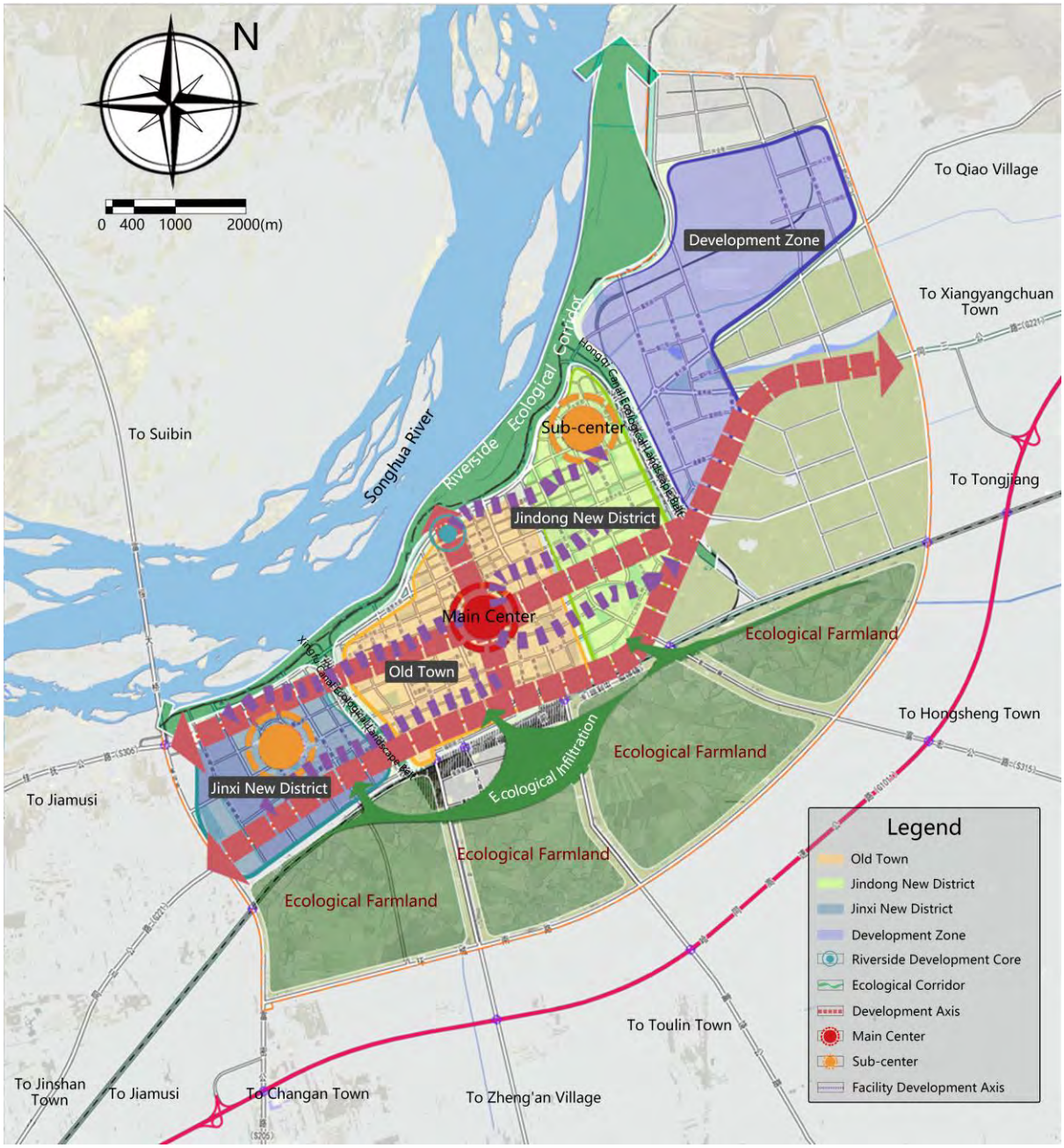


Figure 6. Spatial Structure Plan of Fujin City Centre. Source: The Comprehensive Territorial Spatial Planning of Fujin City.

In the central urban area of Fujin City, the overall urban pattern of "three zones, two cores, one corridor, and two axis belts" is being created (refer to Figure 6), with green spaces and facilities acting as barriers between different functional zones. The city's road system is the foundation for building a segregated urban slow system and a public transportation transfer system. Based on urban slow zones and pedestrian units, a continuous network of slow transportation systems is established, including the development axes for slow community, riverside scenic belt, and slow transportation corridors. By promoting and developing public transportation and slow modes of transportation, the urban transportation network is optimized, and the urban road system is improved. This reduces private car usage and the demand for energy

resources such as petroleum, while improving energy utilization efficiency and reducing energy consumption.

5. Conclusion and Prospects

Achieving the "dual-carbon" goal is a necessary way for China's green development and is a systematic project involving various fields and elements. This paper discusses the response of comprehensive territorial spatial planning for resource-based cities to the "dual-carbon" goal. In the future, incorporating the "dual-carbon" goal as an evaluation factor into the evaluation system [22][23] will help guide decision-making, promote the green development and sustainable transformation of resource-based cities, comprehensively evaluate urban development to achieve sustainable development and carbon emission reduction goals.

6. References

Cai, R., Liu, K. and Tan, H. (2020) 'Impacts, risks, and adaptation strategies of climate change on China's oceans and coastal zones', *China Population, Resources and Environment*, 30(9), pp. 1-8.

Li, M., Chen, Y. and Wu, T. (2024) 'Spatiotemporal characteristics and configuration paths of coupled and coordinated development of digital economy and green logistics under the background of "double carbon"', *Environmental Science*, pp. 1-18.

Sun, S. W. (2020) 'From urban and rural planning to national territorial spatial planning', *Urban Planning Journal*, (4), pp. 11-17.

Wu, B. (2022) 'The ticking of the carbon-neutral clock: Urban carbon emissions account for as much as 75%, how to break through in the "main battlefield" of carbon emission reduction?', *Guangdong Twenty-First Century Global Economic Newspaper*, 14 January[online]. Available at: https://www.21jingji.com/article/20220114/herald/b0f5f320a8084ef634badc46eb72b499.html (Accessed: 10 July 2024).

Zhang, X. D. (2022) 'Correctly understand and grasp the systematic planning and overall deployment of China's carbon peak and carbon neutrality—Interpretation of the spirit and ideas of the Party Central Committee on the double carbon in the new development stage', *Shanghai Economic Research*, (2), pp. 14-33.

Zheng, Z. Y., Qiu, F. D., Zhang, C. L. et al. (2020) 'Heterogeneity of functional transformation and industrial structure analysis of resource-based city', *Resource Science*, 42(3), pp. 570-582.

Wang, T., Zhang, J. M., Yu, X. et al. (2021) 'Sustainable development path of resource-based cities: Taking the creation of a national sustainable development agenda demonstration zone in Taiyuan as an example', *China Population, Resources and Environment*, 31(3), p24-32.

Zhuang, S. Q., Zhao, X. S., Li, C. Y. (2020) 'Dimensions and temperatures of national territorial spatial planning', *Urban Planning*, 44(1), pp. 9-13.

Li, Q., Xiao, J. S. and Yang, K. Z. (2021) 'On the theoretical system of national territorial spatial planning in the era of ecological civilization', *Urban Development Research*, 28(6), pp. 41-49.

Feng, C. C., Zhao, Y. J., Wang, F. H. et al. (2022) 'Planning response to carbon neutrality', *Urban Planning*, 46(2), pp. 25-31.

Xiong, J., Lu, K., Jiang, Z. Y. et al. (2021) 'Research and thinking on the preparation of national territorial spatial planning under the goals of "carbon peak and carbon neutrality"', *Urban Planning Journal*, (4), pp. 74-80.

Ding, M. L., Yang, X. N., Zhao, R. Q. et al. (2022) 'Optimization of national territorial spatial pattern under the goal of carbon neutrality: Theoretical framework and practical strategies', *Journal of Natural Resources*, 37(5), pp. 1137-1147.

Wang, Y.F., Fan, J. and Zhou, K. (2019) 'Territorial function optimization regionalization based on the integration of "Double Evaluation"', *Geographical Research*, 38(10), pp.2415-2429.

Han, G., Yuan, J. D., Zhang, X. et al. (2019) 'The role mechanism of compact urban spatial structure on urban energy consumption: An empirical study based on Jiangsu Province', *Geographical Science*, 39(7), pp. 1147-1154.

Zheng, Q., Wang, C. K., Liao, X. H. et al. (2022) 'Research on the carbon neutral path of urban sub-area based on carbon emission accounting', *Urban Planning Journal*, (s1), pp. 248-253.

Wang, X. H. and Wang, X. (2012) 'Coupling research on industrial structure upgrading and low-carbon economic development', *Soft Science*, 26(3), pp. 29-32.

Yang, W. Y. and Cao, X. S. (2019) 'Research progress on influencing factors of carbon emissions in multi-scale transportation', *Progress in Geography*, 38(11), pp. 1814-1828.

Cao, X. S., Liang, F. W. and Chen, H. L. (2019) 'Influence of spatial morphology differences in mega-cities on the efficiency of transportation networks', *Geographical Science*, 39(1), pp. 41-51.

Cao, X. and Gao, Y. (2021) 'Does the low-carbon city pilot policy promote the formation of urban residents' green lifestyle?', *Chinese Population, Resources and Environment*, 31(12), pp. 93-103.

Fei, Y. and Lin, Z. (2010) 'Research on the development of green buildings in low-carbon city construction', *China Population, Resources and Environment*, 20(S2), pp. 169-172.

Zhang, Z. L., Hou, Y. Z. and Sun, H. H. (2023) 'Calculation of carbon emissions in urban territorial spaces and differences in low-carbon development efficiency', *Journal of Natural Resources*, 38(6), pp. 1464-1481.

Zhao, R. Q., Huang, X. J., Yun, W. J. et al. (2022) 'Key issues in the field of natural resource management under the goals of carbon peak and carbon neutrality', *Journal of Natural Resources*, 37(5), pp. 1123-1136.

ISOCARP
Knowledge for Better Cities

60th ISOCARP World Planning Congress Proccedings

Siena © Municipality of Siena

ISOCARP
Knowledge for Better Cities

Hoefkade 9
2526 BN The Hague
The Netherlands

International Society of City and Regional Planners | www.isocarp.org