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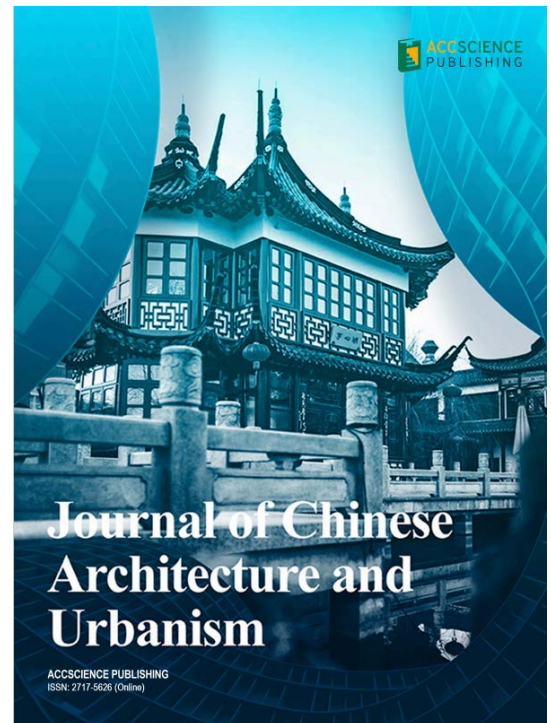
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A typical Chinese-styled building

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EDITORIAL

Insights from “Advanced Technologies and Practices in the Built Environment and Cultural Heritage”

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(This article belongs to the *Special Issue: Advanced Technologies and Practices in the Built Environment and Cultural Heritage*)

In recent decades, there has been a notable surge in technological advancements and innovative practices for optimizing the built environment and safeguarding cultural heritage, driven by the imperative to uphold cultural identity and bolster environmental resilience (Bertolin & Loli, 2018; Dang *et al.*, 2023; Sabbioni *et al.*, 2008).

A primary area of focus is in understanding the hygrothermal behaviors of historical buildings, as their preservation necessitates a comprehensive grasp of ambient conditions. Recent studies not only address immediate preservation needs but also contribute to broader discussions on sustainable conservation practices. In addition, efforts are directed toward exploring novel materials and retrofitting techniques to bolster the resilience of historical structures against the impacts of climate change.

With an increasing emphasis on sustainability and energy conservation, there is a growing demand for innovative approaches to retrofitting existing buildings while maintaining their historical integrity. Researchers and practitioners are actively integrating energy performance considerations into environmental design, drawing inspiration from interdisciplinary fields such as biomimicry.

Moreover, advancements in technologies for heritage digitalization offer exciting opportunities for immersive and interactive accessibility. As research in this domain continues to evolve, there is potential for the development of advanced modeling and visualization techniques that enable more precise virtual reconstructions and immersive heritage experiences.

This special issue titled “Advanced Technologies and Practices in the Built Environment and Cultural Heritage” (2023) endeavors to showcase the latest methodological insights.

Xiong *et al.* (2023) investigate the energy-saving potential of adjusting indoor cooling temperature set points in buildings with different envelope characteristics. Through building simulation and analysis, the study provides valuable suggestions for optimizing energy consumption and guiding occupant behaviors.

Hong (2024) employs image semantic segmentation to analyze the spatial characteristics of streets in Lu Xun’s hometown of Shaoxing, China. This study elaborates on historical street structures through deep learning algorithms, contributing to the integration of artificial intelligence in urban design and planning.

Liu *et al.* (2024) explore the application of digital twin technologies at archeological sites, focusing on the virtual reconstruction of the Pishan site in Huzhou. Through

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the integration of photogrammetry, unmanned aerial vehicles, and geographic information systems, the study demonstrates the potential of digital twins in enhancing both research and visitor experiences.

He *et al.* (2024) present a comparative study of Chinese and Japanese historic urban spatial paradigms. Through a comprehensive analysis grounded in space syntax theory, the study provides identification indicators and assessment systems for the spatial structure of urban residential environments with historical characteristics.

By fostering interdisciplinary collaboration and innovation, we collectively address the challenges ahead and ensure a sustainable future for our cultural heritage and the built environment. All the authors deserve gratitude for their valuable contributions, which inspire further research and collaboration.

Moving forward, the challenges we face are substantial. Foremost among these challenges is the escalating impact of climate change, which poses a significant threat to both cultural heritage and the built environment. The increasing frequency of extreme weather events puts the preservation of historical structures at risk. In addition, the rapid pace of urbanization threatens the surrounding urban environment of historical buildings, potentially altering their original settings and functions. Furthermore, the exploration of energy-efficient retrofitting techniques presents a conundrum, as we strive to balance improvements in energy efficiency with the preservation of historical authenticity.

To address these challenges, it is imperative to foster interdisciplinary collaboration, for instance, leveraging advancements such as machine learning from computer science and scanning technologies from surveying science. These efforts not only facilitate accurate problem identification and resolution but also expand the knowledge maps. Through sustained research and innovation, one should be optimistic about developing effective solutions that ensure the appropriate conservation of cultural heritage and the rational optimization of the built environment, thereby leaving a valuable legacy for future generations.

An upcoming special issue will continue to highlight the latest research findings in China's built environment and cultural heritage, with a moderate expansion in submission topics: not only technical reviews and case studies, but also scientific reflections on theoretical concepts, workflows, and research frameworks. Potential topics may include theories and strategies for heritage preservation in the built environment, air quality and thermal comfort in historical buildings,

the performance and environmental risks of building materials and components, protection, restoration, and renovation of historical buildings, and the digital preservation, exhibition, and management of heritage – with an emphasis on interdisciplinary studies that integrate theory and practice. Contributions involving comparative analyses between the East and the West or between ancient and modern times are encouraged. Stay tuned for more updates!

Conflict of interest

Xinyuan Dang is an Editorial Board Member of this journal and Guest Editor of this special issue. The author declared that he has no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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REVIEW ARTICLE

Technical approaches to addressing ecological red-line management challenges in ecological security

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Abstract

As rapid industrialization, urbanization, and globalization heighten the urgency for ecological security worldwide, China faces a critical challenge in balancing economic development with environmental preservation. In response, China has implemented various ecological initiatives, with the establishment of ecological red lines as a cornerstone of its environmental governance and a fundamental strategy to safeguard ecological security. This study provides a comprehensive examination of the evolution of ecological protection red lines and the recent release of the Technical Guidelines for the Delineation of Ecological Protection Red Lines to develop a technical plan for regional ecological protection red-line management and control. It focuses on ecological security concerns, and the key considerations encompass defining essential concepts, highlighting the adverse impacts of human activities to justify the adoption of restrictive systems, recognizing regional disparities in resources, environment, and socioeconomic context, and employing multi-scale research methodologies for comprehensive data acquisition. The study addresses diagnosing ecological security issues, establishing prevention objectives and management goals, categorizing types of regional ecological protection red-line management and control, delineating spatial boundaries, and incorporating historical insights to propose scientifically grounded response strategies. These strategies aim to address ecological security challenges threatening ecological protection red lines while integrating extensive social feedback to ensure practicality and effectiveness.

Keywords: Ecological protection red lines; Ecological security; Regional management; Technical solutions; Environmental governance

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1. Introduction

The pursuit of ecological security has become increasingly urgent as nations grapple with the challenges posed by rapid industrialization, urbanization, and globalization

(Brauch *et al.*, 2011). In China, rapid economic growth and environmental degradation have accentuated the imperative for ecological security (Liu *et al.*, 2015). China's journey toward ecological security can be traced back to the late 20th century when the country embarked on economic reforms and opened up to the global market, leading to severe environmental degradation (Li *et al.*, 2017). Recognizing the need to address these challenges, China has prioritized ecological security as a key component of its sustainable development agenda (Yin *et al.*, 2019).

Over the years, China has introduced various policies and initiatives aimed at enhancing ecological security (State Council of China, 2011), with the establishment of ecological red lines emerging as one of the most significant measures (State Council of China, 2011a). These ecological red lines have become a cornerstone of China's environmental governance strategy, guiding land use planning and resource management decisions (Wu & Zhang, 2018). However, challenges persist, particularly in balancing economic development with environmental protection (Chen *et al.*, 2020). Effective monitoring and enforcement mechanisms, which require substantial resources, are also crucial for the success of ecological red lines (Li & Li, 2017).

Despite these challenges, opportunities exist to enhance ecological security through innovative approaches such as ecosystem-based adaptation and green infrastructure development (Zhang *et al.*, 2020). Given China's status as the world's largest emitter of greenhouse gases, its pursuit of ecological security has broader implications for global sustainability efforts (Duan & Liu, 2019). Therefore, international cooperation and knowledge exchange are essential for addressing shared environmental challenges and achieving collective ecological security goals (Ding *et al.*, 2018).

China's rapid economic and social development, coupled with extensive land and resource exploitation over the past four decades, has posed a significant threat to its land and ecological security framework (Smith *et al.*, 2020). To mitigate this threat, it is essential to delineate restricted areas for resource and environmental development and utilization (Jones & Wang, 2018). Addressing this threat necessitates targeted initiatives in resource classification, environmental remediation, and ecological restoration and protection to establish a comprehensive land ecological security framework (Li & Zhang, 2019).

The process of delineating ecological red lines, mandated by the State Council since 2011 (State Council of the People's Republic of China., 2011), is gradually nearing completion (State Council of China, 2011a). While this initiative provides a framework for maintaining regional ecological

security, addressing specific environmental security concerns at various "points" within a region remains critical (Smith *et al.*, 2020). Integrating technical solutions for regional ecological protection, red-line management, and control is crucial for refining methodologies and enhancing the institutional framework governing these ecological red lines. This integrated approach will contribute to ensuring ecological security across broader areas and advancing sustainable development goals.

2. Historical evolution of ecological protection red lines

Since the reform and opening up in the late 1970s, China has experienced rapid industrialization and urbanization, resulting in the continual expansion of construction land at the expense of agricultural land and ecological spaces. This trend has exacerbated conflicts between environmental protection and economic growth, underscoring the need for a regional approach to ecological protection red-line management and control from an ecological security perspective (Li & Chen, 2020). In 2000, Gao (2000) introduced the concept of "red-line control" in ecological planning in Anji county, Zhejiang Province, China, advocating for the prioritization of environmental and ecological factors in land use planning. Similarly, scholars such as Wang & Yu (2003) have proposed concepts, such as "urban ecological planning" and "anti-planning," emphasizing the importance of preserving natural and biological processes.

The implementation of these concepts began to solidify with the issuance of the Pearl River Delta Environmental Protection Planning Outline and Basic Ecological Control Line Management Regulations in Guangdong province and Shenzhen city in 2005 (Guangdong Provincial People's Government, 2005; Shenzhen Municipal People's Government, 2005). In 2006, the national Eleventh 5-year Plan advocated for the formation of regional main functional areas, with zones delineated according to development potential and environmental capacity (National Development and Reform Commission, 2006). However, substantive progress was not made until 2011, when the State Council proposed the concept of ecological red lines and delineated specific tasks for their implementation (State Council of China, 2011a).

The subsequent release of the Technical Guidelines for Delineating Ecological Red Lines in 2012 marked a significant advancement, initiating pilot projects in several provinces (Ministry of Ecology and Environment of the People's Republic of China, 2012). In 2013, the ecological red-line system was elevated to a national strategy, further emphasizing its strategic importance (The Central People's

Government of the People's Republic of China, 2013). The inclusion of ecological red-line delineation in the revised Environmental Protection Law of 2015 reinforced its legal status (National People's Congress of the People's Republic of China, 2015). The official release of the Guidelines for Delineating Ecological Protection Red Lines in 2017 marked a milestone in the completion of red-line delineation in 15 provinces, with the remaining provinces awaiting approval (Ministry of Ecology and Environment of the People's Republic of China and National Development and Reform Commission, 2017).

Throughout the delineation process, it became apparent that regional ecological protection red lines faced diverse challenges due to variations in natural environments and economic contexts. Addressing these challenges requires tailored management and control strategies to effectively safeguard ecological security and uphold the integrity of these ecological protection red lines (Li & Chen, 2020).

3. Urgent issues in regional ecological red-line management

3.1. Clarifying key concepts and their significance

3.1.1. Strengthening the ecological protection red line: Addressing human-caused impacts

Enhancing the rationale and imperatives of implementing the ecological protection red line system while mitigating human-caused negative impacts has become crucial. The concept of ecological protection red lines has undergone multiple revisions in documents issued by the Ministry of Environmental Protection since 2012, with the latest definition outlined in the guidelines, which delineate these lines as areas with special and important ecological functions that must be compulsorily and strictly protected (Ministry of Environmental Protection, 2017). The State Council first proposed the concept of ecological red lines in 2011, providing initial guidance for delineation tasks, which subsequently elevated the ecological red-line system to a national strategy in 2013 (State Council of China, 2013). Since then, delineation plans have progressed across provinces. However, challenges have arisen due to diverse ecological security issues, necessitating tailored management and control strategies to safeguard ecological safety (State Council of China, 2011b). The term "strict protection" underscores the imperative to curb human-caused disruptions to vital ecological areas. However, the guidelines currently lack a comprehensive analysis of ecological risks and the adverse impacts of human activities. To bolster the rationale for implementing the red line system and address ecological security concerns more effectively, it is imperative to fortify the concept of ecological protection red lines and raise awareness of the detrimental human

influences (Ministry of Environmental Protection and National Development and Reform Commission, 2017).

3.1.2. Navigating ecological security challenges

The existing guidelines address various ecological security issues, including land degradation, loss of ecological functions, and decline of environmental quality. However, the direct link between these issues and the unsustainable use of resources and the environment by human activities remains unclear. Indeed, complexities arise from the inherent contradiction between local resource and environmental conservation efforts and the imperatives of human economic and social development. These problems manifest differently across regions, with different traits, developmental paths, and effects on ecological red lines, making it difficult to fully understand and differentiate them regionally. As a result, each ecological security issue requires specific analyses and tailored control measures. Moreover, considering spatial dimensions, disturbances to ecological security and human-caused problems can affect the nature, quality, and function of ecological red lines, both within and beyond designated red line boundaries. Therefore, it is important to deepen our understanding of the broader scope, nature, and geographic dimensions of ecological security issues to develop effective, spatially aware, problem-specific prevention, control, and management plans.

3.2. Standardizing research content

3.2.1. Understanding ecological security issues for red line protection

Effectively protecting ecological red lines requires first identifying and then thoroughly analyzing the various ecological security issues that threaten these areas. The process involves the following steps:

- (a) Identifying ecological security issues: China's vast territory encompasses diverse natural resources and ecological environments, with each region characterized by unique resources (such as water, soil, minerals, and biological assets) and distinct environmental contexts (including topography, climate, soil, and vegetation). Consequently, ecological security issues vary across regions, exhibiting unique and intricate characteristics (Li *et al.*, 2020). Therefore, it is imperative to categorize the types, spatial distribution, extent, developmental trajectory, and temporal-spatial dynamics of these issues. (Reichel, A., and Perey, R. 2018). This categorization process entails diagnosing the targets, scope, and severity of ecological harm, ultimately facilitating a comprehensive understanding of regional ecological risk sources and establishing clear objectives for ecological security maintenance (Wang & Zhang, 2018).

(b) Analyzing specific ecological security issues: Understanding the origin, progression, driving forces, and mitigation mechanisms of particular ecological security issues necessitates detailed examination (Chen *et al.*, 2019). These issues may stem from natural causes, such as geological or meteorological phenomena, or from human activities (Yu *et al.*, 2017). For instance, problems, such as water and soil erosion or land desertification often result from natural conditions, including climate patterns and geological features. Conversely, ecological degradation, pollution, and biodiversity loss are largely due to human activities (Zhang *et al.*, 2016). As the ecological red-line system predominantly targets human behavior, preventive and management strategies should focus on human-caused ecological security challenges (Zhou *et al.*, 2020). Thus, elucidating the causative mechanisms behind specific ecological security issues constitutes a fundamental pre-requisite for implementing effective management and control measures

3.2.2. Reviewing historical context and projecting future directions in regional ecological security governance

To gain insights from past experiences and learn from previous challenges in addressing ecological security issues across regions, it is essential to delve into the origins and evolution of these issues. This historical review entails delineating the historical context of ecological security problems, elucidating associated ecological risks, and aligning these challenges with regional economic and social development trajectories and plans (Li & Wang, 2019). Such an approach enables the effective integration of significant ecological security issues, risks, and developmental trends into the ecological protection red-line system. In addition, gaining profound insights into the historical evolution and current state of human-land conflicts within each region is imperative for anticipating future developmental trajectories. Compiling a comprehensive overview of remedial, preventive, control, and management measures will provide valuable references for future interventions in regional ecological security (Zhang *et al.*, 2021).

3.2.3. Understanding the social-environmental system and its processes

The social-environmental system plays a pivotal role in addressing ecological security concerns by encompassing dynamic processes and interactions between human societies and natural ecosystems. Key challenges – such as habitat destruction, pollution, climate change, and resource depletion – threaten ecosystem stability and sustainability. [Figure 1](#) illustrates the interplay within the social-

environment system, specifically between environmental policy, common property management, and political ecology.

To address these challenges, effective management strategies must integrate social, economic, and environmental dimensions. This integrated management approach involves fostering community engagement, promoting sustainable resource use, implementing conservation measures, and enhancing resilience to environmental risks. Moreover, adaptive governance frameworks that facilitate collaboration among stakeholders and incorporate scientific knowledge are essential for navigating complex ecological security issues. By recognizing the interconnectedness of social and environmental dynamics, policymakers and practitioners can develop holistic approaches that safeguard ecological integrity while addressing societal needs (Bebbington *et al.*, 2019).

3.2.4. Inclusively incorporating social feedback and recommendations

The public plays a pivotal role in both the utilization of regional resources and environmental protection efforts. Recognizing this, the 1992 World Conference on Environment and Development introduced Agenda 21, which emphasizes the importance of enhancing public participation and social acceptance in decision-making processes to safeguard resources and the environment (United Nations, 1992). Similarly, the 2015 enactment of the new Environmental Protection Law emphasizes public participation as a fundamental principle of environmental legislation (State Council of China, 2015). In formulating strategies for ecological governance and preventing security issues within red-line areas, it is imperative to actively solicit opinions and suggestions from local residents and relevant governmental departments, including those responsible for land management, environmental protection, water conservation, agriculture, forestry, and animal husbandry. This approach not only enhances the effectiveness of countermeasures but also bolsters awareness and understanding of the ecological red-line system among local departments and the public, thereby garnering broader social recognition and support.

3.2.5. Formulating evidence-based strategies for ecological security management

As previously discussed, ecological security issues impacting ecological protection red lines exhibit a wide array of complexities and diversities, each governed by distinct developmental mechanisms. These issues may manifest both within and outside designated red-line areas. Merely resorting to generic management and control measures, such as outright prohibitions or restrictions on

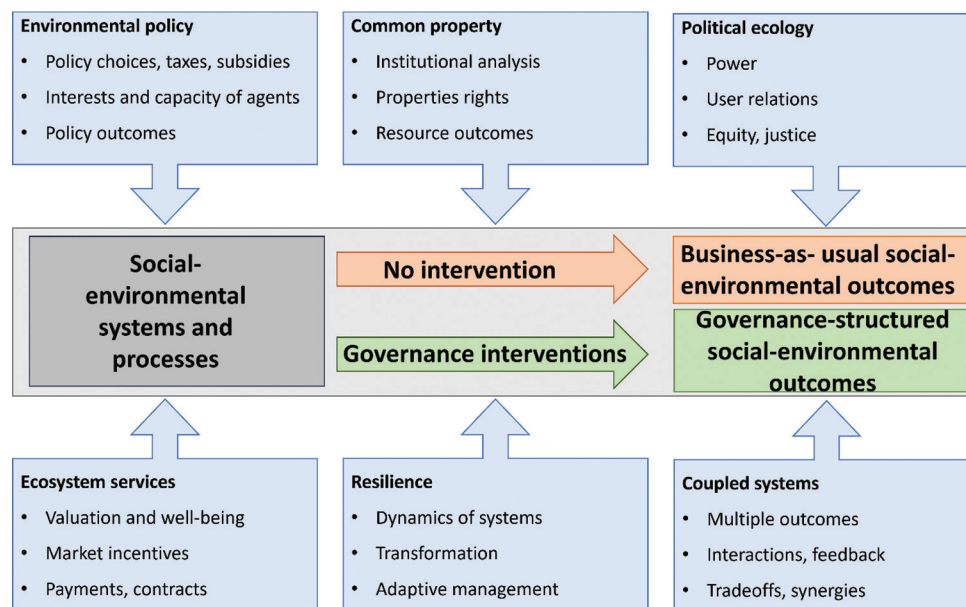


Figure 1. Social-environmental system and processes. Source: Illustration by the author using Draw.io

development and utilization, lacks adequate scientific support (United Nations, 1992). Furthermore, such measures fail to offer viable solutions to intricate ecological security challenges, such as ecological degradation stemming from global climate change or the detrimental effects of external pollution on nature reserves (Li *et al.*, 2019). For instance, pollution resulting from intensive agricultural practices, including the excessive use of chemical fertilizers and pesticides, can significantly degrade downstream habitats, posing a grave threat to endangered species. To effectively address these multifaceted challenges, it is imperative to conduct a systematic and comprehensive analysis of the specific ecological security issues prevalent in each region. Using these insights, we can devise scientifically grounded governance, prevention, and control plans that foster sustainable ecological security management.

3.3. Enhancing the scientific rigor of technical approaches

3.3.1. Ensuring precision in addressing ecological security issues

Efforts must be directed toward precisely delineating the spatial location and scope of ecological security issues to be mitigated. Achieving precision entails visualizing the entire process of identifying, diagnosing, and analyzing ecological security issues to bolster their spatial relevance and targeting specificity. Ambiguities in defining the problems and unclear spatial indications of control targets must be avoided to prevent significant deviations in addressing these issues (Liu *et al.*, 2020).

3.3.2. Integrating multi-scale research techniques

To enhance technical accuracy and improve spatial mapping precision, it is imperative to employ a combination of macro-, meso-, and micro-scale research techniques. Ecological security issues within the region, including their attributes, characteristics, and spatial distribution patterns, result from the complex interplay between natural ecological factors and human socioeconomic activities across various spatial scales (Huang *et al.*, 2018). Leveraging multi-scale research techniques facilitates the acquisition of comprehensive and accurate data, thereby refining research granularity and mitigating precision issues in the on-site delineation of ecological red lines and spatial zoning of ecological security issues (Yan *et al.*, 2019).

3.3.3. Implementing targeted measures for ecological security issues

Addressing the diverse array of ecological security issues impacting the ecological protection red line requires a focused, step-by-step approach. These issues encompass both local and global challenges, each varying in complexity and difficulty to resolve. By adhering to the principle of “easy first, then difficult” and “first local, then global,” tailored countermeasures can be devised in phases. This systematic approach enables continuous exploration, technological refinement, experiential accumulation, cost-effectiveness, and gradual enhancement of ecological protection red-line management and control effectiveness (Wang *et al.*, 2023).

3.3.4. Adopting a dynamic response to ecological protection red lines and security issues

The dynamic nature of natural ecological elements and human socioeconomic activities causes the regional ecological security landscape to evolve continuously. Changes in economic service types, scales, and demands – driven by economic and social developments – necessitate corresponding adjustments. Moreover, the evolving forms of human activities and their impacts on the ecological environment demand a dynamic response. Therefore, it is essential to move beyond fixed ideologies and address ecological issues within ecological protection red-line areas using a dynamic, scientifically grounded, and objective approach that adapts to the ever-changing ecological security landscape (Zhang *et al.*, 2021).

4. Ecological red-line management and control plan from an ecological security perspective

4.1. Technical process and methodology framework

Drawing from the region's natural resources and ecological background – considering factors such as scale, quantity, quality, and spatial patterns – a comprehensive approach is employed. This approach includes departmental interviews, social surveys, expert consultations, and typical sample plot surveys, integrating multi-scale research methods. The goal is to identify the various ecological security challenges confronting the regional ecological protection red line by discerning their types, nature, characteristics, spatial distribution, extent, and patterns. Subsequently, a systematic diagnosis of specific types of significant ecological security issues is conducted. This diagnostic process involves assessing the target of ecological harm, severity levels, and developmental trends, and investigating the underlying mechanisms driving their emergence and evolution. [Figure 2](#) outlines management solutions for ecological red lines, addressing ecological security by assessing ecosystem services, eco-environmental sensitivity, and landscape connectivity.

A clear understanding of the three ecological red-line protection goals – namely, the regional resource utilization bottom line, ecological protection red line, and environmental quality bottom line – guides distinct assessments across different regional areas. This approach facilitates the visualization of spatial information related to ecological security issues and a comprehensive analysis of the spatial distribution and interrelationships among various ecological security challenges jeopardizing the ecological red lines in the region. Across this process, we identify the primary key ecological security issues, drawing insights from

historical experiences and lessons learned. Specific measures are then proposed to address these ecological security issues, along with the formulation of ecological red-line supervision objectives and management and control strategies.

4.2. Analysis of key aspects of technical solutions

4.2.1. Defining concepts pertaining to ecological protection red lines

Scientifically defining relevant concepts and connotations associated with ecological protection red lines is essential to clarify the objectives and significance of their delineation, enabling a rational exploration of technical solutions for effective implementation. The ecological red line is legally established to delineate the upper limit of resource utilization, the bottom line of environmental quality, and designated spaces for ecological protection and restoration, with the goal of ensuring national or regional ecological security. “Ecological security” refers to the state wherein the human economy, society, essential species, and ecosystems within a nation or region develop healthily, stably, and sustainably without facing risks related to resource scarcity, environmental pollution, or ecological degradation.

4.2.2. Defining objectives of ecological red-line protection and risk mitigation

The primary objective of delineating ecological protection red lines is to ensure the security of regional economic, social, and ecological environments. Central to this objective is the preservation of ecological security within areas characterized by high population density, economic concentration, and the presence of critical species and ecosystems. A crucial step in formulating effective measures for preventing, controlling, and safeguarding ecological red lines is identifying sources of ecological hazards and delineating risk mitigation targets. Harm to the regional economy, society, vital species, and ecosystems may stem from natural environmental factors, such as topography, meteorology, and climate, resulting in geological or meteorological disasters such as landslides, floods, and droughts. Alternatively, human activities such as resource exploitation, environmental pollution, and ecological degradation can contribute to these risks. Since ecological protection red lines primarily regulate human activities, they are less effective in mitigating disasters or risks arising from natural environmental factors. Therefore, the primary targets for prevention within ecological red lines should focus on human activities that have caused or may cause ecological risks.

4.2.3. Identifying, diagnosing, and investigating regional ecological security issues

In addressing regional ecological security concerns, it is crucial to first identify, diagnose, and investigate the

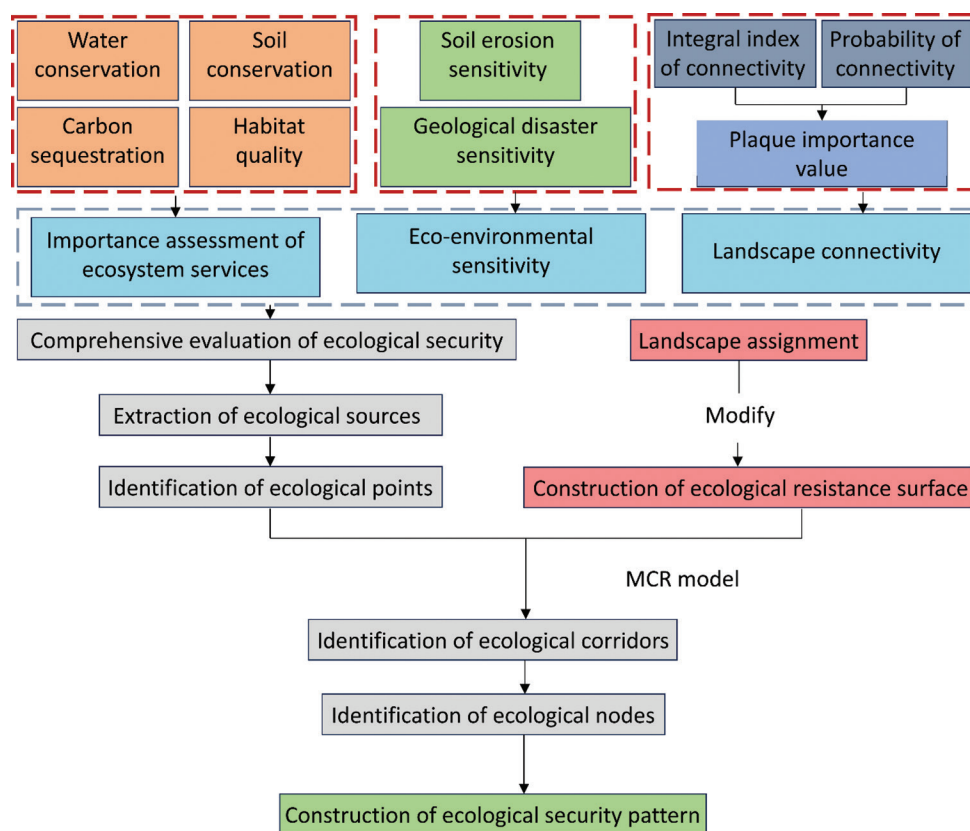


Figure 2. Technical route of management solutions for ecological red lines based on ecological security issues. Source: Illustration by the authors using Draw.io
Abbreviation: MCR: Minimum conservation requirements.

diverse array of ecological security issues present within the area. This investigative process involves comprehensively examining the natural background and socioeconomic development history, current status, and future plans of the region to classify and characterize ecological security problems. These issues may include resource depletion, environmental pollution, and ecological degradation, each presenting unique manifestations and impacts on sustainable development. Furthermore, ecological security issues are categorized based on their temporal occurrence and primary causes, distinguishing between historical legacies, ongoing developments, and potential future occurrences, as well as natural drivers, human disturbances, or a combination of both. Once identified, we must thoroughly diagnose the hazards associated with these ecological security issues by assessing their severity, affected entities, spatial extents, historical trends, and dynamic developments over time and space. This analysis also entails examining spatial relationships among various ecological security issues and their implications for sustainable regional development, with a particular emphasis on types falling within the realm of ecological red-line management and control. In addition,

exploring the underlying mechanisms of these ecological security issues is essential, investigating the resource, environmental, economic, and social factors that drive their development while elucidating their constraining mechanisms. This exploration also entails a systematic and holistic understanding of the interconnectedness of various ecological security issues in the region.

4.2.4. Delineating ecological red-line control types and visualizing spatial mapping

The process of delineating ecological red-line control types and visualizing spatial mapping involves several critical steps to effectively address the diverse ecological security issues that impede regional sustainable development and mitigate future ecological risks. First, the classification of ecological red-line control types is essential, necessitating the identification of major ecological security threats to red lines. These categories – such as pollution damage or habitat fragmentation – are determined through extensive research into the nature and characteristics of regional ecological security issues, ensuring targeted measures are applied to each.

Second, delimiting the spatial location and scope of different ecological red-line control types is crucial, taking into account the spatial attributes of ecological security issues. This spatial delineation process involves understanding the areas where ecological security issues occur and develop, as well as zones where economic, social, and environmental losses are most pronounced or likely to arise. By considering these factors and consulting with local stakeholders and relevant administrative bodies, boundaries for ecological red-line control can be established after thorough, systematic, and scientific deliberation, ensuring effective coverage while minimizing adverse impacts. Given that ecological security issues evolve due to factors, such as global climate change and socioeconomic shifts, it is important to periodically reassess regional environmental problems and adjust limits as necessary. We recommend re-identifying and diagnosing ecological security issues every 5 – 10 years to allow timely adjustments to ecological protection red lines in response to evolving risks.

Finally, we propose an ecological red-line management and control plan tailored to the region's natural resources, environmental backgrounds, and socioeconomic realities. By integrating regional characteristics, historical experiences, domestic and international achievements, and environmental governance technologies, the plan aims to mitigate secondary ecological risks and implement phased solutions. This management plan includes detailed strategies for environmental governance, ecological restoration, risk prevention, and ecological monitoring, ensuring effective management and control of ecological security issues within the delineated red-line areas.

5. Enhancing clarity on human impact

Ecological security is a crucial element of sustainable development, guaranteeing the stability and well-being of ecosystems amid increasing human-caused stressors. Ecological red lines serve as a crucial approach to delineate areas requiring strict protection to preserve ecological equilibrium and biodiversity. This study presents a technical framework for developing ecological red-line management and control plans based on ecological safety principles. The framework uses data-driven methodologies and advanced technical solutions to boost the efficacy of ecological red-line implementations, aiming to protect significant ecological services and functions. Founded on ecological security principles, the framework's primary goals are to mitigate the impacts of climate change on vulnerable ecological areas, conserve ecosystem services that support human well-being, and prevent the deterioration of significant habitats and biodiversity hotspots. Technological developments are essential for managing ecological red lines effectively, using remote

sensing and geographic information systems to monitor environmental and human activity changes in real-time. Big data analytics help forecast potential ecological security risks and analyze environmental data patterns, while decision support systems provide timely and actionable information to decision-makers.

Although this technological framework provides robust solutions for ecological protection, it is critical to further investigate and address the effects of human involvement in important ecological areas. Human activities, such as deforestation, urban expansion, and industrial development, present substantial risks to ecological health, resulting in habitat fragmentation, pollution, and biodiversity loss—factors that undermine the objectives of ecological red lines. To effectively tackle these difficulties, the framework includes zoning regulations and enforcement that clearly define acceptable and unacceptable activities within ecological red lines, supported by strict enforcement measures. In addition, community engagement is encouraged to foster a feeling of ownership and responsibility toward ecological conservation. Economic incentives and alternative livelihood options are also provided, promoting sustainable practices and reducing reliance on activities that harm ecological zones. The technological framework's effectiveness is heavily reliant on robust policy support, reinforced by various policy documents. These policy supports include the National Ecological Red Line Policy, which establishes the legal and regulatory framework for implementing and managing ecological red lines, and the Biodiversity Conservation Action Plan, which provides guidelines for preserving biodiversity and managing human pressures within ecological red lines. In summary, the proposed technological framework for climate change adaptation offers a comprehensive method for ecological red-line management and control by integrating cutting-edge technologies and data-driven strategies. To maintain ecological equilibrium, it is necessary to take into account the consequences of human disturbance. The framework, which incorporates targeted measures to reduce human activities and references key policy documents, offers a robust approach to safeguarding important natural areas. Future research should aim to strengthen ecosystem resilience, enabling ecosystems to better withstand and recover from environmental issues.

6. Practical examples for ecological safety

Providing practical examples is crucial to substantiate the research and showcase its practical relevance in real-world scenarios. For instance, the utilization of remote sensing and geographical information system technologies in ecological red-line monitoring and management can be demonstrated by examining the Yangzi River basin in

China (Wang *et al.*, 2020). In this region, sophisticated satellite imagery and geographic information systems have been employed to identify unauthorized alterations in land use, monitor deforestation rates, and evaluate aquatic habitat conditions. These tools empower local authorities to efficiently enforce zoning restrictions and respond quickly to safeguard crucial habitats. This case study provides concrete proof of the effectiveness of remote sensing and geographic information systems in managing ecological red lines, with data on reduced unauthorized activities and improved ecosystem health. Another concrete example comes from the application of big data analytics in the Amazon rainforest (Dalby, 2016). In this context, big data are employed to analyze extensive environmental data, encompassing deforestation rates, biodiversity indicators, and climatic patterns. This research facilitates the identification of regions at high risk for illegal logging and habitat degradation, enabling targeted enforcement and conservation initiatives. Data demonstrating decreased deforestation rates and increased biodiversity serve as evidence of the effectiveness of big data analytics in addressing ecological security concerns. A further case study involving the Great Barrier Reef's decision support system highlights additional support for this research (Haff, 2014). The integration of real-time data on water quality, coral health, and human activity into decision support systems enhances coral reef management decision-making processes. Evidence of the practical usefulness of these systems can be demonstrated by demonstrating improvements in coral resilience and water quality.

These case studies and real-world data not only validate the effectiveness of the proposed technological methods but also underscore their significance in managing ecological red lines and guaranteeing ecological security. By translating theoretical principles into practical applications, the research enhances its credibility and significance, ultimately contributing to more efficient and sustainable ecological management techniques.

7. Conclusion

Variations in natural habitats and socioeconomic conditions across different regions have posed significant challenges to maintaining the effectiveness and integrity of ecological protection boundaries nationwide. The intricate and diverse nature of ecological security issues further complicates the task of safeguarding these essential natural boundaries. Relying solely on restrictions within designated ecological protection red lines may prove insufficient for ensuring the long-term preservation of these boundaries and the broader ecological security of the region. Therefore, this article advocates for the development and implementation of a comprehensive management and control system for regional ecological

red lines, grounded in a comprehensive understanding of ecological security concerns. Key findings underscore the importance of refining crucial concepts such as ecological red lines and ecological security by focusing on the detrimental impacts of human activities. Highlighting these negative impacts is essential to justify systems designed to mitigate harmful human behaviors that threaten ecological stability. By establishing clear guidelines and enforcing strict regulations, it becomes possible to protect these vulnerable areas from further degradation. In addition, the study emphasizes the necessity of adopting a standardized approach to analyzing and managing regional ecological security issues. This process involves carefully identifying, diagnosing, and evaluating the characteristics, risks, and root causes of ecological challenges, ultimately establishing specific objectives for the prevention and management of ecological red lines. By clearly defining the categories and geographic scope of ecological red-line management and proposing targeted strategies, the study aims to develop effective solutions tailored to address specific ecological security issues across diverse contexts.

Moreover, this research enhances the scientific and practical aspects of ecological red-line management by integrating dynamic development principles and utilizing multi-scale research methods. By setting clear goals for addressing ecological security challenges and assessing the effectiveness of ecological red-line management measures, the proposed approach provides a more robust and adaptive framework for maintaining ecological security. This comprehensive strategy enables a resilient response to evolving challenges, thereby supporting broader goals of ecological safety and sustainable development within the region. Ultimately, this study provides a solid foundation for advancing ecological protection efforts, ensuring that ecological red lines remain a vital tool for safeguarding the natural environment for future generations.

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Conflict of interest

The authors declare they have no competing interests.

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ORIGINAL ARTICLE

A spatial syntactic analysis of temple cultural heritage settlements on the western Sichuan plateau of China

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Abstract

The protection and development of the cultural heritage of temple settlements, the utilization of cultural resources, and the inheritance of settlement characteristics are pressing issues that require urgent attention. To address these challenges, this study employs the spatial syntax research method to delve into the spatial form of the cultural heritage of temple settlements on the western Sichuan plateau. Specifically, the study focuses on four distinct settlement types in Ganzi Tibetan Autonomous Prefecture, China: Baiyu Temple, Ganzi Temple, Dongga Temple, and Gesang Temple. Using Depthmap software, the study quantifies settlement parameter values and analyzes connection value, integration degree, and comprehensibility, to reveal their syntactic structural characteristics. Our findings indicate that these four temple settlements present an organic whole in terms of spatial form. However, there are distinct differences in their syntactic structures, which are closely linked to factors such as settlement scale, historical inheritance, and other contextual influences. Based on our spatial syntax analysis, the study proposes a series of protective measures and development strategies. First, emphasis should be placed on preserving the overall spatial layout and organic integrity of temple settlements to prevent overdevelopment and the disruption of original patterns. Second, planners must strengthen the protection and management of internal spatial elements to maintain their interrelationships. Finally, planners should formulate differentiated protection and development plans tailored to the unique characteristics and values of each temple settlement type. While the study focuses on traditional settlement spatial forms and their relationship with human behavior, further exploration is needed to investigate the impact of political, economic, and environmental factors on these forms.

Keywords: Western Sichuan plateau; Cultural heritage of temple settlement; Space syntax

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1. Introduction

The cultural heritage of temple settlements represents a remarkable cultural achievement, deeply embedded in the landscape of China. Throughout the long history of Chinese

civilization, the settlements of Tibetan Buddhist temples in the western Sichuan plateau have served as convergence points for localized and sinicized human cultural production and life. This heritage is a vital pillar of the diverse and integrated spirit of the Chinese nation.

Temples hold a lofty position in Tibetan society, functioning not only as religious sanctuaries but also as significant economic and political entities. In this light, temples ought to be intricately intertwined with the political and economic dimensions of Tibetan society. Tibetan villages and towns, which embody the social and economic structures of the region, should maintain a close relationship with temples (Li, 2006). However, the Tibetan Buddhist concept of “yin meditation yoga,” which dictates that temples be situated in secluded areas far from populated centers, creates a stark contrast with economic principles. This has led to a complex relationship between Tibetan Buddhist temples and the surrounding villages on the western Sichuan plateau (Duan, 2019).

The protection of cultural heritage is an integral part of cultural resource management and requires sustained, long-term endeavor (Australian ICOMOS, 2013). The exploration of the spatial form of settlements is a prerequisite for safeguarding and developing the cultural heritage of settlements (An, 2023). In this context, safeguarding cultural heritage must be viewed as an organic component of cultural heritage management, necessitating long-term and sustained efforts. The study of spatial form is foundational to ensuring the protection and development of the cultural heritage of settlements.

The primary fields of application for foreign spatial syntax theory encompass the cognition and cognitive processes of settlement spaces, virtual reality, path tracing, and the creation of spatial forms. Since the 1990s, spatial syntax theory has increasingly been integrated into urban and architectural construction projects, including the design of architectural spatial layouts, the planning of urban spatial structures, and the spatial renovation of older urban areas. Notably, European and American countries have led global research efforts in spatial syntax. Hillier B. initiated his research by exploring spatial organization, systematically investigating how human geometric concepts shape urban spatial forms, and in turn, how these forms influence human consciousness. Dara Brams D., on the other hand, applied existing spatial evaluation criteria to investigate spatial memory. His findings indicate that variables such as selectivity and integration within spatial syntax can help elucidate the cognitive experiences of spatial users within a given space. Dara Brams D.’s work further extends spatial syntax theory to the realm of spatial cognition.

Since the 1980s, Chinese scholars have increasingly focused on the spatial forms of traditional villages, gradually expanding the scope of research from spatial structure and typology to influencing factors, evolutionary laws, and spatial cognition. After 2011, there has been an increase in research on the macro morphology of traditional villages. In addition to traditional research methods such as field surveys, questionnaire analysis, and subjective induction, computer technologies such as spatial syntax and geographic information systems have been introduced for quantitative analysis.

The study of spatial form is fundamental to the protection and development planning of traditional villages. Previous research on spatial form largely relied on qualitative descriptions and inductive reasoning. However, these approaches often suffer from subjectivity and randomness, limiting their ability to provide a deep and systematic understanding of spatial form. In contrast, spatial syntax offers a more objective method, enabling the construction of evaluation models that provide visually comprehensible quantitative analyses of spatial forms and structures. These models facilitate rational assessments of past spatial evolution and predictions of future development trends. Given its quantitative strengths, spatial syntax has become widely applied in the research of rural settlement spaces. This body of research provides theoretical support for studying the spatial forms of traditional villages.

Accurately reflecting the spatial organizational structure, social properties, and image cognition remains challenging in relevant research, leaving ample room for innovation in future studies. This article employs spatial syntax theory and methodology, taking into account the unique characteristics of temple–town associations. It examines four distinct settlements in Ganzi Tibetan Autonomous Prefecture on the western Sichuan plateau: Baiyu Temple, Ganzi Temple, Dongga Temple, and Gesang Temple. Utilizing Depthmap software, the article quantifies settlement parameter values, analyzes connection value, integration degree, and comprehensibility, and explores their syntactic structural characteristics. General patterns are summarized, and spatial syntax-based optimization measures are proposed for the spatial form of these settlements, offering valuable insights into the preservation and development of cultural heritage spatial forms in temple settlements.

2. Research area and data sources

2.1. Research area

Located in the western part of Sichuan province, China, Ganzi Tibetan Autonomous Prefecture serves as a significant component of the Qinghai–Tibet plateau,

acting as a secondary platform extending toward the Chengdu plain. The terrain within the prefecture is highly diverse, featuring rugged high mountains and deep valleys. It is characterized by a high elevation in the north and a lower elevation in the south, with a central protrusion. In addition, the terrain rises to the west and descends toward the east. In terms of water systems, the prefecture is traversed by three major tributaries: the Jinsha River, Yalong River, and Dadu River, all running from north to south.

Utilizing data from county, city, township, and village residences, a distance analysis was conducted to examine the spatial relationships between these settlement types and nearby temples. The selected high-correlation distances – 2000 m, 500 m, and 100 m – indicate that within these ranges, temples and urban villages are considered integrated settlements. These temples can be classified into four types: temple-city, temple-town, temple-village, and other temple types (Wang *et al.*, 2021). The study focuses on four representative and influential temple settlements: Baiyu Temple (a temple-city type), Ganzi Temple (a temple-town type), Dongga Temple (a temple-village type), and Gesang Temple (falling under the general temple classification). Through distance analysis, it was determined that these temples exhibit varying degrees of integration with their respective settlement types. Situated in the western Sichuan plateau, these four temple settlements are remarkably well preserved and exhibit rich transitional characteristics. They showcase the cultural wealth, adaptability, and dynamic transition from the inner to the outer areas of the Tibetan Buddhist cultural sphere.

2.2. Data sources

The data used in this study primarily consisted of the spatial distribution of cultural heritage within temple settlements, along with image maps and settlement axis maps. The location and image maps were derived from aerial imagery, while the settlement axis map was manually created in computer-aided design (CAD) software, based on the village image map. Subsequently, this map was imported into Depthmap software for detailed analysis.

It should be noted that due to the limited accuracy of satellite imagery, minor deviations might occur during the creation of branch maps, which potentially result in slight inaccuracies in the research outcomes.

3. Methods

Spatial syntax employs advanced computer technology to quantitatively evaluate space, systematically visualizing and highlighting the structural properties of entire spaces through graphical or numerical representations (Yue,

2020). The most frequently employed analysis techniques include axis analysis, field of view analysis, and convex space analysis. Among these methods, axis analysis and field of view analysis are particularly suitable for analyzing urban and settlement spaces. Furthermore, auxiliary methods such as line segment analysis and the utilization of spatial surrogate robots are frequently utilized to enhance analysis precision and efficiency (Wang, 2021).

This study adopts the axis method, focusing on the analysis of three key parameters:

- (i) Connection value: This parameter represents the total number of connections a node has with other nodes in the system (Liang *et al.*, 2023).
- (ii) Integration degree: Also known as cohesion, this metric measures the extent to which a unit space is aggregated or dispersed relative to other spaces within the system. A higher integration value indicates greater convenience within the system, while a lower value indicates the opposite (Zhou *et al.*, 2023). In global integration analysis, selecting a radius of n allows for the examination of nodes and all nodes within the system, reflecting the relationship between local and global factors (Chen *et al.*, 2023). The calculation method is as shown in Equation I:

$$I = \frac{2(MD - 1)}{n - 2} \quad (I)$$

where n is the total number of axes or nodes in the spatial system, and MD is the average depth. The calculation method for MD is shown in Equation II:

$$MD_i = \sum_{i=1}^n d_{ij} / (n - 1)$$

$$D_n = \frac{2\{n[\log_2 \left(\left(\frac{(n+2)}{3} \right) - 1 \right) + 1]\}}{(n-1)(n-2)} \quad (II)$$

where D_n is part of Equation II and relates to the calculation of average depth.

- (iii) Comprehensibility: This metric reflects the relationship between local space and the overall space. Higher comprehensibility indicates a greater likelihood of understanding the whole through local means, making it easier for users to navigate. Conversely, lower comprehensibility indicates a more challenging spatial understanding (Ye, 2013). By conducting a linear regression analysis of local and overall integration degrees and plotting them on an XY scatter plot, the comprehensibility of the axis system can be measured. This analysis also helps

determine the relationship between local and overall aspects of the village. Based on previous research, comprehensibility can be roughly categorized into four levels: high ($0.7 \leq R^2$), average ($0.4 \leq R^2 < 0.7$), low ($0.2 \leq R^2 < 0.4$), and extremely low ($R^2 < 0.2$) (Hegazi *et al.*, 2022). The calculation method is as shown in Equation III.

$$R^2 = \frac{[\sum(I_{(3)} - I'_{(3)})(I_{(n)} - I'_{(n)})]}{\sum(I_{(3)} - I'_{(3)})^2 \sum(I_{(n)} - I'_{(n)})^2} \quad (III)$$

Where $I_{(3)}$ is the local integration value when the number of steps $n = 3$, $I'_{(3)}$ is the average integration degree for three steps, $I_{(n)}$ is the global integration value, and $I'_{(n)}$ is the average global integration degree.

For this study, Depthmap software was employed as the key tool for spatial syntax analysis. This software is renowned for its comprehensive analysis methods and consistent performance, making it the preferred choice for spatial syntax analysis. Its suitability for meso to microscale applications makes it ideal for this particular analysis. In addition, CAD was used for creating the necessary drawings.

4. Spatial morphology analysis based on spatial syntax

4.1. Baiyu temple

As shown in Figures 1-3, Baiyu Temple is located on Baiyu Mountain, in the southwest of Baiyu County, Ganzi Tibetan Autonomous Prefecture, Sichuan province, China. It is one of the three largest Ningma-style temples in the Kangzang region. The temple settlement covers an extensive area of approximately 114.53 ha.

4.1.1. Connection value

The average spatial connectivity value in the study area is 2.46753. As illustrated in Figure 4, Axis 1 exhibits the

highest connection value, indicating a strong connection with the village, significant spatial permeability, and a close spatial relationship. Axis 1, along with several directly connected axes, forms the core of the Baiyu Temple settlement, extending from south to north in a distinct linear pattern. Axes 2, 3, 4, and 5 also exhibit high connection values, indicating strong spatial permeability and close spatial connections to the village. The village road network features numerous irregular streets and alleys, resulting in complex and diverse connections with poor spatial permeability. This area is less accessible to outsiders due to the high density of residential buildings, contributing to its relative seclusion.

4.1.2. Integration degree

The global integration degree signifies the extent of interconnection between an axis and other axes, thereby reflecting the ease of access to a specific space. A higher global integration degree correlates with enhanced spatial accessibility within the region. Utilizing Depthmap software, we generated a global integration axis map (depicted in Figure 5). On this map, the intensity of the axis colors corresponds to the degree of spatial integration: red, orange, and yellow hues denote core areas with high global integration. These highly integrated axes are predominantly aligned with the main roads parallel to the river and key nodes, exhibiting pronounced linear characteristics that underscore the pivotal role of the village's public spaces in shaping the overall spatial configuration.

As illustrated in Figure 5, the central sections of the street and alley network within the Baiyu Temple settlement exhibit a slight reddish tint, while the axis colors gradually transition to blue as they radiate outward from the river. This gradient illustrates a diminishing integration degree, most notably in the village's peripheral areas, where the integration is lowest. The Baiyu Temple settlement boasts an average global integration degree of 0.58, with 70.1% of the axes exceeding this value. This statistic attests to the

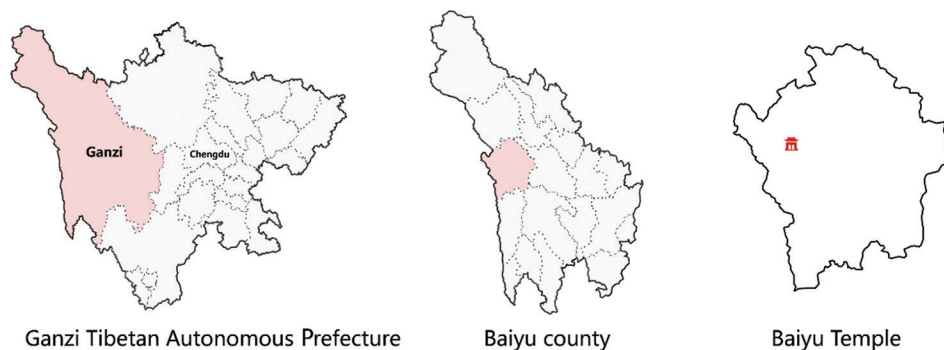


Figure 1. Baiyu Temple location map. Source: Drawing by the author

settlement's high overall integration and commendable spatial accessibility.

Nestled within the surrounding mountains, the Baiyu Temple settlement's main public edifices are strategically positioned along its main road. This layout fosters strong connectivity between the village and the outside world, culminating in a high degree of overall integration and excellent transportation accessibility. Nevertheless, the temples located in the northern part of the settlement are relatively distant from external transportation routes.

4.1.3. Comprehensibility

The comprehensibility of a village's spatial structure reflects the alignment between its overall layout and local spaces. A higher comprehensibility signifies a spatial configuration that is easier to understand in its entirety, whereas a lower comprehensibility indicates the opposite.

To assess this relationship, two datasets were selected from the Depthmap software: the global integration degree and the local integration degree. A linear regression analysis

was conducted between these two datasets. As shown in Figure 6, the XY scatter plot visualizes the comprehensibility of the axis system, with the X-axis representing global

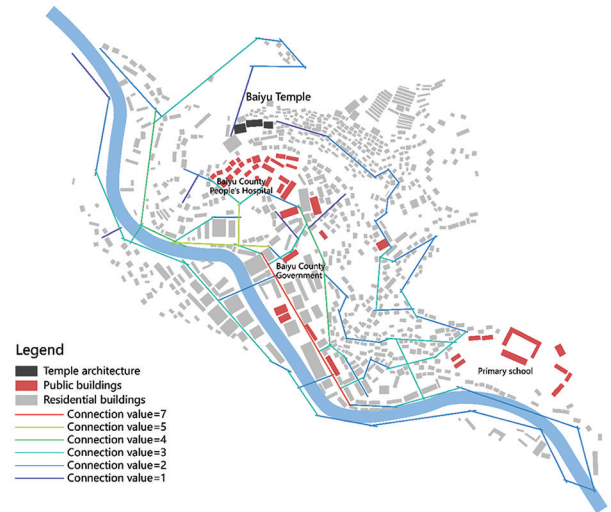


Figure 4. Baiyu settlement connection value and settlement status superposition map. Source: Drawing by the author



Figure 2. Baiyu settlements satellite image. Source: Big Map (2023)



Figure 3. Baiyu settlement. Source: The Internet (<https://www.zangdiyu.com/article/detail/id/3865.html>; 2015)

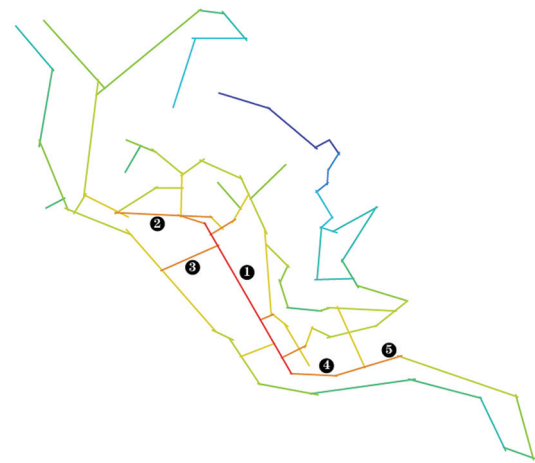


Figure 5. Baiyu settlement integration map. The numbers 1 – 5 represent Axes 1 – 5. Source: Drawing by the author

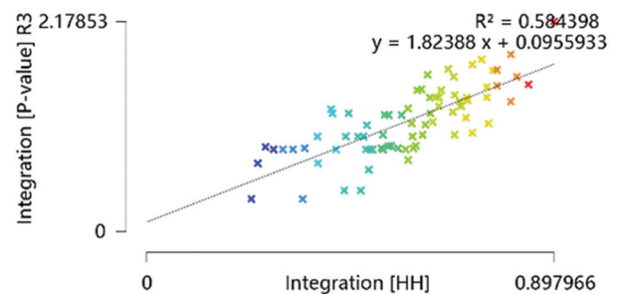


Figure 6. Baiyu settlement comprehensibility map

integration and the Y-axis representing local integration. The R^2 value, which represents comprehensibility, ranges from 0 to 1. The red dot in the upper right corner represents the axis with the highest comprehensibility, while the blue dot in the lower left corner represents the axis with relatively lower comprehensibility.

For the Baiyu Temple settlement, the correlation between global and local integration is moderate, as indicated by the fitting coefficient. The comprehensibility value of 0.58 places the settlement in the “average” category, indicating that the street and alley system in the Baiyu Temple settlement has an average level of comprehensibility.

4.2. Ganzi temple

As shown in Figures 7-9, Ganzi Temple is located on a herringbone-shaped mountain slope in the northern part of Ganzi County, Ganzi Tibetan Autonomous Prefecture, Sichuan Province, China, facing north to south. The temple is built along the mountain and represents a typical Tibetan-Han architectural combination. It belongs to the Gelug school, and the settlement area covers approximately 116.7 ha.

4.2.1. Connection value

The average spatial connectivity value in the study area is 2.93703. As depicted in Figure 10, the road network structure within the settlement is relatively simple. In the overall spatial structure, Axis 1 has the highest connection value, indicating a closer connection between Axis 1 and the village, with the strongest spatial permeability and the closest spatial connection. Axes 2 and 3 run through the settlement from north to south, also exhibiting a strong connection and high spatial permeability.

4.2.2. Integration degree

Figure 11 shows that the central area of the Ganzi Temple settlement’s street and alley system is slightly red, while the axis colors gradually shift to blue as they extend from the river to the periphery. This color gradient reflects a

decrease in the integration degree, especially in the village’s edge areas, where integration is at its lowest. The average global integration degree of Ganzi Temple settlement is 1.34, with axes exceeding this value accounting for 0.52% of the total. This suggests that the overall integration degree of the Ganzi Temple settlement is moderate, with generally good accessibility. Ganzi Temple settlement is located near Ganzi town, benefitting from strong external connections and good transportation accessibility. The main public buildings are located in the central area, where integration is highest.

4.2.3. Comprehensibility

As shown in Figure 12, the comprehensibility value of the Ganzi Temple settlement, based on the global and local integration degree, is 0.94. This indicates a high comprehensibility of the street and alley system in the Ganzi Temple settlement.

4.3. Dongga temple

Dongga temple is one of the temples that inherit the White Jade tradition of the Nyingma sect of Tibetan Buddhism. As depicted in Figures 13-15, it is located on Dongga Mountain in Jinma grassland, Seda County, Ganzi Tibetan Autonomous Prefecture, Sichuan Province, China. Dongga Temple is a large and influential Gelugpa temple in East Asia, with significant historical importance in modern times. The temple houses cultural relics from the late Qing dynasty (1644 – 1912), such as sun-dried Buddha thangkas, and its mural carving art is recognized for its unique ornamental and research value. The settlement area covers approximately 82.81 ha.

4.3.1. Connection value

The average spatial connectivity value in the study area is 2.36364. As shown in Figure 16, the road network structure within the settlement is relatively simple and linear. Axis 1 has the highest connection value, indicating the closest spatial connection within the settlement. The

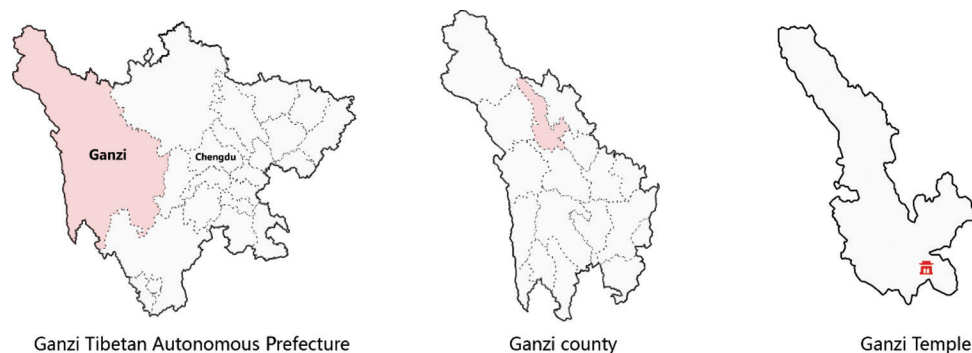


Figure 7. Ganzi temple location map. Source: Drawing by the author



Figure 8. Ganzi settlement satellite image. Source: Big Map (2023)



Figure 9. Ganzi settlement. Source: The Internet (<https://baike.baidu.com/item/%E7%94%98%E5%AD%9C%E5%AF%BA/5423111>; 2023)

axes surrounding the temple are strongly connected to the settlement, exhibiting high spatial permeability.

4.3.2. Integration degree

As illustrated in Figure 17, the central area of the Dongga Temple settlement's street and alley system shows a slight reddish tint, with the edges of the settlement gradually transitioning to blue. This gradient indicates a gradual decrease in the integration degree, with the lowest values observed in the peripheral areas. The average global integration degree of Dongga Temple settlement is 0.57, with axes exceeding this value accounting for 0.50% of the total. This indicates that the overall integration degree of Dongga Temple settlement is average.

4.3.3. Comprehensibility

As shown in Figure 18, the comprehensibility value of the Dongga Temple settlement, based on the global and

local integration degrees, is 0.38. This indicates a low comprehensibility of the street and alley system in the Dongga Temple settlement.

4.4. Gesang Temple

As shown in Figures 19 and 20, Gesang Temple is located in Yulaci township, Xinlong County, Ganzi Tibetan Autonomous Prefecture, Sichuan Province, China. It is a Tibetan Buddhist temple of the Sakya sect, with a settlement area of approximately 5.65 ha, making it relatively small in scale. Due to its simple spatial structure, the syntactic parameters of this settlement are limited.

4.4.1. Connection value

The average spatial connectivity of the study area is 1.3333. As shown in Figure 21, the settlement's spatial structure relies primarily on a single road running from south to north, resulting in limited spatial permeability.

4.4.2. Integration degree

As illustrated in Figure 22, the average global integration degree of the Gesang Temple settlement is 0.21.

5. Analysis and discussion of temple settlements

By thoroughly comparing and analyzing the spatial forms of various temple settlement types, we can gain a deeper understanding of their complex and diverse characteristics, as well as their commonalities. This enables a clearer comprehension of the settlement's overall spatial organization.

When examining the axis diagrams of the four settlements previously mentioned, it becomes evident that their spatial structures consist of a small number of long axes and a large number of short axes. The geometric characteristics of axis composition exhibit two notable trends. First, the longer axes are typically aligned along the main roads of the settlement. These roads tend to be straight, although with slight deviations, preventing a clear view of the road's end from another end of the settlement. This arrangement results in axes consisting of intersecting lines with large obtuse angles, generally extending in the same direction. Second, when two axes intersect, it rarely forms a crossroad; rather, T-shaped intersections are more common. This results in a somewhat discontinuous axis system and a fragmented layout for local spatial organization. The highly connected axes connect the temples and public buildings within the settlement, forming a relatively continuous tourist route. Settlements with higher connection values demonstrate better spatial connectivity and greater overall integrity.

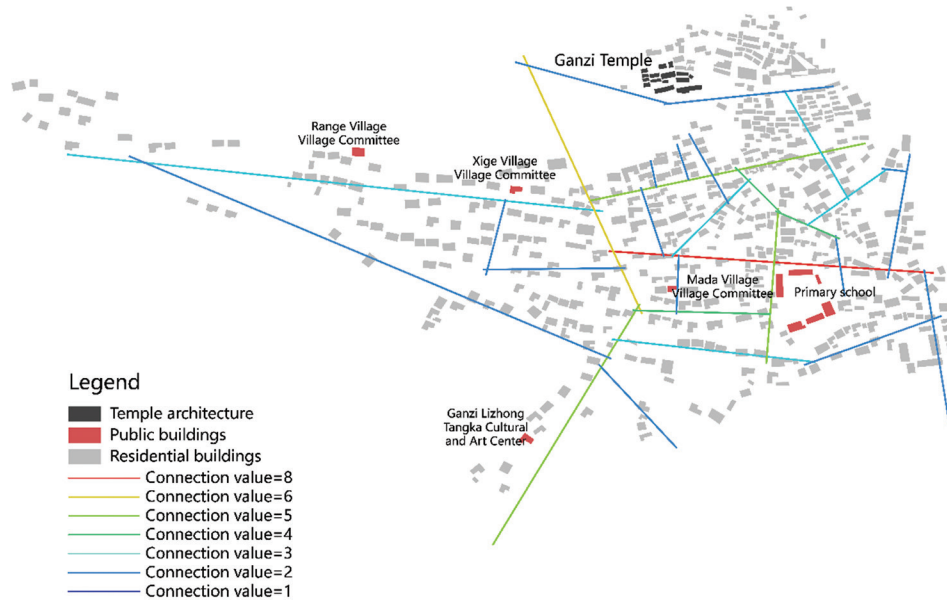


Figure 10. Ganzi settlement connection value and settlement status superposition map. Source: Drawing by the author

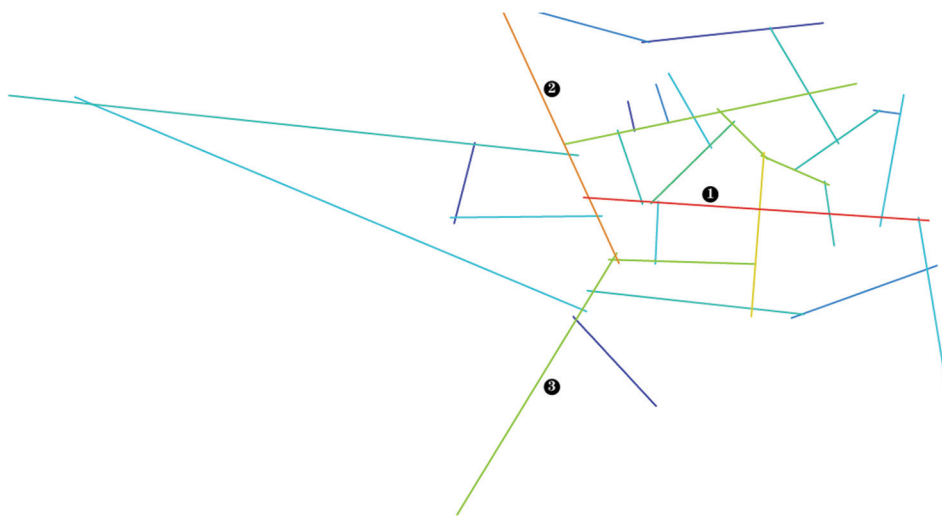


Figure 11. Ganzi settlement integration map. The numbers 1 – 3 represent Axes 1 – 3. Source: Drawing by the author

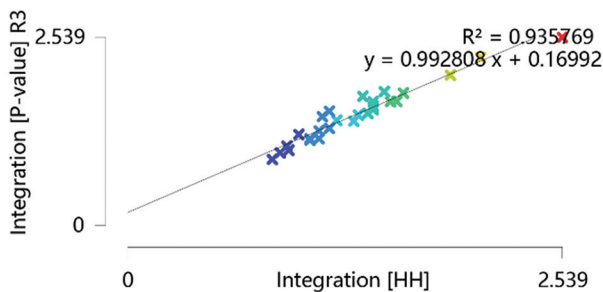


Figure 12. Ganzi settlement comprehensibility map

As shown in Table 1, a comparison of the spatial syntactic parameters of each settlement’s spatial form reveals that these four settlements vary significantly in shape, size, and number of axes. The highest number of axes is 77, while the lowest is just 3. The highly connected axes link temples and public buildings within the settlement, forming continuous tourist routes. The color of the connection value indicates that as the color becomes redder, the road hierarchy increases. Most of these roads are the main thoroughfares within the settlement, similar to those in other villages. The larger the connection values in these settlements, the

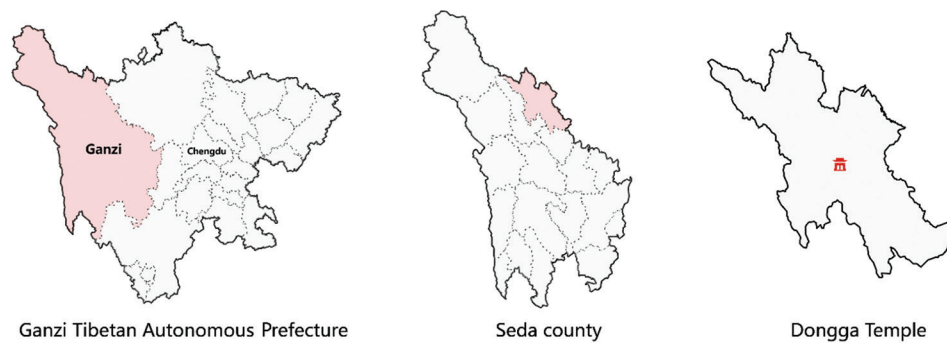


Figure 13. Dongga temple location map. Source: Drawing by the author



Figure 14. Dongga settlement satellite image. Source: Big Map (2023)



Figure 15. Dongga settlement. Source: The Internet (<https://baike.baidu.com/item/%E4%B8%9C%E5%98%8E%E5%AF%BA/3802147>; 2023)

stronger the connectivity between their spatial forms and the overall integrity of the settlement. These findings align with previous research results (Chen *et al.*, 2018).

The key to understanding space in spatial syntax lies in the structural relationships within space and the relationship between space and society (Chen, 2011). Space is not merely the inherent background of human activities; it is an intrinsic attribute of those activities. Actions such as encountering, interacting, gathering, avoiding, negotiating, teaching, living, and dining do not

just occur in space – they actively shape spatial patterns. By conceptualizing space this way, we can create more human-centered spatial structures and gain a deeper understanding of the complex relationships between space and society (Chen *et al.*, 2009). Most public service facilities within the settlement are concentrated in areas of high integration. As settlements evolve, the distribution of these public facilities in the settlement’s integrated core often surpasses that of temple buildings, enhancing accessibility and their connection to daily village life. The settlement is structured around this integrated core, which extends outward, evolving into a continuous and multifaceted space. Therefore, the integrated core portion of the settlement represents the area with the highest centrality in terms of spatial syntax (Chen *et al.*, 2018).

However, some public buildings are situated in areas with lower overall integration within the settlement, such as the Wanxiao of the Baiyu Temple settlement. These more secluded areas have reduced accessibility. Low-integration areas are primarily the residential quarters of villagers and, due to limited accessibility, are generally more peaceful. This gradual transition from high to low integration reflects the spatial evolution of settlement from public to private realms and from outward- to inward-oriented spaces. This finding is consistent with previous studies on spatial syntax (Chen *et al.*, 2018) and is closely related to the long-standing practices of the Tibetan people, who have built houses and villages on mountains for centuries to adapt to the natural environment.

Spatial syntax theory suggests that areas with high integration are more frequently used and populated, making them easier for individuals to remember and form spatial imagery (Xu, 2015). However, there exists a deviation between cognitive imagery and the integration degree of certain spatial nodes. For instance, the Baiyu Temple settlement, despite having a low connection value and integration degree around the temple, serves as a landmark within the settlement due to its historical significance. As

Table 1. Parameters of the temple settlements

Temple	Settlement type	Area (ha)	Number of axes	The connection value	Integration	Comprehensibility
Baiyu temple	Temple-city	154.44	77	2.46753	0.58	0.58
Ganzi temple	Temple-town	135.24	29	2.93103	1.34	0.94
Dongga temple	Temple-village	130.26	22	2.36364	0.57	0.38
Gesang temple	Temple	3.233	3	1.33333	0.21	-

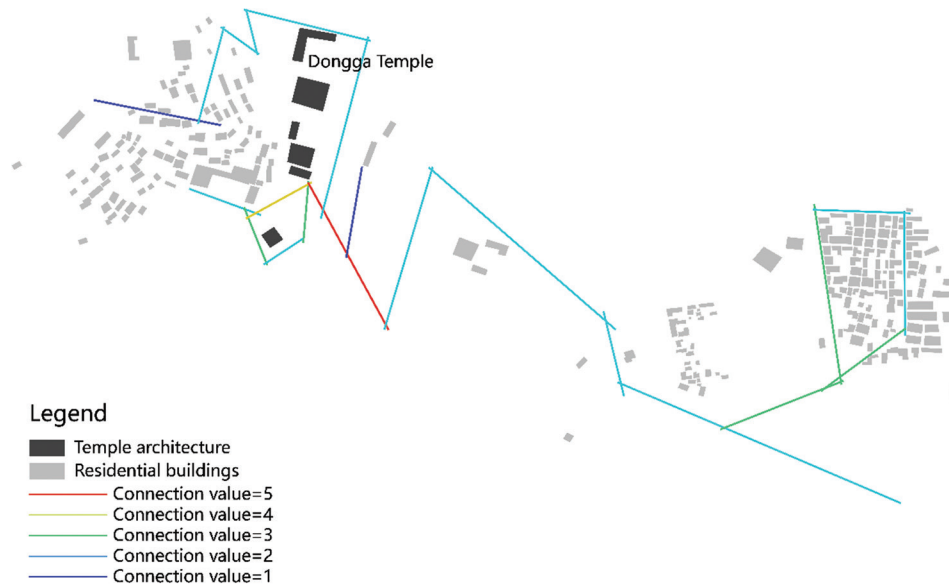


Figure 16. Dongga settlement connection value and settlement status superposition map. Source: Drawing by the author

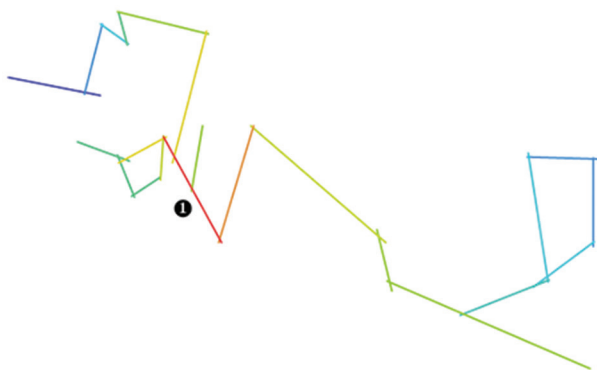


Figure 17. Dongga settlement integration map. The number 1 represents Axes 1. Source: Drawing by the author

a result, local residents have a strong recognition of the temple, and it frequently hosts community activities.

According to comprehensibility values, a lower R^2 fitting degree indicates poorer comprehensibility of the settlement's spatial system (Mairufujiang *et al.*, 2023). These low comprehensibility values indicate that the perception of local space in Dongga Temple

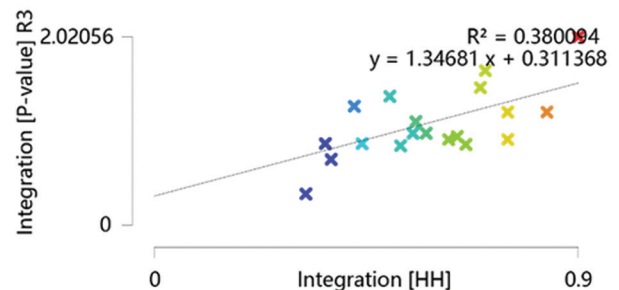


Figure 18. Dongga settlement comprehensibility map

and Gesang Temple settlements is limited. Foreign tourists, in particular, may struggle to comprehend the village's structure, leading to a weaker perception of its overall spatial characteristics. This, in turn, affects their impression and understanding of the village's overall space (Qi *et al.*, 2020). In addition, the irregular connection forms and angles of internal roads within the village contribute to low comprehensibility, impeding tourists' intuitive understanding of the spatial layout. The settlement's extended construction timeline has also led to damage in some street and alley systems, resulting in

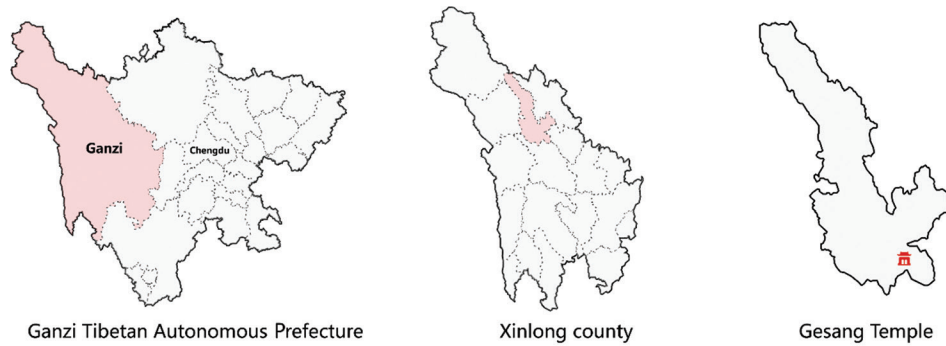


Figure 19. Gesang temple location map. Source: Drawing by the author



Figure 20. Gesang settlement satellite image. Source: Big Map (2023)

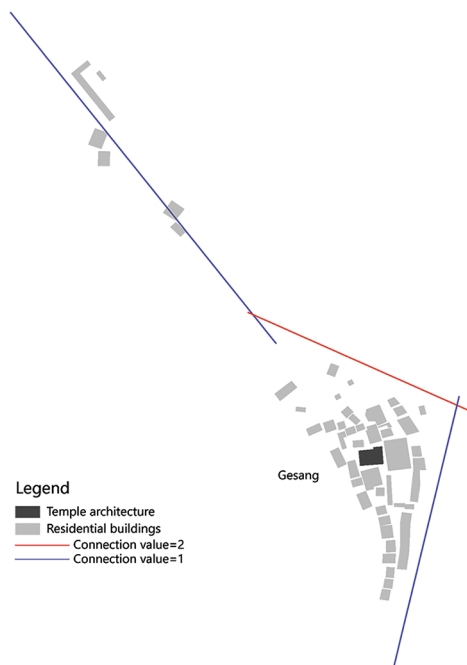


Figure 21. Gesang temple settlement connection value diagram. Source: Drawing by the author

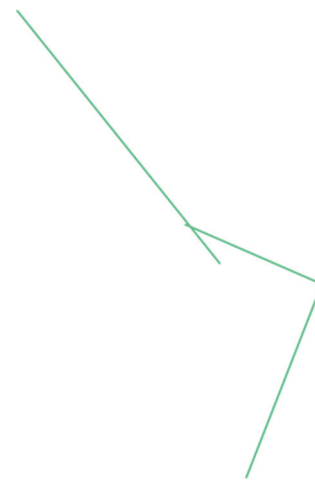


Figure 22. Gesang settlement integration map. Source: Drawing by the author

an incomplete spatial structure. This is a significant factor affecting spatial comprehensibility.

6. Conclusion

6.1. Protection strategy

The cultural heritage of temple settlements is a priceless asset of Chinese civilization, embodying rich historical, cultural, and geographical significance in their spatial configuration. Through in-depth exploration utilizing spatial syntax analysis, this study examines the spatial structural characteristics of temple settlements in the western Sichuan plateau. The study offers several key insights into the preservation of these settlements.

To safeguard the cultural heritage of temple settlements, it is imperative to uphold their spatial patterns, maintain the continuity of the overall spatial form, and preserve the historical context of the temples.

First, safeguarding the street and alley layout is crucial. A highly connected settlement space promotes internal

and external interaction and communication. Therefore, it is essential to preserve and enhance the road network, particularly the main connecting roads. Retaining roads with high integration degrees and improving traffic flow is essential, while dead-end roads in the village should be reorganized and optimized. Dilapidated streets and alleys should be repaired to create comfortable spaces while maintaining the traditional street and alley patterns. Enhancing the accessibility and usability of streets and alleys will ensure that both residents and tourists can easily enter and navigate the settlement.

Second, temple settlements are repositories of rich historical resources. In addition to numerous buildings or structures that are cultural relics, they are also home to a wealth of traditional culture. However, due to natural factors, economic constraints, or people's lack of awareness, the protection of these villages and their buildings has been inadequate, affecting the inheritance of intangible culture. The protection and revitalization of temple and monastery spaces should be integrated with the cultural context, maintaining traditional social and cultural order, meeting villagers' living needs, enhancing their quality of life, and satisfying tourists' experiences. This approach will help drive the protection and development of the village.

Finally, the protection of settlements requires comprehensive consideration of cultural, historical, and environmental factors. The temple settlements in the western Sichuan plateau carry deep religious beliefs and historical legacies, while also being influenced by the natural environment. To ensure the integrity and sustainability of this cultural heritage, a balance must be struck between these diverse factors during protection and development efforts.

In summary, settlement protection is a complex yet vital task that necessitates a thorough consideration of multiple factors. Through spatial syntax analysis, we can better understand the spatial characteristics of these settlements and provide robust support for their preservation and sustainable development. In future efforts to protect settlements, further research should be pursued to develop more specific protection measures that will ensure the long-term preservation and inheritance of cultural heritage.

Despite this study's comprehensive exploration of spatial syntax theory and its innovative application to traditional settlement spatial morphology, several shortcomings remain and warrant further exploration.

6.2. Innovation

Compared with traditional research methods, spatial syntax offers the advantages of objectivity, scientific rigor, and quantification. This study introduces spatial syntax to the analysis of the spatial morphology of temple

settlements in the western Sichuan plateau. By utilizing data and graphical representations, it explores the relationship between the inherent characteristics of space and its social attributes from a more scientific and accurate perspective. Compared to traditional methods, spatial syntax exhibits certain superiorities and complements qualitative research, offering a more comprehensive understanding.

6.3. Limitations and prospects

The present study focuses on traditional settlement spatial forms and the relationship between spatial configurations and human behavior. However, further exploration is needed to understand the impact of political, economic, and natural factors on these forms, as additional theoretical grounding is necessary.

It is important to acknowledge that research on spatial syntax in traditional villages is still in its infancy, with the primary emphasis placed on spatial relationships. However, this approach has inherent limitations as a standalone research method. In addition, due to software constraints, the line segment model often relies on manual drawings, which can introduce potential errors when dealing with large sample sizes. These discrepancies may significantly affect the accuracy and reliability of research outcomes.

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Conflict of interest

The author declares he/she has no competing interests.

Author contributions

Conceptualization: All authors

Investigation: All authors

Writing - original draft: All authors

Writing - review & editing: All authors.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

The datasets generated and analyzed during the current study are available upon reasonable request.

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ORIGINAL ARTICLE

The emerging middle ground: A case study of vernacular Hakka settlements in the peri-urban areas of southern China through an architectural heritage analysis

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Abstract

Rapid urban expansion is transforming rural areas globally, prompting scholars to challenge the traditional urban-rural dichotomy and focus on transitional zones such as the rural-urban fringe and peri-urban areas. This article documents the evolution of architectural morphology in traditional Hakka settlements in peri-urban areas of southern China and coins the hybrid architectural landscape combined with urban and rural characteristics in these ambiguous territories as the “Middle Ground.” Fieldwork was conducted in four Hakka villages in Heyuan, northeast Guangdong, China, between 2021 and 2023. An explorative case study was employed to analyze the architectural morphology of the Middle Ground by mapping village fabric, dwellings, and street markets through aerial photography. A participatory perspective was also incorporated, involving observation, interviews, and documentation of the daily life of local villagers. This research examines how authority and mobility have shaped the Middle Ground, potentially leading to a state of “placelessness,” and explores the role of rural heritage in this context. This research contributes to the broader discourse on peri-urban areas by offering an architectural heritage atlas as an addition to existing research.

Keywords: Middle Ground; Hakka culture; Architectural heritage; Chinese village; Peri-urban condition

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1. Introduction

Rural areas around the world are undergoing dramatic transformations, a global phenomenon driven by rapid urban expansion and development (Bolchover *et al.*, 2016; Koolhaas, 2020; McCarthy, 2008). Increasingly, scholars and academics are challenging the conventional urban-rural dichotomy and conducting extensive research on transitional areas, such as the rural-urban fringe, exurban development, peri-urban areas, suburban sprawl, and subtopia (Brueckner, 2000; Bryant *et al.*, 1982; Marsden, 2006; Mcgee, 1991; Nairn, 1959; Pryor, 1968). This body of research illustrates that, economic structures, transportation networks, labor migration, and land use, have all contributed to the mixed characteristics of urban and rural identities. Until 2023, China's urbanization rate has reached a remarkable 66.16% (National Bureau of Statistics, 2024). However, vast areas of amalgamated territories still exist between China's ever-expanding urban centers

and geographically remote villages, which are becoming a new form of settlement for humanity in China (Guldin, 1996). Unlike the suburban areas in Western countries, various vernacular houses and settlements with historical traditions and distinctive cultures are distributed within Chinese peri-urban areas. Driven by rapid urbanization and the demand for a modern lifestyle, increasing numbers of generic concrete-framed houses are being constructed arbitrarily. Vernacular buildings and modern concrete framed houses are blending and reshaping the Chinese countryside nowadays. In this context, this article attempts to document this hybrid architectural landscape in the areas between metropolises and geographically remote villages, coining it as the “Middle Ground,” a peripheral urban condition distinctive to China.

Due to favorable geographic location and policies, the Middle Ground in southern China, specifically Guangdong province, has emerged intensively with rapid urbanization driven by substantial economic growth over the past decades (Liu, 2010; Zhou, 2020). Architecture and its surroundings, as significant cultural assets, are profoundly influenced by specific cultures and contexts in terms of building forms, ideologies, and techniques (Emmons *et al.*, 2012; Rapoport, 1969). Compared to metropolises or rural villages, the Middle Ground experiences contested influences from modernity and tradition, which inevitably enhance the complexity of its architectural landscape and formation mechanisms. Consequently, by taking the Hakka settlements in Heyuan, Guangdong province, China, as a case study, this article documents the morphological landscape with hybrid rural and urban characteristics observed in the peri-urban area. As the various influencing factors are too complicated to provide exact answers, the research objective is to discuss the future development of the Middle Ground based on the research findings and explore the role of rural heritage for further research.

2. Theoretical framework of the Middle Ground

2.1. The blurring urban-rural territory

As urbanization progresses, various disciplines, including urban planning, social sciences, anthropology, and geography, have shown growing interest in the peripheries of Western metropolises (Liu, 2010). Research on the rural-urban fringe can be traced back to 1942, when Wehrwein (1942) initially proposed that the “rural-urban fringe” was a transitional zone between urban land uses and agricultural areas. Through case studies of American cities, he has elaborated that public transportation and residential expansion contributed to the development of this fringe area. In 1968, Pryor (1968) revised the definition

of the “rural-urban fringe” by incorporating the theory of urban invasion. In his opinion, “rural-urban fringe” was not simply an intermediate zone or a continuum between rural and urban areas, but a collective term for the “urban fringe” and “rural fringe,” characterized by its distinctive location, internal heterogeneity, and transitional nature (Pryor, 1968). He emphasized that the “rural-urban fringe” emerged as agricultural acreage diminished and rural populations declined, largely due to expanding urban areas and growing urban populations. Subsequently, an increasing number of scholars focused on this area of research. Russwurm and colleagues have proposed a new urban spatial model, subdividing the “rural-urban fringe” – also known as the “urban fringe” – into the “inner fringe” and “outer fringe.” In this model, the “rural-urban fringe” was characterized by various indicators, including property structure, land use, agricultural structure, and social and community structure (Bryant *et al.*, 1982). While their research has provided a valuable theoretical framework for understanding the transition between urban and rural areas, it is, to some extent, limited by its focus on urbanization models within the Western paradigm.

Responding to the unique urbanization phenomenon in Asian countries, McGee (1991) has described the emergence of a new territory widely distributed across peri-urban and rural areas as “Desakota,”¹ an interim area that combines characteristics of both rural (*desa*) and urban (*kota*). Similar to research on Western countries, the Desakota concept also strongly relied on well-developed transportation infrastructure. What is unique about Desakota regions, however, is their frequent occurrence in wet-rice agricultural areas, which provide seasonal labor and agricultural products to nearby metropolises, such as the Pearl River Delta and the Yangzi River Delta in China. Desakota regions are highly integrated, “transactive” environments, characterized by migration and commodity exchange. Compared to Desakota regions in other Asian countries, Chinese Desakotas are shaped not only by large-scale rural-to-urban migration but also more significantly, by urbanization in place, specifically through the process of townization² (Guldin, 2001; Zhou, 2020). From the early

¹ Desakota: Aiming to challenge the Western discourse paradigm, McGee (1991) coined the Indonesian term Desakota, which combines *desa* (village) and *kota* (town).

² Townization: This term refers to the transformation of Chinese villages, which increasingly resemble small towns in terms of lifestyle and socioeconomic transformation. Source: Guldin, G. E. (2004). Townizing China. *Urban Anthropology and Studies of Cultural Systems and World Economic Development*, 33(2/4), 139–165.

concept of the “rural-urban fringe” in Western countries to the “Desakota” in Asian contexts, existing research consistently identifies diverse factors influencing peri-urban areas, including economic conditions, labor flow, and transportation. While some scholars have explored architectural transformations in urban villages that mix rural and urban characteristics (Gao *et al.*, 2022; Wang *et al.*, 2009), urban villages represent a specific village morphology within cities. However, for those villages located in ambiguous areas between metropolises and remote villages, how the architectural landscape has been transformed and reshaped still requires further discussion.

2.2. Vernacular versus modern architecture

In the early 20th century, cultural geography began studying and mapping the style and form of everyday or vernacular architecture in North America (Brown & Maudlin, 2012; Sauer, 1925). This initial research viewed architectural form, construction, and style as expressions of a “way of life,” reflecting the technological development and cultural values of a society (Goss, 1988). Influenced by this perspective, pioneering architectural scholars such as Amos Rapoport and Paul Oliver explored the production and evolution of vernacular architecture, integrating it with cultural practices and social rituals (Jackson, 1996; Knapp, 1986; Oliver, 2006; Rapoport, 1969; Rapoport, 2003). Their works have had profound impact on subsequent research into vernacular architecture. As a result, the majority of traditional vernacular architecture research has focused on the cultural significance of architecture constructed by specific identity groups, frequently and geographically defined (Ding & Xiao, 2022; Liu *et al.*, 2019; Oranratmanee, 2020; Zhang *et al.*, 2023). An emerging trend in this field examines how human emotions and cultural identity are expressed or reinforced through architecture and urban spaces, particularly in traditional architecture (Chen, 2011; Chen & Romice, 2009; Semprebon *et al.*, 2020). However, much of this research tends to view traditional architecture as static, neglecting its dynamic context, particularly in transforming peri-urban areas.

Extensive research has criticized the homogenization caused by global modernization and urbanization, which threatens the distinctiveness of various places (King, 2004). This dichotomy between modernization and tradition extends to urban and rural areas, but these characteristics are often complexly and paradoxically integrated rather than distinctly separated (Lutz & Shakhs, 1982; Wu *et al.*, 2010). This intertwining of modernization and tradition creates a new tension that shapes the architectural landscape. To better comprehend the contrasts between vernacular and modern architecture, it is helpful to examine the societies they belong. Vernacular architecture is typically governed

by informal controls, affectivity, and consensus, whereas modern architecture emphasizes impersonality and independent specialization (Breese, 1966). This contrast aligns with the transformation described in Weber’s (2013) theory of domination – from traditional domination based on customs and long-standing practices to legal-rational domination tied to legal authorities, laws, and regulations. In this context, modern architectural landscapes, designed through rational planning and often lacking a sense of place, are described as “placeless geography,” including subtopias and individual features unrelated to their cultural or physical setting (Relph, 1976). To some extent, Relph’s concept explains the architectural landscape of peri-urban areas in Western countries, but the hybrid architectural landscape constructed by the coexistence of traditional and modern buildings in other Asian countries, like China, requires further discussion. Although the meaning of “placeless geography” involves cultural and personal experiences, it also depends on people’s perceptions and feelings about architecture (Kraftl, 2010). As Lees (2001, p. 56) noted, it is important to “...explore the way the built environment is shaped and given meaning through the active and embodied practices by which it is produced, appropriated, and inhabited...” Understanding what people do within architectural spaces significantly contributes to a deeper comprehension of the architectural landscape (Llewellyn, 2003).

2.3. The emerging Middle Ground in China

Over the past few decades, the Middle Ground has prominently emerged in Chinese peri-urban areas, particularly in southern China. Unlike Western urbanization patterns, Chinese urbanization is driven by townization, also referred to as urbanization in place or *in-situ* urbanization (Guldin, 2001; Zhou, 2020). Specifically, “deagriculturization” is occurring in Chinese countryside, where more and more people are abandoning agriculture but continue to live in the villages. Many of these people work in town factories and enterprises, contributing to widespread townization and reducing the differences between different places (Guldin, 1996). According to Guldin, if the Middle Ground is identified according to China’s official urban hierarchy, it encompasses *ji* (集), *xiang* (乡), *zhen* (镇), county (县), and county-level city (县级市), as shown in Figure 1.

The Chinese Middle Ground is shifting toward urbanization, engulfing the vernacular landscape of the local context (Costa & Batista, 2011), including spatial settlement fabric, building forms, and public facilities. In the past, Chinese rural settlements consisted of clustered houses in nucleated settlements or individual homes dispersed among farming fields (Knapp, 1986). The spatial fabric was

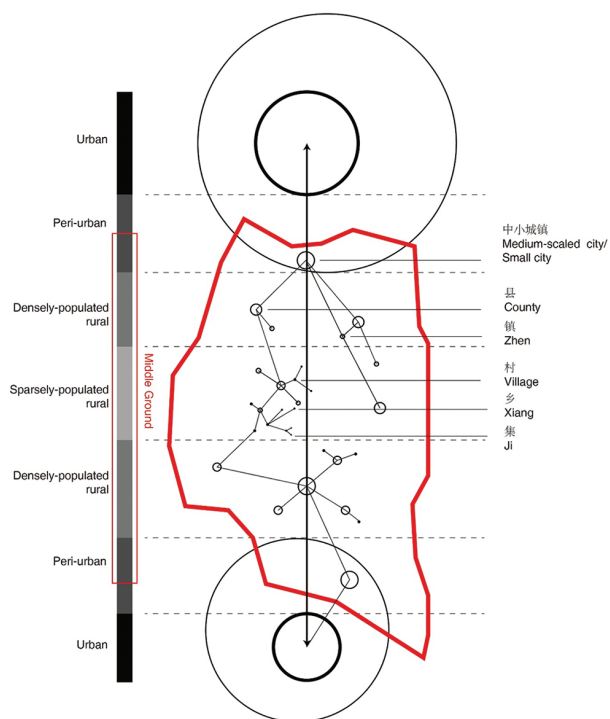


Figure 1. The middle ground in Chinese official urban hierarchy. Source: Drawing by the authors

strictly organized according to specific cultural practices and social rituals. Among these settlements, markets played an essential role as the adhesive of the agricultural social organization, combining the myriad peasant communities into the broader social system (Skinner, 2001). However, the transformation of traditional agricultural production has led to the conversion of these rural settlements, once rooted in the local social environment, into peri-urban areas reliant on spatial mobility. This shift has introduced more modern housing affected by urbanization, accelerating the vanishing of local rural culture. Nowadays, buildings with both rural and urban characteristics coexist in the Middle Ground, although it should be noted that urban influences are gradually overtaking rural ones – an inevitable trend. Consequently, the model of the Chinese Middle Ground is proposed in Figure 2.

The boom in rural house building occurred between 1985 and 1995 in China, transforming building materials and forms from vernacular to modern characteristics (Figure 3). In 1985, building materials were still predominantly local, such as brick and timber, but since 1996, these materials have been replaced by reinforced concrete. Modern materials quickly became dominant in rural buildings, particularly after the 2000s. Nowadays, common housing typologies, typically 2- or 3-story concrete-framed houses, have come to dominate the

streets or settlements resulting from the intrusion of industrialization and the “concrete revolution” that has spread throughout the country (Figure 4). Falling under the top-down regime led by city governments, traditional rural settlements and their indigenous cultures are being devastated at an unprecedented rate (Tao & Wang, 2014). For local inhabitants, houses built with new materials and in ornate Western styles not only satisfy their demand for a modern lifestyle but also serve as symbols of wealth and status. Simultaneously, the government has encouraged the construction of new houses, which creates the prosperous illusions of rural development. These uniform, featureless buildings, driven by both the inhabitants’ aspirations and government policies, may lead the Middle Ground to ultimately become a place where “the richly varied places of the world are rapidly being obliterated under a meaningless pattern of buildings, monotonous, and chaotic” (Lyndon *et al.*, 1962, P.33-34).

3. Methods

3.1. Study area: Hakka settlements in northeast Guangdong

This article focuses on the Hakka settlements in Zhongxin, Dahu, and Xiuduan towns within Lianping county, Heyuan, located in northeastern Guangdong province, southern China (Figure 5). Northeastern Guangdong is adjacent to the Pearl River Delta, which has become a global manufacturing hub due to its advantageous geographic location and favorable policies. Since the economic reforms began in 1979, rapid economic growth has led to significant urbanization, widening the urban-rural divide as the flow of products, capital, and labor intensified (Zhou, 2020). As the Pearl River Delta has upgraded and transformed its industrial structure, its peripheral peri-urban and rural hinterlands have converted into suppliers of affordable labor and agricultural products for metropolises such as Guangzhou and Shenzhen. Concurrently, increasing factories have relocated to these areas to reduce land costs. This evolving urban-rural relationship has triggered a fundamental structural transformation of Guangdong’s countryside.

Between the 16th and 17th centuries, a large number of Han Chinese from the north migrated to southern China to escape war and famine. Known as the Hakka, meaning “guest family” in Chinese, this ethnic Han group primarily settled in the border areas of Guangdong, Fujian, and Jiangxi provinces. Today, it is estimated that approximately 32 million Hakka people live in these regions (Erbaugh, 1996). Northern Guangdong is a major Hakka settlement area and the location of the Yue Gan Trade Route, which historically connected Guangdong and Jiangxi provinces. More than 20,000 traditional Hakka villages, often built

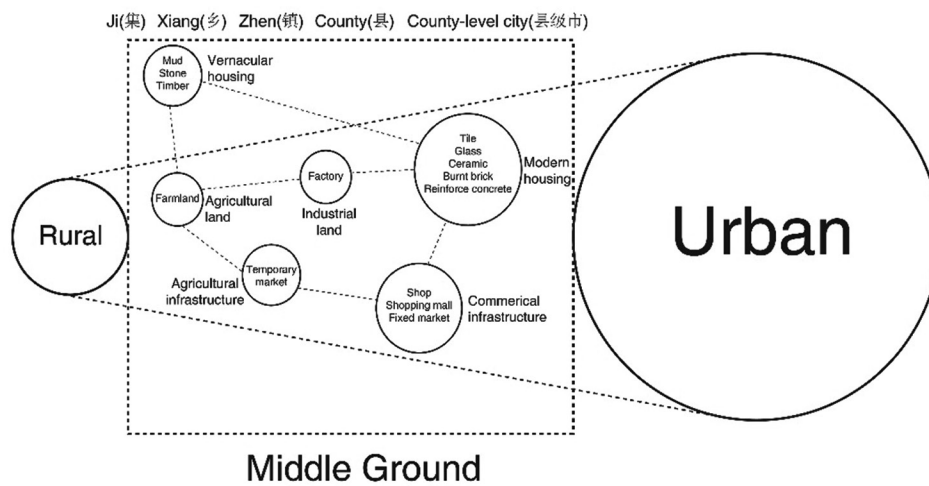


Figure 2. The model of Chinese middle ground. Source: Drawing by the authors

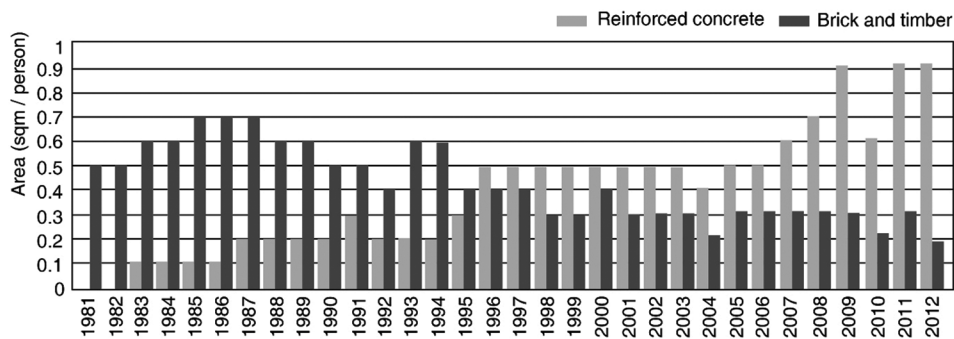


Figure 3. The per capita structural area of new rural housing at the end of the year (1982 – 2012). Source: Adapted from Lu & Jiang (2021)



Figure 4. Street landscape in the middle ground of the peripheral Pearl River Delta. Source: Photo by the authors (2018)

as *Wei Long Wu* (围龙屋, meaning “Rounded Dragon House”), were constructed in this area, shaping the rural landscape of modern Guangdong. These traditional villages were structured according to ancient *Fengshui* principles and based on clear social organization rooted in kinship and clan culture. This bond between family hierarchy and village morphology remains alive today, continuing to

define the identity of the minority Hakka people within a majority Han region (Katayama, 2011).

This article focuses on four historically representative Hakka villages in Lianping: He Xin Wu, Bai Yun Lou, Cha Hu Er, and Da Hu Zhai. Unlike typical mountainous Hakka settlements, these villages are situated in basin areas surrounded by mountains, locally referred to as Zhongxin Little Plain. Settlements are significantly influenced by their environments (Tao *et al.*, 2017). According to local chorography, the advantageous geography around the study villages has historically supported local agriculture, particularly paddy cultivation (Lianping County Chorography Compilation Committee, 1985). This self-sufficient agricultural system has been deeply intertwined with Hakka culture (Lin, 1995), and its transformation has also reshaped contemporary Hakka society.

3.2. Research methodology

In line with the research objective, fieldwork for this study was conducted in the Hakka settlements between

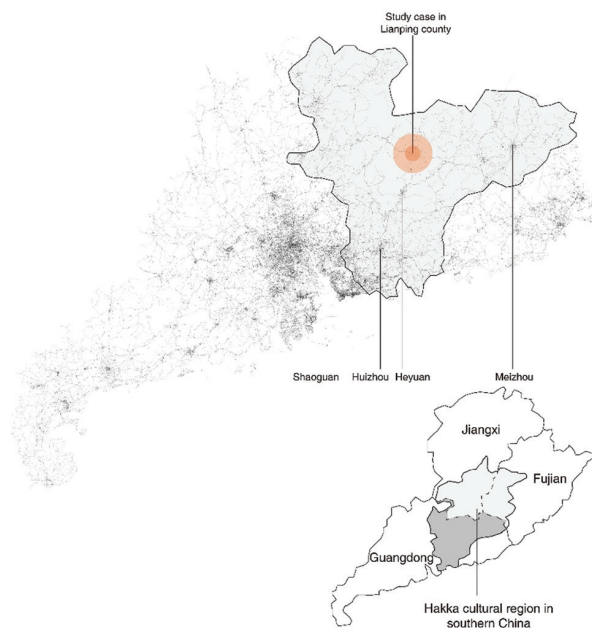


Figure 5. Geographic location of the study area. Source: Drawing by the authors

2021 and 2023 in an exploratory manner. Although diachronic studies effectively contribute to morphological research from a temporal perspective (Moudon, 1994; van Oostrum, 2018), the Hakka settlements examined in this research have been undergoing transformations since before the availability of satellite imagery, but related historical documentation is limited. This research, therefore, adopted a synchronic approach, using a comparison of streets, plots, and buildings – common units in urban morphology research. In this research, the three units are contextualized as settlement fabric, dwellings, and street markets, and these are embedded within a case study.

Following Yin's (2018) recommended data sources for case studies, this research employed documentation, interviews, and participant observation to collect evidence during the fieldwork. Specifically, on-site drawings, measurements, and photographs were used to document the condition of the study area. To gain a deeper understanding of the local context and encourage villagers to share their life experiences, six open-ended interviews were conducted with four interviewees during the participant observation period. These interviewees included a village committee leader, who served as the key informant, and three local villagers as typical informants. Although the number of interviewees was limited, each had lived in the villages for over 40 years and was actively involved in community affairs. Instead of relying on a large number of interviews, the study focused on intensive, in-depth conversations

with this small group, providing a more insightful and detailed understanding of local conditions. The interviews investigated the historical information of the Hakka settlements, their infrastructure networks, the sociocultural factors that have influenced changes in architectural forms, and how these factors have shaped the present settlement morphology. Participant observation was also conducted with the typical informant to document specific family dwellings and inhabitant activities as an elaborated example. This participant observation was carried out over a 2-week period in June 2021.

4. Findings

4.1. Rural features of traditional Hakka settlements

Family structure and kinship are crucial sociocultural factors closely associated with house forms (Rapoport, 1969), particularly within clan-centered societies like the Hakka. The clan society, which developed as a consequence of the paddy economy (Freedman, 2021), has led Hakka people to prefer living in clan clusters. Large, collective Hakka settlements were designed to benefit the entire clan. In this context, the Hakka settlement is not merely a village but also an independent collective housing arrangement that integrates housing units with ancestor halls, reflecting the strong clan-centered community (Figure 6). These Hakka rural architectures belong to a vernacular typology known as *Wei Long Wu*, a type of walled Hakka village. In the *Wei Long Wu*, the ancestor hall is central to village life, serving not only for ritual activities but also as a venue for weddings, funerals, and other daily social interactions. Therefore, it becomes a sacred and communal space within the clan family. Simultaneously, *Fengshui* principles play a significant role in site selection and spatial organization, such as *Fu Yin Bao Yan* (负阴抱阳) (Katayama, 2011; Lin, 1995; Wu, 2018).

A traditional Hakka settlement is characterized by its nucleated cluster, based on its original self-sufficient model. For instance, He Xin Wu is the second-largest Hakka village in the area, with a history of 300 years. In 1679, the He family migrated from Meizhou and initially settled in Jin Zhu Yuan, 1 km from present-day He Xin Wu. As the He family grew, they relocated and built a new fortified village, the present He Xin Wu, in 1724, following *Fengshui* principles. He Xin Wu is a typical *Wei Long Wu*, which begins with the ancestral hall at the center, radiating outward with a series of “rows” (each row consists of identical dwelling units arranged in a circular plan), expanding across the entire settlement. Local villagers explained that He Xin Wu initially had only two rows, which later expanded to five rows as the population grew and eventually developed into nine rows. However, the












Village	Plan	Aerial photo	Internal
Da Hu Zhai			
He Xin Wu			
Cha Hu Er			
Bai Yun Lou			

Figure 6. Traditional Hakka settlements in the case study in northeast Guangdong. Source: Photos by the authors (2021)

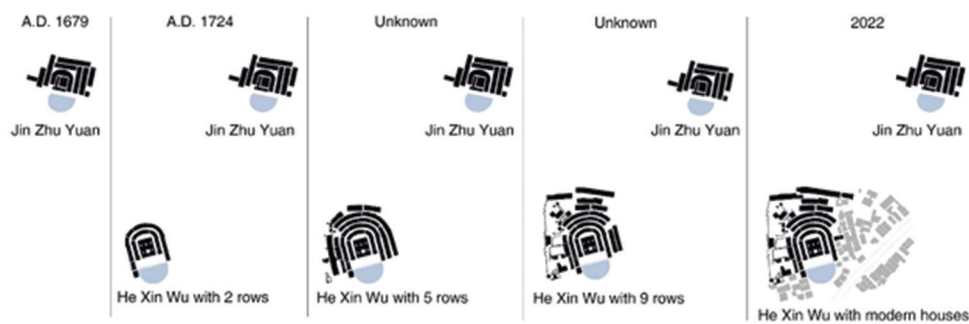


Figure 7. The evolution of He Xin Wu's fabric over different periods. Source: Drawing by the authors

traditional morphology of the Hakka settlement has been altered by these extended dwellings (Figure 7).

Figure 8 illustrates the typical dwelling units and different functional spaces in He Xin Wu. As the fundamental spatial unit of *Wei Long Wu*, each identical dwelling unit is narrow and deep, consisting of a ground

floor with an open-plan living space and a mezzanine floor for storing food or firewood. This design not only maximizes the use of vertical space but also maintains the integrity and privacy of each nuclear family within the broader clan structure. Living rooms, kitchens, bathrooms, and other living spaces are distributed across different dwelling units, shared by multiple families. The integration

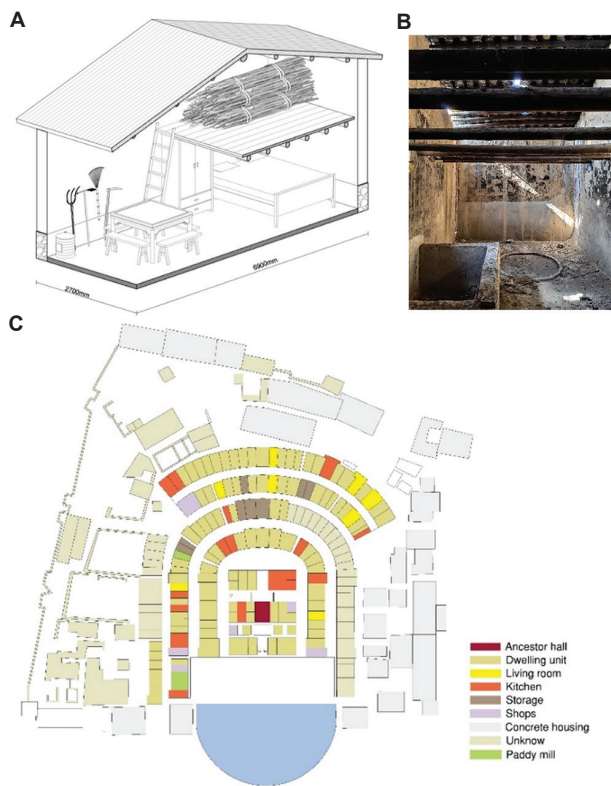


Figure 8. Housing cluster in He Xin Wu. (A) Diagram of a typical dwelling unit. (B) Interior of the dwelling unit. (C) Function distribution in He Xin Wu. Source: Drawings and photo by the authors (2021)

of private and communal spaces for individual families and the whole clan reflects the intention to create a collective living milieu forged in a distinctive characteristic of Hakka settlements. These dwelling units were constructed using local materials, including rammed earth and mud brick for the walls, timber for the structure, and stone and pebbles for foundations and exterior paving. However, these traditional materials and construction techniques are gradually being replaced by modern industrial materials, such as steel, concrete, and glass.

In the study area, traditional markets serve as the social and economic adhesive for these Hakka villages, not only continuing their role in product exchange but also shaping the local social, spatial, and economic systems. Skinner (2001) classified markets in China into three categories: standard market, intermediate market, and central market, with most rural markets falling into the first two categories. This hierarchical system facilitated the upward flow of rural products to higher-level markets and the downward flow of imported items destined for peasant consumption.

According to Skinner's classification, the periodic and permanent markets in the study area can be categorized

as standard and intermediate markets, respectively. Hakka traditional periodic markets still operate on short-term temporal cycles according to the Chinese lunar calendar, alternating with adjacent permanent markets in the studied Hakka villages (Figures 9 and 10). From the author's field notes:

In the morning, the periodic market is extremely bustling. Stalls line both sides of the street, mostly selling local agricultural products grown by their owners, along with living livestock, and homemade Hakka foods such as tofu and rice wine. Some stalls also offer a variety of affordable groceries, clothes, and farm tools. The stall owners and customers are predominantly middle-aged and elderly. The market is a lively symphony of sounds: the clucking of chickens and quacking of ducks, the hum of motorbikes, and the animated haggling between customers and stall owners in the Hakka dialect. Those stall owners with good business, having sold most of their goods, are almost ready to pack up and go home. Instead of operating every day, these markets cycle on different dates as the following:

Zhongxin Town in 3 - 6 - 9 (including 3rd, 6th, and 9th days of the lunar cycle)

Dahu Town in 2 - 5 - 8 (including 2nd, 5th, and 8th days of the lunar cycle)

Xiuduan Town in 1 - 4 - 7 (including 1st, 4th, and 7th days of the lunar cycle).

These periodic markets exemplify the preservation and continuity of local traditions, particularly through the sale of local agricultural products and homemade foods. They serve not only as economic hubs supporting local economies and the exchange of agricultural products but also as social spaces where community members, particularly the middle-aged and elderly, interact and maintain social bonds. In addition, the regular schedules, based on a set of empirical "canons," enable villagers to efficiently combine sales with production and reduce the distance customers must travel to access necessary products and services.

4.2. Toward an in-place urbanism with dual characteristics

Since the 1990s, villages like He Xin Wu have experienced depopulation, as the majority of inhabitants have moved into newly constructed concrete housing in the surrounding area. The partly abandoned *Wei Long Wu* has now become the core of the village, tightly surrounded by scattered houses that have expanded into the hinterland of farmland. In an interview with the head of the He Xin Wu village committee, it was revealed that

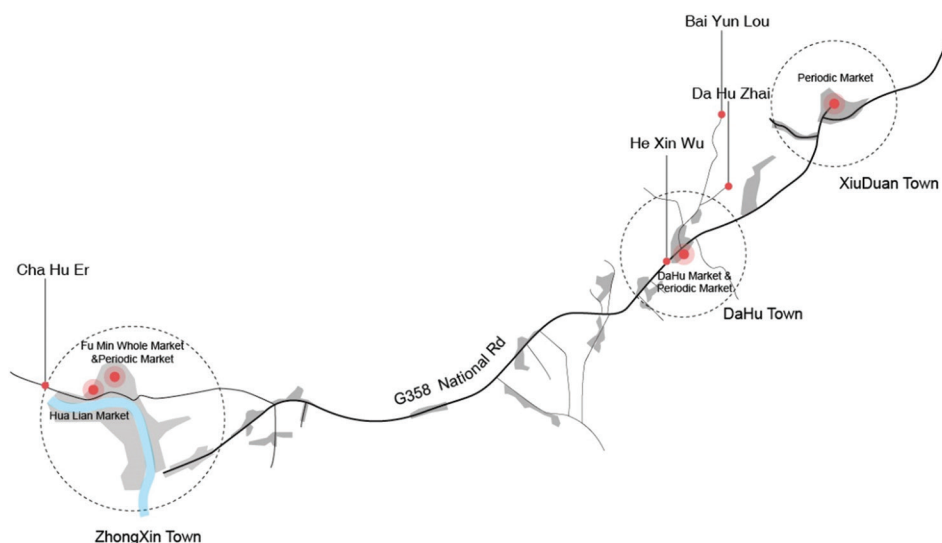


Figure 9. Distribution of periodic and permanent markets. Source: Drawing by the authors

most villagers still view the old village as their spiritual home and ancestral root:

We cannot forget our ancestors, who are our roots. Even though we no longer live in the old village, we continue to hold traditional rituals in the ancestral hall on important occasions such as weddings, funerals, baby's one-month celebrations, and traditional festivals like Qingming, Mid-Autumn Festival, and Chinese New Year. However, the younger generation does not seem to care about these anymore. (interview with He Zhipei in He Xin Wu, June 2021)

By continuing these rituals, the local villagers maintain a sense of identity and coherence. The ancestor hall has become a symbolic and physical space where Hakka cultural practices are enacted, reinforcing its importance as a communal hub. However, there is a noticeable tension between the displacement caused by modernization (moving away from the old village) and the older generation's desire for cultural continuity. Despite the younger generation's lack of interest, these old villages continue to function as communal spaces where villagers gather after dinner and children play.

With the development of the G358 National Highway, villages along the road, such as He Xin Wu and Cha Hu Er, are transforming into new linear settlements (Figure 11) and becoming part of the highway economy (Wang & Xu, 2012). These narrow settlements stretch along the highways, connecting previously independent nucleated clusters. Typically, a single row of houses flanks each side of the road, allowing villagers direct access to their farmland behind these buildings. The ground floor of these houses



Figure 10. Photo of periodic markets. (A) Periodic Market in Dahu Town. (B) Periodic Market in Zhongxin Town. Source: Photos by the authors (2021)

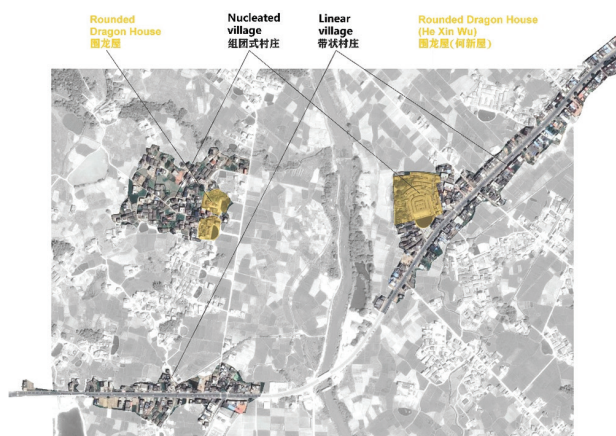


Figure 11. The spatial configuration in the Middle Ground of the peripheral Pearl River Delta. Source: Drawing by the authors

is frequently used for commercial purposes, catering to passing vehicles and drivers by operating family-run restaurants or providing truck maintenance and washing services. This new settlement type, as a by-product of urbanization and industrialization, is challenging the

predominance of nucleated villages and highlighting the closer relationship between urban and rural areas.

It is common to see these new, typically 2- or 3-story concrete detached houses representing modern, fashionable lifestyles dominating the area along the national highway (Figure 12). A household observed on-site in the outskirts of He Xin Wu illustrates how economic activities and house forms have been influenced by the highway. The homeowner, He Deyou, originally lived in He Xin Wu but was compelled to resettle due to the deterioration of the rammed earth buildings 30 years ago. He subsequently constructed two new houses (Figure 13).

At present, he operates a food shop and works as an agent assisting farmers with processing and packaging paddies for sale to city dealers. He and his wife also cultivate paddy and vegetables on their 700 sqm plow, with the majority of the harvest consumed by their family.

He Deyou's first house was built between 1993 and 1995, serving as the current residence for his family at a cost of approximately ¥120,000 RMB. Located adjacent to the G358 National Highway, between Zhongxin and Dahu towns, the ground floor operates as a deli. The 1st floor is the living space for He, his wife, and his mother, while the 2nd floor accommodates their children, who work in



Figure 12. The generic dwellings in the Middle Ground of the peripheral Pearl River Delta. Source: Photos by the authors (2021)

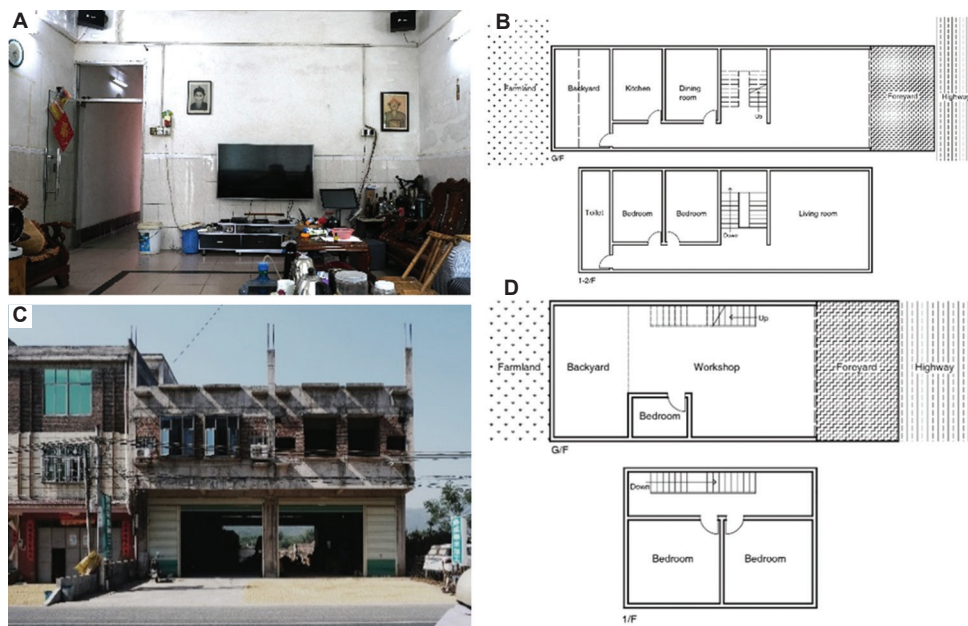


Figure 13. Case study of new concrete dwellings in the Middle Ground of the peripheral Pearl River Delta. (A) Photo of Case 1 housing. (B) Plan of Case 1. (C) Photo of Case 2 housing. (D) Plan of Case 2. Source: Drawing and photos by the authors (2018)

Shenzhen. Each floor is equipped with its own living room and bathroom, allowing different generations to live individually without interference. From the author's field notes:

"When I arrived at He Deyou's first house, he was selling Hakka salted food to a trucker, while his wife was preparing forage to feed chickens in the backyard. He Deyou proudly mentioned that his salted food was popular among truckers transporting goods along the National Highway. Every time they passed by, they would stop to buy from his shop. Sometimes, his customers even order through WeChat, and he delivers his food across the country by express."

More and more Hakka people, like He Deyou, are exploring various opportunities to increase income, such as processing agricultural products and selling Hakka food to other cities. These diverse income sources have reduced the Hakka people's dependence on the clan and facilitated a shift toward household division. This household division has led to a demand for more independent and private living spaces. As a result, many Hakka people have abandoned their collective housing and moved into new detached dwellings. Despite this shift, paddy cultivation remains an important source of income, and traditional agricultural activities continue to affect how local people utilize their space. Specifically, grain sunning, processing, and feeding livestock are still common in these new concrete dwellings and are frequently considered significant functions when building a new dwelling. The foreyard on the ground floor is often used as a parking lot or for sunning grains. Consequently, the architectural landscape in the Middle Ground is increasingly characterized by scattered, fragmentary individual buildings, as opposed to the cohesive, collective traditional Hakka settlements. Yet, the traditional agricultural lifestyle persists within these modern houses. During an interview, He Youde explained that he built his second house with government support:

"In 2012, the village committee informed us that we could receive a ¥20,000 RMB housing allowance from the government if we built a new house. Although the new house must obey the government's planning and regulations, it was a great opportunity for me to provide a house for each of my sons. I applied for the allowance to cover the structural construction, but have not been able to afford the façade and interior decorations yet. Hence, the house is temporarily used as a paddy-processing workshop and storage. Once I earn enough money, the project will continue (interview with He Youde in his first house, June 2021)."

The case of He Deyou's second house representatively demonstrates how new concrete housing in the Middle Ground is influenced primarily by the financial capacity of the inhabitants and support from the local government. In this area, construction periods are often uncertain, depending on the owner's ability to accumulate savings and secure loans (as He Youde noted: "continuing to build the houses once I have enough money"). As a result, one characteristic feature of housing in the Middle Ground is that buildings tend to develop dynamically over time, rather than being completed all at once. Simultaneously, these new houses might exhibit some homogeneity due to strict regulations and master plans, such as limits on the number of stories, building area, and even the façade design (must obey the government's planning and regulations).

With the increasing population density, the seasonality of paddy cultivation also causes imbalanced labor demands, particularly during the off-season, when smaller plots of farmland offer limited work (Oshima, 1986). As a result, many people need to seek alternative employment opportunities during these periods, spurring the growth of small businesses and family enterprises. In addition, urbanization and industrialization have transformed traditional market structures into modern shops and department stores (Figures 14 and 15). As more people live in towns or take up non-agricultural jobs in villages, new demands for industrial goods and services have burgeoned, particularly among the younger generation. In the study area, Zhongxin town is regarded as the central city of its surrounding villages, featuring two permanent market complexes in the town center. These markets act as intermediaries due to their scale and the substantial range



Figure 14. Permanent markets in the Middle Ground of the peripheral Pearl River Delta. Source: Photos by the authors (2018)

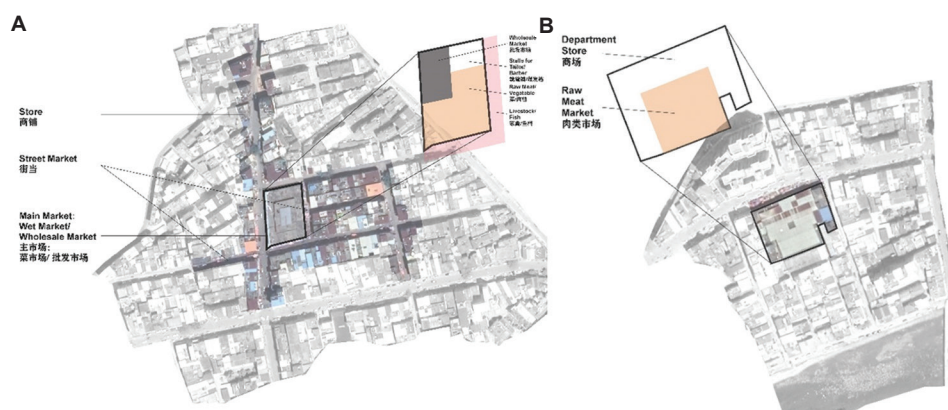


Figure 15. Mapping of permanent markets in the Middle Ground the peripheral Pearl River Delta. (A) Fu Min Wholesale Market. (B) Hua Lian Market. Source: Drawings by the authors

of products they offer from the Pearl River Delta cities, exemplifying how high-end consumption is positioned and adapted within the commercial center of the Middle Ground. From the author’s field notes:

“Fu Min Wholesale Market is a concrete building that includes several restaurants, tailors, and barbers. The ground floor areas of the surrounding building are occupied by various shops selling daily necessities, such as cooked food, snacks and beverages, farm tools, and commodities for festivals and rituals. The adjacent roads and alleys are also lined with temporary stalls selling small wares. Various courier express services and a coach station connecting to the Pearl River Delta cities such as Guangzhou and Shenzhen are also located near the market.”

Hua Lian Market, approximately 500 m away from Fu Min Wholesale Market, is another major market. Although smaller, it offers a greater variety of businesses, which includes a wet market selling raw meat, and a department store, called “Hua Lian Department Store.” Inside the department store, in addition to shops selling clothes and daily necessities, one can find gold jewelry shops, chain-store bubble tea shops, a supermarket, and even a cinema, comparable to those in city shopping malls.

5. Discussion

The findings indicate that the traditional morphology of Hakka settlements is being blended with modern commercial infrastructure and housing, creating an ambiguous condition. This article documents these morphological variations and attempts to explore the underlying socioeconomic factors driving these transformations. Urbanization is particularly overwhelming in peri-urban areas of metropolitan cities. Nevertheless, as observed, numerous rural heritage

elements remain inseparable in the daily lives of villagers. Consequently, this research also discusses the role of rural heritage in the future development of the Middle Ground.

5.1. Authority, mobility, and spatial transformation

In the past, rural Hakka society was a folk society governed by local clan power, with social acquaintance networks formed among family, clan members, and neighbors. Consequently, the spatial morphology of traditional clan-based Hakka settlements was shaped by informal control over local resources, economic conditions, social ethics, and customs. However, with the integration of state power into rural society, this transformation of authority has further driven social and cultural shifts, contributing to the spatial transformation of the Middle Ground. Architecturally, this shift is embodied in top-down planning, development controls, and legislation affecting land use, traffic networks, and housing.

Land, a crucial resource in Hakka society, was historically controlled by clan leaders and distributed to family members. The Hakka clan leader, as the authority, was responsible for the overall village design, including site selection, configuration, housing scale and style, construction process, and coordinating benefits among family members (Lin, 1995). Due to relatively sufficient land resources and the technical limitations of traditional construction, Hakka villages expanded horizontally as the population grew, forming clan-based settlements. Conversely, the Maoist urban-rural dualism in China changed rural land ownership to collective ownership by the state, strictly restricting the scope of land use (Xu *et al.*, 2011). As a result, each household can now apply for only a limited area of homestead land. Consequently, new detached houses have grown vertically rather than horizontally, achieving generational and functional

segregation within families by story. However, homesteads of families descended from the same clan remain adjacent, preserving the traditional Hakka pattern of clan-based clustering.

The state-planned traffic network has enhanced the linkage between villages and the urban cores of the Pearl River Delta, reshaping village morphology and significantly contributing to the mass movement of people and commodities. The traffic network drives the outward expansion of villages (Lin *et al.*, 2024), as evidenced by how the G358 National Highway has transformed cluster villages into linear ones. Simultaneously, within China's *hukou* (户口) system, which divides urban and rural residency status (Liu, 2005), local villagers in the study area are classified as rural farmers. However, occupational diversity resulting from increased mobility has blurred this traditional *hukou* dichotomy, further transforming the social structure. Today, in addition to skilled farmers, local villagers include part-time farmers who work as laborers or businesspeople, as well as migrant workers in cities. This social structure transformation is reflected architecturally, with production, commercial, and living spaces combined within a single housing. Moreover, urban esthetics and lifestyles have been introduced into local villages through labor flows along the G358 National Highway. Villagers who work or conduct business in larger cities express a desire to align with urban architectural trends. Their homes become status symbols, reflecting economic success and cosmopolitan aspirations through ornate designs that feature exotic architectural elements, such as Greek columns and Baroque balconies, as observed in the fieldwork. These "collage houses" are typically located outside the old village and are often surrounded by private walled yards, creating a physical separation that underscores a deeper cultural and economic detachment from traditional village life.

In addition, the flow of commodities resulting from the development of traffic networks has transformed the local economy. This transformation impacts not only production, distribution, and consumption but also the way of life (Relph, 1976). For centuries, agricultural activities overwhelmingly dominated the Chinese economy, and village inhabitants were closely linked with the land and its workings (Freedman, 2021). The Hakka people, in particular, have long survived through paddy cultivation (Aijmer, 1967; Leong *et al.*, 1997), which significantly shaped their traditional trading networks and influenced the architectural forms and landscapes of their villages. Nowadays, however, modern commercial systems are replacing traditional trading networks with new markets and department stores. In this process, the sense of place

has become less important, and the growing "placelessness" has contributed to the booming modern economy due to improved spatial efficiency (Relph, 1976).

5.2. The role of rural heritage in the future Middle Ground

Fieldwork observations suggest that rural heritage in the Middle Ground is only partially inherited and integrated into modern lifestyles. Compared to geographically remote villages, this region exhibits more flux and chaotic characteristics, making the future persistence of rural heritage uncertain. In China, static preservation is a common strategy for conserving traditional villages. However, this approach inevitably results in museumization rather than maintaining a genuine sense of place (Relph, 1976).

In the past decade, a growing number of Chinese architects have returned to the countryside, initiating what has been termed the "Vernacular Frenzy." Although their design philosophies differ, they all aim to revitalize rural culture using traditional materials and crafts, and by imitating historical spatial textures (Zuo, 2020). Architects such as Wang Shu and Huang Sheng-Yuan have proven that architectural engagement, as a form of new knowledge, can address rural culture and heritage (Martinelli & Huang, 2022; Qian & Lu, 2022). However, it is important to be cautious, as architects – are often outsiders – who may have a limited understanding of rural life, which could deviate from its reality. This "Vernacular Frenzy" overwhelmingly emphasizes traditional vernacular styles based on personal experience or interpretation of vernacular imagery (Zhao & Greenop, 2019), often within the dominant discourse of elite architects. For the local community, the cultural values of rural heritage are less important than practicality and functionality. In this context, vernacular architecture risks becoming an "elite design," deepening the paradox of architects and the local community (Caprotti & Cowley, 2017).

The conventional architectural discipline frequently views buildings as objects. However, some architectural scholars and anthropologists argue that process – and knowledge-oriented approaches are far more significant than purely esthetic categories of the vernacular and the modern (Upton, 1993; Vellinga, 2006). Fieldwork indicated that professional architects are largely absent in the rural building construction process, whether for vernacular or modern housing. It is estimated that only 5% of buildings worldwide are designed and constructed by professional architects and experts (Oliver, 1987). Particularly in the countryside, rural buildings have generally been built rather than formally designed (Knapp, 1986). In 2017, rural landscapes were defined as a newly crucial heritage category by the International Council of

Monuments and Sites (ICOMOS), encompassing not only rural buildings, settlements, and vernacular architecture but also the technical and practical knowledge associated with them (ICOMOS, 2017). In the Middle Ground, although many old dwellings have been abandoned, the local community remains alive, unlike in “hollow villages.” Instead of conserving traditional villages and houses as static heritage, encouraging local community engagement with their inherent local knowledge and experience might provide a more effective approach for architects working in rural areas.

De Carlo (2005, p. 13) famously remarked, “Architecture is too important to be left to architects,” advocating for a considered form of architecture that involves active community participation in shaping and transforming their environments. This approach establishes an “open” form of planning that adapts to the demands of local people. Through multiple and continuous participation, and by stimulating public interest in architecture, an organic system can be developed that avoids public indifference. The key to the success of this approach is the process itself. It begins with identifying the local community’s needs, passes through the design of formal and organizational hypotheses, and continues into the “in-use” phase. It is imperative that this process continues even after the prototype is completed, with ongoing feedback to adjust and calibrate the proposal. This community engagement can foster a collective sense of belonging, which can unconsciously enhance the authentic sense of place. This authentic sense of place is critically needed in the fragmented and volatile Middle Ground nowadays.

6. Conclusion

This study identifies a hybrid architectural landscape termed the “Middle Ground,” which integrates vernacular and modern elements within peri-urban areas. Through an analysis of four traditional Hakka villages located on the outskirts of the Pearl River Delta, the research illustrates the transition of village structures, residences, and markets from traditional settings to contemporary environments. Like many other traditional Chinese settlements, these villages boast extensive histories and rural origins influenced by agricultural practices and clan traditions, which have shaped their unique architectural styles and village layouts. Compared to traditional collective Hakka villages, the emergence of concrete housing has led to a spatial separation between residential and communal spaces in the Hakka village. The old village, now serving as a communal space for traditional rituals, is surrounded by new housing developments and has expanded from its traditional nucleated settlement, evolving into a new linear settlement along the emerging highway. Simultaneously,

the social structure has evolved, enabling the integration of production, commercial, and living spaces within modern housing. Although the exteriors of these houses are constructed with modern materials and styles, traces of agricultural lifestyle can still be found in the interior spaces. Moreover, traditional commercial spaces have gradually transformed from streets into more modern and efficient permanent markets and department stores, selling industrial goods from the Pearl River Delta. This transition has further integrated the Middle Ground into the broader process of Chinese urbanization.

Clearly, this transformation of the Middle Ground poses a potential risk to its distinct cultural identity. Without concerted efforts to address this trend, there is a risk that the Middle Ground will lose its uniqueness and blend into a homogeneous concept of “placelessness,” lacking inherent cultural characteristics, as identified by Relph (1976). As the Middle Ground gradually loses its defining features, the distinctive identity of the Hakka people also becomes increasingly blurred. Nairn (1965) aptly notes that the innate human desire for connection to, and recognition within, one’s environment is fundamental. Preserving this unique identity poses a significant challenge. This study highlights that the Middle Ground is rich in both tangible and intangible heritage, which serve as invaluable assets for identity preservation. Heritage is not merely a representation of the past; it holds the potential to be adapted for contemporary use. By bridging the past with the present and envisioning its role in the future, heritage can play a pivotal role in China’s rural modernization efforts. We have coined the term “Living Heritage” to describe the transformation of new forms of rapid urbanization by building connections with heritage that go beyond preservation and encourage the community to actively participate in shaping its contemporary identity.

A sense of place is not merely the product of conceptual designs outlined on plans and maps but rather emerges from personal encounters and interactions, as noted by Relph (1976). Similarly, identity is not only shaped by individual experiences but also expressed and felt within communal affiliations, as Douglas (1997) discussed. Thus, fostering community involvement by directly engaging the public in the development of a new social framework holds the key to establishing crucial connections between heritage and the Middle Ground. Architectural prototypes, as vessels of knowledge, can facilitate this realignment and encourage positive transformations between rural traditions and the inevitable socioeconomic restructuring, achieved through the fusion of heritage and technology. Moreover, when coupled with community engagement, these prototypes have the potential to evoke a sense of place, foster civic

pride, and contribute to the reconstruction of a distinct identity within the ever-evolving Middle Ground.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

Conceptualization: Peter W. Ferretto

Investigation: Xin Xu

Methodology: All authors

Writing – original draft: Xin Xu

Writing – review & editing: All authors

Ethics approval and consent to participate

Our study did not require ethics committee approval as it did not involve human clinical trials and was not unethical. All the participants provided informed consent before participating in the study.

Consent for publication

Verbal informed consent was obtained from the participants before taking and publishing photographs with identifying personal information in this research.

Availability of data

The data used in this work are available upon reasonable request from the corresponding author.

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ORIGINAL ARTICLE

Exploring tourist perceptions of calligraphic landscapes: Insights from social media text analysis

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Abstract

Calligraphic landscapes, as distinctive cultural symbols and landscapes with Chinese characteristics, are widely used in urban design, placemaking, and tourism promotion. In cultural heritage tourism, tourists' perceptions of the symbolic meanings of landscapes significantly influence their travel experiences. This study primarily utilizes social media text analysis to explore the perceptual characteristics and symbolic meanings of calligraphic landscapes in different touristic contexts. Using Python tools, user-generated content was extracted from the Xiaohongshu app and analyzed with ROST CM6, VOSviewer, and NVivo 20 to conduct systematic quantitative and qualitative analyses, including content analysis, semantic network analysis, and co-occurrence clustering. The findings indicate that cultural exchanges on social media significantly enhance public perception of the symbolic meanings of touristic spaces. As online check-in behavior becomes increasingly popular, calligraphic landscapes have gained new esthetic-symbolic meanings among young tourists, becoming part of fashion culture and reflecting the digitalization of a sense of place. In addition, user-generated content reveals that tourists' perceptions of calligraphic landscapes are intricately linked to place recognition, cultural symbolism, calligraphic appreciation, heritage value, and esthetic experiences. As a significant cultural symbol, calligraphic landscapes are frequently encountered during travel, with their symbolic meanings varying according to the surrounding environment, thereby influencing tourists' preferences in diverse settings. Furthermore, this study proposes several innovative strategies for designing calligraphic landscapes. This research not only validates the feasibility of web text analysis for exploring the symbolic meanings of cultural landscapes but also enhances theoretical perspectives on how symbolic landscapes shape tourists' psychological and behavioral responses.

Keywords: Cultural landscape; Calligraphy; Symbolic landscape; Symbolic meaning; User-generated content

1. Introduction

The relationship between tourism and landscape has been extensively researched. Landscapes play a pivotal role in tourism planning and marketing, serving as visual

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representations of destinations and facilitating the connection between tourists and travel locations. The concept of a tourism landscape has emerged within the framework of tourism development, focusing on how landscapes, activities, and developments are shaped to cater to tourism objectives while emphasizing the processes through which landscapes are created (Terkenli, 2021). In the context of tourism, placemaking encompasses urban design, image construction, and the symbolic representation of values (Mansilla & Milano, 2022). Cultural landscapes are utilized to establish urban cultural spaces that fulfill public demands for culture. Heritage serves as an emblematic symbol of tourist destinations and a significant attraction as a local tourism resource (Lei, 2022).

Chinese calligraphy employs written characters to convey specific content and, as an art form, embodies cultural and historical values. Consequently, calligraphy is regarded as the cornerstone of traditional Chinese culture due to its profound cultural significance, esthetic value, and role in shaping social identity (Zhang *et al.*, 2008). As a shared cultural heritage, Chinese calligraphy is prevalent across China and other East Asian countries, particularly in renowned tourist destinations, historic districts, and urban commercial areas. In recognition of its importance, UNESCO designated Chinese calligraphy as an Intangible Cultural Heritage of Humanity in 2009 (UNESCO, 2009).

In the context of cultural tourism, the cultural elements, landscapes, heritage sites, heritage types, and regional historical lineages associated with calligraphic landscapes constitute key attributes for evaluating tourism appeal (Zhang *et al.*, 2008). As a distinctive emblem of cultural landscapes, calligraphic landscapes play a significant role in representing and conveying specific meanings to tourists. Consequently, they are pivotal in shaping tourists' perceptions of landscapes (Tang *et al.*, 2016). By perceiving and recognizing alterations in calligraphic landscapes, tourists can form diverse impressions and establish unique identities for tourist destinations, resulting in distinct tourist experiences.

Extensive research has been conducted on calligraphic landscapes as distinctive cultural landscapes with Chinese characteristics and as significant tourism resources. These studies encompass various aspects, such as the perceptual characteristics of calligraphic landscapes at tourist attractions (Zhang *et al.*, 2012), tourists' attitudes toward these landscapes, their perceptions of originality, experiences, and constraints (Li *et al.*, 2014; Qi *et al.*, 2013; Zhang *et al.*, 2012), tourists' perceptual images of calligraphic landscapes (Ke *et al.*, 2010; Yin *et al.*, 2011),

and residents' perceptions and identifications with these landscapes (Xiao *et al.*, 2012). Previous investigations have comprehensively examined the functions and values of calligraphic landscapes from diverse perspectives, thereby establishing a robust theoretical foundation for future studies.

With the rise of new media, tourists increasingly share travelogues, reviews, blogs, and more through online platforms, offering insights into their real experiences and needs. Xiaohongshu (literal meaning, "Little Red Book"), a social media platform driven by user-generated content (UGC) platform, is widely used by young travelers in China and is particularly popular among young users (Fan & Zhang, 2022; Qin *et al.*, 2024). As of November 2021, Xiaohongshu has more than 200 million monthly active users, including 43 million information sharers, and 72% of its users were born after the 1990s. These factors make Xiaohongshu a significant consumer decision-making platform for many young users (Fan & Zhang, 2022; Qin *et al.*, 2024). Therefore, the selection of Xiaohongshu as a representative social media platform is well-suited for analyzing a sample of the young population.

Specifically, "city check-in" posts on social media combine graphics and text to convey individual perceptions of things, including emotional evaluations and location tags. These posts offer diverse perspectives on a city's imagery and reflect tourists' views on its culture, economy, history, and other factors (Fan & Zhang, 2022; Liang & Li, 2020). "Check-in" data not only reflects the pure material space but also encapsulates a kind of ideological characterization of spatial and temporal behavior, integrating elements of urban cultural life with non-material attributes. To a certain extent, the use of "check-in" data from social media helps address the shortcomings of traditional cultural landscape research, which often focuses on the perceptual awareness of material forms while neglecting cultural and ideological dimensions. The current study aims to extract tourists' perceptions of the symbolic meanings of calligraphic landscapes using data from online platforms through text analysis. By analyzing the connotations of calligraphic landscapes, this study seeks to summarize their symbolic meanings.

The feasibility of the methodology has been demonstrated by previous research analyzing tourists' perceptions, emotions, and behaviors through user-generated data (Gursoy *et al.*, 2022; Xu *et al.*, 2023; Zhou *et al.*, 2023). In this article, we aim to extract the perceived characteristics of calligraphic landscapes among specific user groups by analyzing the subjective narrative perspective of tourists using data from online platforms.

In addition, the study seeks to summarize the symbolic meanings of calligraphic landscapes by analyzing their connotations.

2. Calligraphic landscape

Zhang (2003) has defined the calligraphic landscape as a portion of geographic space with certain visual characteristics and a particular sense of place, shaped by an assembly of calligraphic works that serve as landscape elements.

2.1. Perception of calligraphic landscapes

Calligraphic landscapes are part of geographical space. The perception of calligraphic landscapes can be divided into six dimensions based on public geographical perception: time perception, geographical environment, calligraphic characteristics, forms of calligraphic carriers, value, and psychology (Zhang *et al.*, 2012). From a functional perspective, calligraphic landscapes can be categorized into economic benefits, environmental esthetics, place identification, landscape authenticity, and behavioral orientation (Xiao *et al.*, 2012). Calligraphic landscapes positively influence tourism by shaping intentions through esthetic experiences, place identity, and behavioral orientation (Yin *et al.*, 2011). As a tourism symbol, calligraphic landscapes exert symbolic effects on tourists at three levels: calligraphy appreciation, cultural symbolism, and esthetic guidance. These symbolic effects correspond to behavioral effects at three levels: external behavior, cultural environment perception, and landscape esthetics (Tang *et al.*, 2016). Under the influence of symbolic effects, tourists develop a sense of place within calligraphic landscapes. The typological diversity, as well as the historical, cultural, and artistic value of calligraphic landscape heritage, are key to addressing the lack of cultural functions of the landscape (Yan & Zhang, 2019).

2.2. Symbolic meaning of cultural landscapes

A landscape is not just a physical space; it also reflects people's ideologies and serves as a meaningful experience for individuals (Li, 2013). In cultural geography, values and their associated symbolic meanings are central to the cultural connotations of landscapes, and interpreting these meanings requires the use of symbols (Jones, 2003; Wu & Dai, 2023). Both tangible cultural landscapes (e.g., memorials, historical residences, historic streets, museums, old factories, historical temples, historic hotels, specialty shops) and intangible cultural elements (e.g., place names, festivals, music, cuisine, folk crafts, calligraphy, literature), are rich in symbolism. These symbolic landscapes significantly contribute to the diverse meanings associated

with urban spaces (Fu *et al.*, 2020; Tong & Tang, 2013). Therefore, cultural landscapes often become material carriers that constructs and perpetuate place meanings and identities, serving not only as landscapes with local symbolic significance but also as bearers of community memories and emotions (Sun & Zhou, 2015).

In the context of tourism, visitors perceive heritage symbols (such as architecture, text, and customs) through their external forms and physical carriers, facilitating interaction with cultural heritage sites (El-Sharif, 2023; Zou *et al.*, 2023). The meaning of tourism landscapes is perceived, represented, and narrated within diverse discursive frameworks. Tourists interpret various tourist attractions by referencing different symbolic spaces, such as artistic, national, and religious contexts (Edensor, 2008; Ku, 2011). Perceiving the symbolic meaning of cultural heritage involves mentally constructing an understanding of structures, entities, and spatial relationships. It is essential to consider tourists' subjective experiences within the objective environment and to integrate cultural significance, historical memory, and current value of cultural landscapes in a comprehensive evaluation. As representatives of cultural landscapes, calligraphic landscapes embody the relationship between tourists' understanding, perception, and appreciation of calligraphy culture and the impact of these activities on the landscape.

2.3. User-generated content and cultural tourism perception

User-generated content refers to media created by the public, primarily distributed through the Internet (Xu *et al.*, 2023). Social media has transformed travelers from passive information recipients to active content creators, fostering communication, interaction, and relationship-building with destinations, tourism managers, and fellow travelers (Choe *et al.*, 2017; Sigala & Gretzel, 2017).

Researchers recognize UGC platforms as crucial for defining and exploring tourism experiences and heritage perceptions (Gursoy *et al.*, 2022). Analyzing tourists' social media posts is key to understanding and exploring these experiences. Previous studies have used UGC to investigate heritage tourism experiences, heritage spatial perceptions, destination images (Lee & Park, 2023; Xu *et al.*, 2023), and symbolic representations of tourism imagery (Cai & Song, 2019).

Text analysis methods for UGC usually include multi-word frequency analysis, sentiment analysis, topic modeling, social network analysis, and semantic network analysis. Text clustering and network visualization enhance the intuitive interpretation of the data.

3. Data sources and method

3.1. User-generated content

The data for this study were collected from social media texts published on public social platforms. A Python data extraction tool was utilized to gather UGC specifically related to keywords such as “calligraphy attractions,” “calligraphy tourism,” and “calligraphic landscapes” from the Xiaohongshu app. The text filtering process involved: (i) Removing posts not relevant to calligraphy; (ii) filtering out duplicate and non-textual content; (iii) excluding posts that discussed calligraphic landscapes in non-touristic contexts (e.g., interior decoration, calligraphy teaching, and design cases); and (iv) eliminating promotional and advertising content. After applying these selection criteria, a total of 805 posts comprising 171,243 words were obtained for further analysis.

3.2. Research method

In this study, ROST CM6 was used for field analysis of text content, including word frequency, classification, and social semantics. A co-occurrence matrix was calculated and generated, and co-occurrence cluster visualization was performed using VOSviewer. In addition, based on the co-occurrence cluster analysis results, NVivo 20 was used to conduct an in-depth analysis of the social media text data to interpret the characteristics and differences in tourists’ perceptions of the function and meaning of calligraphic landscapes.

3.2.1. Content analysis method

Content analysis is a research method that transforms unstructured, qualitative symbolic content into structured, quantitative data (Wang & Sun, 2015). Given its significant advantages in analyzing tourists’ spatial perceptions of destinations, this method has been widely applied in recent studies on destination perception (Dai & Xue, 2022).

3.2.2. Semantic network analysis

Semantic network analysis is a technique used to identify relationships between words in UGC texts (Park *et al.*, 2019). In this network, each word is treated as a node, and the co-occurrence relationships between words are represented as links. The strength of the connection between two words is determined by their co-occurrence frequency (Figueiredo *et al.*, 2011). Each pair of linked words has a co-occurrence distribution, which serves as input for generating matrix data.

4. Result

4.1. Analysis of high-frequency words

Through network text analysis, the top 50 high-frequency feature words were extracted to understand tourists’

perceptions of calligraphic landscapes (Table 1). Words related to cities were also categorized and counted, and the top 10 tourist cities related to calligraphy were compiled (Figure 1).

Notably, Shaoxing in Zhejiang province and Xi’an in Shaanxi province, both in China, show the strongest relevance to calligraphic landscapes, displaying significant thematic distinctions that underscore their established tourism images centered around calligraphy culture.

The analysis of the top 50 high-frequency words reveals that nouns predominate, with fewer adjectives and verbs. Many of these high-frequency nouns relate directly to the scenic spots of tourist destinations, reflecting tourists’ keen attention to and awareness of these places. For example, terms, such as “Shuyuanmen,” “Beilin Museum,” “Wang Xizhi’s hometown,” and “Lu Xun’s hometown” appear frequently, indicating that these scenic spots and attractions hold significant positions in the minds of tourists. These locations are not only pivotal carriers of calligraphic landscapes but also form the essence of tourists’ cultural experiences.

The high frequency of terms such as “checking in” ($n = 160$) and “taking pictures” ($n = 149$) partly reflects the motivations of tourists to visit calligraphic landscapes, which many tourists regard as an important social behavior. This behavior is closely related to social media and internet-famous culture, in which tourists mark their visit to significant or popular places by “checking in.” As a type of cultural consumer product, internet-famous culture represents a specific symbolic value, reflecting consumers’ emphasis on cultural connotations while transcending mere utilitarian values (Yan *et al.*, 2022).

Calligraphic landscapes are not only objects of artistic appreciation but also important content for visitors to display their personal cultural tastes and lifestyles on digital platforms. This phenomenon reflects a transformation in the meaning of calligraphy: as an art form, it is gradually losing its status as a representative of elite culture and is increasingly taking on a more popular and entertaining character (Li, 2004). At the same time, due to media publicity and growing recognition of calligraphy culture, it has gained acceptance among younger generations. Text analysis reveals that calligraphy is considered a kind of trendy culture or a representative of Chinese esthetics. The fusion of calligraphy and elements of popular culture has fostered a unique, popular style.

The development of mass media has accelerated the dissemination of calligraphic landscape symbolism, strengthening public perceptions of tourist spaces and their meaning (Tong & Tang, 2013). The act of “checking in” at

Table 1. Frequently used words in web texts about calligraphic landscape perception

High-frequency words	Time	TF-IDF
Calligraphy	506	0.002025134
Scenic area	332	0.004595631
History	206	0.002921228
Check-in	194	0.00288783
Culture	190	0.002828287
Shaoxing	175	0.004679413
Museum	171	0.003161618
China	164	0.003032195
Xi'an	163	0.004460368
Hometown	160	0.004483359
Architecture	144	0.002882468
Art	129	0.002536326
Take photos	125	0.002291242
Park	106	0.002597746
Place	104	0.001811155
Former residence	99	0.002559754
Atmosphere	98	0.001876285
Wang xizhi	94	0.002327978
Feel	93	0.001895619
Lu Xun	93	0.003153161
Sage of calligraphy	86	0.002353323
Experience	80	0.002023944
Orchid pavilion	79	0.002914802
Jiangnan	75	0.002028604
Forest of steles	71	0.002407252
Historic District	65	0.002137205
Bookstore	61	0.001976207
Garden	59	0.001715366
Ancient town	54	0.00195693
Academy	51	0.001605575
Characteristic	49	0.001295472
Ancient city	49	0.001587445
Writing	47	0.001593533
National trend	46	0.001428198
Worth	46	0.001258754
Bell tower	46	0.001697226
Stone carving	45	0.001502202
Travel	44	0.001247948
Master	44	0.001425461
City	44	0.001247948
Ruins	42	0.001380963
Tradition	42	0.001286373

(Cont'd...)

Table 1. (Continued)

High-frequency words	Time	TF-IDF
Location	41	0.001255745
Theme	41	0.00132827
Famous	39	0.001148361
Period	39	0.001148361
Space	38	0.001586702
Square	38	0.001249443
Old street	36	0.001379534
City wall	35	0.001341213

such locations serves to construct personal memories, reproduce local collective memory, reinforce self-identity, and build collective identity (Shao & Wang, 2023). The ultra-popularity of heritage tourism destinations reflects the re-explosion of the long-term accumulation and inheritance of urban historical memory and traditional culture. The act of “punching cards” digitally embodies a sense of place.

4.2. Calligraphic landscape perception semantic network

High-frequency feature words related to calligraphic landscapes help analyze the attention hotspots and distribution patterns in tourists’ online texts. However, they do not present meaningful associations between high-frequency feature words and the deeper structural relationships in the texts (Dai & Xue, 2022). To address this, we constructed a co-occurrence matrix to reveal the co-occurrence relationship between different words. This matrix records how frequently words appear together in the text, allowing us to identify the elements most closely associated with tourists’ perceptions.

Using the text co-occurrence matrix, we applied the VOSviewer clustering algorithm to analyze highly relevant words in clusters, constructing the calligraphic landscape perception network. Each cluster represents a specific semantic field or theme that tourists invoke when describing calligraphic landscapes (Figure 2).

The analysis of the calligraphic landscape perception network reveals three clusters. The red cluster represents overall perceptions of the calligraphic landscape, focusing on symbolic meanings and summarized as place recognition and the cultural symbolism of the calligraphic landscape. Conversely, the green and blue clusters exhibit distinct perceptual characteristics. The green cluster reflects experiences of places and landscapes, summarized as perceptions of calligraphic landscapes based on heritage values. Meanwhile, the blue cluster reflects connections between historical figures and regional culture, summarized

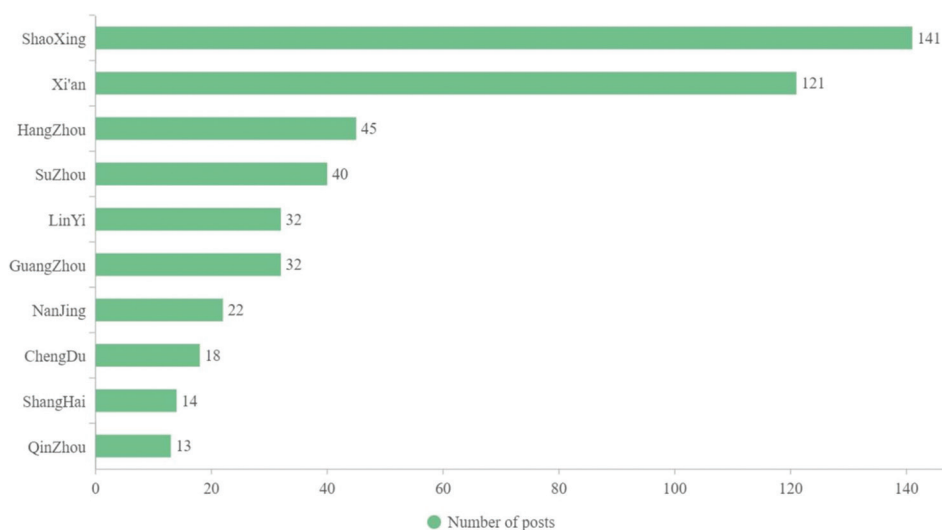


Figure 1. Top 10 tourist cities related to calligraphy. Source: Graph by the authors (created with WPS)

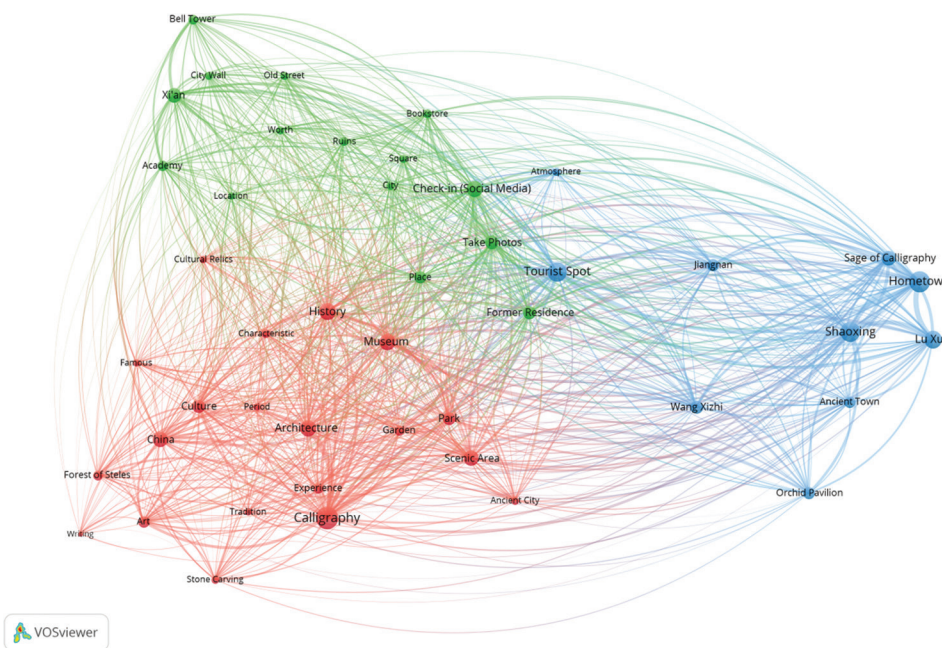


Figure 2. Calligraphic landscape perception network. Source: Diagram by the authors (created with VOSviewer)

as perceptions of calligraphic landscapes based on local culture.

4.2.1. Identification and cultural symbolism of the calligraphic landscape

The red cluster category encompasses two prominent dimensions: place identification and cultural symbolization. The calligraphic landscape perceptual network comprises core nodes such as calligraphy, museums, architecture, and

parks, with sub-nodes including China, history, culture, art, and tradition.

The co-occurrence frequency results proved that “Calligraphy-Architecture” ($n=942$) and “Calligraphy-Space” ($n=738$) had significantly higher co-occurrence than other pairings (Figure 3). This finding suggests that visitors pay considerable attention to architectural features and spatial locations. As an integral element of space and a tool for spatial retrieval, the calligraphic

landscape helps define and identify places. It serves as an important medium through which tourists perceive and define spaces. In tourist descriptions, the perception of the calligraphic landscape focuses on specific, representative places, indicating that the degree of place perception of the landscape environment by tourists may be influenced by the subjective attributes of the landscape. Compared to everyday scenes, tourists tend to perceive higher heritage, esthetic, and cultural values in these attractions. As a result, attractions are often considered synonymous with calligraphic landscapes (Zhang *et al.*, 2012) (Figure 4).

The sub-nodes of China, history, culture, art, and tradition represent the perceived characteristics of the calligraphic landscape, with cultural symbols forming the main content. Co-occurrence frequency results for “Calligraphy-culture” ($n = 379$), “Calligraphy-art”

($n = 326$), and “Calligraphy-history” ($n = 182$) align with the high-frequency terms “history” ($n = 206$), “culture” ($n = 190$), and “art” ($n = 129$). When engaging with the calligraphic landscape, tourists tend to closely associate its meaning with aspects of history, culture, and art. The overall perception of the calligraphic landscape is reflected in the symbolism and cultural connotations represented by the symbolic landscape.

Calligraphic landscapes act as symbols of regional and local cultures. Landscapes with calligraphic elements are easily recognized as visible representations of a particular culture. The content and events recorded in calligraphic works are often seen as reflections of local culture. Most Chinese tourists identify culturally with calligraphy, considering it one of the most important factors in traditional Chinese culture. For example, most overseas Chinatowns use Chinese calligraphy to decorate their streetscapes, highlighting the community’s distinctive features and helping identify specific Chinatown areas. Research by Van Ostade *et al.* (2023) demonstrates that the symbolic function of calligraphy plays a key role in expressing Chinese identity in overseas Chinatowns.

The red cluster class is the densest and most populated cluster class in the overall network graph. Based on the textual information represented by the nodes in this cluster class, we summarize two primary dimensions: place identification and cultural symbolism. This analysis indicates that, in the overall perception of the calligraphic landscape, calligraphy plays a general role in shaping the definition of place and the understanding of culture. Culture is the outer factor of the five major influences on human perception and experience of landscape (Craik, 1986). As a cultural sign, the calligraphic landscape is an important factor in how local landscapes are perceived (Zhang, 2003). The various cultural functions of calligraphy are expressions of cultural values through the calligraphic landscape. Calligraphic landscapes are combinations of symbols that require deeper interpretation within specific contexts. Context, being the environment in which symbols are used, is the most important factor in determining their meaning and limits the uncertainty of symbols to a certain extent.

4.2.2. Calligraphy perception based on heritage value

The green cluster class reflects the experience of landscape and heritage, with core vocabulary related to the physical environment and place type of the calligraphic landscape. Sites such as the forest of steles, the former residence, the city wall, the bell tower, and the academy gate left a deep impression on visitors. Further analysis of the text content associated with these core words shows that this cluster of Xi’an heritage tourism spaces exhibits strong correlations.

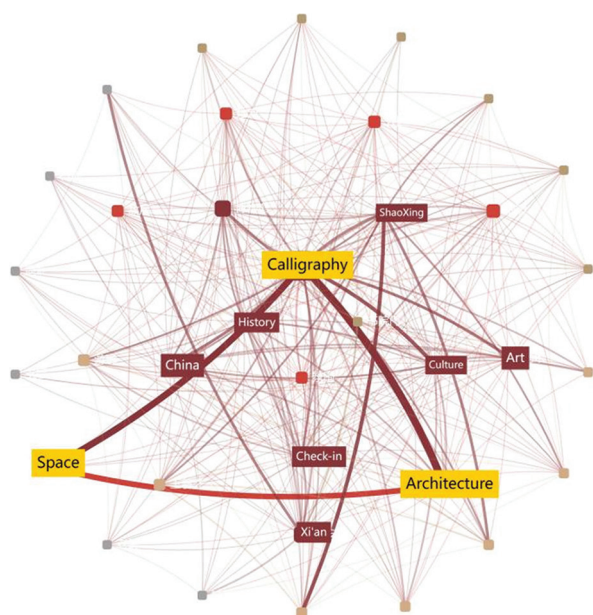


Figure 3. Co-occurrence network relationship diagram. Source: Diagram by the authors (created with Gephi)



Figure 4. Calligraphy tourist attractions. (A) Calligraphic landscapes in historic districts. Source: Photo by the authors (2021). (B) Calligraphic landscapes in natural environments. Source: Photo by Fujianzhoubianyou (available at https://mp.weixin.qq.com/s/LLswzi5_0_5KjksMSUQ6tw) (2024)

Xi'an is a world-renowned historical and cultural city, where 13 dynasties were founded. With a history spanning over 3,100 years, Xi'an boasts a rich cultural and historical heritage, along with numerous historical buildings. Among the notable places, Xi'an Stele Forest Museum and Shuyuan Gate Historical Block show a high correlation with calligraphic landscape. The Xi'an Stele Forest Museum is a specialized calligraphy museum focused on the collection, research, and display of stone steles, epitaphs, and stone carvings. The Xi'an Forest of Steles displays more than 1,000 steles and epitaphs from the Han dynasty (206 BCE – 220 CE) to the Qing dynasty (1644 – 1912).

A review of the associated texts reveals that tourists' perceptions of calligraphic landscapes manifest in three main perceptual dimensions, namely heritage perception, calligraphic appreciation, and cultural symbolism.

Heritage perception pertains to the description of the material-functional value of calligraphic landscapes. Tourists delineate carrier forms, heritage quantity, spatial ambiance, and environmental locations, forming their perceptions of the material attributes of calligraphic works and the environmental context of calligraphic landscapes. In this process, the content, form, quantity, and material carriers of calligraphic landscapes become the most direct standards of perception for tourists. Furthermore, tourists place significant emphasis on the authenticity of calligraphic landscapes. The essence of tourism activities is inherently symbolic, with authenticity being a crucial criterion for assessing the quality of tourists' experiences (Yang & Xi, 2015). Textual analysis reveals that historical physical artifacts and traditional carrier styles leave a more profound impression on tourists. The preservation of the calligraphic landscape's environment and the presentation of its original context are vital to maintaining its authenticity. Landscapes with well-preserved authenticity can enhance the genuineness of a city's cultural landscape to a certain extent.

Calligraphy appreciation focuses on the calligraphic features found within the landscape, encompassing font characteristics, skills, and content. This focus highlights the crucial role that calligraphic features play in shaping the perception of a calligraphic landscape (Zhang *et al.*, 2012). China's writing system has a history of nearly 3,500 years, with the evolution of characters from oracle script to seal script, official script, cursive script, running script, and regular script, often aligning with specific historical periods or dynasties. Each calligraphic font corresponds to unique esthetic characteristics, with calligraphy works encapsulating the skills, emotions, thoughts, and values of their creators.

The calligraphic landscape encountered during travel is a significant tourist attraction for calligraphy enthusiasts,

demanding on-site appreciation and evaluation. It serves as both an object of admiration and a source of learning, representing the pinnacle of calligraphic artistry. Tourist descriptions of their appreciation and sentiment toward the historical relics at Xi'an Stele Forest tend to be polarized. For calligraphy aficionados, Xi'an's calligraphic landscape holds special significance due to its rich diversity in preserved forms, encompassing classic works throughout history. Immersing oneself in this unique historical atmosphere and cultural background allows for a subjective, intricate, and profound tourism activity where one can carefully read and appreciate both the content and artistic characteristics within each piece.

For ordinary tourists, appreciating calligraphic landscapes mainly involves identifying the content of the calligraphy. During this process, calligraphic landscapes are viewed as decorative elements within the environment and as architectural symbols. Although ordinary tourists may rely on guided explanations to meet their expectations and deepen their understanding of the cultural background and historical value of calligraphy, their appreciation often remains at a basic and superficial level. Therefore, the significance of calligraphy appreciation is not universal. Tang *et al.* (2016) discovered that the appreciation of calligraphy in tourist attractions is influenced by tourists' cultural literacy and interest in calligraphy, indicating that a specific group of visitors appreciates calligraphic landscapes as an art form.

Cultural symbols embody the perception of the non-material functional value of calligraphic landscapes. It is usually believed that calligraphic landscapes hold non-material functional values such as cultural, educational, esthetic, and heritage tourism values. Tourists' descriptions often focus on calligraphic activities, historical background, status and popularity of the history of calligraphy, and its status as a World Heritage Site or Chinese Heritage Site. Tourists depicted the strong cultural atmosphere of historic districts, the deep historical heritage of the city, admiration for famous calligraphic works, reflection on the value of art education, and the recognition and pride in the heritage of calligraphic landscapes. Visitors' judgments of the value of calligraphic landscape heritage often trigger reflections on broader social and cultural symbols, which in turn influence their local experience and sense of local identity.

In general, the perception of calligraphic landscape based on heritage value mainly centers on three dimensions: heritage attributes, calligraphic appreciation, and cultural symbols. For calligraphic landscape heritage, tourists' intuitive feelings about the spatial environment and attributes of heritage sites form the basis of

tourists' perceptions of calligraphic landscapes. Given their expectations for the value of the heritage, tourists tend to focus on the originality of both the heritage itself and its spatial environment. Second, specific connoisseur groups place more emphasis on the value of the calligraphic works themselves. For ordinary tourists, however, the calligraphic landscape heritage functions as landscape elements or architectural decorations, contributing to their perception of the cultural atmosphere and heritage of the historical site. Finally, cultural symbols embody the perception of the cultural atmosphere, historical heritage, artistic activities, and other non-material functions, shaping visitors' judgment of the value of the calligraphic landscape in a tourist setting.

4.2.3. Perception of calligraphic landscape based on local culture

The blue cluster category mainly focuses on words related to historical figures and regional culture, such as "Lu Xun," "Wang Xizhi," "Shaoxing," and "hometown." These words indicate that tourists' perception of the calligraphic landscape is often associated with specific historical figures and regional cultures. Further research reveals that the core vocabulary in the blue cluster category is centered around the Shaoxing calligraphic landscape. Shaoxing, located in north-central Zhejiang province, China, is a renowned Chinese historical and cultural city, famous for its water town, bridge town, calligraphy town, and famous scholars. Key attractions include Lanting Scenic Spot, the hometown of Wang Xizhi, and the hometown of Lu Xun, which are important literary tourist destinations. In the related texts, tourist perceptions of calligraphic landscapes can be categorized into three main dimensions: landmark and place identification, cultural symbols, and esthetic experience.

Calligraphic landscapes, as feature markers, help define the boundaries of specific areas (Qi *et al.*, 2013). These characteristic calligraphic landscapes are commonly used as signifiers and markers to attract tourists' attention and enhance their experience. Typically positioned at important spatial nodes or significant geographical locations, they serve as focal visual points with a high degree of prominence and iconicity. In this context, tourists tend to focus less on the artistic features of calligraphy and more on its easy recognition and environmental coordination. These are the main perceptual characteristics of calligraphic landscapes, reflecting a preference for legible and consistent scenery (Liu *et al.*, 2019). As tourist attractions, calligraphic landscapes play an essential role in creating scenic places and establishing a sense of place. In addition, they serve as referent symbols that signify being present; thus, tourists' behavior shifts from merely taking photos or noting the

time, to collecting symbolic representations during their visits (Wu & Dai, 2023).

Cultural symbolism reflects the way calligraphic landscapes contribute to the cultural atmosphere. Visitors experience the landscape in a holistic way, combining their immediate perceptions with their knowledge and memories (Antrop, 2005). First, the combination of calligraphic works and the green tiles and white walls in the historic district creates a scene reminiscent of poetry, fulfilling tourists' expectations and imaginations of the scenery of Jiangnan landscape as depicted in the literature. In this context, calligraphy becomes a tool to enhance the cultural atmosphere of the place. An analysis of tourist posts reveals that tourists often photograph calligraphic landscapes, captioning them with references to the Lanting Preface. Second, calligraphic landscapes are strategically placed near major entrances and bridge passages, correlating geographic locations with stories, legends, or historical events. This design deepens tourists' memories of the sites and enriches their experiences (Figure 5). Finally, calligraphy serves as a reminder in various forms, such as street signboards and store plaques, which invariably strengthens visitors' perceptions of local characteristics.

Esthetic experience includes environmental esthetics and mood association. On the one hand, the calligraphic landscape has a guiding role in shaping the landscape esthetic. When the content and artistic styles of the calligraphic works are harmonized with the landscape features of the scenic area, they can prompt and guide the overall scenic landscape's esthetics. In scenic spots related to literary works, tourists are more inclined to follow the order depicted in the poems.

On the other hand, in the traditional Chinese view, any successful work of art elicits an emotional response that matches the "soul" that informs or animates it (Antrop, 2005; Baihua & De Meyer, 2017). As an environmental element, the role of calligraphic landscapes is usually



Figure 5. Calligraphic landscape in Shaoxing city. (A) Lanting scenic area. Source: Photo by Shaoxing Culture and Tourism (available at <https://mp.weixin.qq.com/s/Wm-tL6q4lR5H-CDfYNINPA>) (2024). (B) Tishan bridge. Source: Photo by Huang Ke (2024)

similar to that of painting and music, as it manifests artistic symbols used to accentuate the atmosphere of a scenic spot, regulate the mood of tourists, and create an esthetic conception. The emergence of artistic conception implies that the objective scenery has become a symbol or token of one's subjective affections. Visitor descriptions note that through the guidance of the calligraphic landscape, visitors are more easily engaged in the mood depicted by literary works, allowing for an immersive experience. At this time, real-life landscapes are transformed into imaginary scenery (Baihua & De Meyer, 2017). Whether tourists can devote themselves to the mood of the calligraphic landscape is an important indicator of their esthetic experiences (Jiang *et al.*, 2015).

In summary, the perceived dimensions of calligraphic landscapes presented on social media mainly include place recognition, geographic indications, heritage perception, calligraphic appreciation, cultural symbols, and esthetic guidance. Place recognition and geographic indications are similar in function and are thus combined into the same dimension of place recognition. The preferences for perception in different contexts vary greatly, though cultural symbols remain common across different contexts.

5. Discussion

This study utilizes social media texts as data sources, employing text analysis methods, such as high-frequency lexical analysis, semantic network analysis, and co-occurrence clustering visualization. It examines tourists' perceptions of calligraphic landscapes and their symbolic dimensions across different touristic contexts, providing insights into the interplay between cultural symbolism and spatial perception in tourism.

Overall, calligraphic landscapes, centered around calligraphy, are vital tourism resources and key perceptual elements for tourists. The rapid dissemination of their symbolic meanings through mass media has enhanced public perception of tourism spaces and their symbolic significance. Furthermore, with the rise of online check-in behavior, calligraphic landscapes have developed new esthetic-symbolic meanings among young tourists, representing a digital embodiment of the sense of place.

Further research reveals that tourists' perceptions of calligraphy primarily manifest in five aspects: place identification, cultural symbolism, appreciation of calligraphy, heritage value, and esthetic guidance. These elements demonstrate the diversity and complexity of the symbolic meanings of calligraphic landscapes in the era of popular culture. Calligraphic landscapes serve as crucial tools for defining space and identifying places, playing a

significant role in constructing symbolic urban spaces and mediating tourists' spatial perceptions.

Calligraphy, as a traditional cultural landscape with distinctive Chinese characteristics, has been widely integrated into daily life, work, and leisure, shaping significant cultural places in China. It also plays a crucial role in cultivating a unique sense of place. However, the symbolic meanings of calligraphy must be contextualized, as tourists' perceptual preferences for calligraphic landscapes vary across different settings.

This study offers three strategic recommendations for designing calligraphic landscapes based on tourists' perceptions of their symbolic meanings. First, it is essential to fully understand the perceived characteristics of tourists when designing calligraphic landscapes and creating a cultural atmosphere for scenic areas. The integration of calligraphic landscape symbols, fingerprint symbols, architectural symbols, street symbols, and commercial symbols should be done organically, considering the overall environment and atmosphere to avoid rigid copying. Second, effectively highlighting local culture through calligraphic landscapes has proven to resonate with tourists' perceptual experiences, enriching the symbolic meanings of these landscapes. Third, in an era dominated by popular culture, calligraphic landscape design should embrace innovation in form and content to attract younger audiences, moving beyond traditional elitist esthetics to foster creativity, exploration, and innovation in artistic concepts and practices.

The research validates the feasibility of web text analysis in studying the symbolic meanings of cultural landscapes, enriching the theoretical outcomes of calligraphic landscape perception studies. By understanding the characteristics of symbolic perception, further research can explore tourists' psychological reactions and behavioral intentions during interactions with calligraphic landscapes, enhancing our understanding of the symbolic effects of these landscapes. The variability in the representation of Chinese calligraphic landscapes across different discursive contexts highlights how unique cultural elements impact tourists' perceptions, emotional responses, and the overall cultural and historical characteristics of a place. Theoretically, these findings support the design of calligraphic landscapes and the cultivation of cultural atmospheres in tourist areas.

6. Conclusion

Overall, the findings indicate that calligraphic landscapes are more than esthetic elements; they are potent symbols of culture and history, with social significance, influencing individual perceptions and collective memories. Integrating these symbolic landscapes into urban design

can enhance cultural identity and tourism appeal, making them vital components of cultural and heritage tourism strategies.

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Conflict of interest

The authors declare they have no competing interests.

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Ethics approval and consent to participate

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Availability of data

The raw/processed data required to generate the findings in this study cannot be shared at this time, as this data also forms part of an ongoing study.

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ORIGINAL ARTICLE

Investigating the non-equilibrium in territorial space utilization benefits of urban agglomerations under new urbanization: A case study of the Pearl River Delta of China

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Abstract

The National Development and Reform Commission's 14th 5-year Plan for New Urbanization aims to enhance the integrated development of urban agglomerations and promote coordinated growth among large, medium, and small cities to improve the comprehensive development capacity of urban agglomerations. This study examines the systemic coupling and coordination of land use benefits and the concept of balanced territorial space utilization. A comprehensive evaluation index system is constructed, employing the coupling coordination degree model and the land development imbalance index model to assess both the comprehensive benefits of land use and the balance of land development in the nine cities of the Pearl River Delta urban agglomeration in 2019. The findings are as follows: (i) Shenzhen has the largest territorial space development scale, with minor differences indicating balanced development; (ii) the territorial space development scale and urban economic benefits in the Pearl River Delta urban agglomeration are generally in a coordinated development stage. While Guangzhou and Shenzhen exhibit lagging input, the other cities demonstrate lagging output; and (iii) there is an extreme imbalance in territorial space development. Based on these findings, the study recommends the following: (i) maintain coordinated development between territorial space development scale and urban economic benefits by adjusting inputs and outputs across different cities to control land development intensity and enhance the economic output of land; and (ii) for cities facing overdevelopment, prioritize improving urban land supply capacity, control the expansion of construction land, and explore the redevelopment of existing land; for cities facing underdevelopment, provide preferential access to construction land quotas to support efficient land development.

Keywords: New urbanization; Territorial space development; Urban economic benefit; Land supply capacity; The Pearl River Delta urban agglomeration

1. Introduction

China, with its vast territory and large population, exhibits significant regional variations in natural resource endowments, a phenomenon rarely observed elsewhere in the world. These variations make regional development coordination a critical challenge. Since the implementation of the reform and opening-up policies, China has undergone the largest and fastest urbanization process in world history, achieving globally recognized accomplishments. Urbanization has provided a substantial platform for both urban and rural residents to share the benefits of socio-economic development. However, this rapid and often disorderly urbanization process has led to several issues, including imbalanced regional development, resource and environmental constraints due to extensive development, and unequal access to public services (Yao *et al.*, 2014). As a result, urbanization has become a central and complex issue in the socio-economic development of contemporary China.

In response, the 2015 Central Urban Work conference proposed a people-centered urbanization, emphasizing that city size should adapt to its resource and environmental carrying capacity. The conference also highlighted the need for urban development to coordinate space, scale, and industry. With urban agglomerations as the main form of development, the conference advocated for the scientific planning of city spatial layouts to achieve compact, green, and efficient growth. In this context, the National Development and Reform Commission proposed key tasks for new urbanization in 2019, focusing on deepening the development of urban agglomerations, implementing orderly planning, and accelerating the construction of China's three major urban agglomerations. In 2022, the commission issued the 14th 5-year Plan for New Urbanization to further advance the people-centered urbanization strategy. This plan promotes the categorized development of urban agglomerations, encouraging megacities and very large cities to transform their development approaches by scientifically determining urban scale and development intensity. In addition, it seeks to enhance the vitality of small cities, strictly control incremental growth, and revitalize existing resources.

Efficiency in territorial space utilization is a crucial indicator for assessing a region's sustainable development capacity. This concept evaluates the extent to which territorial space resources are effectively used to generate economic, social, and ecological benefits under given input conditions (Chen *et al.*, 2024). The existing literature on the benefits of territorial space development covers various spatial scales, including national, urban agglomeration, watershed, provincial, and municipal levels (Deilmann

et al., 2016). Some scholars have analyzed the efficiency of territorial space utilization in resource-based cities, focusing solely on construction land (Chen *et al.*, 2022; Lu *et al.*, 2022). Following the release of the National Major Function-Oriented Zoning by the State Council in 2010, other studies have analyzed land development intensity by calculating the proportion of construction space relative to total land area (Chen *et al.*, 2012). Recognizing that land finance significantly enhances land use efficiency; scholars have gradually examined the relationship between land development intensity and economic benefits from the perspective of land input and output (Huang *et al.*, 2021). Typically, land, labor, and capital are considered inputs, while various benefits are regarded as outputs (Ma *et al.*, 2022). In recent years, the academic community has emphasized sustainable development, requiring coordinated and orderly synergy between resources, the environment, and socio-economic factors, grounded in the harmonious unity of humans and nature (Bryan *et al.*, 2018; Rebolledo-Leiva, R *et al.*, 2019). However, a significant conflict exists between the infinite demands of human societal development and the finite supply of territorial space resources (Kalabamu, 2019). As a result, research has shifted toward evaluating the balance between land development and environmental carrying capacity by measuring construction land development intensity and land supply capacity (Wei *et al.*, 2023). Ecosystem services, which provide essential environmental information for accurately identifying natural value and urban-level impacts, are increasingly integrated into spatial planning tools. These services enhance urban planning and resilience (Hernández & Camerin, 2023) and help prioritize and allocate nature-based solutions in urban areas based on ecosystem service needs (Longato *et al.*, 2023). Building on the integration of various research aspects, a few scholars have begun to study the scale of territorial space development from a more comprehensive perspective (Qu & Long, 2018; Sun *et al.*, 2021), focusing on the coordination of economic, social, and environmental benefits (Tian *et al.*, 2019). However, research outcomes in this area remain relatively limited. The primary methodologies include the coupling coordination degree model (Tian *et al.*, 2019; Sun *et al.*, 2021), coordination tests, impulse responses (Zhao & Hu, 2016), and data envelopment analysis (Tone & Tsutsui, 2010).

Current research on the Pearl River Delta urban agglomeration primarily focuses on population-economy and land-ecology aspects. Studies indicate that economic development has slowed due to the depletion of the demographic dividend and a decline in economic globalization (Shang *et al.*, 2022). Research into the industry-population-space interaction mechanism within urban agglomeration development reveals a gradual fading

of the positive mutual influence between population growth and industry expansion (Liu & Tian, 2018). Land-ecology studies examining the coupling coordination between urban development and resource-environmental carrying capacity have found a significant increase in land development intensity within the urban agglomeration (Hu *et al.*, 2021). However, more than half of the cities in the region are on the brink of ecological-economic system imbalance, with a negative correlation observed between land exploitation intensity and ecosystem service value (Chen & Wang, 2021; Wu *et al.*, 2020).

Overall, given the rapid pace of urbanization and the limited ecological carrying capacity, current research on the benefits of territorial space development predominantly focuses on the binary input-output perspective. This approach lacks an in-depth analysis of the coupling relationship between land economy and ecology. There is a pressing need for an objective evaluation of the economic benefits of territorial development in the Pearl River Delta urban agglomeration, as well as a more comprehensive assessment of the balance between land economy and environmental sustainability.

This article focuses on the nine cities of the Pearl River Delta urban agglomeration. It constructs a comprehensive index system at the urban scale, encompassing the territorial development scale, urban economic benefits, and land supply capacity. Employing a coupling coordination degree model and a land development imbalance index model, the study explores the relationships between territorial space development, urban economic benefits, and land supply capacity. It also evaluates the economic efficiency of land use and the state of ecological balance. The findings provide a scientific basis for planning the Pearl River Delta urban agglomeration, promoting ecological urban development, and ensuring the rational utilization of land resources.

2. Study area

The Pearl River Delta urban agglomeration is located in the southern part of Guangdong province, China. It is one of the most market-oriented and dynamic urban agglomerations in the country, encompassing nine cities: Guangzhou, Shenzhen, Zhuhai, Foshan, Dongguan, Zhaoqing, Jiangmen, Zhongshan, and Huizhou. The total area spans approximately 54,800 sqkm. Its proximity to Hong Kong and Macao Special Administrative Regions of China has bolstered its prominent role in China's reform and opening-up initiatives. Over the years, the Pearl River Delta has evolved through phases of rural industrialization, urban industrialization, and metropolitan planning, establishing itself as an important growth pole in China. Alongside the Yangzi River Delta and Beijing-Tianjin-

Hebei urban clusters, it plays a key role in driving China's economic development.

Recent studies on the Pearl River Delta urban agglomeration have identified a high intensity of land exploitation and a strong demand for construction land, with notable regional disparities in exploitation levels. Over the past two decades, the area of construction land in the Pearl River Delta has increased nearly fourfold. For instance, by 2013, Shenzhen's land exploitation intensity had approached 50%. Simultaneously, issues such as resource scarcity, environmental pollution, and ecological damage have emerged, highlighting the need to enhance ecological resource management. In 2016, Guangdong province issued the Implementing Opinions on Accelerating the Construction of Ecological Civilization, which emphasized building an environmentally friendly society through green, low-carbon development and establishing an ecological civilization system. The Pearl River Delta urban agglomeration is expected to lead in building green, ecological city clusters, with a focus on scientific spatial planning and ecological restoration based on resource and environmental carrying capacity. Furthermore, the Key Task of New Urbanization in 2019 proposed using these principles to promote the healthy development of urban agglomerations, advocating for a spatial urbanization pattern that coordinates the development of large, medium, and small cities and towns. This article takes the Pearl River Delta urban agglomeration as the case study, exploring the balance between economic efficiency and land development. The insights gained are of practical significance for guiding future urban agglomeration development strategies in China.

3. Method and data

3.1. Evaluation index system

This study integrates findings from previous research, emphasizing the need for a systematic, scientific, and operable index system. Table 1 presents the evaluation index system used to assess the economic benefits and balance of land development. This system is structured around three major aspects: territorial space development, urban economic benefits, and land supply capacity. The scale of territorial space development is primarily measured by indicators such as land development breadth, population capacity index, and environmental pressure index. Urban economic benefits are assessed through the regional average gross domestic product (GDP). Land supply capacity is represented by the carrying capacities of land and water resources, where "arable land per capita" indicates the capacity of land resources, and "water resources available per unit of land area" indicates water resource capacity.

Table 1. Evaluation index system for economic benefit and balance of land development

First-level index	Second-level index	Connotation of the index	Note
Territorial space development	Land development breadth	Percentage of construction land (Yang <i>et al.</i> , 2022)	Area of urban construction land/Area of the municipal district
	Population capacity index	Population density (Tian <i>et al.</i> , 2019; Zhao & Hu, 2016)	Population of the municipal district/Area of the municipal district
	Environmental pressure index	Industrial SO ₂ and NO _x emissions per unit of urban land area (Ye <i>et al.</i> , 2023)	$\frac{1}{2} \left(\frac{SO_2 + NO_x}{2} + \sqrt{SO_2 \times NO_x} \right)$
Urban economic benefit	Economic density	Regional average GDP (Yun & Dong, 2013; Zhang <i>et al.</i> , 2020)	GDP of the municipal district/Area of the municipal district
Land supply capacity	Per capita arable land	Arable land per capita (Wei <i>et al.</i> , 2023)	Arable land area/Resident population
	Water security	Water resources available per unit of land area (Zhang <i>et al.</i> , 2017)	Total available water resources/Total area of land

3.2. Research method

The data for each index were standardized using the extreme variance treatment method (Equation I) (Huang *et al.*, 2021; Wu *et al.*, 2020):

$$A_{ij} = \frac{x_{ij} - \min(x_i)}{\max(x_i) - \min(x_i)} \quad (I)$$

where A_{ij} represents the standardized index, x_{ij} denotes each index, and x_i signifies i index of nine cities. To avoid complications in measuring relationships due to data standardization resulting in 0, this study adopts a non-zeroing process for all standardized indices (Equation II):

$$A'_{ij} = A_{ij} \times 0.9 + 0.1 \quad (II)$$

After standardizing the raw data, the territorial space development scale (TD) and land supply capacity (LS) are calculated using a combination of arithmetic and geometric averaging methods, respectively. The specific formulas are as follows (Equations III and IV) (Huang *et al.*, 2021; Wu *et al.*, 2020):

$$TD = \frac{1}{2} \left(\frac{LB + PC + EP}{3} + \sqrt[3]{LB \times PC \times EP} \right) \quad (III)$$

$$LS = \frac{1}{2} \left(\frac{PA + WS}{2} + \sqrt{PA \times WS} \right) \quad (IV)$$

In these formulas, LB represents land development breadth, PC signifies population capacity index, EP denotes environmental pressure index, PA is per capita arable land, and WS indicates water security. The coupling coordination degree model is used to measure the relationship between the territorial space development scale and urban economic benefit. The specific formulas are presented in Equations V, VI, and VII (Huang *et al.*, 2021):

$$C = \frac{(TD \times EB)}{\left[(TD + EB) \times 0.5 \right]^2} \quad (V)$$

$$T = \alpha TD + \beta EB \quad (VI)$$

$$D = \sqrt{C \times T} \quad (VII)$$

Where C is the coupling coordination coefficient, reflecting the degree of coordinated development between the territorial space development scale and urban economic benefit. D indicates the degree of coupling coordination, and T represents the overall level of land use benefit. α and β represent the importance weights of territorial space development scale and urban economic benefit, respectively; in this study, both α and β are set to 0.5. The value of C ranges from 0 to 1. Table 2 presents the division intervals and the meaning of the interpretation (Tian *et al.*, 2019; Wu *et al.*, 2020).

The final measurement of the balance between territorial space development scale and land supply capacity is conducted using the land development imbalance index model. The specific formula is as follows (Equation VIII) (Zhang *et al.*, 2017):

$$CD = \frac{TD}{LS} \quad (VIII)$$

where CD is the land development imbalance index, defined as the ratio of territorial development scale to land supply capacity. A value closer to 1 indicates more balanced development; values below 1 indicate insufficient development, and values above 1 indicate overdevelopment. Based on existing research, the balance of territorial space development is classified into five intervals according to the value of CD . Table 3 explains the CD division intervals and their meanings.

Table 2. Coupling intervals and meanings of territorial space development scale and urban economic benefit

First level	Second level		Third level
	D	Typology	
Coordinated development class (acceptable interval)	0.900 – 1.000	Excellent-level coordinated development category	TD>EB: Output lag type; TD=EB: Input-output synchronized type; TD<EB: Input lag type
	0.800 – 0.899	Good-level coordinated development category	
	0.700 – 0.799	Medium-level coordinated development category	
	0.600 – 0.699	Primary-level coordinated development category	
Transition class (transition interval)	0.500 – 0.599	Barely coordinated development category	TD>EB: Output loss profit type; TD=EB: Input-output co-loss type; TD<EB: Input loss profit type
	0.400 – 0.499	On the verge of dysfunctional recession category	
Dysfunctional recession class (unacceptable interval)	0.300 – 0.399	Mildly dysfunctional recession category	
	0.200 – 0.299	Medium dysfunctional recession category	
	0.100 – 0.199	Severe dysfunctional recession category	
	0.000 – 0.099	Extreme dysfunctional recession category	

Notes: EB: Urban economic benefit; TD: Territorial space development.

Table 3. Land development imbalance index intervals and meanings

Imbalance index/CD	State
0 – 0.4	Severe underdevelopment
0.4 – 0.8	Underdevelopment
0.8 – 1.2	Balanced development
1.2 – 4	Overdevelopment
>4	Severe overdevelopment

3.3. Data source

Due to the impact of COVID-19 on urban data after 2019, this study utilizes data from 2019. The variables considered include GDP, GDP per capita, municipal district land area, urban construction land area, municipal district population, year-end resident population, industrial SO₂ emissions per unit of construction land, industrial NO_x emissions per unit of construction land, urban arable land area, and total urban water resources for the nine prefecture-level municipalities in the Pearl River Delta urban agglomeration. The data on urban arable land area were obtained from the Guangdong Statistical Yearbook on Agriculture (2019), and the data on the year-end resident population were sourced from the Guangdong Statistical Yearbook (2019). Information on urban construction land area was acquired from the Ministry of Housing and Urban-Rural Development of the People's Republic of China (2019). The remaining data were sourced from the China City Statistical Yearbook (2019).

4. Results

4.1. Analysis of territorial space development scale

Based on the research methods, the original data were processed to yield the land exploitation intensity index,

Table 4. Analysis of land development breadth, population capacity index, and environmental pressure index in the Pearl River Delta urban agglomeration

City	Proportion of urban construction land to an urban area (%)	Population density (persons/sqkm)	Environmental pressure index
Guangzhou	9.71	1,283	12.37
Shenzhen	47.05	2,759	2.99
Zhuhai	22.50	766	12.05
Foshan	3.80	1,214	125.08
Jiangmen	8.85	817	78.25
Zhaoqing	4.02	488	233.32
Huizhou	10.34	634	64.85
Dongguan	48.55	1,020	11.99
Zhongshan	7.86	1,026	35.88

population capacity index, and environmental pressure index for each city within the Pearl River Delta urban agglomeration in 2019, as shown in Table 4.

Shenzhen and Dongguan have relatively high proportions of urban construction land and population density, while Zhaoqing has a smaller proportion, with other cities positioned in the middle. However, Zhaoqing exhibits the highest environmental pressure index, whereas Dongguan and Shenzhen show relatively lower values. There is significant variation in the indices among the cities within the area. For example, Dongguan's proportion of urban construction land is close to 50%, while Zhaoqing's is only 4%. Similarly, Shenzhen's population density reaches 2,759 inhabitants per sqkm, more than 5 times higher than Zhaoqing's 488 inhabitants per sqkm. Regarding environmental pressure, Zhaoqing's index reaches 233.32, while Shenzhen's is only 2.99. These findings indicate that

Table 5. Analysis of territorial space development scale in the Pearl River Delta urban agglomeration

City	Standardization of construction land use proportion	Standardization of population density	Standardization of environmental pressure index	Territorial space development scale
Guangzhou	0.22	0.42	0.14	0.24
Shenzhen	0.97	1.00	0.10	0.57
Zhuhai	0.48	0.21	0.14	0.26
Foshan	0.10	0.39	0.58	0.32
Jiangmen	0.20	0.23	0.39	0.27
Zhaoqing	0.10	0.10	1.00	0.31
Huizhou	0.23	0.16	0.34	0.24
Dongguan	1.00	0.31	0.14	0.41
Zhongshan	0.18	0.31	0.23	0.24

although Shenzhen has greater land development breadth and a higher population density, its economy is primarily based on a green model, resulting in a lower environmental impact. In contrast, Zhaoqing's economic development is predominantly reliant on heavily polluting industries, which significantly impact the environment.

After standardizing the data, the territorial space development scale was determined, as shown in Table 5.

The processed territorial space development scale reveals relatively small variations among the cities after synthesizing the three indices. Shenzhen has the highest territorial space development scale at 0.57, followed by Dongguan at 0.41. Huizhou, Guangzhou, and Zhongshan show the lowest values, at 0.24, while the remaining cities range between 0.32 and 0.27. The ranking of the territorial space development scale in this study aligns closely with related research on the Pearl River Delta urban agglomeration. This finding indicates that land development in the urban agglomeration is mainly centered around Shenzhen, with an overall uniform distribution across the cities.

4.2. Analysis of urban economic benefit

The raw data were processed according to the research methods outlined earlier. Table 6 presents the results of the economic density and the standardized urban economic benefit for each city within the Pearl River Delta urban agglomeration in 2019.

There are significant differences in the regional average GDP among the cities within the Pearl River Delta urban agglomeration. Shenzhen's regional average GDP (1,345 million yuan/sqkm) is 25 times higher than Zhaoqing's (53 million yuan/sqkm), the lowest among the cities. Shenzhen's economic performance stands out considerably, far exceeding Dongguan (385 million yuan/sqkm), which ranks second, and Guangzhou (318 million yuan/sqkm), which ranks third. Overall, the urban economic benefit

Table 6. Analysis of urban economic benefit in the Pearl River Delta urban agglomeration

City	Regional average GDP (hundred million yuan/sqkm)	Standardization of regional average GDP
Guangzhou	3.18	0.28
Shenzhen	13.48	1.00
Zhuhai	1.98	0.20
Foshan	2.83	0.26
Jiangmen	0.99	0.13
Zhaoqing	0.53	0.10
Huizhou	1.04	0.14
Dongguan	3.85	0.33
Zhongshan	1.74	0.18

analysis reveals that Shenzhen is particularly prominent in terms of economic density, followed by Dongguan and Guangzhou. The remaining cities exhibit lower, but relatively consistent, levels of economic benefits.

4.3. Analysis of land supply capacity

Using the research methods outlined above, the raw data were processed to determine the per capita arable land and water security for each city within the Pearl River Delta urban agglomeration in 2019, as shown in Table 7.

Jiangmen, Zhaoqing, and Huizhou have a relatively high proportion of per capita arable land area, while Guangzhou and Shenzhen have smaller proportions, with other cities falling in between. Overall, the difference in per capita arable land area across the cities within the Pearl River Delta urban agglomeration is relatively small, though all values are significantly below China's national average of 1000 m³ per capita in 2019. In terms of available water resources per unit of land area in the Pearl River Delta urban agglomeration in 2019, significant differences are observed. Jiangmen stands out with 8.936 m³/sqm, while

the rest of the cities remain below 5 m³/sqm. Foshan has the lowest availability at just 0.966 m³/sqm.

Table 8 presents the results of the land supply capacity after standardizing the data. The analysis of the standardized land supply capacity index shows that Jiangmen, Zhaoqing, and Huizhou are in the top tier, with strong land supply capacity, clearly differentiating them from the remaining cities. The lowest land supply capacities are observed in Shenzhen and Dongguan. Overall, there is a noticeable difference in land supply capacity across the cities within the Pearl River Delta urban agglomeration.

4.4. Evaluation of the coupling degree between territorial space development scale and urban economic benefit

Using the selected coupling coordination degree model, the relationship between territorial space development

Table 7. Analysis of per capita arable land and water security in the Pearl River Delta urban agglomeration

City	Arable land area per capita (m ³ /person)	Amount of water resources available per unit of land area (m ³ /sqm)
Guangzhou	51.33	1.006
Shenzhen	2.67	1.134
Zhuhai	86.00	1.162
Foshan	44.00	0.966
Jiangmen	336.00	8.936
Zhaoqing	353.33	4.991
Huizhou	284.00	4.654
Dongguan	15.33	0.971
Zhongshan	34.00	1.295

Table 8. Analysis of land supply capacity of the Pearl River Delta urban agglomeration

City	Standardization of arable land area per capita	Standardization of water resources available per unit of land area	Land supply capacity
Guangzhou	0.23	0.10	0.159
Shenzhen	0.10	0.12	0.109
Zhuhai	0.31	0.12	0.207
Foshan	0.21	0.10	0.149
Jiangmen	0.96	1.00	0.978
Zhaoqing	1.00	0.56	0.761
Huizhou	0.82	0.52	0.660
Dongguan	0.13	0.10	0.116
Zhongshan	0.18	0.14	0.158

scale and urban economic performance in the Pearl River Delta urban agglomeration is presented in Table 9.

Figures 1-3 illustrate the territorial space development scale, urban economic benefit, and coupling coordination degree in the Pearl River Delta urban agglomeration for 2019. The analysis shows that the overall level of coupling coordination in the Pearl River Delta urban agglomeration is relatively high, with all cities achieving a coordinated development status. The average coupling degree is 0.683, which corresponds to a primary level of coordinated development. The disparity between the highest and lowest coupling degrees is relatively small, with Guangzhou having the highest (0.705) and Zhaoqing the lowest (0.607), a difference of only 0.098. Specifically, among the nine cities, five are classified as having medium-level coordinated development, while the remaining four cities are at the primary coordination level. None of the cities reached excellent or good coordination levels. This result suggests that, while the economic benefits from land development in the Pearl River Delta urban agglomeration are generally high, no city demonstrates outstanding performance. The differences in economic benefits among the cities are minimal, indicating a relatively uniform development across the region.

4.5. Analysis of land development balance

Table 10 presents the results of land development in the Pearl River Delta urban agglomeration based on the selected land development imbalance index model.

Figure 4 illustrates the land development imbalance index of the Pearl River Delta urban agglomeration in 2019. The land development imbalance index is the ratio of the scale of land development to the land supply capacity, reflecting the degree of imbalance between land use and supply. A ratio closer to 1 indicates a more balanced state. Values below 1 signify underdevelopment, whereas values >1 indicate overdevelopment. Regarding the balance of land development, the entire Pearl River Delta urban agglomeration exhibits significant imbalances. Specifically, Shenzhen is in a state of severe overdevelopment. Guangzhou, Zhuhai, Foshan, Dongguan, and Zhongshan also display overdevelopment, with varying degrees of imbalance. On the other hand, Zhaoqing is underdeveloped, and both Jiangmen and Huizhou are experiencing severe underdevelopment. These findings indicate that the overall land development balance in the Pearl River Delta urban agglomeration is poor, with extreme polarization between overdeveloped and underdeveloped cities.

5. Discussion

Based on the findings, this section discusses the implications of the results in relation to territorial space

Table 9. Coupling and interpretation of territorial space development scale and urban economic benefit in the Pearl River Delta urban agglomeration

City	TD	EB	D	Coordination ordering	Type
Guangzhou	0.24	0.28	0.705	1	Medium-level coordinated development input lag type
Foshan	0.32	0.26	0.703	2	Medium-level coordinated development output lag type
Dongguan	0.41	0.33	0.703	2	Medium-level coordinated development output lag type
Zhuhai	0.26	0.20	0.702	4	Medium-level coordinated development output lag type
Zhongshan	0.24	0.18	0.701	5	Medium-level coordinated development output lag type
Shenzhen	0.57	1.00	0.681	6	Primary-level coordinated development input lag type
Huizhou	0.24	0.14	0.680	7	Primary-level coordinated development output lag type
Jiangmen	0.27	0.13	0.664	8	Primary-level coordinated development output lag type
Zhaoqing	0.31	0.10	0.607	9	Primary-level coordinated development output lag type

Notes: D: Degree of coupling coordination; EB: Urban economic benefit; TD: Territorial space development.

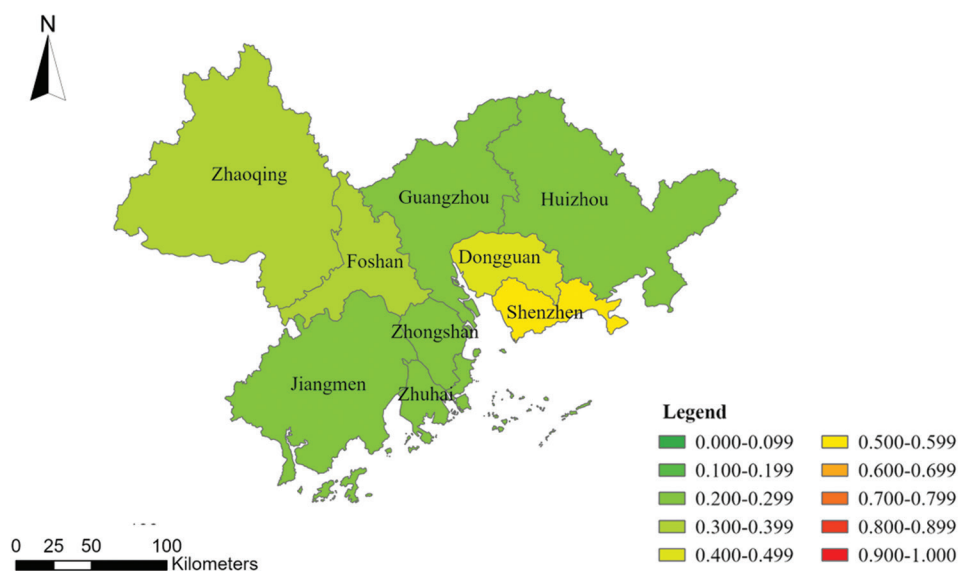


Figure 1. Territorial space development scale of the Pearl River Delta urban agglomeration, 2019. Source: Drawing by the authors

utilization, economic benefits, and land supply capacity within the Pearl River Delta urban agglomeration. The territorial space development scale within the Pearl River Delta urban agglomeration is the largest in Shenzhen, with only minor differences across the cities. Specifically, Shenzhen and Dongguan exhibit higher proportions of construction land and population density, while Zhaoqing is smaller in these aspects. Conversely, their environmental pressure indices show opposite trends. When these three indicators are integrated, the territorial space development scale across the Pearl River Delta urban agglomeration is relatively balanced.

In terms of urban economic benefit, Shenzhen stands out as the most significant, followed closely by Dongguan and Guangzhou. The remaining cities exhibit lower but more consistent economic benefits.

Regarding land supply capacity, there are significant differences within the Pearl River Delta urban agglomeration. The differences in per capita arable land are small and uniformly low across cities. However, in terms of water resources available per unit of land area, Jiangmen stands out, whereas other cities have lower values. When both indicators are combined, Jiangmen, Zhaoqing, and Huizhou exhibit higher land supply capabilities, whereas Zhongshan ranks lower.

The territorial space development scale and urban economic benefit in the Pearl River Delta urban agglomeration are overall in a phase of coordinated development, with minor differences in the coupling degree between the two aspects among cities. Shenzhen leads in both territorial space development scale and urban economic benefit within the agglomeration, while the

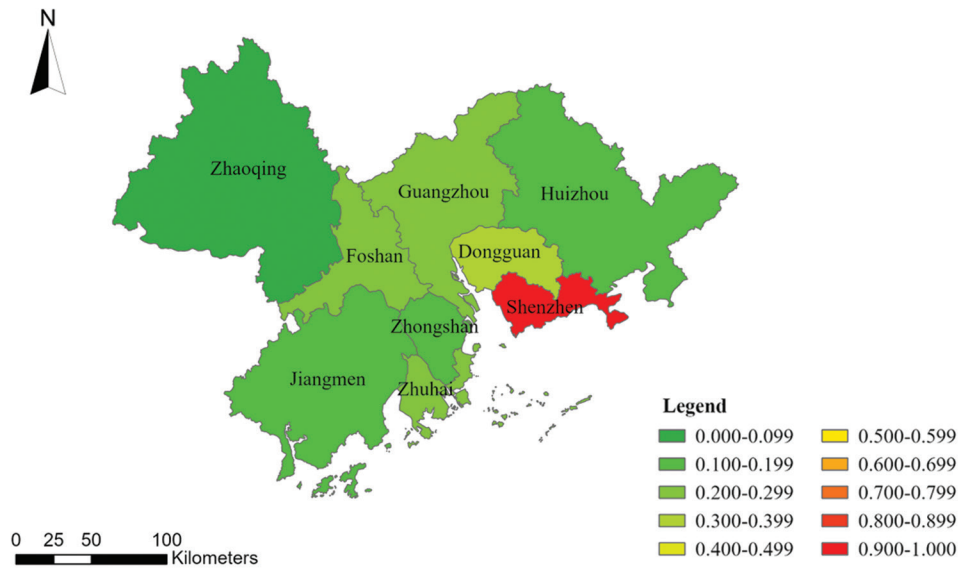


Figure 2. Urban economic benefit of the Pearl River Delta urban agglomeration, 2019. Source: Drawing by the authors

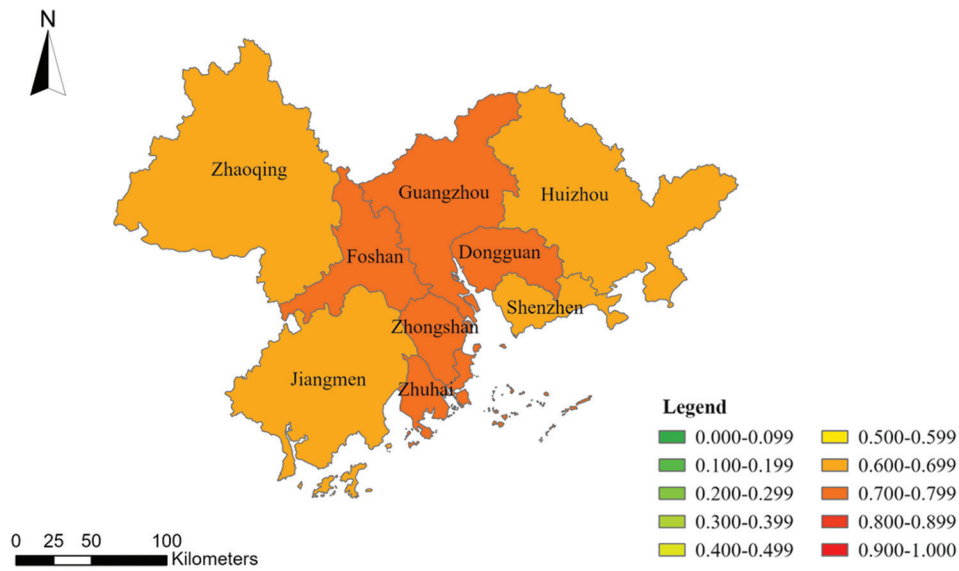


Figure 3. Coupling coordination degree of the Pearl River Delta urban agglomeration, 2019. Source: Drawing by the authors

provincial capital, Guangzhou, exhibits the highest balance between these two aspects. When comparing inputs and outputs, Guangzhou and Shenzhen are characterized as having lagging inputs, while the remaining cities are categorized as having lagging outputs. To maintain coordinated development, adjustments should be made to align inputs and outputs for different cities, effectively controlling the intensity of land development and enhancing the economic output efficiency of land.

The land development balance in the Pearl River Delta urban agglomeration exhibits extremes. Among the nine

cities, six are in a state of overdevelopment, with Shenzhen and Zhongshan experiencing severe overdevelopment. The remaining three cities are underdeveloped, among which Jiangmen and Huizhou are in a state of severe underdevelopment. It is advisable to reference the land development limits set by each province and city. For cities experiencing severe overdevelopment, emphasis should be placed on improving urban land supply capacity, controlling the scale of construction land, and exploring the redevelopment of existing land. For severely underdeveloped cities, construction land indicators should

Table 10. Land development imbalance and interpretation in the Pearl River Delta urban agglomeration

City	TD	LS	CD	State
Guangzhou	0.24	0.16	1.53	Overdevelopment
Shenzhen	0.57	0.11	5.26	Severe overdevelopment
Zhuhai	0.26	0.21	1.24	Overdevelopment
Foshan	0.32	0.15	2.14	Overdevelopment
Jiangmen	0.27	0.98	0.28	Severe underdevelopment
Zhaoqing	0.31	0.76	0.41	Underdevelopment
Huizhou	0.24	0.66	0.36	Severe underdevelopment
Dongguan	0.41	0.12	3.59	Overdevelopment
Zhongshan	0.24	0.16	1.50	Overdevelopment

Notes: CD: Land development imbalance index; LS: Land supply capacity; TD: Territorial space development.



Figure 4. Land development imbalance index of the Pearl River Delta urban agglomeration, 2019. Source: Drawing by the authors

be prioritized to explore efficient land development. In addition, in the context of supply-side reforms, enhancing the output efficiency of agricultural land and establishing an eco-friendly land development model can strengthen land supply capacity. This approach can unearth new development potential for areas facing tense construction land supply and maintain a dynamic balance between overall regional land development and supply.

Urban land serves as a crucial spatial carrier for the interaction and exchange of various urban elements, playing a fundamental role in urban and regional development (Chen *et al.*, 2022). Chinese cities have achieved significant developmental progress during the rapid urbanization phase. However, the substantial expansion of urban space has accentuated conflicts between urban development, farmland protection, and ecological conservation, generating various social and environmental pressures and impacts (Hernández & Camerin, 2023). These

issues considerably constrain the advancement of high-quality regional development. Thus, sustainable urban development demands continuous improvements in land use efficiency to achieve economic, social, and ecological benefits (Shang *et al.*, 2022).

This study focuses on the contradictions between development needs and ecological capacity caused by rapid urbanization. Building on existing research, it comprehensively considers the balance between land, economy, and ecology in urban development. Through scientific quantitative analysis, it evaluates the balance of land development in the Pearl River Delta urban agglomeration. As one of China’s three major urban clusters, the Pearl River Delta has undergone significant changes in land use patterns in recent years due to regional planning efforts. Rapid regional economic development, large-scale population aggregation, and the continuous expansion of urban and construction land have made land resources increasingly scarce, highlighting the human-land conflict. Coordinating land development with ecological construction is especially important (Hu *et al.*, 2021). This research enriches the theory and practice of land space development and sustainable development, contributing to the coordinated development and utilization of land space.

However, this study has certain limitations. First, due to the varying degrees of impact of the COVID-19 pandemic on post-2020 urban data, this study only uses data from 2019. Consequently, it may not fully reflect recent trends in territorial development in the Pearl River Delta urban agglomeration. Second, the study’s scope could be expanded to include micro-scale analyses at the town and township levels for more precise results. Finally, data limitations affect the comprehensiveness of the land supply capacity evaluation. Future research should integrate approaches such as major function-oriented zoning, the delineation of “three zones and three lines,” and the “double evaluation” (i.e., resource and environment carrying capacity evaluation and territory space suitability evaluation) to enhance the depth of the evaluation mechanism.

6. Conclusion

In conclusion, this study investigated the non-equilibrium of territorial space utilization benefits in nine cities within the Pearl River Delta in 2019. By developing a comprehensive evaluation index system that incorporates territorial space scale, urban economic benefits, and land supply capacity, the study provides a holistic analysis of land use benefits and their coordination. The analysis of land development imbalance reveals that overdevelopment is a key issue for many cities, particularly Shenzhen, while

underdevelopment is a challenge for other cities, such as Jiangmen and Huizhou. These findings underscore the importance of balancing land use intensity with sustainable urban growth, particularly in regions experiencing rapid urbanization. Overall, this research contributes to a deeper understanding of land space development and provides practical insights for promoting more balanced and sustainable urban development in the Pearl River Delta.

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Conflict of interest

The authors declare they have no competing interests.

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Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

In this paper, data from 2019 were selected for nine prefecture-level municipalities in the Pearl River Delta urban agglomeration, including GDP, GDP per capita, land area of the municipal district, urban construction land area, municipal district population, year-end resident population, industrial SO₂ emissions per unit of construction land, industrial NO_x emissions per unit of construction land, urban arable land area, and total urban water resources. The data on urban arable land area are available from the Guangdong Statistical Yearbook on Agriculture (2019), and the data on the year-end resident population are available from the Guangdong Statistical Yearbook (2019). Information on urban construction land

area is available from the Ministry of Housing and Urban-Rural Development of the People's Republic of China (2019). The remaining data are available from the China City Statistical Yearbook (2019).

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ORIGINAL ARTICLE

Development of a machine-simulated human scoring model for assessing child-friendly street environments: A case study of Sham Shui Po, Hong Kong SAR, China

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Abstract

With a growing interest in liveable cities, scholars and urban planners are increasingly studying the characteristics of child-friendly cities, including the ability to walk and move freely in public spaces. While machine learning techniques and street view imagery analysis have enabled the systematic analysis of streets, they have not yet been applied to assess street environments from a child's perspective. This study explores the use of deep learning models to address this gap by developing a machine-simulated human scoring model to assess health and safety indicators in urban streets. Using a high-density, old urban district in Hong Kong SAR, China, as a case, the study used semantic segmentation to analyze street environmental features and extract elements related to safety, such as greenery, vehicles, and fences. Subsequently, the model generated safety ratings, which were compared with scores provided by volunteer caregivers. The results indicate that natural elements and fences enhance safety, whereas an excess of buildings diminishes it. In contrast to European cities, where high visibility and larger sky proportions are considered beneficial for health, these factors were less relevant in the high-density, tropical context of Hong Kong. This analysis highlights the robustness and efficiency of the model, which can assist researchers in other cities in collecting empirical user rating data and informing strategies for more child-friendly urban planning.

Keywords: Child-friendly cities; Street perception; Street view imagery segmentation; Machine-simulated human scoring model

1. Introduction

As contemporary cities continue to expand in size and complexity, their internal reorganization often leads to inequalities in neighborhood characteristics, with varying physical attributes and differing economic and social prospects for communities (Salesses *et al.*, 2013). Children, comprising nearly 30 percent of the world's population (UNICEF, 2023), experience a range of impacts from their environments. The child-friendliness of streets is an important factor in promoting their physical health and

psychological well-being (Li, 2016), particularly in low-income neighborhoods (Hou *et al.*, 2022).

Urban planning and design guidelines for child-friendly streets emphasize the necessity for safe and healthy mobility options, ensuring secure infrastructure, equitable access to city services, and promoting well-being for children and their caregivers (Nikku & Pokhrel, 2013; Sapsağlam & Eryılmaz, 2024). Key elements include continuous and accessible pedestrian infrastructure (Peng, 2020; Rini, 2019), safe cycling and transit facilities (Kingston *et al.*, 2007; Smith *et al.*, 2022), green spaces (Vidal & Castro Seixas, 2022; Yuniastuti & Hasibuan, 2019), and adequate natural daylight (Ding *et al.*, 2023; Jahromi, 2020). In addition, a visually stimulating environment can stimulate the development of cognitive skills in children (Berk, 2015; Bornstein, 1985), especially during their peak growth and learning periods (Read *et al.*, 1999). For comfort and convenience, streets should be well-connected, providing a diverse array of pedestrian pathways (Burden *et al.*, 1999), reliable public transport (Bertolini, 2020), clear signage and schedules (Bain *et al.*, 2012), climate-appropriate shade and shelter (Wheeler *et al.*, 2019), and facilities such as restrooms and drinking fountains (NYC, 2010).

Urban scholars have long been assessing urban street environments, particularly in understanding how the physical environment and its visual impact shape observers' experiences (Ewing & Handy, 2009; Lynch, 1964; Nasar, 1990; Sanoff, 2016; Zhang *et al.*, 2018). These studies have primarily relied on traditional data collection methods such as interviews and questionnaires (Montello *et al.*, 2017; Raimbault *et al.*, 2003; Sholihah & Heath, 2016), which require substantial manpower, costs, and time. Such methods limit research scalability, often constraining studies to small geographic areas (Zhang *et al.*, 2018). Previous street studies have predominantly focused on adults' experiential aspects, with minimal attention given to the comfort and safety of children, such as their ability to travel alone. Torres (2020) has argued that many cities prioritize traffic and parking in street planning, reducing the walkability and sociability of street environments and adversely affecting local communities.

This study explores the application of machine learning predictive models in assessing the comfort and safety of children on urban streets. A street view recognition approach was to identify potential barriers to children's safe and free movement and to highlight locations for improvement. The rest of this article is divided into four sections. First, it introduces the background of using machine learning methods for street analysis. Second, it presents the case study project and technical workflow. Third, it evaluates the outcomes of the deep-learning

method. Finally, it discusses general conclusions and recommendations for further research.

2. Child-friendly streets and emerging research methods

2.1. Child-friendly streets

Streets serve as crucial conduits for children's travel and play a key role in facilitating child-friendly mobility. Child-friendly streets not only provide safe and comfortable environments for children's journeys but also contribute positively to their physical development, mental well-being, and social interactions (Cheng *et al.*, 2024). By examining how children navigate urban areas, researchers can gain valuable insights into how streets influence children's safety, development, and independence (McMillan, 2005). Brown *et al.* (2019) emphasize that prioritizing active travel and separating motor vehicles from streets and public spaces can enhance children's safety.

Street design guidelines are widely available across regions and countries; however, they often prioritize traffic over the needs and travel patterns of children (Harirchian *et al.*, 2018). Despite regional variations, children encounter various travel-related risks, such as road crossings, nighttime travel, and unaccompanied use of public transportation (Shaw *et al.*, 2015), which typically require adult supervision or a companion (Mehtap, 2016). Johansson (2006) found that children's outdoor activities are influenced by individual factors, such as parents' perception of the quality of traffic environments, sidewalks, and bike lanes. Due to their young age, children often travel with others (McDonald, 2006), such as their caregivers. Villanueva *et al.* (2013) posited that street accessibility and safety are associated with children's ability to travel independently.

2.2. Emerging research methods using computer vision

Visual observations provide one of the most intuitive ways for urban residents, including children, to perceive their surroundings (Ulrich, 1979). The availability of online data resources, such as Google Street View, has introduced new opportunities for analyzing urban perceptions through geo-tagged imagery. Street-level image processing now allows for the extraction of spatial features and quantifiable data, employing machine learning protocols to process extensive datasets rapidly and assess city blocks on a large scale (He & Li, 2021). Map service providers such as Google Maps facilitate automated workflows connected to their Application Programming Interfaces (APIs), enabling researchers to systematically gather imagery across thousands of cities

in more than 20 countries on four continents (Anguelov *et al.*, 2010).

Since 2017, there has been a significant advancement in street-level image recognition research, with most scholars focusing on the quantitative assessment of urban spatial qualities, street morphology, and street-based human activities (He & Li, 2021). The Massachusetts Institute of Technology (MIT), for example, has leveraged street-level imagery to study greenery levels and sunlight exposure on streets (Salesses *et al.*, 2013). Researchers at the University of Connecticut introduced a technique to categorize different land-use types and landscape features through street-level imagery (Li *et al.*, 2015). Meanwhile, the City University of Hong Kong and Tsinghua University focus on researching street canyon quality, with an emphasis on physical environments and human activities in high-density cities. These scholars have proposed a framework for studying cities from a human-scale perspective (He & Li, 2021).

However, there is a scarcity of research explicitly addressing children's points of view, such as their safety and comfort. Torres (2020) advocates for the consideration of children and adolescents, along with their activities, in street network design and development. He emphasizes the necessity of creating a street environment where parents and guardians feel at ease without the need for constant supervision to ensure their children's safety. Newly developed technologies and methods for analyzing street characteristics are particularly suited to studying factors influencing children's safety, health, and well-being. Relevant factors include sidewalks, crosswalks, traffic density, green spaces, and other environmental aspects that may affect children's sense of safety, comfort, and spatial awareness in the streetscape.

Deep learning is a research tool inspired by the structure and function of the human brain. It enables computer vision technology to process large-scale street view images (SVIs) efficiently in a hierarchical manner, extracting features and making predictions (Trichès Lucchesi *et al.*, 2023). Typically, a large number of annotated images are required for training. To extract street elements, the most commonly used semantic segmentation models are SegNet (Badrinarayanan *et al.*, 2017; Song *et al.*, 2023), DeepLab (Nagata *et al.*, 2020), FCN-8 (Kim *et al.*, 2021), and Pyramid Scene Parsing Network (PSPNet) (Koo *et al.*, 2022). This study used PSPNet due to its high accuracy in image segmentation and target detection tasks, as well as its robust performance in ensuring accurate and reliable street feature extraction (Zhao *et al.*, 2017).

Despite the trend toward incorporating user feedback in urban space design, most urban assessment tools are

geared toward adults. Standard methods for predicting image labels include convolutional neural network methods, which significantly outperform traditional methods (Dubey *et al.*, 2016). The fully convolutional neural network is particularly useful for identifying objects in images or segmenting street views, as it retains spatial information throughout the network. Support vector machines are another class of supervised learning models that perform well in classification and regression tasks (Naik *et al.*, 2014; Ordonez & Berg, 2014; Porzi *et al.*, 2015), particularly in processing high-dimensional space data such as city image features, which contain extensive visual information. Experiments in Ordonez & Berg's (2014) work demonstrate that even when trained and tested across different cities, the support vector machine model maintains a high degree of accuracy in predicting human perceptual attributes (such as wealth, uniqueness, and safety) in urban environments, demonstrating its generalization and robustness. Yao *et al.* (2019) have proposed a deep learning-based human-machine adversarial framework that utilized a random forest-based module to investigate the relationship between street view elements and user scores.

Using these models, researchers have successfully predicted human perception indicators in SVIs, such as safety, liveliness, and attractiveness (Zhang *et al.*, 2019). In addition, the linkages between street view elements and user ratings reveal how visual elements affect residents' perception of streets (Yao *et al.*, 2019; Zhang *et al.*, 2018). However, previous studies have largely failed to consider the distinct requirements of children, such as low sight lines, the need for safe play spaces, and heightened sensitivity to traffic noise. Conducting surveys with children also poses unique challenges compared to those with adults. This research gap underscores the need for a dedicated approach to assessing child-friendly streets. For this study, we developed a new method, the "machine-simulated human scoring model," to address the challenges of assessing child-specific urban environment perception. This method combines computer vision segmentation and deep learning techniques, using an iterative feedback mechanism to simulate the subjective perception of pedestrians in evaluating the spatial characteristics of streets.

To test the usability of the perceived score prediction model, we used the Sham Shui Po district in Hong Kong SAR, China, as the case study area. This district was chosen for its street block-based planning model (Hui, 2015) and mixed demographics, including a relatively large proportion of low-income residents and families with young children (Cheng, 2013).

3. Methodology framework

3.1. Sham Shui Po district

According to the 2016 Population By-Census Statistics, the Sham Shui Po district has a population of approximately 405,000 people, with 12% below the age of 15, as seen in Figure 1. As a historic and culturally rich district undergoing urban transformation and gentrification, targeted research is needed to ensure that urban planning and development do not exclude vulnerable groups such as ethnic minorities, recent immigrants, and low-income families (Hong Kong Census and Statistics Department, 2016). The high building density and small apartment sizes in this area make public open spaces essential for fostering a sense of belonging among children and supporting their development. Through their influence on everyday activities, these spaces significantly impact children’s health, well-being, and quality of life. The district’s streets form a public space network that promotes social inclusion and equity and supports the community’s cultural identity and traditions.

3.2. Methodology workflow and indicators

The research framework for this study, illustrated in Figure 2, focused on developing a street view imagery-based visual perception assessment process. Using Hong Kong geographic mapping data and Google Maps, we gathered information from specific street segments within the case study area. First, we collected Google Street

View photographs of these segments, merging them into panoramic images. The panoramas were generated automatically using Python and OpenCV protocols, then processed through semantic segmentation to detect distinct elements such as individuals, structures, and the sky. Feature detection and matching were performed using the scale-invariant feature transform (SIFT) algorithm, and the random sample consensus (RANSAC) algorithm was employed to estimate the homograph matrix, ensuring precise alignment and seamless image merging. The SIFT and RANSAC algorithms were chosen for their exceptional robustness and accuracy in image matching and panorama creation (Fischler, 1981; Lowe, 2004). Street view features were then statistically examined, with categorized results filtered to construct a dataset for evaluating perceptions of safety and health.

Second, the classified data were input into a deep learning model combining a fully convolutional neural network with a support vector machine. This model was used to predict visually perceived quality scores of the street environment. In the third stage, we performed Spearman correlation analysis to explore correlations between perception scores and image features. In the final phase, these results were used to refine the extraction and classification of streetscape elements, improving the machine learning-based prediction method for street perceptions and validating the study’s methodology workflow.

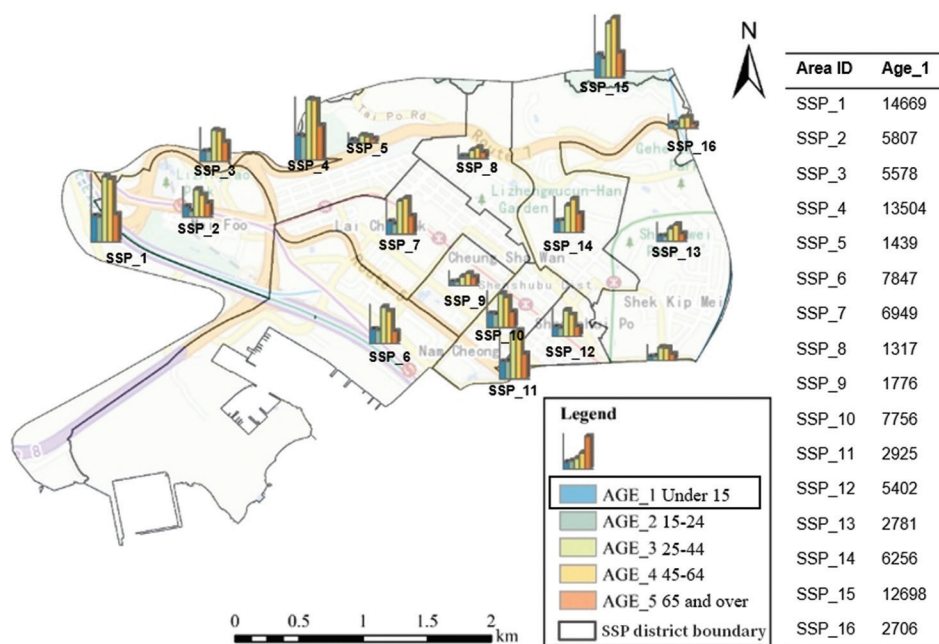


Figure 1. Age distribution in the Sham Shui Po district, Hong Kong SAR, China. Source: Drawing by the authors

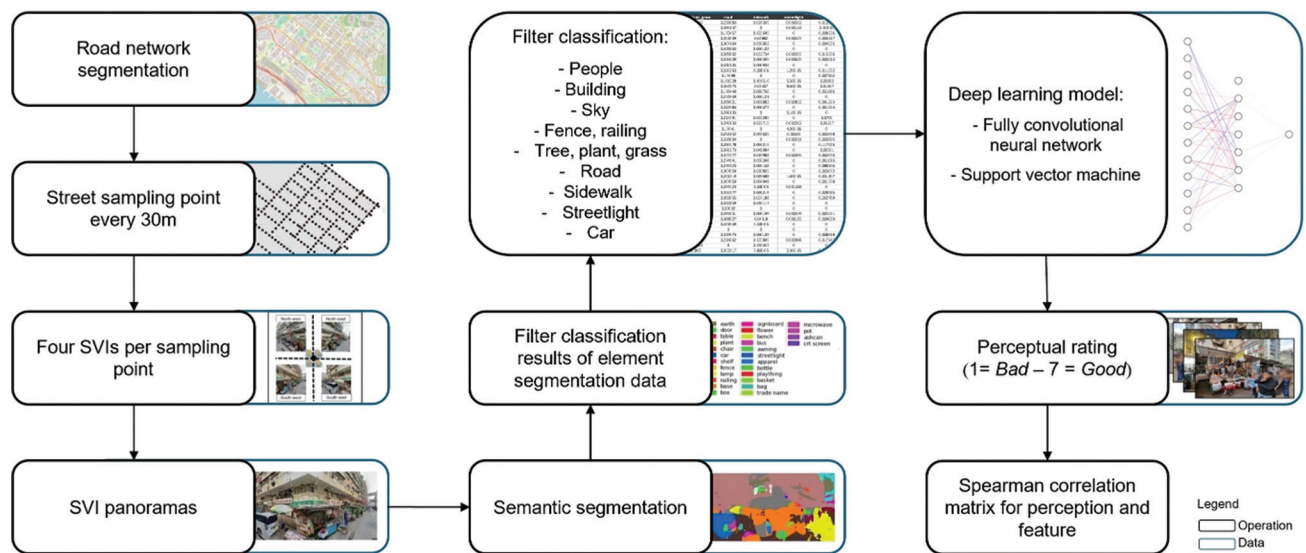


Figure 2. Research framework. Source: Chart by the authors
Abbreviation: SVI: Street view image.

This article introduces new data-driven workflows for the acquisition and panoramic synthesis of SVIs and the use of machine learning for feature analysis and prediction. These methods have the ability to systematically quantify and analyze visual elements in street spaces and environments, providing a means to explore how urban design affects children’s perceived safety and health. The workflow-enabled measurement, comparison, and interpretation of various street characteristics, illuminating how these factors contribute to creating a safe and healthy street environment.

For this study, we defined the child-friendliness of a street environment as its capacity to meet children’s physical safety, psychological well-being, and developmental needs. To operationalize this definition for analysis, we derived the following street environment indicators:

- (i) Pedestrians: High pedestrian density indicates safer, more social streets, often meaning reduced vehicular traffic, increased supervision, and more opportunities for children’s social interactions.
- (ii) Buildings: The layout and density of buildings affect children’s perceptions and interactions within their environment. Façade openings and well-organized layouts encourage exploration and activity.
- (iii) Sidewalks and roads: Safe, well-designed sidewalks are crucial for children’s safe walking and play, while well-maintained roads help prevent traffic accidents, ensuring children’s safety.
- (iv) Fences and railings: Fences and railings prevent children from accessing dangerous areas, including busy roads or construction sites, ensuring their safety in play areas.

- (v) Sky: Visible sky contributes to children’s mental well-being by reducing the sense of urban confinement and making outdoor environments more comfortable.
- (vi) Greenery: Urban greenery supports psychological health, improves air quality, reduces noise, provides shade, and enhances children’s physical and mental health, making outdoor activities more attractive.

This quantitative analysis of specific elements informed the integration of a machine-learning model to assess the presence and quality of these features, as detailed in Table 1.

3.3. Data structure

Table 1 lists the indicators used for assessing street vitality, documenting the literature sources, equations, and definitions applied in the study.

The research data structure is shown in Figure 3, comprising quantitative assessments based on safety and health indicators derived from machine-simulated models and manual ratings. Correlation data were analyzed to examine the relationships between street elements and safety/health scores. Data sources included Google Street View, Google Maps API, and PSPNet. Images were processed using Python and OpenCV and then identified through deep learning models, such as fully convolutional neural network and support vector machine, implemented using TensorFlow and Keras. The outputs were safety and health scores, which were used as input features for training and validating a robust predictive model. In addition, insights from correlation analyses were generated.

The data processing in this study involved the integration of diverse data components. The workflow started with collecting geolocation data on street

Table 1. Child-friendly street indicators contributing to safe and healthy environments

Indicator	References	Equation	Explanation and interpretation in SVI
Pedestrian	Burden <i>et al.</i> , 1999	$\frac{P}{T}$	<i>P</i> (People) is the percentage of pixels in an SVI.
Building	Bornstein, 1985	$\frac{B}{T}$	<i>B</i> (Building) is the percentage of pixels in an SVI.
Road	Burden <i>et al.</i> , 1999	$\frac{Road}{T}$	<i>R</i> (Road) is the percentage of pixels in an SVI.
Sidewalk	Burden <i>et al.</i> , 1999:	$\frac{S}{T}$	<i>S</i> (Sidewalk) is the percentage of pixels in an SVI.
Lights	Ding <i>et al.</i> , 2023; Jahromi, 2020	$\frac{L}{T}$	<i>L</i> (Lights) is the percentage of pixels in an SVI.
Fences	Kingston <i>et al.</i> , 2007	$\frac{F}{T}$	<i>F</i> (Fences) is the percentage of pixels in an SVI.
Railing	Kingston <i>et al.</i> , 2007	$\frac{R}{T}$	<i>R</i> (Railing) is the percentage of pixels in an SVI.
Sky	Vidal & Castro Seixas, 2022	$\frac{Sky}{T}$	<i>Sky</i> (Sky view) is the percentage of pixels in an SVI.
Tree, plant, grass	Yuniastuti & Hasibuan, 2019	$\frac{G}{T}$	<i>G</i> (Greenery coverage) is the percentage of pixels in an SVI.

Note: *T* represents the total pixels in a street view image (SVI).

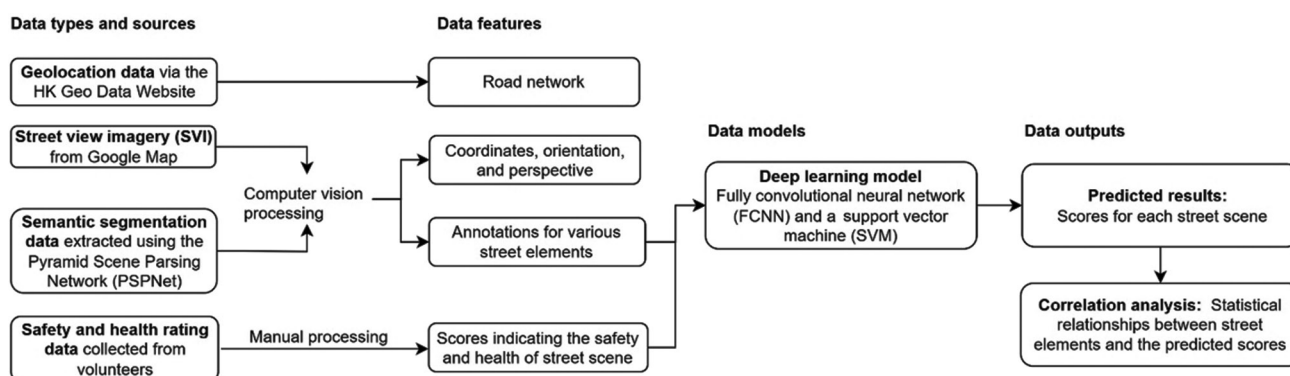


Figure 3. Data structure. Source: Chart by the authors

networks, SVIs, and semantic segmentation data from the SVI dataset. This combination of data inputs enabled a comprehensive analysis of street environments, connecting visual components with their geographic details.

Model training and validation utilized safety and health indicators, as well as correlation data. Numerical ratings were assigned to represent the safety and health characteristics of each street scene. The correlation data helped identify statistical links between various street elements and their

corresponding perceived safety and health scores. This workflow allowed efficient model training and testing, leveraging the intricate input features and critical safety and health indicators to forecast street condition assessments.

4. Technical workflow

4.1. SVI data processing

Previous studies have discussed the accuracy of using SVIs as research data, acknowledging limitations related

to interval distance and time-of-day variations. However, a consensus has emerged that the methodology produces reliable results when the study area is sufficiently large (Kim *et al.*, 2021). For example, some previous studies have used 50 m intervals for street greenery research (Lu *et al.*, 2019; Ye *et al.*, 2019), while others applied sampling points every 50 and 100 m (Law *et al.*, 2020; Yang *et al.*, 2019). In this study, we selected a 30 m interval to capture SVIs, using Python in conjunction with the Google Maps platform and Google API to capture parameters such as geolocation coordinates, orientation, perspective, and field of view. Each sample point included four images facing south, north, east, and west.

We used detailed street mapping data obtained from the Hong Kong GeoData website, which required street consolidation, simplification, and topological treatment of road networks to streamline the SVI data collection process. For this study, we selected 29 living streets in the central area of Sham Shui Po (Figure 4) and excluded expressways and elevated roads to focus on public streets that foster connectivity and socializing for local residents.

To ensure quality in SVI extraction, precise parameters for perspective and dimensions were set. Python's urllib module was used to download SVIs with strategic overlaps, enabling four images from different angles to be merged into a single panoramic view. Tools like OpenCV and Numpy facilitated image integration, enhancing the efficiency of the image segmentation processes. Our project adopted the semantic segmentation method PSPNet (Zhao *et al.*, 2017)

to extract the pixels of streetscape features (Figure 5). This approach enhanced scene comprehension at both global and local scales by up-sampling and concatenating features across various scales, allowing efficient semantic segmentation by accurately categorizing each pixel through the classification layer. PSPNet was trained on the ADE20K dataset, which can segment 150 object classes. For this study, we focused on 10 object classes of streetscape features relevant to children commuting to school, to evaluate streetscape features contributing to the concept of “child-friendly cities.”

To evaluate PSPNet’s performance on the output dataset, we used the pixel accuracy metric, the simplest classification accuracy measure that calculates the percentage of correctly classified pixels in the image.

For each row (each SVI), we calculated the sum of the correctly classified pixel proportions across all categories:

$$\text{Total Accuracy}_{-i} = \sum_{-j=1}^O \{O\} p_{-ij} \tag{I}$$

where p_{-ij} represents the proportion of correctly classified pixels for category j in row i , and O is the total number of object classes.

Next, we calculated the average of the total accuracies across all rows (SVIs):

$$\text{Pixel Accuracy} = (1 / N) \sum_{-i=1}^N \text{Total Accuracy}_{-i} \tag{II}$$

where N is the total number of images.

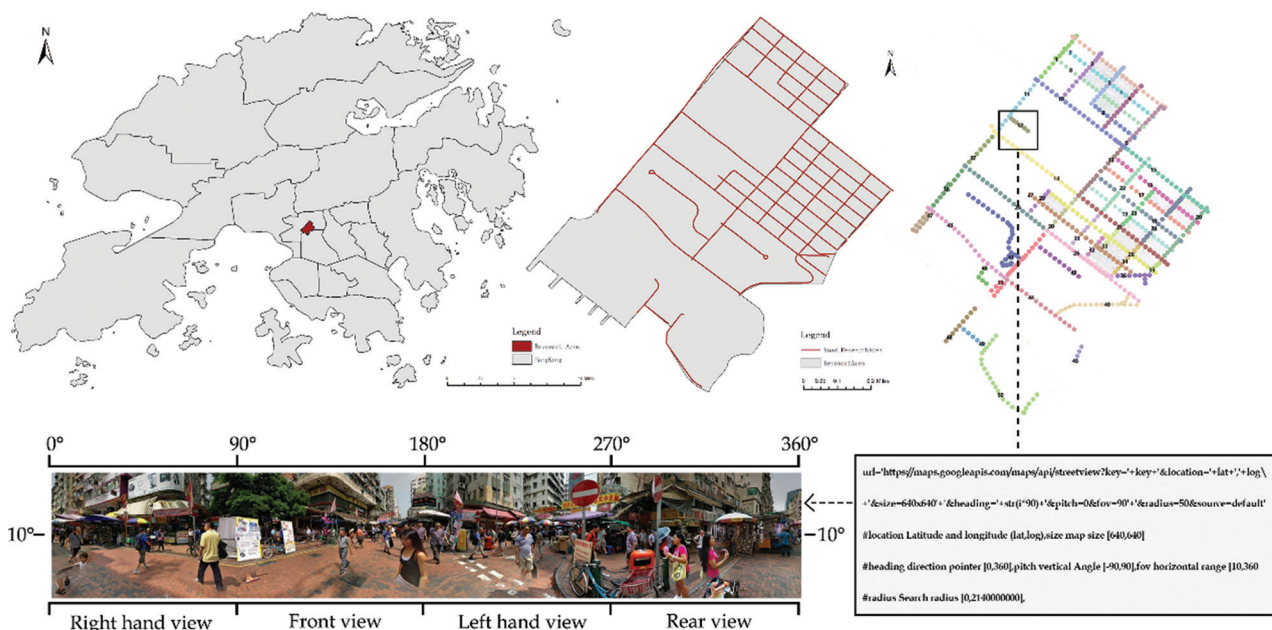


Figure 4. Site location, street segmentation, and example of the street view image collection process. Source: Drawing by the authors



Figure 5. Image segmentation process. Source: Drawing by the authors

Each row of data represented the proportion of correctly classified pixels for each label, allowing us to directly obtain pixel accuracy by summing the proportions for all categories and averaging. Using this approach, we calculated a pixel accuracy of 0.9794, indicating high accuracy and effective model performance on this dataset.

Achieving child-friendly streets requires continuous, accessible walking paths and a safe walking environment (Global Designing Cities Initiative, 2019). The separation of sidewalks from vehicle traffic was measured by identifying fences or railings in the SVI data. Green spaces and parks were identified by highlighting trees and landscaped areas, creating a natural environment that contributes to physical and mental health. In addition, social safety was evaluated by identifying street lighting devices that contribute to creating safer urban environments for children and their caregivers.

4.2. Machine-simulated human scoring model

After collecting and processing SVI data, a fully convolutional neural network, and a support vector machine prediction model were developed to forecast scores for specific scenes based on urban landscape characteristics. The model design is based on the scoring framework for human-machine adversarial models proposed by Yao *et al.* (2019) and Zhang *et al.* (2018). The prediction of human perception is presented as a classification task. Support vector machine, known for its practicality and widespread use in classification tasks, is used here to fine-tune the score range from 0 – 10 based on a single sample, differing from MIT Place Pulse’s binary classification format, which emphasizes comparative scoring (Zhang *et al.*, 2018). The model used in this project to predict safety perception was trained after construction by referring to the datasets of Yao *et al.* (2019) and Han *et al.* (2022), specifically incorporating a dataset of Shenzhen with real score annotations provided by volunteers for each image. In this research, we utilized 4,000 annotated SVIs to enhance feature extraction precision, dividing these images into two sets: 80% for training and 20% for

validation. The dataset covered nine feature categories along with a default scoring system for training purposes.

Support vector machine models provided the capability to handle non-linear decision boundaries, offering precise and dependable predictions. They are particularly suited for regression tasks and effectively handle intricate datasets, a crucial advantage in urban design applications where high precision is of utmost importance. Model evaluation involved calculating the mean square error for predictions made on the test dataset, with the mean square error scores utilized to evaluate the model’s performance and reliability.

Figure 6 illustrates the sequence of steps involved in training and operating the prediction model. This workflow demonstrates the steps required to initiate the fully convolutional neural network model for SVI feature extraction, followed by the support vector machine model for generating scoring predictions. The interconnected components and steps were designed to ensure robust and accurate model training, contributing to improved prediction accuracy and system robustness.

The fully convolutional neural network model’s input data comprised the first nine columns of the segmented dataset, with the final attribute being the score predicted by the model. The dataset featured nine distinct elements, namely “people,” “building,” “sky,” “fence_railing,” “tree_plant_grass,” “road,” “sidewalk,” “streetlight,” and “car.” The initial nine features served as input variables for the model, while the final feature represented the model’s target score. The dataset was partitioned into a training set (80%) and a test set (20%) with the “random_state” parameter ensuring reproducibility of the outcomes. The model, constructed using the TensorFlow Keras framework, employed a sequential architecture with a fully connected layer and a dropout layer to reduce overfitting. It was trained for 10 epochs, with 20% of the training data reserved for model validation, using the Adam optimizer and mean square error as the loss function.

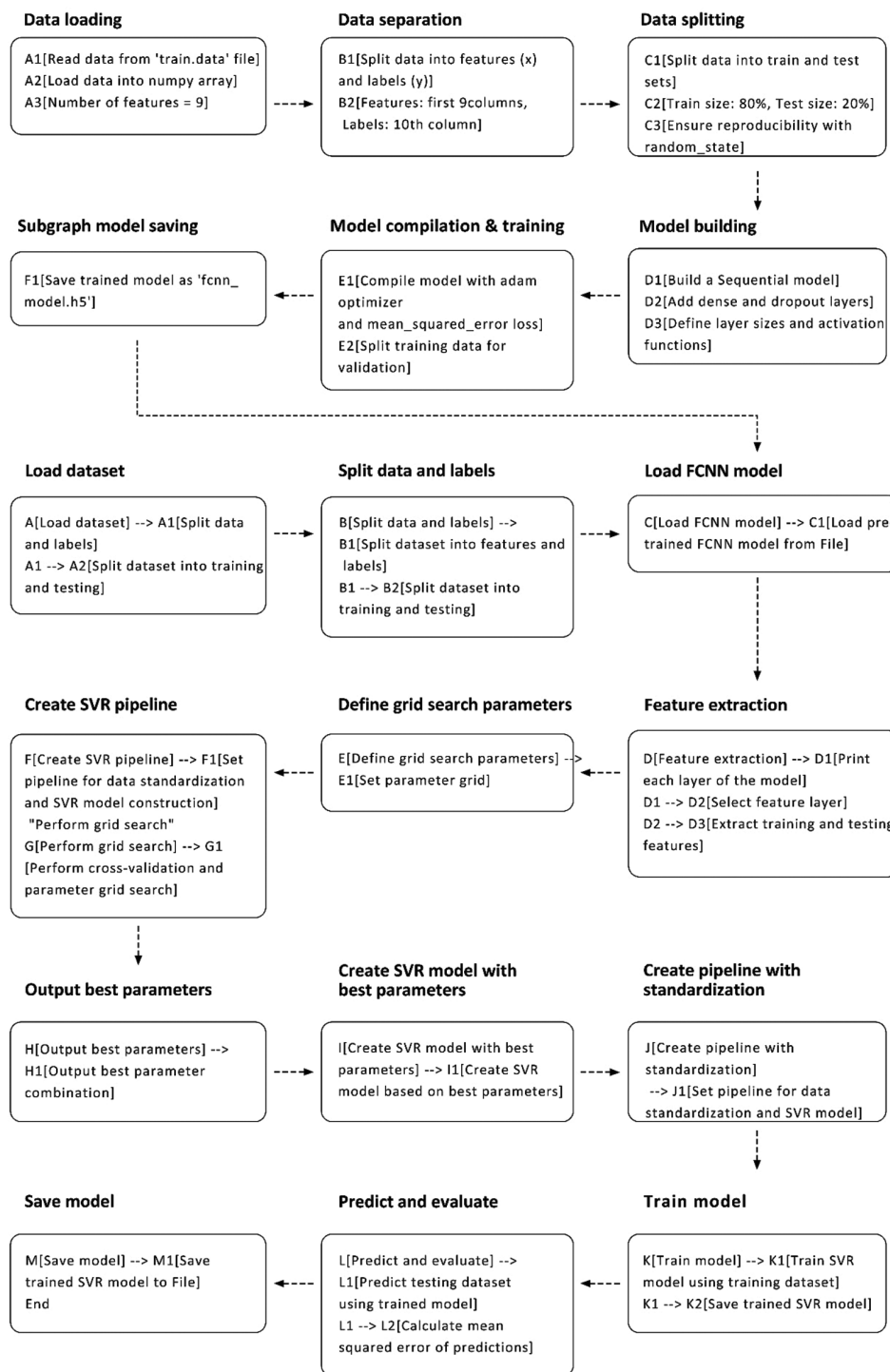


Figure 6. Machine-simulated human scoring model workflow. Source: Flowchart by the authors
Abbreviations: FCNN: Fully convolutional neural network; SVR: Support vector regression.

The fully convolutional neural network of our model was trained on the data from the training set to recognize and extract the most critical information or characteristics for assessing street safety. Support vector regression was

employed to optimize a set of parameters, enhancing prediction accuracy and reliability. Regularization parameters helped prevent overfitting (i.e., when the model becomes overly sensitive to the training data, leading to

poor performance on new data), while the kernel function enabled the model to manage non-linear relationships in the data. In addition, the gamma parameter and epsilon tolerance fine-tuned the accuracy and error tolerance of the model's predictions.

5. Analysis and results

5.1. Feature-score correlations

To investigate the relationships between perception scores and SVI features, a Spearman correlation analysis was conducted, considering both data characteristics and analysis objectives. This method helps to understand how different variables interact and influence the predicted scores for street child-friendliness, uncovering the relationship between multiple environmental features and predicted scores. Spearman correlation was chosen as it does not assume linear relationships, unlike other correlation measures. Variance inflation factor checks were performed, as Spearman correlation does not assume or assess linearity between variables. Table 2 illustrates inter-variable correlations, identifying key and redundant features that influence the perceived child-friendliness of streets and clarifies how each variable impacts prediction scores to guide model refinement. For instance, a strong positive correlation (0.937, $p < 0.01$) was observed between natural elements (trees, plants, and grasses) and perceived safety, suggesting that more natural elements enhance perceived safety. Streetlights also positively correlated with the score (0.157, $p < 0.01$), especially at night, when streetlights contribute to safety. In contrast, buildings showed a significant negative correlation with predicted scores (-0.589, $p < 0.01$), suggesting that urban environments

may be perceived as less desirable. In addition, cars had a slight negative correlation with predicted scores (-0.089, $p < 0.01$), reflecting the negative effect of motor vehicles on perceived safety.

The correlation heat map (Figure 7) visually illustrates the strength and direction of correlations between features and predicted scores, with colors ranging from blue (negative correlation) to red (positive correlation). A strong positive correlation (0.94) between “tree_plant_grass” and “predicted score” indicates that green coverage has a significant impact on predicted scores, while a strong negative correlation (-0.59) between “building” and predicted scores indicates that places with more buildings have lower predicted scores. The correlations for “person” (-0.21) and “sky” (0.12) were weaker, indicating a limited direct impact on predicted scores.

In contrast to the correlation heat map, the scatter plot (Figure 8) provides visual evidence of the distribution of different eigenvalues above and below the predicted median score. The blue portion of the graph represents scores above the median, while the red portion represents scores below it.

The analysis shows that subjective perceptions of safety are lower in areas with higher pedestrian and vehicle elements, potentially due to noise and traffic, which can be disruptive, especially for children. The influence of architectural and sky elements on the predicted scores appears more uniform, with higher scores associated with fewer architectural elements in the streetscape, suggesting that open views positively correlate with the subjective experience of health and safety. In addition, the scatter plot (Figure 8) shows that areas rich in greenery tend to have

Table 2. Spearman correlations between features and predictive scores

Feature	Predicted score	person	Building	Sky	Fence and railing	Tree, plant, and grass	Road	Sidewalk	Streetlight	Car
Predicted score	1									
Person	-0.211**	1								
Building	-0.589**	0.503**	1							
Sky	0.120**	-0.434**	-0.609**	1						
Fence and railing	0.090**	-0.203**	-0.314**	0.306**	1					
Tree, plant, and grass	0.937**	-0.189**	-0.508**	0.063*	0.251**	1				
Road	0.027	-0.133**	-0.131**	0.277**	-0.02	-0.143**	1			
Sidewalk	0.023	0.417**	0.463**	-0.428**	-0.162**	0.034	-0.255**	1		
Streetlight	0.157**	-0.104**	-0.233**	0.351**	0.180**	0.132**	0.108**	-0.055	1	
Car	-0.089**	0.271**	0.371**	-0.316**	-0.179**	-0.075*	-0.116**	0.206**	-0.035	1

Notes: * $p < 0.05$, ** $p < 0.01$.

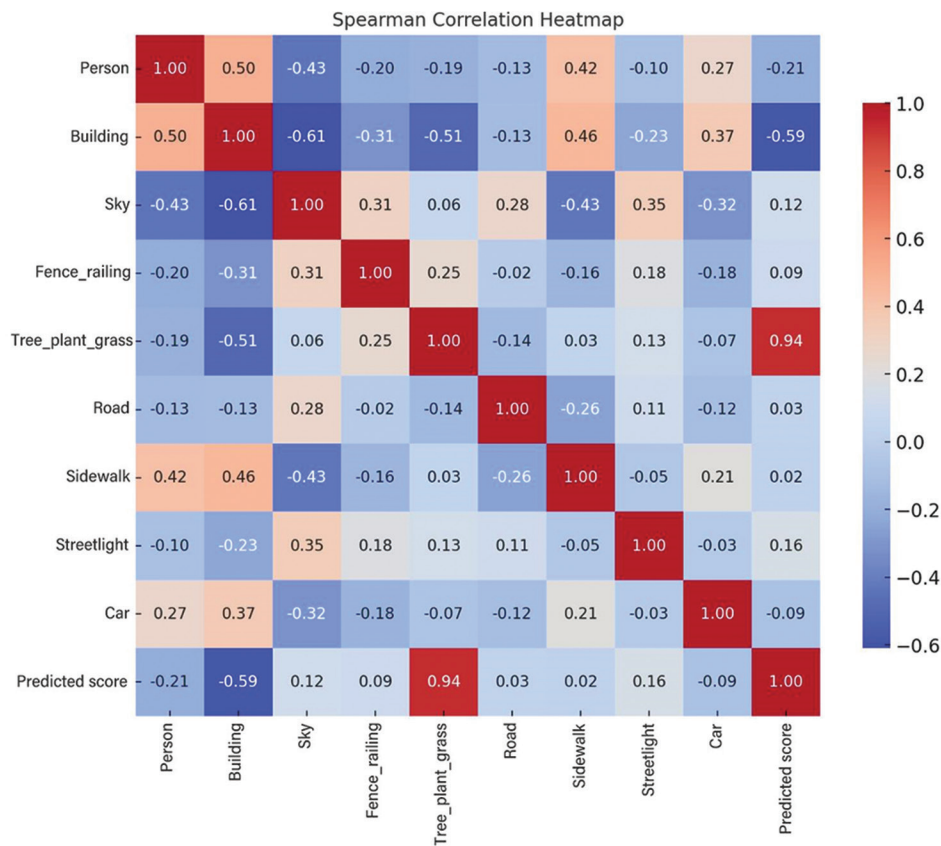


Figure 7. Spearman correlation heatmap of features and predictive scores. Source: Heatmap by the authors

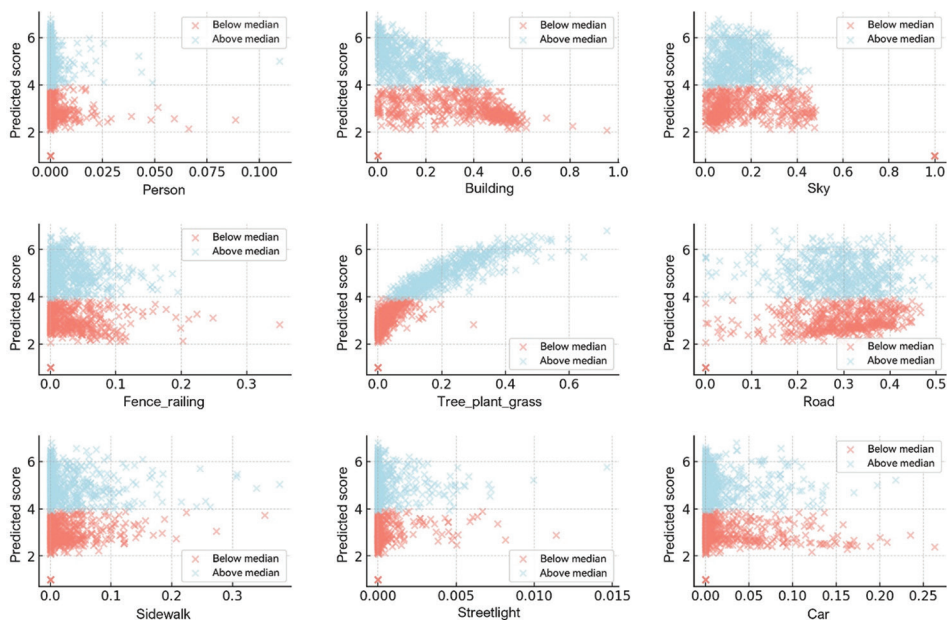


Figure 8. Scores versus features: Positive and negative correlation scatter plots. Source: Graphs by the authors

higher perceived safety and health quality. Sidewalks and streetlights had minimal influence on perceived scores, which could relate to children’s limited street use at night or in darker environments.

In summary, open skies, abundant vegetation, clear pedestrian routes, and good lighting conditions are among the positive environmental factors influencing scores. Natural landscapes (such as skies and vegetation) and quality infrastructure (such as roads and sidewalks) contribute positively to street environment ratings.

5.2. Human validation of model predictions

Common methods for verifying machine learning model accuracy include cross-validation, user counter-validation, accuracy metric calculation, or iterative refinement. Greene & Oliva (2009) noted that humans have a superior ability to recognize global properties in images. In this project, to test the consistency between machine-simulated human ratings and actual human ratings, an additional set of manual ratings was collected from volunteers for comparison. The control group included two volunteers with professional backgrounds in urban planning and design, who were also parents of a 1.5-year-old child. Using their subjective first impressions, they rated 1,000 street images from a predictive street view dataset via Jupyter Web’s interactive computing platform (Figure 9). Ratings were assigned on a 1 – 7 scale to refine the recording of user opinions while minimizing decision fatigue from excessive choices. Volunteers typically took about 5 seconds to score each image. The ratings were saved in a CSV file, and the system stored SVIs in separate folders according to their scores for verification and comparison.

First, volunteers conducted a comprehensive observation of each street scene, paying attention to the presence of various elements listed in Table 1. Perceived safety and healthy environmental conditions were judged based on the sufficient presence of combinations of various indicators, as detailed as follows:

- (i) Safety: Consider traffic safety facilities and community safety measures. Check for adequate traffic signs and lights. Evaluate the adequacy and effectiveness of street pedestrian safety features, such as sidewalks, fences, and signals that enhance safety near fast-moving vehicles. Are these safety facilities adequate to keep children safe?
- (ii) Health: Consider the environment of greenery and street furniture, favoring natural elements. Assess green coverage. Check for adequate street furniture, such as seating and shelter, and consider the extent to which the sky is enclosed and the degree of air circulation in the street space. Determine if these elements add beauty and comfort to the environment. Are the environmental facilities harmonious, adding to the street’s comfort?

After considering each category and its details, volunteers were asked to give an overall score based on how well the streetscape met the criteria for an ideal urban environment. In this case, scoring focused on quick, intuitive, global attribute identification rather than an in-depth analysis of every detail.

As shown in Table 3, a total of 291 SVIs received scores ranging from 1 to 3, while 447 images were rated between 4 and 6. Forty-three images scored above 6. The mean manual rating was 4, indicating that, in general, the streets in the Sham Shui Po district scored relatively low.

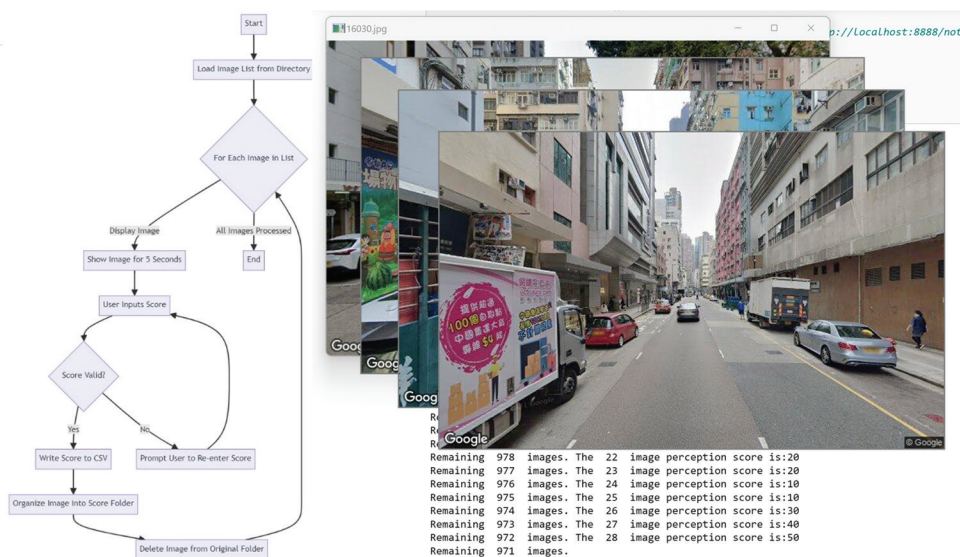


Figure 9. Manual rating system interface

Figure 10 shows a selection of SVIs in Sham Shui Po based on their manual ratings. On the left are samples with low safety and healthy scores, while the right displays samples with high safety scores. Samples with lower safety and health scores depict environments with minimal natural elements, dense urban structures or buildings, and potential for traffic congestion. This finding is consistent with the strong negative correlation (-0.59) between “building” density and predicted scores shown in Table 2. In contrast, the right side of the figure displays samples with higher scores in safety and health, showcasing wide, well-maintained walkways adorned with street trees, abundant greenery, and clearly defined boundaries demarcated by fences. This result aligns with the strong positive correlation (0.94) between “tree_plant_grass” and the predicted scores, underscoring the significant positive impact of green cover on perceived safety. Bright, clean, and wide sidewalks with street trees, greenery, and fences contribute to enhanced safety and improved health.

Compared to the scatter plot, which intuitively illustrates that scores near the median are higher in areas with ample greenery, it is evident that these street scenes

scored higher in perceived safety and health properties. This observation is consistent with our findings described in Section 5.1, where we identified open skies, abundant vegetation, clear pedestrian routes, and effective street lighting as key environmental factors influencing street vitality ratings. Conversely, dense building structures and a high presence of vehicles negatively impact perceived safety, aligning with visual representations in the heatmap.

In summary, the manual scores in Figure 10 closely match the previous model’s scoring data, generally confirming the model’s validity.

6. Discussion

This project confirms the impact of various built environment elements on the perception of safety in street environments; however, questions remain that warrant further exploration in future studies, particularly regarding the multifaceted ways children interact with their environment. These interactions are currently beyond the scope of objective environmental quality measurements for safety. The street environment element categories used in this study are based on existing literature and may be further developed and refined in the future as new insights and priorities emerge within the field. In future studies, examining the role of street fronts and businesses in children’s urban experiences could provide additional insights. Shop-lined streets may be attractive to adults for their convenience and variety, yet they can pose safety risks or distractions for younger pedestrians. In addition, the diversity of vegetation in urban planning should be analyzed to distinguish between grassy areas suitable for play and ornamental shrubs and trees designed primarily for beautification. Such differentiation may better match children’s preferences and needs.

Reflecting on perceptions of open sky highlights important cultural and climatic differences in urban design preferences. In Western cities, open skies are often associated with a sense of freedom, spaciousness, and connection to nature. However, in a densely populated city

Table 3. Manual rating statistics

Statistic	Value
Count	1,000
Score range 1 – 3	291
Score range 4 – 6	447
Score range above 6	43
Mean	4.000
Standard deviation	1.187
Minimum	1.003
25 th percentile	2.918
Median	3.926
75 th percentile	4.951
Maximum	6.800



Figure 10. Image samples showing perceived safety and health ratings, ordered from low to high (left to right)

such as Hong Kong with high summer temperatures and humidity, intense sunlight can make urban environments uncomfortable or even dangerous. Pedestrians generally prefer shaded areas that offer cooler and more pleasant conditions.

Although this project shows research potential, it also has several limitations. First, the dataset size restricted the analysis's breadth and depth; a small sample size may not fully capture the complexities of urban environments and children's diverse needs. In addition, the study was constrained by practical conditions, including a limited number of participants in the validation group and a lack of variation, thereby introducing potential sample bias. Second, the study's focus on specific urban areas may limit the generalizability of the findings, as children from different urban and cultural backgrounds may have different experiences and needs. In addition, the indicators and predictive models used may not adequately capture children's unique perspectives and needs, particularly regarding perceptions of safety and social interaction spaces.

7. Conclusion

This project represents an initial attempt to use a machine-simulated human scoring model to replicate human perception of street environments using deep-learning models, with the goal of identifying metropolitan areas suitable for children. We hope that once matured, this method can serve as a valuable reference for the renewal of older urban areas.

A machine learning-based model was developed to analyze the quality of streets in the Sham Shui Po district of Hong Kong SAR, China. The model focuses on evaluating various factors in the street environment and their impact on the perception of child-friendliness. Results emphasize the significance of natural elements (such as sky views and vegetation), well-developed urban infrastructure (such as sidewalks and streetlights), and reductions in population density, building density, and vehicle traffic to enhance street environment quality and encourage a child-friendly atmosphere. These factors improve the safety and health of streets, promoting a more liveable and inclusive urban environment.

Through systematic analysis and assessment of different street locations in Sham Shui Po, this research confirmed that open sky views, ample green spaces, and clear pedestrian paths positively impact street environment scores. Conversely, overcrowding and heavy traffic negatively affect the comfort and attractiveness of the environment and pose potential threats to children's physical and mental health and safety.

By employing the latest machine learning technologies for processing, analyzing, and interpreting online street view data, this project has demonstrated the potential of deep learning methods for large-scale, systematic urban environment analysis at the district scale. This approach can assist urban scholars and city planners in conducting comprehensive studies for child-friendly characteristics in various neighborhoods, identifying bottlenecks, and implementing strategic urban improvement initiatives.

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Conflict of interest

The authors declare they have no competing interests.

Author contributions

Conceptualization: All authors

Investigation: All authors

Methodology: All authors

Writing – original draft: All authors

Writing – review & editing: All authors

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data

The data for this study include three types: OpenStreetMap data (Road network), Google Street View Images data, Hong Kong Geographic Information (from Hong Kong CSDI portal <https://portal.csd.gov.hk/csd-webpage/>)

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ORIGINAL ARTICLE

Adaptations in early 20th-century modern Chinese architecture: The pursuit of a “new architectural style” in Art DecoPrudence Lau* and Zuoyi Chen

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Abstract

Since the late 19th century, foreign influences have shaped modern Chinese architecture, prompting early 20th-century Chinese architects to blend Western modernism with local traditions. This article focuses on the adaptations and transformations in modern Chinese architecture during this period, exploring how the concept of the “modern” was embraced by both Western and Chinese architects. At the time, modern architecture in China faced a wide array of critiques, including concerns about excessive cost and impractical designs. In the early 1920s, Western architects began experimenting in Chinese cities such as Tianjin, Hankou, and Hong Kong, introducing various new design forms and attempting – often in vain – to convince their Chinese clients to integrate local characteristics into the architecture. Meanwhile, other architects entered a stage of exploration, debating distinctions between restoring traditional Chinese architecture and adapting Chinese features for modern purposes. According to Dong Dayou (1899 – 1973), a prominent first-generation modern architect, they were seeking a new style of architecture. Finally, this article addresses how Chinese architects responded to modern international expositions, particularly the 1925 *Exposition Internationale des Arts Décoratifs et Industriels Modernes* (International Exhibition of Modern Decorative and Industrial Arts) in Paris, highlighting Liu Jipiao (1900 – 1992), another first-generation Chinese architect, and his experiments with Art Deco.

Keywords: Modern Chinese architecture; Adaptation; Art Deco; Early 20th-century***Corresponding author:**Prudence Lau
(plklau@eduhk.hk)**Citation:** Lau, P., & Chen, Z. (2025). Adaptations in early 20th-century modern Chinese architecture: The pursuit of a “new architectural style” in Art Deco. *Journal of Chinese Architecture and Urbanism*, 7(1): 3710. <https://doi.org/10.36922/jcau.3710>**Received:** May 20, 2024**Revised:** August 14, 2024**Accepted:** August 19, 2024**Published online:** November 27, 2024**Copyright:** © 2024 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution-Non-Commercial 4.0 International (CC BY-NC 4.0), which permits all non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.**Publisher's Note:** AccScience Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

Researchers have commented that external influences have significantly shaped modern Chinese architecture since the late 19th century (Denison & Guang, 2008; Rowe & Kuan, 2002; Zhu, 2009). While recent studies often focus on the technical aspects of modern architectural design (Lucchi, 2023; Sabatino, 2016); it is worthwhile to consider the architects themselves as well as the contextual and sociohistoric factors behind their designs. Scholars have also argued that colonial modernity lacks the “historicity of the subject,” suggesting that examining architecture can reveal the social power and resistance inherent in response to oppressive ruling power (Hsia, 2002, p. 13).

After the Opium Wars in the 19th century, China was abruptly forced to open itself to external powers and influences, marking a shift from national isolationism. This historical context not only permeated foreign architects into Chinese architecture but also stimulated domestic architects to reflect on their architectural ideas and practices. During the same period, Western modernist architecture emerged, featuring new forms, materials, and technologies. In contrast to China's external permeation in modernism, Western modernism was largely an endogenous movement, responding to social, political, and philosophical shifts of the time. Beginning in Europe, architects sought a theoretical and practical break from the past. One of the core spirits of European modernism, derived from Walter Gropius (1883 – 1969) and his Bauhaus school, emphasized rational, functional, and radically simplified forms. This concept of modernism gradually spread from Paris, London, and Berlin in Europe to New York and Chicago in the United States of America. It was a significant period in the evolution of modern architecture, which embodied “an architecture conscious of its own modernity and striving for change” (Colquhoun, 2002, p. 9).

In other words, the development of Chinese architecture transitioned into a stage of modern exploration against the context of external influences and pressures, as well as internal sociohistoric upheaval and revolution. This article traces how such modern exploration was specifically reflected and transformed. The first Western construction firm in China was established in Shanghai around 1853, as a brick, tile, and wood factory set up by British merchants (Wu, 1997). The 1843 – 1894 Foreign-Funded Industries in Shanghai list includes 86 foreign industries, seven of which were related to construction. These construction industries included timber, glass, and furniture manufacturing. It was only in the 1860s that the architectural and construction practice began to flourish in Shanghai. Most practitioners at the time were from Britain and were civil engineers who also produced architectural designs. William Kidner (1841 – 1900) was the only registered architect in the Royal Institute of British Architects who was practicing in Shanghai during the 1860s and supervised the construction of Holy Trinity Cathedral in 1866, which was designed by Sir George Gilbert Scott (1811 – 1878).

Around the turn of the 20th century, foreign settlements in Shanghai obtained more land than they had in previous years. The expansion of the International Settlement in Shanghai greatly benefited urban development and the real estate market. During this period, new real estate companies entered the field, including *Crédit Foncier d'Extrême-Orient*, which was founded by Belgian and French investors and architects

in Tianjin in 1907. This company was particularly active within the French Concession in Shanghai and expanded into other cities and treaty ports in China, including Hankou and Hong Kong.

The rationale behind this article is to study selected examples of the architectural practices mentioned above, as well as other architects active in the early 20th century, particularly during the early 20th century. It will also explore how these architects adapted and transformed modern Chinese architecture and how the “modern” was embraced in Chinese architectural design.

2. Data and methods

A major part of this research relies on archival materials. A specific Belgian-French architectural company, *Crédit Foncier d'Extrême-Orient*, is the primary focus of this study. The company's archives, stored in the State Archives of Belgium in Brussels, contribute to a significant portion of the primary materials of this article. These primary resources include photos, company reports, architectural drawings, and newspaper clippings. Additional materials were also retrieved from site visits conducted by Lau, the first author of this study, in Brussels and Hangzhou.

The research aims to link architecture with broader social and urban issues by analyzing the work of selected early 20th-century Western and Chinese architectural practices and examining how these practices adapted to and targeted specific segments of society. Much of the research is based on historical archival sources, both local and international, as well as fieldwork in existing historic sites. The modernist architectural approach observed in these locations contextualizes early 20th-century Chinese architecture within broader modern developments outside China.

Regarding data analysis, this study is primarily qualitative and contextual. The main analytical method used is a comparative approach – one of the most traditional and established methods in architectural history, as noted by Fletcher (1975), and particularly relevant for research in Southeast Asia (Andersen, 1991). This study compares architectural development not only between Hong Kong and other cities in China but also between Hong Kong and the cities in the West (Figure 1).

Ultimately, this research reveals the challenges faced by these architects in adapting to local conditions and tailoring their designs to different social and urban contexts. This sociocultural architectural history incorporates previously overlooked or under-researched materials on modern architecture in Hong Kong and other cities in China. Furthermore, it aims to provide a clearer narrative for the

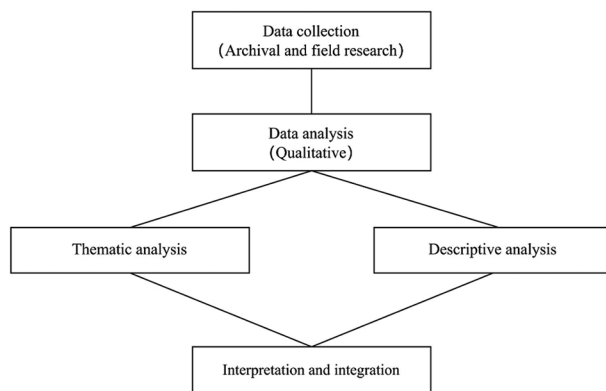


Figure 1. Research methodology. Source: Flowchart by the authors

currently fragmented knowledge and scholarship on the architectural development of Chinese cities. Thus, this research contributes not only to the architectural history of Chinese cities but also to broader international discourses of modern architecture.

3. Results

3.1. Crédit Foncier d'Extrême-Orient as an early propagator in modern Chinese architecture

Beginning in Tianjin's French Concession, the Belgian-French company Crédit Foncier d'Extrême-Orient sought to make a statement by introducing "French modern" architecture, reflecting contemporary architectural trends in France. The French authorities had high expectations for these commissions, especially considering that one prominent structure – the Belfran Building (built in 1922) – was located at a key location facing the International Bridge (now Jiefang Bridge), which linked the French Concession to the rest of the city. French architect Leo Mendelssohn (1894 – 1965) appeared to have enjoyed a great degree of freedom in his architectural designs, as evident in the ornate, Art Deco style of the Belfran Building (Figure 2). Crédit Foncier d'Extrême-Orient later then opened a branch office in Hankou in 1911, directed by Belgian architect Gabriel Van Wylick (1897 – 1964), who introduced new urban forms that reflected his "adaptive" design intentions for China, which he had elaborated on in an article discussed in the following.

In 1927, Gabriel Van Wylick of Crédit Foncier d'Extrême-Orient, authored an article entitled "L'Architecture contemporaine en Chine" (Contemporary Architecture in China) in the Belgian architectural journal *L'Emulation* (Van Wylick, 1927). The article provides insights into Van Wylick's early experiences in China's building sector, where he expressed frustration with his Chinese clients' preference for traditional Chinese styles, remarking,

"rarely was I able to convince them."¹ In 1928, Van Wylick designed his own residence in Brussels (Figure 3), incorporating Chinese elements – a personal realization of a style he was unable to fully implement for his Chinese clients in Hankou. He went on to have a prolific career as director of the Crédit Foncier d'Extrême-Orient office in Hong Kong, a position he held from 1931 to 1946, having managed the architectural office since 1927 (Lau, 2018). In 1929, he designed a similar residence as part of a major urban development project in the Kowloon area of Hong Kong, introducing "an entirely new style in architecture"² to the city in the form of semi-detached houses with locally adapted Chinese elements (Figures 4 and 5).

3.2. The rise of modern Chinese architecture

In the 1920s and 1930s, journals and associations began documenting the evolving architectural landscape in China. The *Journal of the Association of Chinese and American Engineers* was launched in 1920. Two major Chinese-language architectural magazines, *Zhongguo Jianzhu* (中国建筑; *The Chinese Architecture*) and *Jianzhu Yuekan* (建筑月刊; *The Buildings Monthly*), began publication in 1932, making them among the pioneering Chinese architectural journals established by Chinese architects in China (Rowe & Kuan 2002). Contributors to these journals included Chinese architects, building contractors, and other professionals in the architectural construction industry.

The idea of a "modified" Chinese architecture surfaced as early as 1924. John Van Wie Bergamini (1888 – 1975), a church architect in China, addressed this issue in *The Chinese Recorder*, criticizing the notion of a "Chinese style of architecture" as increasingly impractical and costly in contemporary projects. He wrote:

There is considerable controversy at the present time [...] regarding the so-called Chinese style of architecture. The criticisms are that it is expensive and impractical and that the Chinese themselves do not want it. [...] Considered from a historical standpoint, Western architecture is not likely to be accepted by the Oriental without considerable modifications. [...] In the treaty ports, I find the contractors are not keen to build Chinese roofs [...] That is, using Chinese architecture will add from three to seven percent to the total cost of a building (Bergamini, 1924, p. 654).

¹ Van Wylick (1927, p. 99): "J'ai souvent essayé, lorsque j'avais à construire des résidences pour des riches Chinois, de leur faire accepter des projets qui, tout en offrant le confort de l'occident, auraient pu s'allier avec le caractère du pays; rarement j'ai pu arriver à en convaincre."

² Newspaper article dated December 27, 1932, retrieved from Gabriel Van Wylick's personal scrapbook of newspaper clippings. Courtesy of Edouard Van Wylick.

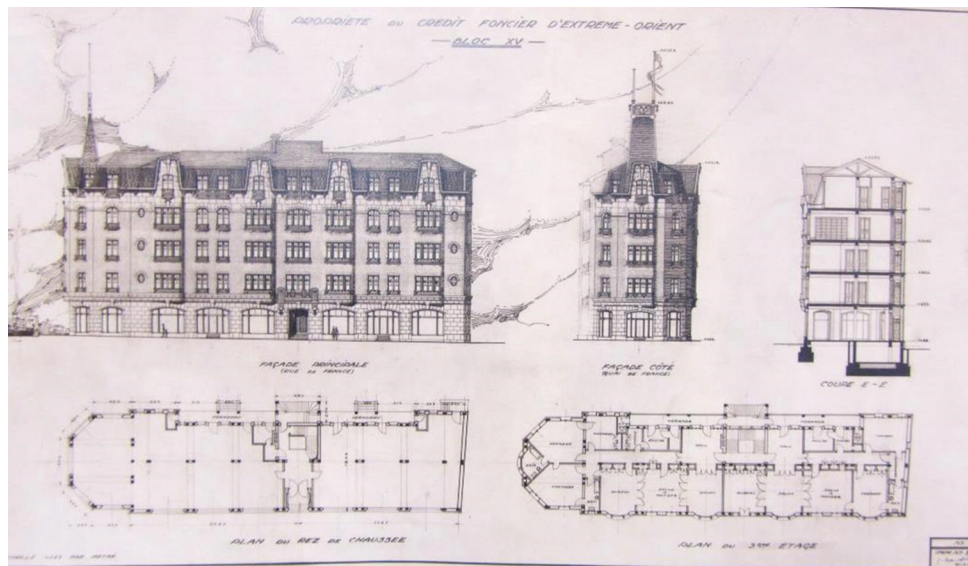


Figure 2. Architectural drawings of the Belfran Building, Tianjin, China. Source: File 172, Crédit Foncier d'Extrême-Orient, State Archives of Belgium



Figure 3. Gabriel Van Wylick's former residence in Brussels, built in 1928. Source: Photo by Lau (2011)

In 1936, an article in *The Buildings Monthly* discussed “the new trend of modern architectural style” (Gu, 1936, p. 4), noting that responses to modern architecture in China, there were divided into three groups: progressives, who supported modern trends; conservatives, who



Figure 4. Newspaper article dated December 27, 1932 (Lot B, K.I.L. 2098). Source: File 394, Crédit Foncier d'Extrême-Orient, State Archives of Belgium

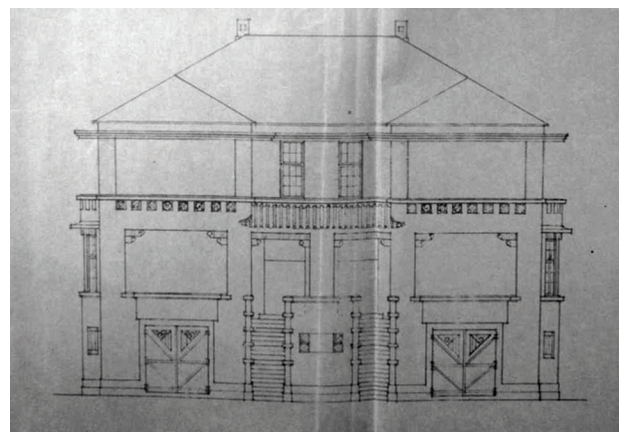


Figure 5. Elevation drawings of residences with Chinese details along Prince Edward Road. Source: File 394, Crédit Foncier d'Extrême-Orient, State Archives of Belgium

opposed them; and skeptics, who were “willing to wait and see whether these new ideas were passing fads or whether they were going to last. In their compromising stance, they practiced various forms of eclecticism.” (Denison & Guang, 2008, p. 314). The author cited Eliel Saarinen (1873 – 1950) but added this third group, describing them as practicing various forms of eclecticism in their compromise. It is, therefore, evident that architectural discussions in China during the 1920s and 1930s critically reviewed the “modern trends” of the day, while reflecting on past traditions and struggling to find a balance between the two. The following section illustrates an example of a foreign-educated Chinese architect who struggled with his architectural designs during the 1930s.

In 1936, Dong Dayou (董大酉, 1899 – 1973), a first-generation Western-trained Chinese architect, echoed Bergamini’s view from a decade earlier by advocating for a “modification” in Chinese architecture. Dong Dayou (also known as Doon Dayou) received his architectural training at the University of Minnesota, before further studies at Columbia University, returning to China thereafter (Kuan, 2011). As a former employee in Henry Murphy’s office, Dong acknowledged Murphy’s influence on Chinese architecture: “Although the new movement owes its development to the pioneering spirit of a few foreign-educated [Chinese] architects, its origin must be traced to the earlier work of the missionaries who adapted Chinese style for their buildings” (Dong, 1936, p. 358). In the same article, written for a monthly periodical, Dong described this movement as an awakening of Chinese architecture:

A group of young students went to America and Europe to study the fundamentals of architecture. They came back to China, filled with ambition to create something new and worthwhile [...] to do away with poor imitations of Western architecture and to make Chinese architecture truly national. This movement is often referred to as the Renaissance of Chinese Architecture (Dong, 1936, p. 359).

Similar to Gabriel Van Wylick of *Crédit Foncier d’Extrême-Orient*, Dong advocated adapting Chinese features for modern purposes in architecture. He described his recently completed buildings for the Greater Shanghai Plan, including the Municipal Government Building and the City Stadium, referring to them as modern buildings that demonstrated the spirit of the new movement. He noted that the “otherwise monotonous roof is raised in the middle to give importance to the middle portion of the building [...] showing the possibilities of adapting Chinese decorative features to modern structures” (Dong, 1936, p. 361).

The buildings mentioned above are, in fact, Dong’s own projects for the Greater Shanghai Civic Center in the 1930s,

located in the Jiangwan area of Shanghai. He received this commission from Shanghai’s City Planning Commission upon his return to China from the United States in 1928. Dong’s master plan for the Greater Shanghai Civic Center consists of two intersecting axes, with open programs such as the library, concert hall, and museum arranged along the north–south axis, and closed programs along the east–west axis. The design exhibits elements of *Beaux-Arts* architecture, characterized by a monumental approach and architectural balance.

An interesting ambivalence appears in Dong Dayou’s architectural designs during the 1930s. His struggle between *Beaux-Arts* and modernism is evident, particularly as *Beaux-Arts* architecture in China, as in Europe at the time, was associated with the state. In contrast, Dong’s own design for his residence differed markedly from his monumental buildings in the Jiangwan area of Shanghai. His residence featured an asymmetrical form with a white exterior, a flat roof, and longitudinal window arrangements, indicating familiarity with the work of contemporary European modernists at the time. In the late 1930s, Dong also built two additional private residences in similar modernist styles.

Although first-generation Chinese architects such as Dong predominantly received traditional architectural training in the *Beaux Arts* tradition, they were nonetheless aware of evolving changes in international discourse in architectural design during the 1930s. In an article he published in 1936, Dong was highly critical of his era and his peers, concluding that “Chinese architecture is going through a fundamental change. Chinese architects are producing buildings of an experimental nature [and] will result in a definite new style of Chinese architecture” (Dong, 1936, p. 361).

4. Discussion

4.1. A transition in modern Chinese art and architecture

After the 1930s, an “Art Deco modern and a pure modernist or international style” (Zhu, 2009, p. 71) emerged in China, with certain European firms introducing Art Deco designs with modern inclinations in Chinese cities such as Tianjin, Shanghai, and Hong Kong. This transition coincided with the prevailing modernist manifestos from the West becoming accessible in China during the 1930s. As these modernist architectural trends entered China, architects largely regarded them as a modern product of eclecticism, resulting in a revival style unique to modern Chinese architecture and decoration. In Shanghai, the Czechoslovakian architect László Ede Hudec (1893 – 1958) made a drastic change toward an Art Deco and modern

approach (Wu, 1997). The lavish ornamentation of the Art Deco style became, when translated into Western culture, “a new mediation between the neoclassicism of British imperial power [...] and the ebullient new spirit of American capitalism” (Lee, 1999, p. 11). Others have argued that the strong decorative heritage of Chinese culture allowed Art Deco’s incorporation into modern times (Minick & Jiao, 1990).

During this period, modernism achieved a breakthrough in China. The 1919 May Fourth Movement spurred remarkable development in Chinese publishing, resulting in hundreds of new periodicals in the society. Until 1927, these periodicals included *Hui-ha Zazhi* (绘画杂志; *Painting Magazine*) published by Peking University, *Mei-yu* (美育; *Art Education*) from the China Association of Art Education, *Meishu Zazhi* (美术杂志; *Art Magazine*) edited by Shanghai Art Schools, *Yishu* (艺术; *The Arts*) and *Xin Yishu Banyuekan* (新艺术半月刊; *New Art Fortnightly*) by the Society for Art, *Yishu Pinglun* (艺术评论; *Art Criticism*) by the Eastern Art Research Association and the Dawn Art Association, and *Yishujie* (艺术界; *Art World*), a column introduced in the newspaper *Shanghai Daily* in 1925 (Chen, 2009; Zhou, 1960).

A significant shift in attitudes toward Western art also occurred after the 1911 revolution, largely due to the influence of Cai Yuanpei (蔡元培, 1868 – 1940), a remarkable figure in modern China. Chai joined the Revolutionary Alliance (同盟会; *Tongmenghui*) under Sun Zhongshan (1866 – 1925) in 1905, and studied philosophy in Europe from 1907 to 1912. He advocated for an emphasis on esthetic art and education in China (Zheng, 2007). Chinese art historian Kao Mayching (高美庆) has traced the establishment of a Western painting school in China and the gradual assimilation of Western influence into traditional painting. Kao describes this as a historical process that transformed both the form and content of Chinese art, which contemporary Chinese artists interpreted as a “consequence of China’s encounter with foreign cultures and attempted to place this process within a historical perspective” (Kao, 1972, p. 202). French influence on the modern Chinese art scene was also introduced through the Catholic (French Jesuits) Aurora University (Zhendan University) in Shanghai’s Xujiahui district, founded in 1903 (Sullivan, 1959).

Modern Chinese painter and educator Lin Fengmian (林风眠, 1900 – 1991), considered a pioneer in blending Chinese and Western painting styles in modern Chinese painting, remarked in the 1930s that artists were a fundamental force in reforming society (Lin, 1934). Responding to Cai Yuanpei’s call for education through art, Lin Fengmian, together with Liu Jipiao (刘既漂,

1900 – 1992) and Lin Wenzheng (林文铮, 1903 – 1989), established the Phoebus Society (later known as the Overseas Art Movements Society) in 1924. In 1928, Lin Fengmian, together with Liu Jipiao, founded the Hangzhou National Academy of Art (now China Academy of Art) and launched the avant-garde “China’s Art Movement” (Denison & Guang, 2008, p. 92). Their declared aims for the Academy were: “To introduce Western art; reorganize Chinese art, combine Chinese and Western art, and create an art for this epoch” (Sullivan, 2006, p. 92).

Artist and architect Liu Jipiao’s strong artistic beliefs of “Architecture as Fine Art” greatly influenced the development of a new artistic and architectural movement in early 20th-century China. As with Lin Fengmian, he attended the *L’Ecole Nationale des Beaux-Arts* in Paris, receiving a diploma in 1926. During his studies in France, Liu not only co-organized the first overseas Chinese art exhibition but also served as the architect and general director of the Chinese pavilion at the 1925 *Exposition Internationale des Arts Décoratifs et Industriels Modernes* (International Exhibition of Modern Decorative and Industrial Arts) in Paris. Originally scheduled for 1915 but postponed a decade due to the First World War, the Exposition gathered many avant-garde ideas in architecture and applied arts. China’s participation in the 1925 Paris Exposition, in which the Overseas Art Movements Society was closely involved, marked a significant contribution. Chinese artist Lin Wenzheng, who had studied Western painting in Paris and co-founded the Society of Overseas Artists with Lin Fengmian and others in 1924, wrote a prologue in French, entitled *Zhongguo Canjia Bali Guoji Zhuangshi Yishu He Xiandai Gongye Bolanhui Fulu* (中國參加巴黎國際裝飾藝術和現代工業博覽會附錄; Appendix of Chinese Participation in the International Exposition of Modern Industrial and Decorative Arts) (Clunas, 1989; Lin, 1999). In this prologue, Lin mentions that Liu Jipiao’s “execution method, modeling, colors, and style make him a truly modern artist. He even excels in the European way of painting; his oil paintings were very successful during the Exposition of the Chinese Modern and Ancient Art, which took place last June in Strasbourg.”³

For the design of the Chinese pavilion at the 1925 Paris Exposition, Liu Jipiao demonstrated his knowledge of Chinese art by weaving traditional elements into the interior decorations. However, it was Liu’s designs for the Hangzhou West Lake Exhibition in 1929 that seemed to

³ By Lin Wenzheng, then President of the Association of Chinese Artists in Europe, in the catalogue of the *Exposition Internationale des Arts Décoratifs et Industriels Modernes*, 1925. Retrieved from <http://liujipiao.com/>



Figure 6. One of the entrances to the original 1929 Hangzhou West Lake Exposition, reconstructed within the current West Lake Expo Museum. Source: Photo by Lau (2024)



Figure 7. External entrance of the original exhibition hall of the Hangzhou West Lake Exposition from 1929, showcasing Art Deco features on the bas-reliefs and decorative moldings. Source: Photo by Lau (2024)

fully express his aspirations for “architecture as fine art.” The architecture of the West Lake Exhibition is characterized by streamlined forms and the use of relief or stepped-back techniques with abstract Chinese decorations (Figure 5). In his article, *Xihu Bolanhui Yu Meishu Jianzhu* (西湖博览会与美术建筑; West Lake Exhibition and Architecture as Fine Arts), Liu wrote:

I intend for the nation to learn about “architecture as fine arts” at the West Lake Exposition. Architecture as fine arts is a combination of science and arts; one not only needs to understand engineering and other

sciences but also understand fine arts” (Liu, 1929, p. 87).⁴

Although it is uncertain as to what impact Liu Jipiao and his writings (Liu, 1927; Liu, 1928) had on other Chinese architects and cities, what we do know is that he was already practicing in both Shanghai and Hong Kong by 1929, as indicated by an advertisement for his architectural offices located in Hangzhou, Shanghai, and Hong Kong, printed in a journal *Liangyou* (良友; *The Young Companion*). Liu’s works ultimately highlight the efforts of a Chinese architect not only to move beyond mere stylistic applications in architecture but also to seek meaningful integration of Chinese and Western traditions (Xu, 2010). Fortunately, the West Lake Expo Museum, still standing today in Hangzhou, serves as a testament to the city and China’s avant-garde movement in the 1920s (Figures 6 and 7).

5. Conclusion

In the past, there have been notable studies on architectural modernism in occupied regions, including analyses of politics in French colonial urbanism (Wright, 1991) and examinations of the relationship between culture and power in British-designed architecture in India (Metcalfe, 1989). Other scholars have focused on the relationship between modernism and the new characters of nations and nationalities (Crimson, 2003). However, there is still no unified understanding of how modernism was perceived, interpreted, and developed in China. This research, therefore, probes some of the under-researched areas in the field of Chinese modern architecture. Architects in early 20th-century China were not only experimenting with modern methods and materials but were also searching for deeper meanings in their pursuit of a “modern” architectural identity, both domestically and internationally.

The first part of this article delineated several Western architects who sought to adapt architecture to local needs and characteristics, particularly in the works of the *Crédit Foncier d’Extrême-Orient*. This exploration was followed by an examination of several first-generation Chinese architects in the early 20th century, such as Dong Dayou and Liu Jipiao, who were, in Dong Dayou’s words, in search of a “new style of architecture” (Dong, 1936, p. 361). This quest was shared by the architects of the *Crédit Foncier d’Extrême-Orient*, as discussed earlier. Gabriel Van Wylick’s designs, for instance, evolved from Chinese-inspired bay windows in the early years around

⁴ Original text by Liu Jipiao (1929): “我希望這次西湖博覽會可以給國人瞭解美術建築的機會。美術建築是科學與藝術結合的產兒，不僅要懂工程學和各種純粹科學，而且要懂得藝術。”

1928 – 1929 to modernist and Western Art Deco forms in the mid-1930s. His stylistic exploration and evolving adaptations were echoed in the works of Dong and Liu. Dong Dayou adopted the Chinese “classical” or traditional style in his designs for municipal buildings in the Greater Shanghai Plan, while his own residence conveyed abstract, simple, modernistic forms. Liu Jiupiao, in contrast, appeared to share more similarities in design intention with Van Wylick. Both architects were evidently inspired by modern decorative movements, particularly the Art Deco style. After all, Liu Jipiao served as the chief architect of the Chinese Pavilion at the 1925 Paris Exposition, an experience that greatly inspired him in his architectural designs at the Hangzhou West Lake Exposition of 1929, as well as his personal writings advocating for architecture as fine arts.

The modernistic designs in these cities were also partly reflective of the Western art and architectural milieu, particularly at a time when the 1925 Paris (Art Deco) Exposition featured similar forms that could be interpreted as a contestation against traditional and colonial styles in striving for modern expressions. For Gabriel Van Wylick, Dong Dayou, and Liu Jipiao, their architectural works were modern reinterpretations of Chinese architecture in the early 20th century. In summary, these architects ultimately transformed the urban landscape in China, particularly in Hong Kong, Shanghai, and Hangzhou, evolving from early efforts to introduce modernist exteriors characterized by Western Art Deco forms to experimenting with new living spaces that paved the way for further developments in modern Chinese architecture.

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Conflict of interest

The authors declare no conflicts of interest.

Author contributions

Conceptualization: Prudence Lau

Formal analysis: Prudence Lau

Investigation: Prudence Lau

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Writing – original draft: Prudence Lau

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Ethics approval and consent to participate

Not applicable.

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Not applicable.

Availability of data

Data in the study on the Crédit Foncier d’Extrême-Orient can be obtained from the State Archives of Belgium in Brussels.

Further disclosure

Part of or the entire set of findings has been derived from the author’s doctoral dissertation on the research of Crédit Foncier d’Extrême-Orient (<https://repository.lib.cuhk.edu.hk/en/item/cuhk-327755>).

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ORIGINAL ARTICLE

Spatial production and evolution of commercial ports in the ocean shipping era: A case study of modern Fuzhou and Xiamen in Fujian province, China

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Abstract

Commercial ports are vital regional intersections in the era of globalization, relying on maritime networks and local convergence to facilitate the movement of goods, people, and ideas. The term “The Five Treaty Ports” marks the beginning of foreign territorial leases for trade in China. During this period, the spatial planning and infrastructure development of commercial ports dynamically responded to the rapid progress of globalization. This article uses the commercial port cities of Fuzhou (Foochow) and Xiamen (Amoy) as case studies, examining how advancements in shipping technology influenced the evolution of port spaces. It traces the transformation of urban port spatial landscapes through the “sailing ship era,” “steamship era,” and “oil tanker era.” These eras not only carried the enlightenment of mercantilist ideas and featured characteristics of “industrialization for the nation,” but also reflected the significant influence of capitalist “market expansion” ideas in spatial configurations. Furthermore, the article argues that the spatial representation of modern commercial ports embodies the collaborative forces of mercantilism, colonialism, and capitalism, promoting globalization through trade. This research aims to explore the evolution of modern commercial port spaces, analyze the progressive transition from mercantilism to capitalist production modes, and ultimately enhance understanding of the globalization process within port spaces.

Keywords: Commercial port; Modern Fuzhou; Modern Xiamen; Spatial production; Comparative study

1. Introduction

The ocean has long been a critical resource for sustaining the livelihoods of coastal residents in southeast China, where industries, such as fisheries and salt production depend significantly on ships and docks. These regions, functioning as trading ports, have historically attracted interest from European navigators. Since the signing of the Treaty of Nanjing on August 29, 1842, areas such as Nantai Island, Mawei Port, and Taijiang in Fuzhou (formerly spelled as Foochow), along with the inner and outer ports of Xiamen

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(formerly known as Amoy) and Gulangyu (Kulangsu), have become focal points for cross-border trade practices and pioneers in China's modern economic development. Industrialization and technological innovation continuously challenge traditional urban port landscapes. Ports have expanded spatially outward, extending into the sea through the construction of docks, ship channels, and navigational aids, and inland along highways and railway lines. The Industrial Revolution, which transformed global trade and maritime trade, prompted the opening of the Suez Canal in 1869, thereby significantly shortening the route to Europe. Since the mid-19th century, ships have increasingly favored liquid petroleum over coal, reflecting a global plan of technological advancement intertwined with trade. Consequently, port spaces and infrastructure have had to evolve in real-time. This article focuses on actively categorizing various stages of port facility evolution in response to technological changes.

Due to the shallows of the Min River, oceangoing vessels were unable to reach Nantai Island directly, necessitating anchorage at Pagoda Anchorage in Mawei Port, an early base for shipbuilding. Lighter vessels transported goods from Pagoda Anchorage to the upper reaches of the Min River, where international merchants residing on Nantai Island engaged in trade. In 1879, siltation and riverbed degradation made the waterway impassable for small steamships, prompting the proposal of the Min River Dredging Project in 1918. By the end of the 20th century, modern motorized oil tankers posed a threat to traditional sailing ship transportation, gradually replacing conventional transportation methods (Cartier, 1991).

Yamu Island, situated across from Fanchuanpu Port on Nantai Island, served as a commercial port during the Song dynasty (960 – 1279) and expanded gradually during the Ming dynasty (1368 – 1644) (Lin, 2008). In the 19th century, George Tradescant Lay (c. 1800 – 1845), the inaugural British consul and missionary in Fuzhou, resided and worked on Yamu Island, describing it as a “dilapidated house built on muddy shores” (Nield, 2015, p. 86). At that time, Yamu Island was still largely a sandbar. In the early 20th century, sawmills and oil depots were established on the island (Tie Dao Bu Ye Wu Si Diao Cha Ke, 1933), and in the 1920s, the Japanese Consulate in Fuzhou proposed establishing a commercial port area there.

In the late 16th century, the British East India Company established a trading post in Xiamen to facilitate foreign trade. Initially, the Fuzhou Customs Xiamen branch office was situated south of the city, near inland areas, but it later relocated to the inner harbor during the Daoguang period (1782 – 1850). Between 1766 and 1832, the construction of the Longquan Palace ferry terminal in southern Xiamen

Island catalyzed the gradual southward expansion of the port (Onda, 2003). The Xiamen British Concession, established in 1852 at the inner harbor, was primarily intended for commercial use and developed with respect to traditional business and urban networks (Yu, 2008).

In the early 20th century, municipal reforms accelerated urban development. In the early 1930s, Xiamen's Bureau of Public Works and The Office of Dike Construction initiated road and dock construction, including land reclamation at Yundang and Songyu. Songyu underwent grid-patterned street planning focused on zoning and the construction of ports and transportation facilities. Simultaneously, parks were built, enhancing the city's adaptability to meet the growing demand of overseas Chinese communities.

Previous studies have revised the “Impact-Response Model,” contending that Fujian's modern urban development resulted from a combination of internal and external forces. Policies implemented following treaty signings directly facilitated urban modernization (Lin, 2004). The urban development process, marked by both conflicts and compromises, underscored the strong influence of Chinese authorities. This study draws inspiration from Henri Lefebvre's (1901 – 1991) triad of the production of space, interpreting treaty ports as global hubs for the movement of goods and people. It examines how different economic forces shaped port spaces across spatial and temporal scales (Hein, 2019). Reimagining this historical process connects local imaginaries with the port's historical context, providing valuable insights for contemporary urban waterfront planning and industrial heritage revitalization.

2. Planning and implementation: Developing global perspectives in port spaces

2.1. Modern Xiamen port spatial planning

From the mid-16th century to the mid-19th century, sailing ships dominated international trade and naval warfare. The subsequent emergence of steamships reduced voyage times for long-distance transportation. In the 1840s, treaties between China and Britain, as well as China and the United States, led to the successive opening of ports in Xiamen and Fuzhou, where consular affairs related to commercial ports fell under the jurisdiction of consuls. In 1846, Britain abolished the Corn Laws, implementing free trade, and in 1851, the successful laying of a submarine cable across the English Channel connected financial markets worldwide (O'Rourke & Williamson, 2001). During this period, new ideas began to flow into East Asia, gradually influencing architectural forms and urban planning concepts.

Grid planning, already used in ancient Asia, proliferated across European colonies in North America during the Renaissance (14th – 16th centuries). Port cities often based their layouts on the anticipated number and characteristics of future ships, requiring several years to develop suitable infrastructure. In early 1844, the Xiamen British Concession was initially sited at the southern end of the main island, near the outer harbor, which provided convenient water transport yet was distant from the old city center (Wang, 1997). Consul Rutherford Alcock (1807 – 1897) changed the site selection, citing commercial inconvenience due to its distance from the docks. In early 1852, Consul Sullivan and interpreter Harry Smith Parkes (1828 – 1885) planned to reside there but faced rejection due to the presence of barracks, cultivated fields, and a cemetery. By the end of 1852, the British Concession had moved to a beach area covering approximately 19.6 acres, close to the traditional commercial district and conveniently connected to a shipyard at the island's northern end. The coastal area of the British Concession was uniformly divided into six plots with planned straight public roads, drainage ditches, and other infrastructure. Each lessee was required to comply with the terms stipulated by the British Consulate, undertaking the construction and maintenance at their expense. Local authorities in Xiamen requested the reservation of a 10 ft strip of land for road construction. Seizing this opportunity, the British Consul proposed further expanding the British Concession. In the 1860s, the concession area had expanded to 24.6 acres. The British government paid an annual rent of \$50 per plot of land, and lessees obtained land-use rights by paying rent to the consulate (PRO: FO678/14, 1852 – 1871). Land transfers required registration with the British Consulate, allowing lessees the right to subdivide, transfer, or sublet the land. Subleasing, partitioning, and re-leasing became increasingly common in the 1920s, and overseas Chinese actively participated in market competition, with the fluidity of concession land facilitating the flow of land as capital.

Since 1845, the value of imported goods at Xiamen had grown exponentially. In 1867, Jardine, Matheson and Co. constructed the Jardine Floating Bridge and Hulks. The opening of the Suez Canal shortened the Eurasian maritime route, and from 1877 onward, *hangs* (or *hongs* in Cantonese; trading firms or types of Chinese merchant establishments and their associated building styles) frequently reclaimed beaches. Embankments and road construction costs were shared between the Qing government and the *hangs*. The following year, the “Regulations on Reclaiming Beaches” clarified the public nature of newly reclaimed beaches (Xiamen Shi Weiyuanhui Wenshi Ziliao Yanjiu Weiyuanhui, 1963). The involvement of the Chinese government reflects

the interventionist characteristics of state intervention under mercantilism. With improved construction techniques, infrastructure gradually extended into the sea, and in 1919, Jardine, Matheson and Co. unilaterally built a reinforced concrete pier and a flying bridge. Xiamen, a transit trade port at that time, witnessed new forms of trade, with individuals profiting from warehouse and lightering operations. In 1920, inspired by the Gulangyu Municipal Council, overseas Chinese established the Xiamen Municipal Bureau, which took on the construction of piers and roads (Taiwan Warehouse Co., 1917). In 1922, the *Haihou Tan Shanhou Banfa Hetong Santiao* (海后滩善后办法三条; Contracts for the Aftermath of Xiamen Beach Ground) required the British Concession to remove road barriers to improve transportation (Shangwu Yinshuguan Bianyi Suo, 1925). From 1925 to 1932, the Public Works Bureau and the Embankment Department jointly planned harbor roads and piers (Figure 1). Oil companies such as Standard Oil and Asiatic Petroleum began constructing oil tanks and piers, with the Zhangzhou-Xiamen Railway attached to these developments (Figure 2). In 1931, the Songyu Planning Committee was established. Songyu's planning underscored the evolution of the modern city from a “consumption center” to an “industrial production site” (Esherick, 2000). In 1937, the Naval Headquarters for Zhangzhou and Xiamen paid significant attention to port management, leading the Public Works Bureau to draft the Revised Preliminary Plan for Xiamen Public Piers.

2.2. Modern Fuzhou port spatial planning

Nantai Island, designated as a treaty port, served as a key location where foreigners could procure raw materials and promote their goods. In 1852, British Consul Rutherford Alcock proposed leasing multiple areas on Nantai Island to the Fuzhou authorities, facilitating the storage of goods for *hangs* (Li, 2000). *Hangs* leased land by executing deeds with residents, subsequently registering these deeds with the consulate. American missionary Justus Doolittle (1824 – 1880) observed that buyers and sellers frequently engaged intermediaries and noted that, for a land deed to possess legal validity, it required the intermediary's signature (Doolittle, 1865). Due to the absence of unified planning, the arrangement of Fuzhou's *hangs* developed irregularly, shaped largely by the local terrain. In 1862, a group of foreigners spontaneously formed the Fuzhou Road Trust to oversee the maintenance of roads on Nantai Island (Brand, 1933). By 1866, The Fuzhou Arsenal acquired land for the Majiang Shipyard, and the subsequent year saw the establishment of the Fuzhou Naval College. In 1872, the China Merchants' Company expanded to Xiamen and established an office in Fuzhou, entering into competition

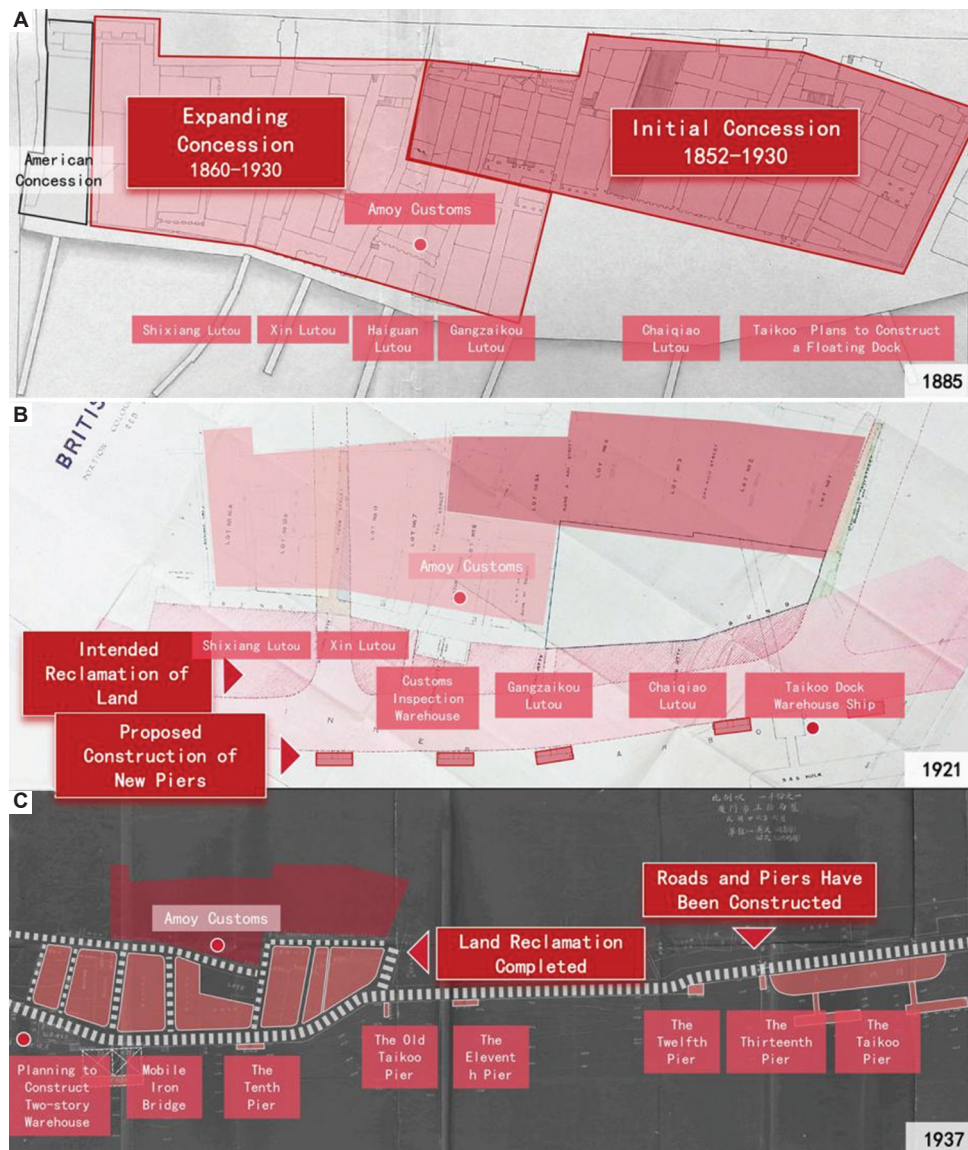


Figure 1. Spatial evolution of the Xiamen British Concession. (A) Xiamen British-American Concession, 1885. (B) Xiamen British Concession, 1921. (C) Lujiang River banks, 1937. Source: Drawing by the authors.

with foreign shipping entities, with backing from the government and management by compradors. In 1875, Boyd and Co. signed agreements with residents to secure permanent land leases for constructing new roads (PRO: FO678/493, 1881). Deeds from 1880 show that foreigners continued leasing land from residents to support road development, and that year, the Asiatic Petroleum Company approved the Taikoo Lane expansion project on the west side of the road. Situated in Nantai, the petroleum company constructed oil tanks and warehouses in Pagoda Anchorage and Yamu Island (Figure 3). In the 1920s, the Japanese Consulate in Fuzhou sought to establish a trading port on the western side of Yamu Island (Figure 4).

They set up the Fuzhou Trading Port Preparatory Office, conducted surveys, and completed architectural designs for the proposed port area. The resulting Outline of Fuzhou Trading Port Preparatory Office Design and Sketches of Port Engineering Design reflect detailed planning, including specific docks designated for ships of varying draughts (JACAR: B10073426500, 1922), indicating an emphasis on organized spatial control and structured economic activity.

Examining the evolutionary process of commercial ports in Fuzhou and Xiamen, we can categorize this development into three stages aligned with the advancements in shipping technology: The Age of Sailing

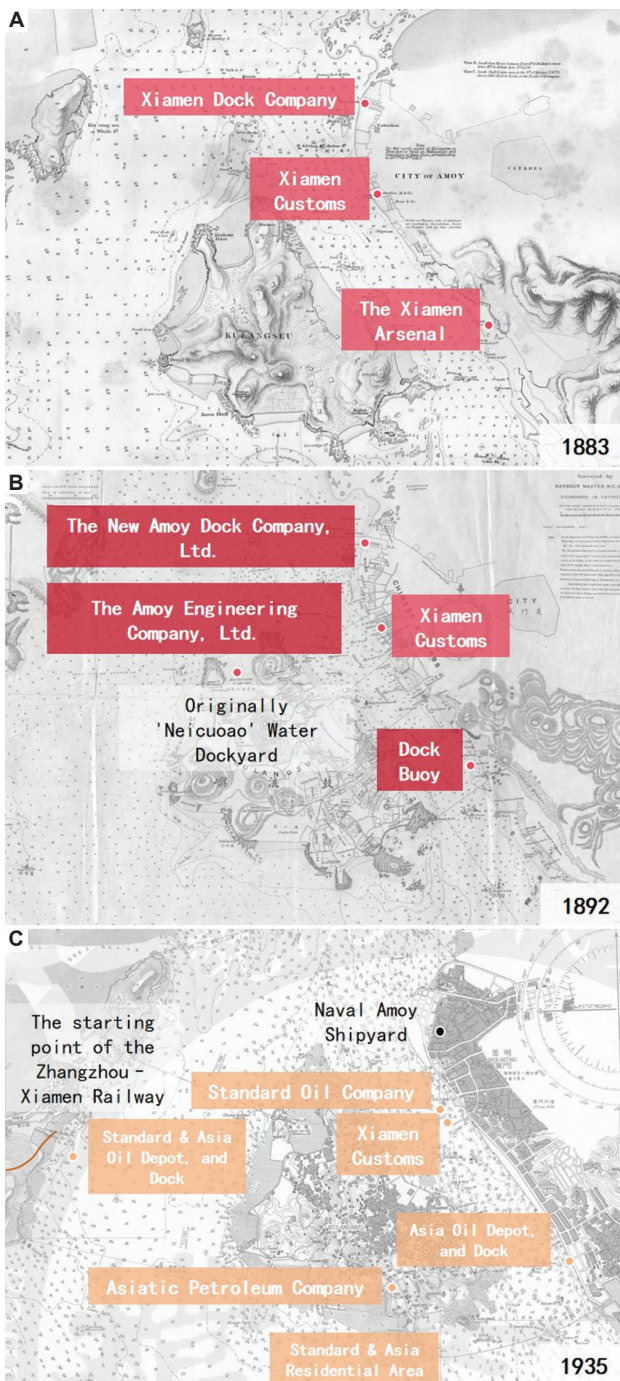


Figure 2. Spatial evolution of Xiamen outer port. (A) Xiamen outer port, 1883. (B) Xiamen outer port, 1892. (C) Xiamen outer port, 1935. Source: Drawing by the authors.

Ships, the Age of Steamships, and the Age of Oil Tankers. During the Age of Sailing Ships, the rise of maritime trade, driven by the mercantilist ideology, spurred the development of the shipping industry, with spatial arrangements primarily serving trade operations. In the Age of Steamships, the core of the mercantilist ideology

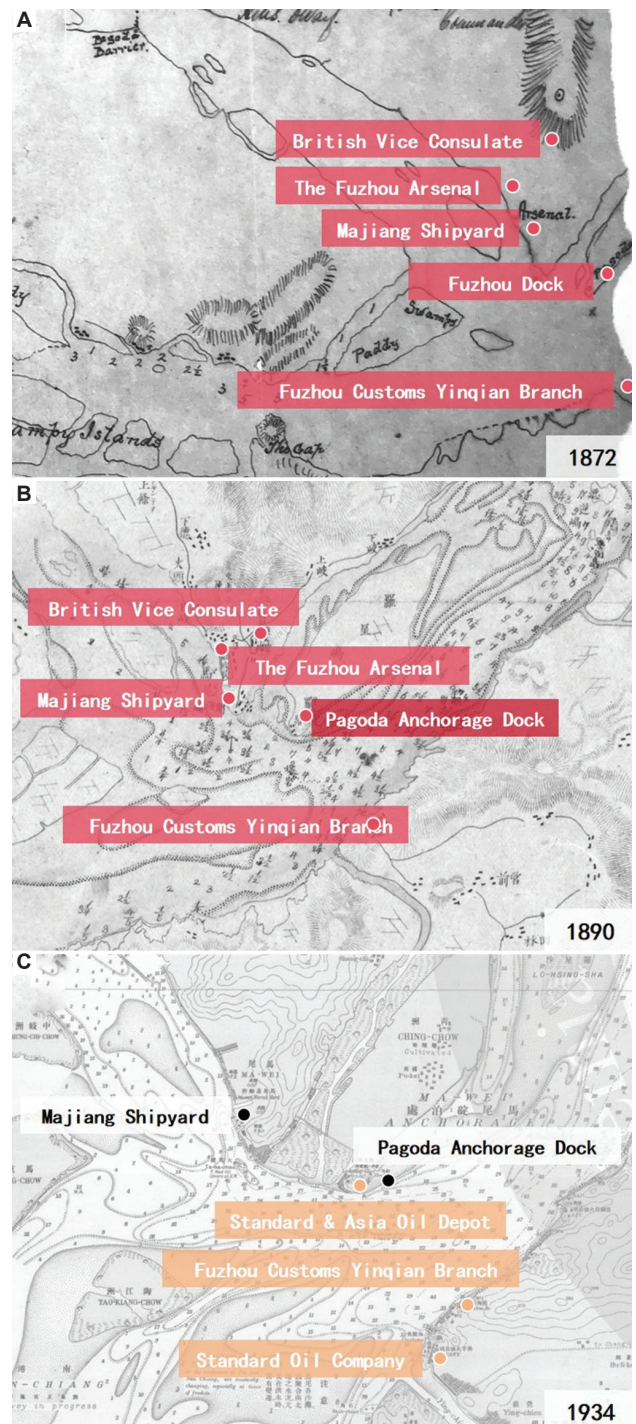


Figure 3. Spatial evolution of Mawei Port. (A) Mawei Port, 1872. (B) Mawei Port, 1890. (C) Mawei Port, 1934. Source: Drawing by the authors.

shifted toward “revitalizing industry,” where capitalism and mercantilism jointly expanded the market, facilitated port construction, and promoted spatial production through trade. The Age of Oil Tankers introduced liberal economic thought, fostering the rise of oil companies in a

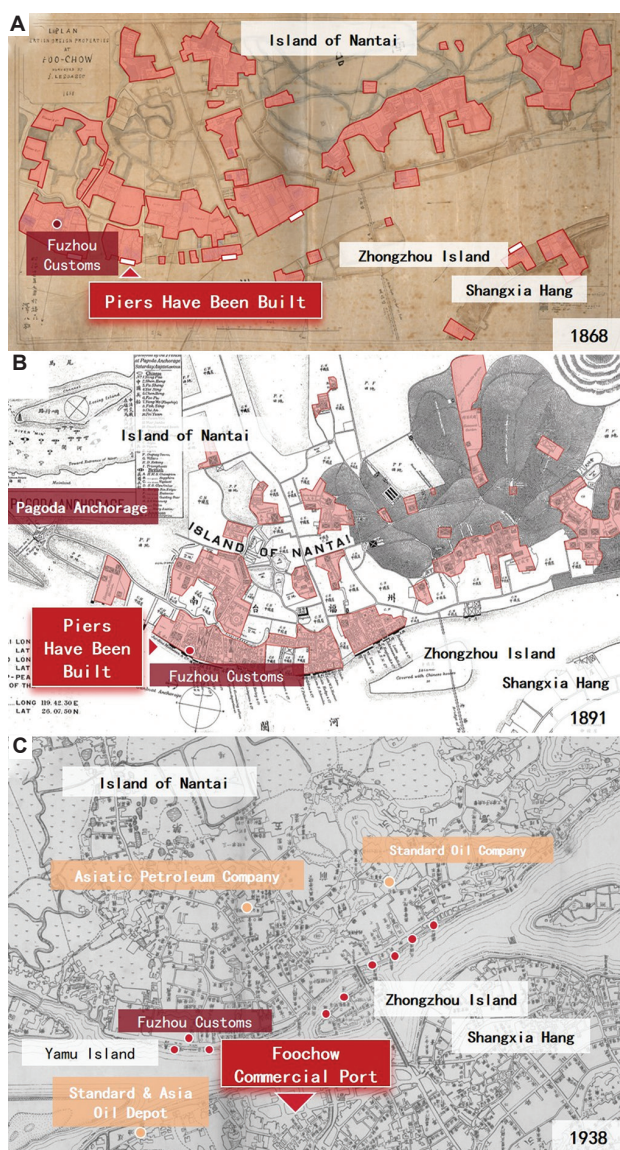


Figure 4. Spatial evolution of the Min River basin. (A) Min River basin, 1868. (B) Min River basin, 1891. (C) Min River basin, 1938. Source: Drawing by the authors.

landscape of both competition and collaboration. In this era, commercial ports evolved into vital exchange hubs within the global trade network.

3. Urban life: Port spaces and sociocultural practices

3.1. The Sail era (1840 – 1870)

Western capitalists initiated shipyard construction in treaty ports, ostensibly to expand market trade but with the true intent of territorial expansion. This approach combined commercial and military interests, using warships to protect merchant vessels and funding naval

force through taxes on merchant ships¹. This integration of military support with commerce increased Chinese exposure to steamship technology. The extensive water areas owned by commercial ports became focal points for the Self-Strengthening Movement, serving as a pioneering ground for resisting foreign aggression and safeguarding economic interests. Concurrently, the introduction of Western shipbuilding technology further spurred Chinese exploration in this field, laying the foundation for a socio-economic ideology that encouraged transitioning from an agrarian to an industrial nation. During this phase, the Self-Strengthening Move’s “business warfare” philosophy underscored the military strategic value of port space. Advocates of mercantilism leveraged these spaces, intertwining national power reinforcement with technological progress.

In 1854, Westerners established the Dobie and Co. shipyard at Pagoda Anchorage. Initially lacking dry docks, the shipyard’s capacity for ship repair operations was limited. In 1864, John C. Skey founded the Fuzhou Dock, further advancing ship repair capabilities. The dock, with its expansive scale and equipped with features such as steam pumps, provided a conducive environment for vessel maintenance (The North-China Daily News, 1868). In 1866, an advertisement seeking craftsmen for Fuzhou Dock was published in The North-China Daily News. By 1869, the shipyard expanded to include a new mechanical workshop, forging plant, and updated machinery (The North-China Daily News, 1869). In 1873, John Forster and Co. assumed control of the dock, expanding its structure to accommodate larger vessels, thereby advancing ship repair technology and enabling an expanded range of services (The North-China Daily News, 1873). From the 1880s, the dock could even manufacture steamships. However, unfavorable trade conditions in Fuzhou gradually led the shipyard into economic decline. In 1884, with the outbreak of the Battle of Fuzhou, ownership transferred to the Fuzhou Arsenal. While new capital brought technological upgrades and equipment investments, the foreign-operated shipyard struggled to maintain continuous prosperity due to fluctuating market demands and political factors.

In the mid-19th century, Lindsay and Co., a British *hang*, encountered local resistance when attempting to lease land and construct buildings in Fuzhou. Under pressure from the British naval forces, the governor-general of Fujian and Zhejiang reluctantly granted permission for *hangs* to conduct business in Nantai (Dai, 1988). During the 1860s, the concepts of business warfare began to sprout

¹ “To defend merchant ships with the strength of warships is to use the taxes from merchant ships to support warships.” This line appears in the first volume of *Yi Yan* (易言).

as the Qing government initiated the Self-Strengthening Movement, with Zuo Zongtang (1812 – 1885) advocating for the development of steamships. This initiative led to the establishment of the Fuzhou Arsenal, strategically located at the foot of the mountains to serve both military and commercial purposes. The shipyard's internal layout was ingenious, featuring dry docks, ironworks, wheelhouses, and machinery factories. Surrounding structures include quarters for foreign craftsmen, a naval college, a coal factory, and a dedicated business street (Zhang, 1971). In 1869, the French consul attempted to establish a consulate and intervene in shipyard affairs; however, Shen Baozhen (1820 – 1879), asserting the shipyard's autonomy from consular jurisdiction, rejected the French consul's proposals. In 1882, a Fujian censor proposed the construction of the Pagoda Anchorage Dock, completed in 1893, which could accommodate the repair of large warships. However, following its completion, financial constraints within the Fuzhou Arsenal led to its slow development (Fuzhou Gang Shizhi Bianji Weiyuanhui, 1996). In 1908, with the expiration of key contracts and mounting financial difficulties, all foreign staff were disbanded.

The developmental trajectory of the maritime industry in Xiamen distinctly reflects the impact of capitalism and mercantilism on its industrial landscape. In 1729, a shipyard specializing in naval warships was established in Quanzhou, establishing an early connection between the shipbuilding industry and military production. Private shipyards handled civilian vessels, thus laying the groundwork for an initial division of labor between commercial and military interests. In 1845, the British set up a shipbuilding yard in Xiamen Harbor, and the founding of the Xiamen Dock Company in 1859 marked a new phase of foreign intervention. Centrifugal steam

pumps drove technological advancements (Daily Press Office, 1868), while departments managed by experienced Europeans elevated organizational efficiency, showcasing the specialization brought about by the capitalist division of labor (Figure 5). In 1892, the New Xiamen Dock Company, Ltd. invested nearly \$100,000 in advanced machinery, enabling it to undertake virtually any navigational repair work. The Xiamen Engineering Company, Ltd., established by Chinese capital in 1893, exemplified successful collaboration with British managers (Wright, 1908). Supervisor J. D. Edwards, a trained ship engineer, joined the British firm Douglas Lapraik and Co. in 1882. The ship's slipway, extending 290 ft (mostly submerged), was equipped with double-powered winches and a crane with a 10-ton lifting capacity. In 1918, the company was restructured by Tait and Co., and in 1919, the Republic of China government, under the leadership of Li Houji (1869 – 1942), nationalized the Xiamen Dock Company under the Regulations for the Trial Implementation of Prize Bonds for the Establishment of Xiamen Dock (Min Du Du Fu Zheng Wu Yuan Yin Zhu Ju, 1919), redeeming it for RMB ¥410,000 and transforming it into the Xiamen Shipyard.

During this era, Western advancements in science, technology, and industrial reform were pivotal in shaping and implementing the mercantilist ideology of business warfare. The construction of the Fuzhou Arsenal, an 8-year endeavor from the initial recruitment of Western technicians to the achievement of technological independence, was marked by fervent debates between advocates and detractors. Despite support from the Prime Minister's Office, the arsenal's progress stagnated due to opposition from certain domestic and foreign officials. This clash of perspectives throughout the arsenal's gradual

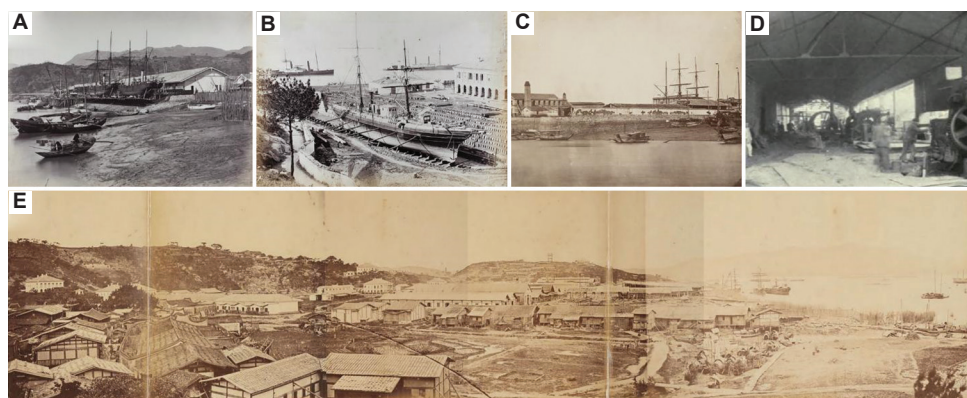


Figure 5. Port spatial landscape: Docks. (A) Patent Slip at the Imperial Arsenal, Mawei, Fuzhou. (B) Forster's Dock, Pagoda Anchorage, Fuzhou. (C) Sail Loft, Xiamen Dock Company. (D) The New Xiamen Dock Company, Ltd. (E) The Fuzhou Arsenal. Source: (A and B) Archives and Special Collections, SOAS Library, University of London, 1870s, 1880s – 1890s; (C) Album of Hongkong Canton Macao Amoy Foochow Vol. 1, George Ernest Morrison, Toyo Bunko; (D) Twentieth Century Impressions of Hongkong, Shanghai, and Other Treaty Ports of China, 1908, p. 823; (E) *Nan Zhi Na Bing Beijing Di Fang Zha Xian Tie* (南支那並北京地方写真帖; Southern China and Beijing Regional Photographs), Imperial Household Agency Library, Japan.

development highlighted issues in national finance and personnel management, closely tied to diplomacy and national defense. Local capital's direct involvement in Xiamen's shipyard development represented a strategic adjustment to capitalism and reinforced national strength.

3.2. The Steamship era (1871 – 1894)

After the rise of the steamship manufacturing industry, Western residents on Nantai Island in Fuzhou and within the British Concession in Xiamen had completed initial land leases and housing construction, which spurred continued urban development in both locations. In 1870, the Suez Canal became navigable, facilitating global trade. From 1884 onward, Zheng Guanying's (1842 – 1922) *Shengshi Weiyan* (盛世危言; *Words of Warning to a Prosperous Age*) systematically expounded the ideology of business warfare, proposing that the “chief objective of commerce lies in revitalizing the silk and tea industries.” This ideology evolved internally, sparking an awakening within China's national industrial and commercial sectors. The gradual replacement of sailing ships with steamships in transportation facilitated the prosperity of tea and foreign yarn trade across two treaty ports. Fuzhou Port emerged as the largest tea export hub in China, while Xiamen became a primary hub for distributing cotton yarn and thread (Xiamen Gang Shizhi Biancuan Weiyuanhui, 1993). Commercial activity reached unprecedented levels, leading to an increased urgent demand for harbor space by various trading firms. This demand prompted successive projects that involved beach reclamation and dock construction.

With the rise of the shipping industry, the China Merchants' Company became the primary shipping enterprise in Xiamen Port. Operating under a model of official supervision and commercial management, it competed with *hangs* such as the China Navigation Company and Douglas Lapraik Company. The China Merchants' Company's office was located adjacent to the north side of the British Concession, featuring a 50-sqm warehouse capable of holding around 2,500 tons of cargo (Taiwan Warehouse Co., 1917). In 1876, the company also established an office in Fuzhou. Maritime usage rights evolved into trade privileges, gradually extending commercial activities from land to shallow coastal areas.

In 1877, the Boyd Company undertook beach reclamation, extending over 100 ft, but faced opposition from Chinese local authorities. In the same year, Brown and Company (水陸洋行; *shuilu yanghang*). Exceeded its authority by reclaiming an additional 10 ft of beach, which the local government later funded to transform into a public road. By 1884, the Qing government invested in

the construction of a 540-ft-long embankment, officially declaring the reclaimed beach as state-owned land in China, managed by various foreign merchants. The *Tianzhu Haitan Zhangcheng* (Regulations on Reclaiming the Beach) adhered to the provisions of the *Daqing Lvli* (大清律例; The Great Qing Code), affirming principles of state control and tax obligations. The reclaimed beach was allocated exclusively to subsequent leaseholders, with other leases valued based on the principles of fair British pricing². However, capitalist influences continued to expand, as companies such as Tait and Malcampo repeatedly constructed embankments. All construction costs for these embankments were borne by the *hangs*, and occupied land required corresponding land rent payments based on the area remitted to the local government.

In 1880, port engineering gradually expanded into deepwater areas. The China Navigation Company constructed a floating dock at Daomei Road, featuring a bridge approximately 53 m long and three warehouses onshore, covering an area of 567 sqyd. Multinational companies emerged as powerful forces in this capitalist era, leveraging substantial capital to introduce advanced engineering technologies and disseminate practical engineering methods. During the same period, foreign firms along the Fuzhou riverbanks established docks, securing a dominant position in the riverine trade.

In 1918, the longstanding issues of colonialism and local political influence in the contestation of port space became apparent in the *Haihou Tan Shijian* (Beach Ground Incident). During the Zhangzhou-Xiamen conflict, the British blockaded the Beach Ground under the pre-text of defense, implementing measures such as constructing brick walls, obstructing official roads, installing iron gates, displaying slogans, such as “British Concession Area, unauthorized persons not allowed to enter,” and hoisting the British flag to protect and expand their commercial interests. Xiamen residents actively resisted, asserting their sovereignty in response (Xiamen Shi Weiyuanhui Wenshi Ziliao Yanjiu Weiyuanhui, 1990). In 1922, following this incident, the government made concerted efforts to construct Lujiang Road and promulgated the *Haihou Tan Shanhou Banfa Hetong Santiao* (Contracts for the Aftermath of Xiamen Beach Ground) as well as the 1937 Revised Draft of Xiamen Public Wharf General Plan, asserting official political authority in the management and planning of port space (Figure 6).

² In the 53rd year of Qianlong's reign (1788), the edition was established. Refer to Aigui's *Daqing Lvli* (大清律例; The Great Qing Code).

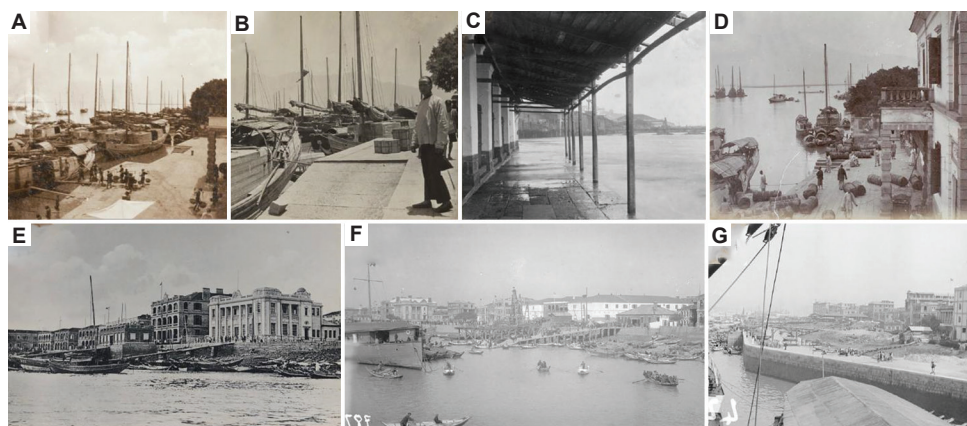


Figure 6. Port spatial landscape: Embankments and piers. (A) Sampans at the bund, Fuzhou. (B) Cargo boats along the bund, Fuzhou. (C) Rising floodwater at Tai Hing jetty, Fuzhou. (D) The bund, Fuzhou. (E) The bund, Xiamen. (F) Butterfield and Swire ship Shanghai at Xiamen, in front of the C.N. and Co. building. (G) Construction of the new bund, Xiamen. Source: (A, C, D, F, and G) Archives and Special Collections, SOAS Library, University of London. ([A and C] The 1890s, [D] The 1880s, [F] 1923 – 1924, and [G] 1933 – 1934); (B) Library of Congress; (E) The collection of Chen Yayuan.

In the 20th century, mercantilist ideologies shifted toward business warfare and industry. The implementation of the *Shiye Jihua* (Industrial Plan) encouraged a strategic focus on the development of railways, highways, and ports (Sun, 1981). Xiamen actively undertook extensive construction projects, including embankments and docks. Notably, new docks were progressively established on Gulangyu and Songyu. This period marked a gradual departure from the mercantilist emphasis on commerce alone. Economic thinking evolved to prioritize the essence of capitalism, particularly on modern industry and its associated socio-economic structures, with a particular emphasis on machine production (Ma, 2014). This transformative shift was prominently evident in the development of Fuzhou. In the region, local gentry and merchants drew inspiration from Russian brick tea factories, leading to the establishment of their own brick tea manufacturing plants. The foundation of the Fuzhou Machinery Manufacturing Bureau marked a significant step, followed by the setup of machinery-based flour mills, sugar factories, weaving mills, and tea factories. The launch of the Xiamen canning factory further symbolized Xiamen's gradual industrialization.

As transit ports, Fuzhou and Xiamen witnessed Western interests engage in construction with minimal capital investment to meet their needs, reflecting localized economic and social dynamics where capitalist expansion was tempered by local constraints. *Hang*-led port construction prompted the Qing government to intervene with capital investment to actively address external involvement. Recognizing that foreign countries all prioritize commerce for prosperity, and any country engaging in foreign trade must establish consuls to protect

merchants,³ the Qing government took a proactive role, investing in response to challenges from foreign economic forces. Faced with these challenges, the government began to self-reflect on its responsibilities, exploring new avenues to expand national commerce at an institutional level. Simultaneously, on an urban level, Western commercial construction methods and corporate building systems were emulated to accommodate growing national business demands. The development of port spaces not only satisfied the requirements for the reproduction of capitalist space but also provided robust support for the expansion of capital, maximizing efficiency. By reshaping urban space, successful efforts fostered the possibilities of capitalist reproduction, laying the groundwork for the development of liberal capitalism.

3.3. The Oilship era (1895 – 1937)

From the late 19th century to the early 20th century, the Hundred Days' Reform spurred the rise of economic liberalism. Oil demand extended beyond its role as a commodity and economic resource, becoming an indispensable fuel source during wartime. The establishment of companies such as Standard Oil Company, Asiatic Petroleum Company, and Texas Company, transformed the existing port landscapes, accompanied by the construction of railways and docks.

In 1892, the Shell Transport and Trading Company was established, and by 1895, it pioneered the containerized transportation of oil to Xiamen, leading

³ Xue Fucheng (1838–1894), a representative figure among early bourgeois reformists in the Qing dynasty and a pioneer of capitalist commerce and industry, presented his views in Volume I of the *Memorial of Missions*.

to the operationalization of the Xiamen kerosene wharf and depot. In 1897, the company was renamed Shell Oil Company, and it assumed ownership of an oil tanker fleet. The tanker fleets featured safety innovations to prevent kerosene ignition and explosions, representing a technological breakthrough. In addition, the Royal Dutch Company, founded in 1890, played a significant role in exploiting the Sumatra oil fields and, in 1901, constructed docks and oil depots in Xiamen. The 1903 merger of Royal Dutch with Shell Oil Company and the Paris Rothschild family resulted in the establishment of the Asiatic Petroleum Company.

In 1889, Standard Oil Company established a presence in the Xiamen British Concession, with Robert W.B. Jardine (1868 – 1927) (PRO: WORK10/467, 1894 – 1930), the hereditary head of Jardine Matheson, as the lessee (Ukers, 1927). During this period, Standard Oil Company engaged Butterfield and Swire Co. and Jardine Matheson as its main distributors in mainland China, later establishing a distribution agency system through Chinese compradors. In the early 20th century, American sales representatives were appointed, leading to the establishment of direct sales points and a sales network.

In 1907, Standard Oil Company constructed large oil tanks in Songyu, with a capacity of 1,750,000 gallons (Wright, 1908). The following year, the tank's wharf was completed (Xinwen Bao, 1908). In the Chinese market, the two major oil companies, Standard Oil and Asiatic Petroleum, engaged in cooperation and competition. Their oil tank constructions often mirrored each other, with some tanks positioned across the river from each other or standing side by side (Wu, 2017).

Initially, the Asiatic Petroleum Company imported kerosene through Malcampo Company, reselling it to Chinese merchants before establishing its own sales system. In 1907, Pasedag Company sublet beach land in Dazhi Street to Asiatic Petroleum Company, which purchased 10,298 sqm of warehouse land and built oil tanks on 9,999 sqm of beach land. However, due to the proximity to the city and concerns about resident safety, the company moved to Songyu in 1928. The new location covered 10,665 sqm of mountain land and 9,332 sqm of beach land, slightly smaller than the original area by 1,411 sqm. The Embankment Department covered the relocation costs, totaling RMB ¥77,000 for relocation and RMB ¥6,000 for dock fees (Xiamen Shi difang zhi bianzuan weiyuanhui bangongshi, 1999). This area, an important transit point between Zhangzhou and Xiamen, witnessed significant developments. In 1905, the Fujian Railway Company was established, initiating the construction of the Zhangzhou-Xiamen Railway. Using this as a starting point, the railway

company set up a central station and a platform at the dock, while the Naval Headquarters for Zhangzhou and Xiamen launched the Songyu redevelopment plan (Gongshang Guanggaoshe Tuixiaobu, 1932) (Figure 7). In 1931, the Songyu Planning Committee was established to zone and plan Songyu, aiming to develop Xiamen's modern industrial zone and create a new satellite city (Figure 8).

Meanwhile, the development of Fuzhou's petroleum industry unfolded with intriguing details. In 1880, the establishment of Standard Oil Company marked a transformative moment for Fuzhou's economic landscape (Gongshang Guanggaoshe Tuixiaobu, 1932). Fast forward to 1899, M. W. Greig Company had initiated a gasworks on Yamu Island (Institute of Modern History: 01-18-083-08-003, 1901) while simultaneously operating the Fujian Match Factory, Ltd. Simultaneously, Dodwell, Carill and Co. began constructing oil tanks in Majiang. In 1901, M. W. Greig Company built oil tanks on Yamuzhou, accompanied by two circular stone piers with a diameter of three *zhang* (丈; a customary Chinese unit of length), eight feet, and six inches (approximately 10 m), as well as nearby warehouses and gasworks. In 1902, Dodwell, Carill and Co. further expanded by constructing oil tanks on Yamu Island, followed by the establishment of a gasworks the next year. In 1907, Standard Oil Company received approval to establish an oil depot in Fuzhou's suburbs (The North-China Daily News, 1907). They leased around 30 acres of private land in Banzhouwei, Mawei, to construct oil tank warehouses for kerosene storage. The chosen area posed no safety hazards,

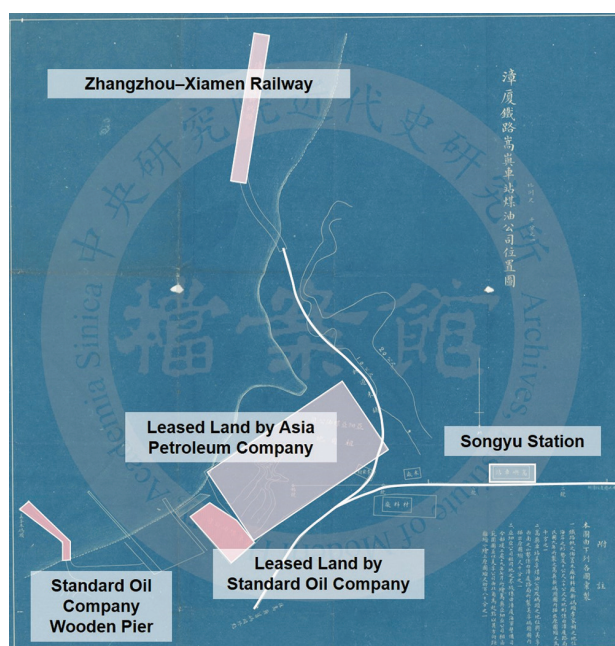


Figure 7. Map of the petroleum company location at Songyu Station on the Zhangzhou-Xiamen Railway. Source: Drawing by the authors.

as it was free of farmland or graves and only contained temples (Institute of Modern History: 02-13-003-02-002, 1907). During negotiations with the Chinese government, Standard Oil Company frequently referenced prior Qing approvals for building oil tanks but failed to produce any regulations. Operating without formal authorization for years, they eventually sought permission to expand. Only in the Republican era were regulations amended and security deposits required, as in the case of Yamu Island in Fuzhou. In 1916, the Ministry of Foreign Affairs approved Standard Oil Company's addition of two tanks on Yamu Island, each measuring approximately 30 ft in diameter and 10 ft wide (Institute of Modern History: 03-16-004-02-001, 1916). That same year, Dodwell, Carill and Co. transferred its two oil tanks in Mawei and Yamu Island to Asiatic Petroleum Company (Institute of Modern History: 02-13-003-02-002, 1901). The 1920s marked a new chapter as Japanese consuls outlined plans for a commercial port on Yamu Island. By 1926, Standard Oil Company unfolded a visual spectacle – a distribution map for its South China Branch, showing locations near Pagoda Anchorage in Fuzhou. The narrative reached a peak in 1927 when workers at the Asiatic Petroleum Company staged a strike in Fuzhou (The North-China Daily News, 1927) (Figure 9).

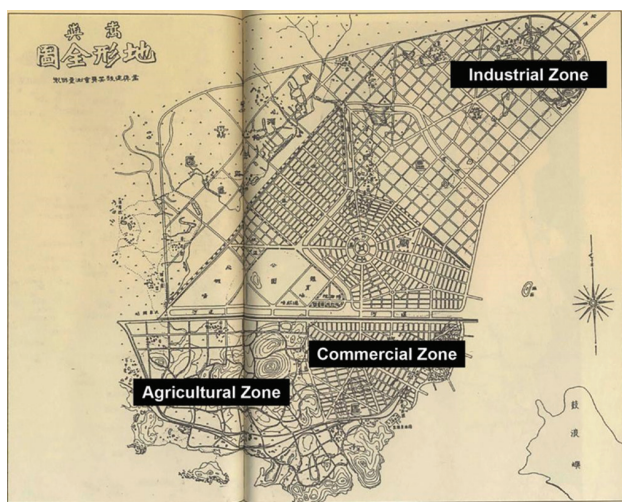


Figure 8. Topographical map of Songyu, 1932. Source: Drawing by the authors.

The development of petroleum companies in trading ports has provided new impetus for port economies, spurring the construction of oil depots, docks, and other facilities across various locations. To begin, regulations must be established to ensure the safety of surrounding residents and water areas. In addition, in land leasing, intermediaries or agents facilitate land purchases, with further requirements set for the installation of dock bridges. Petroleum companies often collaborate in constructing oil tanks, resulting in these facilities being located close to each other or directly facing one another. In the 1920s, during a period of exclusionary policies in China, kerosene import volumes and prices rose, reflecting the influence of the “invisible hand” of market mechanisms. This phenomenon led petroleum commodities to return to free-market values, underscoring the essential role of petroleum products in the daily lives of Chinese people, particularly in lighting and fuel applications. Furthermore, influenced by multiple forces, petroleum companies and their commodities demonstrated the impact of the “visible hand,” illustrating the interactive relationships between colonialism, mercantilism, and capitalism within the context of the globalized market.

4. Conclusion

Through an in-depth examination of the spatial evolution of the ports in Fuzhou and Xiamen amid maritime technological changes, this article unveils the intricate interplay between colonialism, mercantilism, and capitalism in shaping urban spaces. It sheds light on the complex interactions between port development and socio-cultural practices, revealing similar patterns in the development of interrelated port cities. In this process, modern mercantilism plays a transformative role, significantly influencing the development of port spaces.

During the era of sailing ships, Western colonizers introduced new technologies that became a key driving force in shaping the port spaces of Fuzhou and Xiamen. Colonizers integrated these cities into the global colonial network by establishing shipyards and other infrastructure, creating urban spatial forms aligned with strategic objectives. Simultaneously, mercantilist ideology during



Figure 9. Port spatial landscape: Oil company. (A) Stone Dashizi and Asia Petroleum Company oil depot. (B) Asia Petroleum Company factory buildings and oil depots. (C) View of the relocation site for Asia Petroleum Company from Qilin Mountain. Source: Ziri Collection (<https://mp.weixin.qq.com/s/SNjsH94XBeJBjpkgrhSUXw>).

this period emphasized national economic independence and strength. The concept of “business warfare” gained popularity, leading to the militarized planning of port spaces.

With the advent of the steamship era, the opening of the Suez Canal accelerated the globalization of commerce and trade. The thriving tea and cotton yarn trade became a crucial driving force behind the development of Fuzhou and Xiamen. During this period, industry became the core of mercantilist ideology, with national capital playing a significant role in shaping port spaces. Water usage rights transformed into trade privileges, while the integration of land and water areas was facilitated by partnerships between official and foreign capital.

With the arrival of the oil tanker era, petroleum emerged as a new force in urban development. The infrastructure brought by oil companies transformed port landscapes, highlighting capitalism's role in the global evolution of ports. Mercantilism gradually evolved into a capitalist ideology focused on a free-market economy. Oil company construction guided urban space toward industrialization, driven by profit motives. These companies exploited mercantilist loopholes in land leasing, directly impacting the safety of surrounding residents and water areas with the construction of oil depots and docks. To accommodate industrialization needs, port operations gradually shifted away from city centers.

In summary, the treaty ports of Fuzhou and Xiamen, shaped by the forces of colonialism, mercantilism, and capitalism, transformed from militarized cities to commercial hubs and, eventually, to industrialized urban spaces. Throughout this process, the influence of modern mercantilism not only marked the evolution of commercial ideas but also played a crucial role in shaping the globalized spatial development of port cities.

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ORIGINAL ARTICLE

Red industrial heritage: A vibrant medium
for disseminating contemporary Chinese
mainstream cultureSunny Han Han^{1*}  and Amal Zhuo Li² ¹National Institute for Cultural Development, Wuhan University, Wuhan, Hubei, China²School of Marxism, Shanghai Jiao Tong University, Shanghai, China

Abstract

Red industrial heritage represents historical evidence and important revolutionary cultural relics of Chinese-style modernization under the leadership of the Communist Party of China. It possesses distinct characteristics in terms of its temporal, conceptual, and value dimensions. Beyond serving as a repository of media memory, red industrial heritage functions as a vibrant medium for the dissemination of mainstream culture. Its defining features include the “Gaze-Immersion” effect, which evokes a return to historical scenes; the “Abstraction-Embodiment” process, which fosters material perception; and the “History-Reality” connection, which highlights contemporary relevance. However, current management practices for industrial heritage often follow the principle of “age priority,” resulting in challenges for the effective protection of red industrial heritage. Furthermore, when the cultural tourism industry intervenes in the protection and utilization of industrial heritage, it frequently emphasizes age value, location value, or esthetic appeal, while inadequately exploring and developing the cultural significance of red cultural resources. This oversight diminishes the role of red industrial heritage in disseminating mainstream culture. In recent years, increased attention to industrial heritage has expanded the pathways for mainstream culture dissemination, including conservation and renewal, intellectual property empowerment, and community participation. These approaches have generated valuable experiences and insights into enhancing the cultural and social functions of red industrial heritage.

Keywords: Red industrial heritage; Mainstream culture; Dissemination; Memory sites; Media memory

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1. Introduction

Red industrial heritage represents the historical material evidence of the Chinese Communist Party's (CPC) leadership in Chinese-style modernization. It holds multifaceted values spanning history, economy, science and technology, art, and society, serving as a testament to the CPC-led journey of modernization. As a material embodiment of industrialization and a key component of revolutionary cultural relics, red industrial heritage encapsulates a rich repository of mainstream culture. This mainstream culture refers to the system of socialist core values established under the

CPC's leadership during national development. It reflects the CPC's value orientation, the spirit of perseverance embraced by the Chinese people since modern times, and the dominant cultural system in contemporary China (Zou, 2002). Moreover, it embodies the CPC's governance philosophy and mirrors the prevailing cultural concepts within Chinese society.

The mainstream culture embodied in red industrial heritage has inspired both the CPC and the Chinese people to achieve significant advancements in industrialization. With its unique appeal and profound spiritual and cultural significance, this heritage holds important contemporary value. Internally, red industrial heritage can be integrated with themes related to the CPC's governance, fostering the nation's centripetal force and cohesion and providing the spiritual motivation to further the Party's leadership in modernizing national culture. Externally, as a product of globalization, red industrial heritage reflects technological transfers and cultural exchanges that have shaped human history through global interactions. By revitalizing and utilizing the history of socialist development and technological evolution globally, sharing the stories behind red industrial heritage, and promoting its active role in cross-cultural exchanges, this heritage can evoke shared global values. Moreover, it can effectively contribute to shaping China's national image positively and support the CPC's efforts in modernizing national culture.

In recent years, the study of industrial heritage has gained prominence with the arrival of the post-industrial era, attracting increasing attention within the contexts of urban restructuring, spatial transformations, and stock renewal. Academic research on industrial heritage has expanded beyond archaeology and architecture to become an interdisciplinary field encompassing history, urban planning, public administration, the cultural industry, the history of science and technology, and tourism management. In China, reflecting the country's unique path to modernization, research has shifted from focusing on *how to transform* industrial heritage to evaluating *what to protect* and exploring its cultural core (Gao & Xiao, 2021).

Another point worth noting is that since the post-2012 Xi Jinping administration, China's dominant cultural narrative has increasingly been defined by a concept of Chinese-style modernization shaped by both industrial and revolutionary culture. This idea was further reinforced at the 20th National Congress of the CPC 2 years ago (Xi, 2022). The fusion of industrial and revolutionary cultures is materially represented through red industrial heritage.

Chinese scholars have shown increasing interest in the cultural dissemination function of industrial heritage.

For instance, research explores how industrial heritage conveys technological culture (Feng, 2008), how industrial heritage communities, as urban communities, contribute to preserving urban history (Sun & Sun, 2013), and how industrial social culture and urban life memories can be disseminated through the visualization of industrial heritage (Wang & Xu, 2022). With the increasing diversification of tourism forms and the rise of industrial tourism in China, some argue that "the integration of industrial culture and red culture should become one of the basic directions for the future integration of the two tourism models" (Zhang, 2020, p. 82). In the context of cultural tourism integration, scholars are exploring how to effectively promote the dissemination of industrial culture by leveraging the inherent connections between industrial heritage and natural and cultural resources (Li & Chu, 2023). These studies offer valuable perspectives on advancing the dissemination of mainstream culture through red industrial heritage.

International scholars have also explored similar themes, emphasizing the potential of industrial heritage transformation to provide cultural facilities for diverse urban populations (Swensen & Skrede, 2018). Examples include the protection of working-class ways of life and cultural values in South American communities (Da Costa, 1989), the impact of Incheon's cultural policy on repurposing outdated spaces to create cultural values (Cho & Shin, 2014), and the role of industrial museums in Japan in preserving local culture (Han, 2023). In Germany, the case of Duisburg highlights efforts to protect industrial culture in the Ruhr region (Ćopić *et al.*, 2014). Meanwhile, ecological museums in Catalonia not only promote a new culture of sustainable development in the region but also contribute to the construction of collective memory (Prat & Cànoves, 2012). In Gdansk, Poland, industrial architecture plays a key role in preserving cultural identity and distinguishes the city from others (Szymański, 2017).

In addition, scholars have examined industrialization within socialist countries, including the Soviet Union's industrial support to its republics and the fate of those factories today (Benjamin, 2018), the industrial technology transfer agreements among Warsaw Pact nations (Stent, 2021), and the industrial legacies in East Asian countries such as China, Vietnam, and North Korea (Gill, 2024). However, while these studies explore the relationship between industrial heritage and culture, they primarily focus on the post-Cold War era and often overlook the contemporary and future significance of these legacies.

In terms of conceptual formation and evolving connotations, the idea of "red industrial heritage" extends far beyond towering buildings or industrial complexes.

Scholars have long engaged with this topic. As early as 1994, Deborah A. Kaple introduced the concepts of the “industrial heritage of the CPC” and the “red factory,” arguing that these should be regarded as part of the broader “Cold War industrial heritage” (Kaple, 1994). However, her interpretation, rooted in the context of post-Cold War thinking, reflects notable political biases. Similar perspectives appear in other works, such as referring to the “industrial heritage of the CPC” as “industrial heritage without [its own nation’s] history” (Gillette, 2017, p. 217), or labeling it as “[China’s] political industrial heritage” (Frazier, 2019, p. 62). According to the authors’ rough calculations, these viewpoints rank among the most frequently cited in overseas research on China’s industrial heritage, and their erroneous conclusions—driven by cognitive biases or intentional misrepresentations—have been widely disseminated. While these early studies contributed to defining the initial concept of “red industrial heritage,” their interpretations are heavily skewed by linguistic and ideological prejudice, where the disadvantages far outweigh the benefits.

Despite these early international discussions, red industrial heritage has not received the attention it deserves in Chinese society for several reasons.

First, China’s current cultural relic protection policies only recognize artifacts that are at least 60 years old, unless they possess exceptional historical significance. Since many red industrial heritage sites were constructed after the 1960s, they often fall outside the scope of protected cultural relics. This policy limitation has led to the mistaken belief that “if it isn’t a cultural relic, it doesn’t warrant protection.” Theoretically, this belief stems from the uncritical adoption of Western heritage theories. Some scholars argue that the core of “heritagization” lies in the recognition of heritage value by official institutions. However, this approach oversimplifies the complexities of how historical value is formed. Scholars have long pointed out the limitations of this perspective (Li & Peng, 2009).

Second, red industrial heritage has suffered significant damage during urban renewal efforts, largely due to insufficient recognition of its historical value. As a latecomer to industrialization, many Chinese cities expanded rapidly through factory development. These factories were often centrally located, occupying large areas and contributing to pollution. In the push for modernization and redevelopment, many historically valuable industrial sites were demolished because their high-value urban locations made them prime candidates for redevelopment. Without adequate time for cultural relic protection or efforts to preserve photos or architectural specimens, these heritage sites were lost, erasing integral

aspects of local history. Further compounding this issue are factors such as factory bankruptcies, changes in property rights, management reforms, and industrial restructuring (Tang, 2007). Industrial archives, which are crucial for understanding this history, have often been discarded as waste. The decentralization of archive protection (Shang, 2019) has further complicated efforts to preserve local history and organize historical data effectively.

Third, the role of red industrial heritage in disseminating mainstream culture has not yet been fully recognized or widely understood. Public perceptions of mainstream culture often focus on historical and cultural relics, with limited awareness of the industrial civilization that has emerged in modern times. This lack of awareness has led to insufficient societal acceptance of industrial culture, presenting significant challenges to its preservation and transmission (Fan *et al*, 2020).

Overall, red industrial heritage remains an emerging concept. Its scope, historical significance, and value have yet to be fully explored or comprehensively interpreted, and systematic research on the subject is still in its infancy. This gap not only limits in-depth academic exploration but also hinders the practical application of red industrial heritage. Addressing these challenges requires continued efforts to deepen both academic exploration and practical applications, particularly in understanding how red industrial heritage can propagate mainstream culture and offer deeper insights into contemporary China.

2. Overview of the red industrial heritage concept

While relatively mature and widely accepted criteria exist for determining what qualifies as industrial heritage, no clear or well-established set of indicators has been defined whether red industrial heritage specifically falls within this category. This lack of clarity poses a significant obstacle to the in-depth exploration of its meaning and value.

2.1. Conceptualization of red industrial heritage

The history of the CPC is fundamentally the history of its leadership in guiding the nation toward modernization. Industrialization, a pivotal element of modernization, has played a crucial role in China’s progress. As a political party representing the interests of the workers’ and peasants’ alliance, the CPC has a natural and intrinsic connection to industrialization. From its inception, the CPC prioritized the workers’ movement and industrial production as key focuses of its mission (Harper, 1969). Early CPC leaders, such as Mao Zedong (1893 – 1976), Liu Shaoqi (1898 – 1969), Deng Zhongxia (1894 – 1933), and Chen Tanqiu (1896 – 1943), were actively involved in industrial

production and played significant roles in establishing some of China's earliest trade union organizations at locations such as the Anyuan Coal Mine, the Daye Iron Mine, and the Changxindian No. 27 Locomotive Factory. These leaders believed in unifying Chinese workers into an organization capable of collective struggle.

Before 1949, the CPC had already made significant strides in industrial production within its revolutionary bases, border regions, and liberated areas, integrating military struggle with industrial development. For example, the Central Red Army established a printing factory and an arsenal in Ruijin to achieve self-sufficiency in military supplies. The New Fourth Army set up factories such as the Daji Tobacco Factory and the Donghai Tobacco Factory in northern Jiangsu province and southern Anhui province, respectively. In the Shanxi-Hebei-Shandong-Henan border area, the Eighth Route Army operated quilt and paper factories, fostering a system where industry supported the war effort. In addition, the CPC organized facilities such as the Limin Woolen Spinning Factory, Xinhua Chemical Factory, and Zhenhua Paper Factory, laying a solid foundation for military and industrial production in the once economically weak Yan'an region.

After the founding of the People's Republic of China in 1949, the CPC set its overarching goal of "transforming our country as soon as possible from a backward agricultural country to an advanced industrial country." Through this process, the industrial system became a cornerstone of the CPC's leadership in national modernization.

Building on this historical context, this study proposes the following definition for "red industrial heritage": It refers to the modern industrial heritage system formed as a result of the nation's modernization under the leadership of the CPC, from its founding in 1921 to the present day. This definition encompasses significant cultural relics recognized within the framework of cultural heritage preservation, as well as historical and material evidence—such as a wealth of industrial heritage from the reform and opening-up period—that may fall outside official preservation frameworks but hold substantial value. As an irreplaceable red cultural resource, its core value lies in its representation of modern history, securing a significant and unique place within China's industrial and cultural heritage systems.

2.2. Interpretation of the value of red industrial heritage

Red industrial heritage is a vital repository of China's contemporary mainstream cultural resources. In addition to sharing multiple values with other types of industrial heritage, it holds unique cultural significance as a

representation of the CPC's entire historical legacy. As the essence of China's industrial heritage system since modern times, red industrial heritage embodies values spanning history, culture, economy, technology, and art. However, the broad scope of these values can obscure the uniqueness and precision of red industrial heritage. Its distinct characteristics and contributions to global industrial development can only be fully appreciated when contextualized within the broader frameworks of national history, economy, defense, diplomacy, and social culture.

First, as a historical witness to the CPC's leadership in the modernization of socialism with Chinese characteristics, red industrial heritage holds profound historical significance (Brown, 2017). The extensive system and scale of red industrial heritage serve as tangible evidence of the CPC's achievements in industrial construction across different historical periods. It also embodies the CPC's values and spiritual pursuits. Politically, red industrial heritage is symbolic, recording China's industrial evolution from its infancy to its emergence as a global industrial powerhouse, showcasing the CPC's ability to balance construction with revolution. Culturally, it encapsulates the national spirit of self-reliance, the steadfast commitment to national rejuvenation, and the historical trajectory by which China became the "world factory."

Secondly, red industrial heritage holds multi-dimensional economic, social, and cultural significance. As a repository of social memory, it preserves valuable historical information and provides a platform for the public, especially younger generations, to learn about the country's industrial development and the achievements of socialist construction. As a unique cultural heritage, it reflects China's industrial trajectory and cultural soft power. The revolutionary spirit it embodies plays a vital role in shaping socialist core values and moral standards. Furthermore, red industrial heritage has been repurposed into art parks, creative studios, and cultural exhibition spaces, fostering innovation and creativity. These revitalized spaces serve as hubs for emerging industries and new cultural expressions, supporting regional brand development and offering creative opportunities for artists and designers.

As a cultural tourism asset, the renewal and transformation of red industrial heritage enrich public cultural experiences and stimulate local tourism, creating employment opportunities and promoting economic and cultural activities in surrounding areas. Community engagement in conservation and utilization projects fosters social cohesion and the accumulation of social capital, improving overall community well-being. In addition, the preservation and reuse of red industrial heritage support

sustainable development through brownfield management and ecological restoration.

The uniqueness of red industrial heritage, compared to other forms of cultural heritage, is also reflected in its technical value. It not only stands as a testament to the CPC's leadership in Chinese-style modernization but also represents a crucial chapter in the history of China's industrial and technological advancement. This is particularly evident in the progression of production processes and industrial innovation. For example, during the 156 Project, the Soviet Union provided critical design work, equipment, technical assistance, and expert guidance. The Soviet collaboration also included training China's scientific, technological, and managerial talent (Chen, 2015). Within a decade, China's industrial technology advanced from being nearly a century behind industrialized nations to reaching the level of the 1940s (Chen, 1999). The industries established during this period spanned almost every major industrial sector and were instrumental in the development of China's modern industry.

Further technical advancements were made through assistance and technology transfers from countries such as the former German Democratic Republic, Poland, and Czechoslovakia. These efforts enabled China to master technologies in seamless steel tubes, superconducting glass fibers, and high-precision silicon semiconductors. Moreover, the technical value of red industrial heritage is reflected in the vast archival materials it generated. Despite the relatively short timeframe, these archives document diverse aspects of industrial fields, including early site selection, layout, construction, equipment procurement, enterprise party organization development, and the recruitment of technical personnel. This wealth of technological archival heritage, encompassing administrative, scientific, personnel, and financial records, serves as a testament to the evolution of China's industrial technology.

3. Advantages and mechanisms of red industrial heritage in disseminating mainstream culture

Red industrial heritage possesses dual attributes as both material and spiritual heritage. The mainstream culture embedded within it relies on material entities—particularly buildings, structures, and scenes—that carry rich elements of mainstream culture following renovation and updates. These physical components have a strong narrative function, enabling the dissemination of cultural values.

3.1. Advantages of red industrial heritage in disseminating mainstream culture

The ability of red industrial heritage to serve as a vehicle for disseminating mainstream culture is deeply rooted in

the historical context of the Chinese Civil War (between the CPC and the Nationalist Party) before 1949, as well as during World War II. During these periods, the CPC played a critical role in organizing workers' movements, often through underground trade unions. Simultaneously, the Party established arsenals and other factories to support wartime efforts by producing essential supplies and generating funds. These industrial sites, shaped by the CPC's involvement, represent some of the earliest examples of red industrial heritage. They are rich with stories and personalities reflecting the Party's efforts and ideology.

Following the CPC's rise to power and the subsequent nationwide industrialization after 1949, the concept of red industrial heritage evolved and matured, adapting to the shifting needs and developments of the times. This progression laid the groundwork for red industrial heritage to naturally embody the elements necessary to propagate mainstream culture. Its historical significance, combined with the CPC's influence, offers a strong foundation for cultural dissemination and ensures its continued relevance within mainstream cultural narratives.

Several key factors contribute to this unique capacity. First, red industrial heritage is deeply embedded in the history of the CPC's struggle and eventual victory, symbolizing perseverance, resistance, and national rejuvenation. Second, its association with key historical moments and influential figures in modern China's history creates a tangible connection to the country's development. Finally, the preservation and adaptive reuse of these industrial sites ensure their continued relevance, allowing them to resonate with contemporary audiences and serve as both historical markers and active participants in mainstream cultural dissemination.

From a cultural standpoint, red industrial heritage transcends its role as a static landscape imbued with specific cultural symbols. It serves as a site of memory and plays the role of a "mediated memory." By reconstructing historical scenes of mainstream culture through buildings and structures, it fragments specific locations to create collective memories. This reconstruction fosters a deep sense of pride and identity among individuals (Lu, 2012). The mediated memory function of red industrial heritage grants these sites unique narrative abilities. Many of these sites can be spatially renewed and transformed, carrying both a missionary purpose and practical value. This function underscores the vital role of history in shaping contemporary identity narratives—a capability not found in traditional revolutionary relics, literature, news reports, or live performances.

Moreover, red industrial heritage serves as both a material site of memory and a cultural landscape capable of

scene reconstruction. From small-scale cultural exhibitions and creative displays to large-scale urban renewal projects, red industrial heritage fosters a deeper level of engagement. It offers a broader platform for cultural dissemination through the lens of everyday life esthetics, enriching public interactions with history and culture.

3.2. Dissemination mechanism of mainstream culture in the development of red industrial heritage

The dissemination mechanism refers to the interaction between the disseminating subject, the disseminating object, and the dissemination framework. Theoretically, this mechanism is not determined by any single party but is jointly shaped by all three components (Malin, 2016). Typically, within this dynamic relationship, the communication subject occupies a central position and plays a crucial role in establishing the mechanism. Red industrial heritage facilitates the effective transmission of mainstream culture by offering immersive experiences, unique scene presentations, and value interpretations that align with contemporary needs (Ryan, 1994). The dissemination mechanism can be categorized into three distinct forms: “Gaze-Immersion,” “Abstraction-Embodiment,” and “Historical-Reality.” These forms represent different methods through which cultural values are communicated and absorbed.

3.2.1. Gaze-Immersion: Constituting embodied cognition

In communication, symbols rely heavily on visual transmission. The visual communication system captures information through the symbolic refinement of “encoding-decoding,” making it accessible to the viewer through visual rhetoric (Pinker, 1984). From a biological and cognitive psychological perspective, the viewer first perceives light through eye movements, which then generates biological vision through the cornea, pupil, lens, vitreous humor, retina, and optic nerve. This process stimulates the cerebral cortex, forming short-term memory and creating a retained message based on visual rhetoric. In cultural studies, this entire process is referred to as the “gaze” because it involves complex layers of power, desire, capital, and identity. The gaze is bidirectional, encompassing both the viewer as the gazer (the observer) and the gazed (the heritage as the subject) (Urry, 2007).

Gazing serves as a form of communication that facilitates the visual decoding and exchange of symbols (Perfetti, 1984). With the continuous advancement of cultural science, technology, self-media, and tourism concepts, red industrial heritage as a cultural landscape introduces a “new cultural relationship between subject

and object” (Hu, 2010, p.72). This transition shifts from “gaze” to “dialogue” and from “communicability” to “plasticity” and “participation.” “Plasticity” refers to the audience’s ability to reshape the scene itself through secondary dissemination, such as transforming a site into a famous internet attraction through self-published content. “Participation” involves the audience actively engaging in the scene’s presentation, such as turning visitors into part of the landscape through immersive travel art shoots. Participation extends to experiences of clothing, food, shelter, and transportation, merging the audience with the ontology of the scene. This engagement leads to embodied cognition, where physical experiences are activated by psychological ones. Both plasticity and participation depend on the presence of immersive environments, allowing the audience to enhance the sense of “gaze” through deeper immersion, thereby strengthening the dissemination of mainstream culture.

While gazing is a direct form of communication (Tang, 2020), immersion is more indirect. Immersion transforms the cultural landscape from a static site into a dynamic historical scene, providing audiences with abstract experiences and enabling conceptual interaction with the setting over time (Kenderdine, 2015). In terms of communication effectiveness, the threshold for accepting “gaze immersion” is relatively low, making it particularly adept at mobilizing the target audience’s knowledge, cognitive structure, and psychological preconceptions. Through embodied cognition, this form of communication creates a “get what you need” effect, promoting media memory and, ultimately, enhancing the effective dissemination of mainstream culture.

3.2.2. Abstraction-embodiment: The formation of material perception

The dissemination of mainstream culture relies on various media, and red industrial heritage, as one of these media, possesses a distinctive feature in its communication mechanism: It achieves a material leap from abstraction to embodiment in terms of perception.

Compared to other forms of mainstream cultural communication, such as revolutionary cultural relics, red industrial heritage shares the ability to vividly present key historical moments of the CPC through tangible artifacts, creating concrete impressions of CPC history. However, most revolutionary cultural relics—especially immovable ones—are often limited in their capacity to transform from static cultural landmarks into immersive historical experiences. This limitation arises from their inherent heritage attributes and their close association with grand cultural narratives. In contrast, red industrial heritage

offers two unique characteristics. First, it profoundly influences and often defines local cultural landscapes, embedding unique geographical information within these spaces. Second, it offers vast potential for renewal, enabling the creation of new spiritual symbols built upon traditional cultural ones. This spatial materiality provides opportunities for reinvention.

This materialization not only offers audiences tangible and participatory experiences – through concrete artifacts or reconstructed historical scenes – but also lays the groundwork for enriching the material aspects of cultural symbols. By bridging abstract spiritual values of mainstream culture with the embodied spirit of the present era, red industrial heritage aligns past ideals with contemporary needs. For example, Daqing city in Heilongjiang province, China, the birthplace of the “Iron Man Spirit,” is home to numerous red industrial heritage sites centered on this theme. In recent years, however, Daqing has shifted its focus toward becoming an environmentally friendly city, prioritizing environmental protection in its urban development. Through the implementation of the “green water and green mountains” strategy and the promotion of the concept of “dual restoration,” the city has reinterpreted the once-dominant “Iron Man Spirit” to suit modern values. This transformation involved converting red-themed buildings, structures, and equipment into public parks, sculptures, and commercial districts. The result is a new urban culture that integrates the “Iron Man Spirit” with environmental sustainability goals of “green water and green mountains” (Figure 1). This reimagining aligns the “Iron Man Spirit” with the vision of building a “People’s City,” giving it a renewed and specific meaning for the contemporary era.

The mechanism of transmitting mainstream culture through red industrial heritage not only reflects its material attributes but also vividly interprets the practicality of mainstream culture rooted in the CPC. This mechanism creates a synergistic effect, where the whole is greater than



Figure 1. Site of Iron Man Well No. 1 in Daqing Oilfield. Source: Photo by Daqing Culture and Tourism Bureau (2024)

the sum of its parts, amplifying the dissemination and impact of cultural values.

3.2.3. History-reality: Explaining the value of reality

In contemporary China, mainstream culture is a product of the CPC’s historical practices in war, nation-building, and reform, embodying the distilled essence of its governance experience. Many red industrial heritage sites are closely linked to this mainstream culture, preserving the physical spaces necessary for its dissemination. However, as economic structures shift and urban renewal progresses, these sites face challenges, such as the erosion of media memories and the gradual fading of historical markers, particularly as their original productive functions are lost. By leveraging the plasticity and participatory characteristics of red industrial heritage, reinterpreting cultural symbols, and constructing new media memories tied to “historical realities,” these heritage sites can ensure the continuation of the mainstream culture they embody while establishing meaningful connections with other specific cultural qualities (Zhang & Lu, 2024).

In this context, the concept of “historical reality” emerges as a crucial communication mechanism, reflecting the reinterpretation of mainstream cultural values within a modern framework. An example is the NICE2035 Future Neighborhood project in Anshan Xincun, located on Chifeng Road in Shanghai’s Yangpu district. This area, an important industrial heritage site, contains numerous residential buildings from the 1950s that were once part of the Shanghai Tool Factory. These buildings, which also housed workers from the Watch Factory and the Water Treatment Plant, were once considered “model staff dormitories.” It was famously said, “If one person lives in the new village, the entire factory is honored” (Zhou, 1958, p. 137-138). Hundreds of national and provincial model workers resided in this area, making it a key red industrial heritage community. However, over time, most factories have been reorganized or ceased operations, and the old labor patterns have faded, causing the “new village” to gradually lose its former prestige.

In recent years, faculty and students from Tongji University have revitalized the community through participatory initiatives, transforming the old industrial heritage area into the NICE2035 Future Communities (Figure 2). This effort has blended red industrial heritage with modern community development to create a “fashionable community,” themed around “City Creators and New Communities” (Ma & Lou, 2022). By framing the project in terms of “urban makers and new craftsmen”—concepts that resonate with younger generations—the initiative continues to uphold the “spirit of labor” and the



Figure 2. NICE-2035 Future Life Prototype Street at night. Source: Photo by Sunny Han Han (2023)

“spirit of craftsmanship” in the new era. This approach effectively promotes the traditional “model worker spirit” while generating a positive cultural impact.

Explaining the real value of mainstream culture by combining “history and reality” reflects the flexibility of red industrial heritage as a communication medium, which is also its key advantage. How to fully utilize this advantage, enhance its dissemination, plasticity, and participation, and maximize its effectiveness in the process of dissemination remains a practical issue that requires further exploration.

4. The current situation of the protection and utilization of red industrial heritage

As a non-renewable cultural resource, industrial heritage serves as a carrier of historical, cultural, and technological development, representing its greatest value and a key focus of industrial archaeology research. Over the past two decades, due to proactive efforts by relevant departments and the effective implementation of laws and policies, many valuable industrial heritage sites have been properly protected and utilized. However, a significant number of red industrial heritage sites remain excluded from the cultural protection framework, creating a legal gap in their preservation. This exclusion often leads to the paradoxical phenomenon of sites that “should be protected but should not be protected.” Furthermore, even among those protected, emphasis is frequently placed on their historical or regional significance, while their value as red cultural resources receives insufficient attention (Lv, 2019).

4.1. Double-blind spot in attention: The paradox of “should be protected but should not be protected”

Currently, most red industrial heritage sites in China have not yet reached the legal age threshold for protection as cultural relics. Consequently, they remain largely

unprotected and undervalued, with limited recognition of their esthetic and historical significance. Characterized by simple architectural styles and low historical landscape esthetics, such industrial sites are often overlooked in both cultural relic protection and industrial heritage reuse efforts. This issue is particularly pronounced for industrial buildings such as factories, wharves, and office structures from the early Deng Xiaoping (1904 – 1997) era, which bear witness to China’s reform and opening-up period. Despite their historical importance, these buildings are not old enough to qualify for cultural relic protection. Moreover, many are located in prime urban areas and are frequently demolished in favor of urban development (Liu & Gao, 2023).

The industrial heritage of the reform and opening-up era, a vital component of red industrial heritage, faces an uncertain future due to insufficient attention and protection. For instance, in Shenzhen, hundreds of Deng Xiaoping-era industrial buildings have been demolished over the past decade. In Shekou, Shenzhen’s first industrial zone, most industrial structures were dismantled, with only a small portion transformed into the Nanhai Yiku Cultural and Creative Industry Park. Similarly, in 2017, the urbanization of the Dongqiaotou Oil and Gas Reservoir, Shenzhen’s largest gas storage site, marked the beginning of its demolition and redevelopment. Several members of the Shenzhen Municipal Committee of the Chinese People’s Political Consultative Conference proposed converting the site into a park commemorating the city’s reform and opening-up era (Shenzhen Municipal Committee, 2017). The Shekou Street Office similarly envisioned turning the site into a “warm ecological park on industrial land” (Ding, 2017). However, these proposals have not yet materialized, and the Dongqiaotou Oil and Gas Reservoir has been entirely demolished and no longer exists.

This pattern is not unique to industrial heritage from the reform and opening-up period but also affects key sites from the early years of the People’s Republic of China, which have not yet reached the threshold for legal protection. In Wuhan, known as the “eldest son of the Republic,” a significant amount of industrial heritage dates back to the Mao Zedong era. Fieldwork reveals that of the 231 industrial heritage sites in Wuhan built after 1949, 157 are either almost completely dismantled or entirely destroyed. These sites include major buildings from the 156 Project, such as the Wuhan Heavy Machinery Factory, where only the entrance remains. In contrast, industrial heritage from the late Qing (1644 – 1912) and Republican (1912 – 1949) periods, such as the Banco Bakery, Zongguan Waterworks (Figure 3), and the Hankou Light and Power Co., Ltd (Figure 4), has been well-preserved.



Figure 3. The century-old Wushui Red Mark Theme Exhibition inside Zongguan Water Plant. Source: Photo by Changjiang Daily (<https://baijiahao.baidu.com/s?id=1702794908548335820&wfr=spider&for=pc>)



Figure 4. Hankow Light and Power Co., Ltd. Source: Photo by Wuhan Local Records Committee

This issue is not only confined to Wuhan but also a nationwide problem. The “double-blind spot” in attention – both in terms of protection and reuse – has created a situation where red industrial heritage is “nowhere to be found,” leading to the loss of valuable cultural assets. The failure to recognize the significance of these sites as part of the Chinese-style modernization narrative has resulted in the destruction of vast amounts of red cultural resources and the erosion of their social value. This is a matter that demands urgent attention in future industrial heritage management.

4.2. Neglect of historical significance leading to the lack of red cultural symbols

China’s red industrial heritage has long grappled with the tension between protection and demolition. This challenge is exacerbated by the prioritization of time value

or economic value in industrial heritage management, with criteria such as esthetic, technical, and locational value taking precedence. As a result, the historical value – particularly the significance of the “red” cultural aspects – has been marginalized. In many cases, the preservation of red industrial heritage emphasizes general heritage value over the historical significance of its red cultural symbols. This emphasis has diluted the role of red industrial heritage in preserving and transmitting spiritual and historical memories, particularly those related to CPC history.

Unlike other historical heritage sites, industrial heritage typically comprises modern buildings and facilities located in urban centers, making them highly reusable (Wang and Wang, 2012). As a result, red industrial heritage sites are frequently transformed into industrial museums, cultural and creative parks, specialty towns, or commercial complexes (Liu *et al.*, 2012). However, the focus has predominantly been on industrial monuments from the period before and shortly after the CPC’s founding. Furthermore, many restoration projects have simply adopted foreign models of industrial heritage restoration, emphasizing esthetic and chronological aspects while neglecting red cultural symbols, thus leading these restoration efforts astray.

For example, consider the Wuhan Boiler Factory, established in 1954, as one of Wuhan’s four major factories; it was a key base for boiler production in the People’s Republic of China and an important site for defense and heavy industries. Visits by notable CPC figures such as Zhu De (1886 – 1976) and Zhou Enlai (1898 – 1976) further cemented its red cultural significance. However, after the factory’s relocation in 2014, the original site was redeveloped into a cultural and creative neighborhood featuring restaurants, theaters, and bookstores. While these changes have transformed the area into a vibrant public space, the factory’s red cultural resources remain underdeveloped, and the representation of relevant cultural symbols is insufficient.

The reuse of China’s industrial heritage generally centers on the transformation of urban public spaces through cultural tourism, involving the decoding and encoding of cultural symbols. This transformation often entails converting former old factory buildings into city parks using two main approaches: (i) the complete removal of previous industrial symbols, replacing them with “nostalgia/commercial” composite symbols; (ii) the retention of original industrial symbols, reshaping public spaces with social value by tracing the city’s industrial genealogy. In practice, however, most red industrial heritage sites are protected and reused through the former, more commercialized approach.

Research reveals that red cultural symbols, especially those tied to CPC history, are particularly challenging to establish and present. This difficulty stems from the sensitivity surrounding topics related to the Party's historical figures or major events. Consequently, some red industrial heritage sites with significant social value have been transformed into commercial spaces for popular brands, bar streets, small business parks, or express hotels, thereby losing their inherent historical and red cultural significance.

The complexity of transforming red industrial heritage does not imply that such efforts should be abandoned. Instead, the transformation process should adhere to the principle of preserving historical value and maintaining factual accuracy. By recoding red cultural symbols during the renewal and transformation of industrial heritage, China can ensure these sites continue to serve as carriers of red cultural values while also realizing their potential for modern reuse.

4.3. Driving force of top-level design

Under comprehensive top-level planning, significant progress has been made in bringing attention to the preservation of red industrial heritage. This progress is evident in two key areas.

First, society at large has increasingly focused on the future of red industrial heritage, generating a broad public consensus around its protection. The historical, cultural, and tourism significance of these sites is gaining increasing recognition. Since 2019, media coverage has brought many red industrial heritage sites into the spotlight. For instance, the Factory History Museum of Shandong Locomotive and Rolling Stock Co. (Figure 5), which previously received little attention, garnered widespread interest after being featured



Figure 5. History Museum of Shandong Locomotive and Rolling Stock Co., Ltd. Source: Photo by History Museum of Shandong Locomotive and Rolling Stock Co., Ltd

by *Qilu Evening News* as the Jinan Railway Factory that achieved two red firsts in Shandong. Similarly, Xinjiang's Dushanzi Oil Refinery, included in the Fourth Batch of Industrial Heritage List, has attracted significant media coverage. The local government has also emphasized the refinery's significance as the site of Xinjiang's first oil well, a vital red industrial landmark. In September 2023, the Third Batch of China's Industrial Heritage Protection List was unveiled, featuring, for the 1st time, 100 red industrial heritage sites symbolizing Chinese-style modernization efforts. The inclusion of these sites marks an important milestone, reflecting growing official recognition and appreciation for the research and preservation of red industrial heritage.

Second, various government departments have gradually introduced policies aimed at protecting red industrial heritage. In July 2020, the National Development and Reform Commission, the Ministry of Industry and Information Technology, and five other agencies jointly released the Implementation Plan for Promoting the Protection and Utilization of Industrial Heritage in Old Industrial Cities. This plan specifically emphasized the importance of preserving and utilizing industrial heritage, particularly from different historical periods following the founding of the People's Republic of China. In the same year, the National Cultural Heritage Administration published the Top Ten Cases of National Revolutionary Cultural Relics Protection and Utilization, highlighting three significant red industrial heritage sites: the China Jiuquan Satellite Launch Center Historical Exhibition Hall, representing aerospace industrial heritage; the Qinghai Atomic City Memorial Hall, reflecting national defense industrial heritage; and the Red Flag Canal in Linzhou, Henan, a key water conservancy project.

Under strategic, high-level planning, the preservation of red industrial heritage has gained increased emphasis, fostering a broad consensus regarding its social value. However, heritage conservation remains a complex and ongoing endeavor, one that extends beyond the immediate influence of political power. Therefore, approaches to preserving and utilizing red industrial heritage should adhere to principles of scientific decision-making, prioritization of protection, and effective utilization. Building on current momentum, it is essential to strive for a qualitative leap forward in safeguarding and functionally utilizing red industrial heritage.

5. Strategies for the protection of red industrial heritage

In the current landscape of industrial heritage protection and reuse in China, a significant portion of successfully

transformed heritage sites has primarily been repurposed through urban renewal, the integration of culture and tourism, or cultural reengineering. These transformations are typically aimed at creating a museum or cultural creative district, a model that has become central to the preservation and reuse of industrial heritage in China.

However, in the dissemination of mainstream culture, red industrial heritage – as a unique medium – follows two primary pathways. The first pathway involves advancing the protection and revitalization of industrial heritage by combining mainstream culture with the mass line, which focuses on public engagement and participation. The second pathway enhances the value of red industrial heritage as intellectual property (IP) by merging mainstream culture with innovative approaches to red culture. This dual approach not only preserves the historical significance of these sites but also revitalizes them within contemporary cultural narratives.

5.1. Protection and renewal of red industrial heritage through “Double M” (mainstream culture + popular culture)

Unlike revolutionary cultural relics, much of red industrial heritage is represented by historical buildings or structures, some of which remain operational and many of which maintain strong community connections. These sites often belong to former large state-owned enterprises and form extensive heritage clusters deeply integrated into the daily lives of residents. Given the community-oriented nature of red industrial heritage, it is crucial to establish communication pathways aligned with contemporary popular culture to ensure their protection and revitalization.

As noted by Yang (2020), only when culture is embraced by the public can it evolve into a practical force for societal progress. Mass communication that resonates with the needs of the time is essential for mainstream culture to remain relevant. However, the dissemination of mainstream culture often exhibits tendencies toward simplification and one-sidedness, with a top-down indoctrination approach of “setting an example → promoting typical examples → public acceptance.” This model overlooks individual active choices and cultural experiences, making it difficult to achieve the expected dissemination effect (Wei & Du, 2015).

Cultural heritage, as an important carrier for disseminating mainstream culture, has received widespread attention. In the field of cultural heritage, revolutionary cultural relics have served as the primary material medium for promoting mainstream culture. However, their protection is often inadequate, their historical excavation

insufficient, and their utilization superficial (Chen & Wang, 2021). In contrast, red industrial heritage has garnered attention for its malleability, particularly its participatory and interactive nature, which makes it more accessible and engaging to the public.

Adapting to the contemporary contexts is a key to the successful preservation and renewal of red industrial heritage. Presenting these heritage sites in engaging, culturally resonant ways can subtly disseminate mainstream cultural values, creating a path of “mainstream culture + popular culture.” Popular culture transcends the boundaries between itself and mainstream culture, fostering a dynamic exchange and integration of diverse cultural elements that enrich the daily lives of the masses (Liu, 2021). Through diverse forms of dissemination, mass culture can address the limitations of dry content and one-dimensional formats often seen in mainstream cultural communication. By blending theoretical indoctrination, moral education, and emotional engagement, mass culture effectively conveys the ideological core of mainstream culture (Peng, 2012). Consequently, there is a need to strengthen research into industrial culture pathways to support industry development. This includes encouraging industry associations and other organizations to host specialized events aimed at integrating industrial culture with development strategies. Leveraging innovative models and formats, such as “culture + product” initiatives, industries can better harness cultural elements to enhance branding, improve quality, increase efficiency, and ultimately boost the competitiveness of industries, enterprises, and products. A prominent example is the Shenzhen Overseas Chinese Town (OCT) Creative Industry Park, originally the Eastern Industrial Park established during Deng Xiaoping’s era. Once home to over 60 factories and recognized as the “first industrial park in the Special Administrative Region” and a “living fossil” of Shenzhen’s development, it was transformed by the Shenzhen Municipal Government in partnership with the state-owned OCT Group. It became the OCT Cultural and Creative Park, focusing on cultural and creative industries to meet the evolving economic, spiritual, and cultural needs of the population. According to incomplete statistics, the park attracted 148 million visitors by 2023 (OCT, 2024), becoming a viral social media destination and a favored “micro-vacation” spot for nearby residents, as well as a vital space for promoting the spirit of reform and opening up.

Moreover, popular culture must leverage both self-media and mass media to enhance its public presence. In the era of the digital economy, industrial heritage is no longer merely a site for nostalgia but an appealing

destination in its own right (Hashimoto & Telfer, 2017). This shift has shaped a new cultural identity for industrial heritage, fostering a sense of belonging and reshaping its cultural image (Xie, 2015; Schofield, 1996). To maximize this potential, cultural works centered on industry should be encouraged, including industrial narratives and iconic figures presented through various mediums such as films, literature collections, and summit forums. These efforts help communicate the mainstream cultural values embedded in industrial heritage. Supporting media outlets in establishing dedicated channels and columns on industrial heritage can amplify the industry's voice, helping more people understand and appreciate its cultural significance and promote preservation, transmission, and innovation. For instance, the "Two Bombs City" in Zitong County, Sichuan province, China, integrates tourist activities such as selfies and live broadcasts to expand visibility and social impact. Similarly, in March 2021, cultural relic expert Shan Jixiang collaborated with celebrities to produce the series *Riding Alone for Thousands of Miles* in Huangshi city, Hubei province, China, introducing the region's red industrial heritage and the history of its workers' movement (Li, 2021). In July 2021, CCTV News Channel partnered with the Ministry of Industry and Information Technology to produce *Internet Famous Places and Industrial Heritage*, a program spotlighting several red industrial heritage sites. These broadcasts vividly conveyed mainstream cultural values, such as the "CPC Spirit," "Lei Feng Spirit," and "Iron Man Spirit," playing a vital role in promoting and preserving mainstream cultural narratives.

However, as of September 2024, China lacks dedicated media platforms – both academic and public – focused on industrial heritage. Even on self-media platforms such as Bilibili, Xiaohongshu, and TikTok, prominent accounts dedicated to this subject, particularly the promotion of red industrial heritage, are absent. This notable shortcoming underscores the vast opportunities for future development in this area.

5.2. Promote IP empowerment of red industrial heritage through "mainstream culture + red cultural innovation"

The ability of red industrial heritage to serve as a medium for disseminating mainstream culture is deeply rooted in its unique cultural value. From the perspective of cultural industry theory, red industrial heritage contains a wealth of IP resources, with IP being a key symbol that highlights the distinct characteristics of cultural heritage. The core IP of red industrial heritage is undeniably mainstream culture.

IP refers to the property rights creators hold over their intellectual achievements, such as graphics, brands, and

concepts, which are protected under IP ownership. It is an intangible property that can be shared and transferred to generate economic benefits. This stage is considered the foundational level of IP (Li, 2017). The IP of red industrial heritage revolves around mainstream cultural values, conveying explicit and implicit information through symbolic forms that embody the mainstream culture and the red spirit. These symbols grant red industrial heritage a dual attribute of cultural and commercial value (Yuan & Miao, 2020).

In recent years, the rapid growth of Chinese museums' cultural and creative industries has led to the flourishing of historical theme IPs, creating a robust system represented by cultural creations from the Forbidden City and Dunhuang. This evolution reflects a shift from physical products to a broader range of commercial services and virtual products, alongside a vertical transformation from IP authorization to IP conversion. However, cultural creativity in the realm of red museums has lagged behind other areas of cultural innovation. This gap can be attributed to various factors, particularly public opinion and political risks associated with red culture IP. As a result, many cultural institutions and museums, including those managing revolutionary cultural relics, have adopted a cautious approach to red culture IP conversion, significantly slowing progress (Han & Gao, 2021).

In contrast, red industrial heritage offers greater flexibility for IP conversion compared to revolutionary cultural relics. Without achieving IP transformation, red industrial heritage sites risk neglect or even dismantlement. The pathway to overcoming this challenge lies in IP empowerment, which involves converting the historical and cultural memory embedded in these sites into IP and employing market-driven strategies to recreate experiences and enhance their capacity to disseminate mainstream culture. This potential stems from the inherent innovativeness of red industrial heritage.

In the digital era, IP empowerment of red industrial heritage has become a critical tool for promoting mainstream culture. First, accurately identifying the carriers of this IP is essential. The development of red industrial heritage IP should not be confined to tourist souvenirs but extend into fields such as artistic performances, film and television productions, and cultural and creative products. These diverse mediums can evoke deep emotional resonance among consumers through physical and virtual displays.

Second, innovation is crucial for red industrial heritage IP content. While highlighting the historical and cultural significance of red industrial heritage, efforts should focus on exploring and creating fresh IP content. Local historical and cultural resources should be transformed

into visually appealing, creatively rich products. By engaging consumers, these stories and cultural values can be effectively communicated to tourists, with creative solicitations continuously generating new content. This process fosters the development of cultural IP products that resonate with the psychological needs of the audience (Li & Wang, 2021).

Finally, community involvement is vital. Residents should be encouraged to actively participate in the preservation and renewal of industrial heritage, with their opinions and suggestions collected through community meetings and workshops. In addition, community education and science popularization initiatives can raise awareness and appreciation of industrial heritage, especially among younger generations. Promoting the construction of public venues, such as museums and exhibition halls that integrate industrial heritage with cultural tourism, can help establish a new trend of “cultural creativity + science popularization.”

In recent years, China has increasingly focused on building industrial museums, particularly community museums, as part of local government public cultural initiatives. For example, industrial heritage communities in cities such as Shanghai, Wuhan, and Guangzhou have begun constructing museums that educate current residents – many of whom are no longer descended from the original workers – about the area’s industrial history. These museums highlight notable individuals, such as model laborers and engineers who once lived there, and showcase items such as community newspapers produced by the factories. While these narratives may not hold a prominent place in the nation’s grand history, they are nonetheless vital to the community’s local identity and are officially recognized as part of red industrial history.

Ultimately, the value of red industrial heritage IP lies not in tangible objects but in its potential for commercialization. To successfully integrate cultural IP with tourism and creative products, efforts must focus on merging cultural resources with technology while also optimizing and upgrading these initiatives at the market level (Li & Wang, 2021).

For example, Pingfang district in Harbin, Heilongjiang province, China, is a significant hub of red industrial heritage. During China’s Fifth 5-year Plan period, the central government established three national-level military industry enterprises in the district: AVIC Harbin Aircraft Industry Group Co., Ltd. (Hafei), AVIC Harbin Dong’an Engine (Group) Co., Ltd. (Dong’an), and Northeast Lightalloy Fabrication Plant (Dongqing). These companies, along with the Harbin Engineering University (formerly known as PLA Military Engineering Institute),

formed a military-industrial town, a configuration known as “one school, three factories.” In recent years, Pingfang district has harnessed its resources to create a tourism model centered around red industrial heritage, blending existing industrial sites with the Japanese Kwantung Army Seventh Trinity Unit Invasion Evidence Sites into a comprehensive tourist route. This approach has helped promote the “Northeast resistance spirit” (Liang, 2021). The integration of the “Northeast resistance spirit” with “craftsmanship” has successfully empowered the IP of red industrial heritage, elevating the regional cultural tourism industry and enhancing the influence of local heritage.

The combination of “mainstream culture + red cultural innovation” is a critical pathway for red industrial heritage to disseminate mainstream culture. IP empowerment provides this heritage with the ability to generate creative and dynamic value, breathing new life into these sites. However, this process also places high demands on the environmental conditions of red industrial heritage itself, making it a topic worthy of focused attention and careful planning.

6. Conclusion

The dissemination of mainstream culture is a complex and multifaceted endeavor, with red industrial heritage serving as just one of many mediums through which it can be communicated. It is important to recognize that these various media do not operate in isolation; rather, they can complement one another to broaden the channels of cultural transmission. However, two major pitfalls must be avoided in this process.

First, it is crucial to avoid homogenization. Each site of red industrial heritage possesses its own distinct media memory and cultural significance, and treating these diverse heritage sites as uniform representations of mainstream culture is a mistake. Instead, the unique cultural symbols of each site should be highlighted, with individual historical narratives crafted to reflect their specific contributions.

A one-size-fits-all approach to transforming and repurposing industrial heritage not only risks stripping these sites of their distinctiveness, thereby diminishing their cultural impact, but also overlooks the unique historical and architectural value each site holds. Effective communication of mainstream culture must focus on three main aspects: transformation and reuse, innovation, and humanization. These elements are essential for building a cultural narrative that aligns with Chinese-style modernization. Relying on empty slogans or combative rhetoric devalues these efforts and may provoke negative reactions that undermine the intended message.

While red industrial heritage is often linked to the socialist bloc and Cold War-era industrialization, this historical context should not be viewed as a detriment or “original sin.” Although these heritage sites were shaped by the political realities of the Cold War, this experience is shared by many forms of industrial heritage worldwide. It is unreasonable to subject red industrial heritage to greater controversy than, for example, Japan’s Meiji-era (1868 – 1912) industrial sites, which have already been designated as World Heritage Sites. Notably, China’s red industrial heritage also includes numerous sites from the late imperial era’s foreign affairs movement and the period of Deng Xiaoping’s reforms, both of which have sparked significantly less debate.

Red industrial heritage is a vital element in understanding China’s broader industrial legacy and is increasingly becoming an important medium for the dissemination of contemporary Chinese culture. Recognizing the evolving role of these sites is key to appreciating the cultural and historical narrative of modern China. In this context, red industrial heritage not only provides insight into the country’s industrial achievements but also contributes to shaping its ongoing national identity and cultural development.

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ORIGINAL ARTICLE

Hangs and trading posts: The global development of the Thirteen Factories in Guangzhou

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Abstract

The Thirteen Factories in Guangzhou were a product of economic globalization and China's foreign trade policies in the 18th century. Previous studies have discussed the Westernization of their building façades but overlooked their global and local origins. This article examines the Western origins of the Guangzhou factories, their local prototypes, and how they integrated Western and local architectural elements. The origins of the Thirteen Factories trace back to *funduqs* or *fondacos*, Mediterranean commercial establishments from the late Middle Ages, which spread globally with Portuguese overseas trade after the Age of Discovery. Built along the Pearl River, the Thirteen Factories were modeled on local hangs, characterized by narrow frontages, large depths, storage on the 1st floor, and accommodation above. Western merchants, leasing these hangs, transformed them into factories by adding Western architectural elements, such as columns, arches, colonnades, and triangular pediments while reorganizing interiors with arched corridors. This integration demonstrates the global mobility of architectural forms driven by economic globalization. The Qing dynasty's (1644 – 1912) strict regulation confined foreign factories to a designated area along the Pearl River, forming the Thirteen Factories quarter. Continuous planning by Western merchants introduced early elements of "modernity," making the quarter a site of architectural and functional innovation. Globalization and modernization were central to the Thirteen Factories' development, blending architectural traditions and influencing Guangzhou's evolution. These forces profoundly impacted the site's transformation and contributed to the globalization of Guangzhou today.

Keywords: Guangzhou; Thirteen Factories; Hang; Trading post; Globalization

1. Introduction

The Thirteen Factories in Guangzhou were integral to the foreign trade system of Qing China (1644 – 1912). Established in 1685, the Guangzhou Customs marked the beginning of the Guangzhou System, which managed foreign trade through a structured hierarchy. Under this system, Customs collected tariffs, the Thirteen Factories facilitated

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<https://doi.org/10.36922/jcau.3676>**Received:** May 15, 2024**Revised:** August 10, 2024**Accepted:** August 26, 2024**Published online:** January 6, 2025**Copyright:** © 2025 Author(s). This is an open-access article distributed under the terms of the Creative Commons Attribution-Non-Commercial 4.0 International (CC BY-NC 4.0), which permits all non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.**Publisher's Note:** AccScience Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

and regulated trade with foreign merchants, the Huangpu (previously known as Whampoa) district served as the mandatory anchorage for foreign vessels, and Macao functioned as a residential area for Western merchants (Zhang, 2009). The Thirteen Factories System was pivotal within the Guangzhou System, as it created a monopoly through Hang merchants, who controlled foreign trade. On arrival at Huangpu, foreign vessels were required to select a “security merchant” from the Thirteen Factories, who assumed full responsibility for their behavior. These hangs acted as intermediaries between officials and foreign merchants, ensuring the safety of lives and properties (Liang, 2009).

By the early 18th century, Guangzhou had begun to attract significant interest from Western traders. Before the 1850s, vessels from the East India Companies of Britain, Holland, France, Denmark, and Sweden docked at Huangpu. During this period, other traders, including the Royal Philippines Company of Spain, the Ostend Merchants of the Austrian Netherlands, and ships from Prussia and the United States of America (USA), also conducted trade in Guangzhou. In addition, merchants from Hamburg and Bremen in Germany, as well as Livorno, Genoa, and Tuscany in Italy, joined the Guangzhou trade by the mid-18th century (Zhang, 2009). In parallel, country traders from Asia – such as Parsees, Indians, Armenians, Malays, Moors, Turks, Arabs, and Jews – seasonally gathered in Guangzhou aboard “country ships” (Van Dyke, 2017a). From 1758 to 1838, a total of 5,107 ships traded at Guangzhou Customs, averaging 63.8 ships/year (Huang, 1986).

As a cosmopolitan port city, Guangzhou attracted a diverse range of people in the 18th and 19th centuries. The Thirteen Factories provided lodging and storage for foreign merchants during trade seasons. Over time, some evolved into long-term trading posts and eventually became permanent factories for certain countries. For example, the British East India Company established a factory in 1715, the Dutch East India Company in 1729, the French East India Company in 1698, and the Royal Spanish Philippine Company in 1731. Subsequently, other countries such as Prussia, Denmark, Sweden, and the USA also set up factories in Guangzhou (Zhang, 2009).

Researchers have long emphasized the importance of Guangzhou’s factories. In 1937, Liang Jiabin’s (1910 – 1995) *Study of the Thirteen Hongs of Canton* described the Thirteen Factories as “offices and residences of foreign merchants, all leased from the Thirteen Hongs,” and detailed the distribution of factories and streets (Liang, 2009, 307). Zeng Zhaoxuan (1921 – 2007) explored site selection in terms of urban geography and discussed

planning developments from the 1830s to the 1850s, including descriptions of the factories’ internal functions, decoration, and appearance (Zeng, 1993). Peng Changxin examined the layout of the Thirteen Factories in the 18th and 19th centuries and traced changes in their exteriors in a thematic format (Peng, 2012). He also provided an in-depth discussion of the American and English gardens located in front of the Thirteen Factories quarter (Peng, 2014). Using archives from the Peabody Essex Museum, Johnathan Farris investigated how the spaces of Thirteen Factories were shaped through Sino-Western collaboration and confrontation (Farris, 2007).

The studies outlined above-addressed issues such as site selection, scale, distribution, and architectural form of the Thirteen Factories, as well as the evolution of their layout and the construction of their gardens. Recently, Patrick Conner carried out a detailed examination of the evolution of the Thirteen Factories by analyzing large collections of export paintings. His work included depictions of the buildings themselves, shopping streets, fire damage, and their final destruction (Conner, 2014). Using both export paintings and historical literature, Paul A. Van Dyke conducted an extensive analysis of Old China Street and New China Street within the Thirteen Factories quarter (Van Dyke, 2015). He also explored the development of the factories before 1822 (Van Dyke, 2017b). Gu Xueping and Peng Changxin conducted a time-lapse study of the architectural space, block planning, and façade characteristics of the Thirteen Factories, offering a comprehensive overview of their historical development (Gu & Peng, 2023). Their findings advance the discussion of the Thirteen Factories beyond the 19th century and address critical questions about changes in ownership, the timing of street development, and the evolution of architectural space.

Previous studies have primarily focused on the construction processes and architectural forms of the Thirteen Factories within the framework of Qing China’s trade system. While the concept of Westernization has been examined, much of the research has focused on the factory buildings themselves, often neglecting their global origins. Consequently, the globalization of their architecture has typically been discussed only in terms of stylistic changes to their façades.

This article examines the Thirteen Factories from the perspective of economic globalization, tracing the origins of their architectural forms and analyzing their construction processes within the context of global trade routes. By comparing the architectural forms of the factories and neighborhood planning in both Chinese and foreign contexts, this study scrutinizes the manifestations

of the buildings and the Thirteen Factories quarter within the context of globalization while also examining their local characteristics in the trading environment of Qing China.

2. Trading posts and factories in global trade

The word “factory” originates from the Arabic word *funduq* and the Latin term *fondaco*, both of which referred to commercial facilities in the Mediterranean world during the medieval period (Sicking, 2020). A *funduq* was an urban facility designed to meet the lodging, commercial, and financial needs of merchants, pilgrims, and rulers. These establishments were widespread, from Syria to Spain (Figure 1A), and provided vital support for trade and travel (Constable, 2003). *Fondaco* was a term used by Christian merchants engaging in trade within Muslim markets. Modeled after the *funduq*, *fondacos* provided lodgings and storage for European traders arriving at Islamic ports. These facilities ensured the safety of merchants within local communities and allowed them a degree of autonomy, operating under the supervision of Muslim authorities (Constable, 2003). Over time, *fondacos* evolved into trading posts where merchants from one country could establish a presence in another. They served as spaces for cultural exchange and interaction between diverse groups.

By the late Middle Ages, *fondacos* spread to Mediterranean Europe alongside expanding European trade and diplomatic activities. They appeared in regions such as southern France, northern Italy, and the Dalmatian coast, functioning as centers for habitation, commerce,

and storage; however, *fondacos* in European contexts increasingly prioritized the security of goods over the safety of individuals, reinforcing their role as storehouses (Figure 1B) (Constable, 2003). *Funduqs* and *fondacos* shared core functions, such as accommodating travelers and providing storage for goods, as part of the lineage of commercial facilities in the Mediterranean world. Over time, *fondacos* evolved to serve not only as trade hubs but also as small communities for foreign traders. The Portuguese adopted the *fondaco* model in their overseas trade operations due to its well-established provisions for residence, storage, security, and management. In Portuguese, a *fondaco* was known as a *feitoria*, a term that influenced the Dutch *factorij* and the English *factory*.

The Portuguese initially established *feitorias* in Bruges and Antwerp in Flanders, Belgium, to facilitate trade with Europe’s most important port areas. Following the mid-15th century, as the Portuguese opened new maritime routes to the East, *feitorias* were established along these routes in various locations, including Arguin Island on the west African coast, the Cape of Good Hope, the Kenyan coast, Ormuz in Iran, Calicut, Cochin, and Goa in India, Ceylon, as well as Malacca and Ternate in Southeast Asia (Sicking, 2020). In the Portuguese expansion of overseas trade, a factory functioned as a marketplace, warehouse, customs house, defense base, and logistical support for voyages and expeditions; it could also serve as an effective branch of Portuguese governance abroad. With the rise of Dutch and British maritime power in the 17th century, the East India Companies of various countries adopted the Portuguese model, establishing factories along key navigation routes. Factory buildings subsequently appeared in numerous port

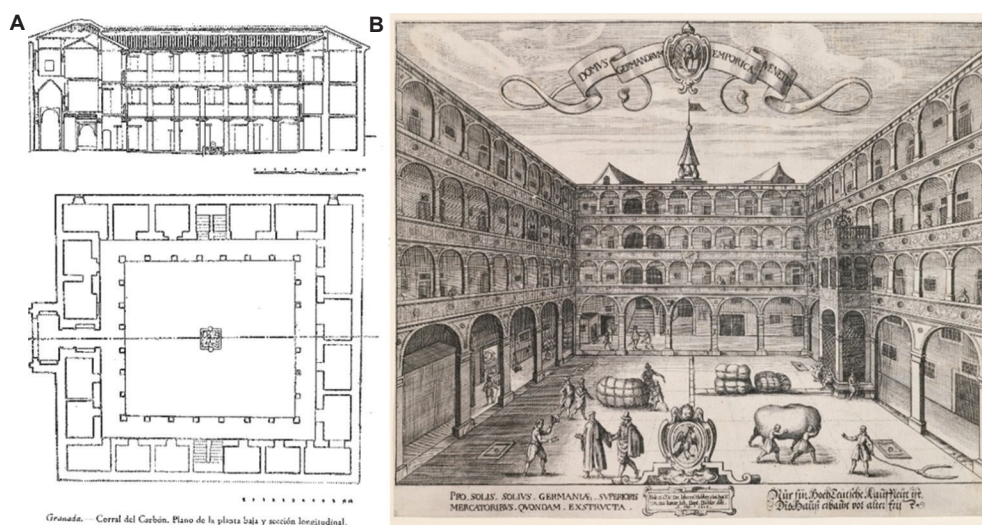


Figure 1. *Funduq* and *fondaco*. (A) Plan and section of a *funduq* in Granada, Spain. Source: Torres Balbás, Leopoldo (1946). *Las alhóndigas hispanomusulmanas y el Corral del Carbón de Granada*. “Al-Andalus”, v. XI; pp. 464. (B) View of the interior of a *fondaco* in Venice, Italy. Source: Germanisches Nationalmuseum, Nürnberg

cities across Africa, Asia, and the Americas, exemplifying the infrastructure of early modern economic globalization.

Factories varied widely across different regions due to variations in climate, environment, population, and culture, as well as the nature of interactions – cooperative or antagonistic – between Western traders and indigenous peoples. Westerners designed these factories as fortified complexes to facilitate trade, provide defense, and serve as multifunctional spaces for residence, storage, and business activities. Early factories often featured distinctively castle-like elements, including surrounding walls (Figures 2 and 3B), soaring façades (Figures 3A and 4A), and trenches (Figure 4B) to isolate their occupants from local populations and minimize potential conflicts. The spatial organization of these factories typically featured an enclosed layout with a spacious inner court that served as a core space for cargo transportation and organization. Warehouses were often positioned around this inner court, reflecting influences from the architectural space of Mediterranean *fondaco* (Figure 1B). Watchtowers were commonly integrated into the factory walls or positioned centrally within the inner courts for surveillance and defense purposes. It is worth noting that, while the spatial organization of factories was often inspired by *fondacos*, their exterior architectural styles were largely shaped by local influences. For example, the Dutch factory in Vengurla, India, displayed a distinctive “Hindu temple” style (Pendse, 2018) (Figure 2A), while the Dutch factory

in Bengal adopted a distinctive Islamic style (Figure 3B). Similarly, the factories in Ambon, Indonesia, and Nagasaki, Japan, incorporated distinct local architectural elements (Figure 4).

As overseas trading posts established by Western countries after the Age of Discovery, factories functioned as economic nodes along global trade routes, serving as tangible manifestations of economic globalization. These specialized establishments, situated in trading ports and open communities worldwide, symbolized the intersection of global and local influences. In their early construction, most factories incorporated local architectural styles, which were adapted and remodeled to fulfill the functional requirements of a trading post. This context raises several questions: What local architectural prototypes influenced the design of factories in Guangzhou? How were these designs adapted to meet the demands of global trade? And what insights do these adaptations provide about the broader process of architectural globalization?

3. Local prototype of the Thirteen Factories

3.1. Local hangs as a prototype for the Guangzhou factories

Hangs (行 [*hang*], or *hong* as pronounced in Cantonese) were important commercial facilities in late imperial China, functioning both as storehouses for goods and as intermediaries for buying and selling. To manage overseas

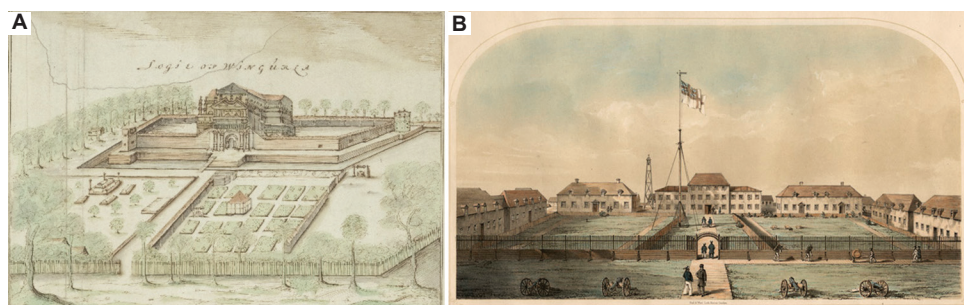


Figure 2. (A) The Dutch factory at Vengurla, India (1678). Sources: Nationaal Archief, Den Haag; (B) The York Factory in North America (1853). Source: Library and Archives Canada, Acc. No. 1996-475-2

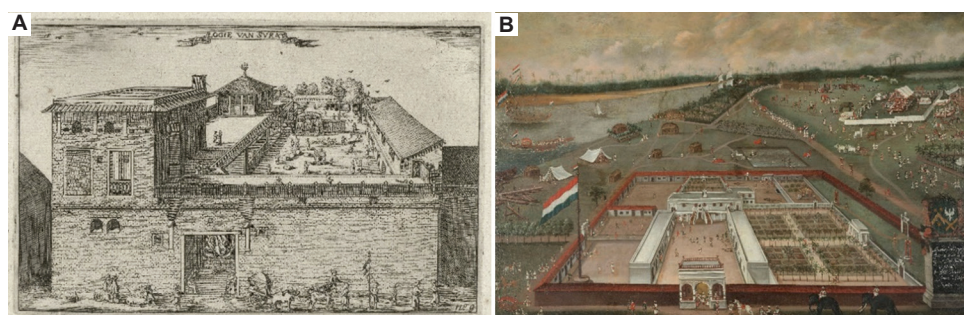


Figure 3. (A) Dutch factory in Surat, India (1646); (B) Dutch factory in Bengal (1665). Source: Rijksmuseum, Amsterdam

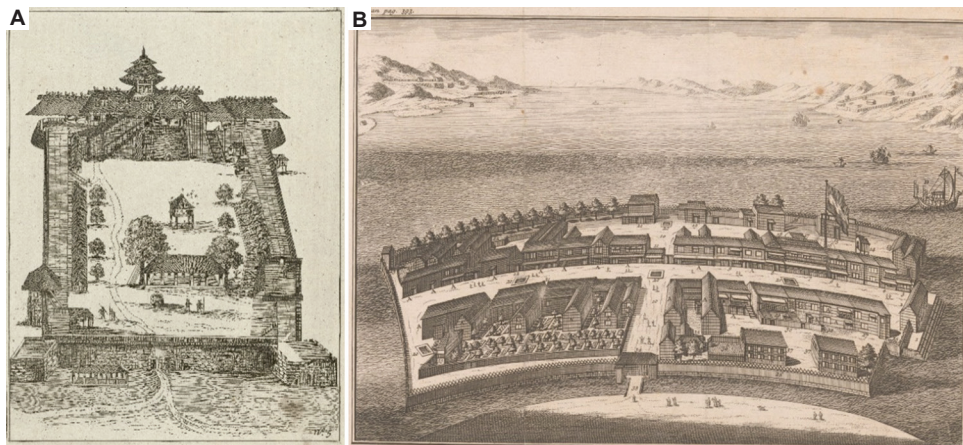


Figure 4. (A) Dutch factory in Ambon, Indonesia (1644); (B) Dutch factory in Nagasaki, Japan (1729). Source: Rijksmuseum, Amsterdam

trade and store imported and exported goods, the hang merchants of Guangzhou constructed large-scale hangs along the Pearl River. Osmond Tiffany described their scale and activity:

The mighty storehouses, stretching as they do for miles along the Canton River, filled during the busy season with hundreds of thousands of chests of tea, and employing armies of operatives, bear witness to the immensity and importance of the tea trade. (Tiffany, 1849, p. 108)

In addition to tea and silk, the hangs in the southern suburbs of Guangzhou stored a variety of goods from around the world to serve the local market. These goods include *biche-de-mer* from Sumatra and Sulu, grains of paradise from India, Sichuan, and Siam, fish maws from the Archipelago and Persian Seas, dried mussels from Siam, pepper from Sumatra, Borneo, and Malacca, shark fins from Bombay and the Persian Gulf, sinews of deer from the Malay Archipelago and Siam, salted prawns from South China, and apricots seeds from North China, among others (Gray, 1875). Hunter (1885) notes that during the Second Opium War (1856 – 1860), a hang merchant named Howqua lost several large warehouses along the river at Shamian due to a fire, with damages amounting to 750,000 – 800,000 US dollars, including cargo losses. On maps of Guangzhou drawn by Westerners, these hangs were labeled as “storehouses” or “pick houses.” They were also featured in export paintings depicting scenes along the Pearl River in Guangzhou (Figure 5).

The façade of a hang consisted of an alcove porch with brick and stone footings on the 1st floor, and a veranda with partition doors and balustrades on the upper floor. Each hang building featured a pier extending to the river, enabling convenient transport via sampans. Some riverfront hangs were equipped with stilt platforms over

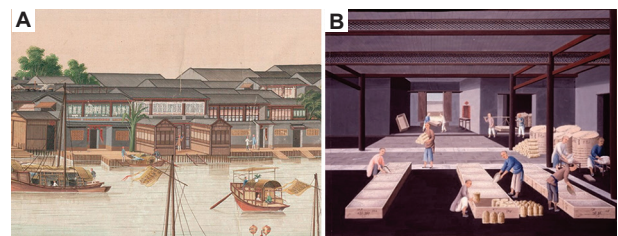


Figure 5. (A) Painting of hang buildings along the river in Guangzhou. Source: The British Library archive; (B) Painting of interior view of hang buildings in Guangzhou. Source: The Trustees of the British Museum

the water, topped with gates displaying the hang’s name. Certain hangs also had stilt houses flanking their gates, which may have been the residences of the guards of the warehouse (Figure 5A). Hangs also functioned as hotels, offering storage, accommodation, and trading facilities for traveling merchants. On arrival in Guangzhou, merchants would select a hang to store their goods. The hang owner would provide comfortable accommodations, entertainment, and trading channels, in exchange for service fees and a commission on goods sold (Gray, 1875).

The 1st floor of a hang served as a warehouse, featuring a wide three-bay front and multiple courtyards extending from front to back; these spaces were used for storing goods and for processing, sorting, weighing, and packaging commodities prior to trade (Figure 5B). Sometimes, the 2nd floor accommodated traveling traders. During his visit to a tea hang, Osmond Tiffany observed:

“In one part of the building, a 2nd floor is added, for immense suits of beautiful rooms, furnished with costly elegance, and adorned with rarities and articles of virtu...they are merely for show and the occasional reception of guests.” (Tiffany, 1849, pp. 112 – 113)

The architectural layout of Guangzhou hangs, integrating storage and living quarters, reflected the

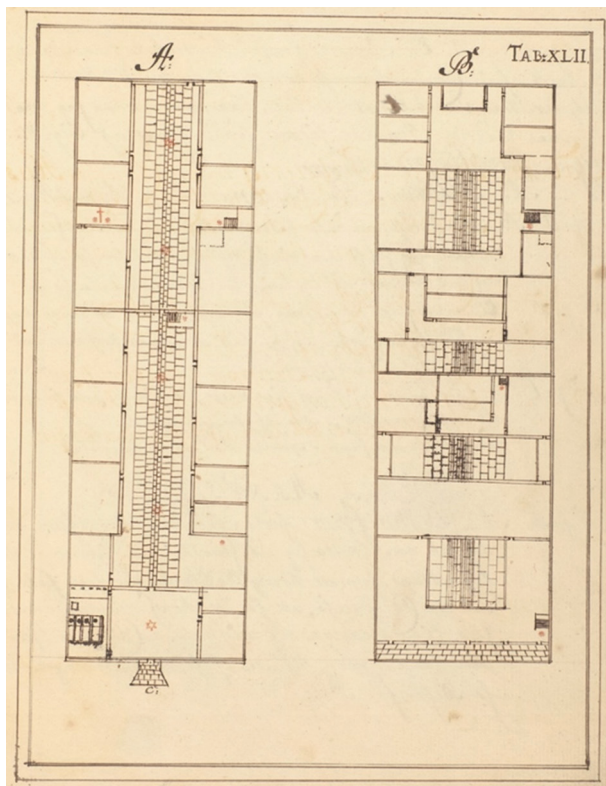


Figure 6. Plan of the Swedish Factory, 1748. Source: Gustaf Fredrik Hjortberg, *Ost-Indisk Resa 1748 och 1749*, World Digital Library

trade system's reliance on brokers, who played a central role in commodity trading. In Guangzhou, these brokers not only facilitated trading channels for traveling merchants, including foreign merchants, but also provided accommodation and storage spaces. This business model laid the foundation for the creation of the Thirteen Factories: local merchants rented out hangs to Western traders, who subsequently transformed them into trading factories. The Portuguese were unique in being granted permission to reside on the island of Macao in 1557, which served as their base for trading with Guangzhou for several centuries. Due to their special position in Macao, the Portuguese maintained regular trade with Guangzhou before the establishment of the Guangzhou Customs in 1685. Instead of maintaining a factory in Guangzhou, they leased warehouses from local merchants.

3.2. Spatial characteristics of the hangs in the Guangzhou factories

The Guangzhou hangs shared many functions with Western factories, such as providing traveling merchants with space for both storage and accommodation. These characteristics made them the natural choice for Western merchants to establish their trading posts in Guangzhou. In the early 18th century, foreign merchants arriving in

Guangzhou could rent a house from a hang merchant to use as a factory. Several ships from the same country could consolidate their goods in a single factory, and merchants were also free to rent other Chinese houses (Noble, 1762). Therefore, early factories displayed clear features of local architecture. These buildings typically faced both north and south, with façades three bays wide and depths of three or more halls separated by courtyards. Surrounding walls were constructed of bricks (possibly mixed with wood), while internal partitions were made of wood. Each building had two gates: one facing Factory Street and the other opening onto the Pearl River. Charles Frederick Noble of the British East India Company recorded in 1747:

The English Factories are situated in one of the best streets in town. It is very large, has a number of courts, halls, and warehouses, with convenient rooms for lodging a great number of people. One large gate opens to the street, and another to the river, where our boats load and unload. At each gate, a centinel is kept day and night (Noble, 1762, p. 223)

In the early period, the buildings of the hangs retained their native architectural characteristics after their conversion into factories. For example, the Swedish Factory (Figure 6) retained the typical layout of a hang. Its plan (drawn in 1748) illustrates a three-bay building with a depth of five halls. The southernmost section of the 1st floor featured a porch leading to the foyer of the first courtyard. Auxiliary rooms, including kitchens, sentry rooms, and lodgings for compradors, flanked the foyer. A large corridor, paved with square sisal stones, connected the foyer to other areas, with storage rooms or warehouses opening off the corridor. The final hall had a door on its back wall, providing access to Factory Street. The 2nd floor of the Swedish Factory accommodated a dining hall or venue hall in the first and second halls, while Swedish merchants' offices and residences occupied the third to fifth halls. Despite undergoing renovations, the Swedish Factory retained the original hang building's scale and layout. It preserved the spatial pattern of five halls separated by courtyards, maintaining the same spatial elongated, narrow composition: bordering the Pearl River, with storage space on the 1st floor and living space on the 2nd floor. These localized architectural features were also preserved during the later renovations of the Thirteen Factories.

As more Western merchants rented Chinese hang buildings for their factories and Western architectural forms spread globally, the Thirteen Factories gradually transitioned from local to Westernized architectural styles. This transformation reflected the globalization of the Thirteen Factories, not only as nodes of global trade but also through the global mobility of their architectural

forms. Specifically, this transformation was evident in the Westernization of the building's appearance, the incorporation of arched corridors, and the "modernization" of neighborhood planning.

4. Global characteristics of the Thirteen Factories

4.1. Westernization of the Thirteen Factories in Guangzhou

The Guangzhou factories were typically established along the riverside, forming a cluster of Western-style buildings over more than a century of development. This transformation occurred as Western merchants, after renting the buildings, initiated the "Westernization" of the factories. Carl Gustaf Ekeberg described the process:

Once upon a time, factories were built in the Chinese style, but not long ago, the owners of factories allowed Europeans to furnish their houses according to their own preferences and convenience, and also installed glass windows... Since then, Westerners have been competing to remodel the exterior and interior of the factories to make them look beautiful (Conner, 2014, p. 35)

In other words, hang merchants granted Western merchants the freedom to modify both the interiors and façades of the factories. As a result, almost all factories leased for extended periods underwent a transformation from the local style to a Western one.

The Westernization of the Thirteen Factories began during the period 1760 – 1770 (Figure 7). In 1760, the area officially became the Thirteen Factories district, a development that accelerated the Westernization of the complex's architecture (Gu & Peng, 2023). During this period, all factories were 2-story buildings featuring an alcove porch on the 1st floor and a veranda facing the Pearl River on the upper floor. While the façades of the Swedish and French factories incorporated some Western decorative elements, the others still retained their

traditional Chinese architectural style. Notably, the Dutch and English factories introduced colonnades in their central bays, embellished with pediments and cornices—features adapted to Guangzhou's humid climate. These corridor-style designs became a dominant architectural form during the development of the Thirteen Factories.

From 1770 to 1822, the Westernization of the Thirteen Factories advanced further (Figure 8). The façades of the Swedish and Old English factories were redesigned with pilasters and arched gates on the 1st floor, as well as colonnades and arcades on the upper floor, completing their transformation into fully Westernized buildings. Following suit, the Danish Factory, Spanish Factory, Old Cohong, American Factory, Baoshun Factory, Chow-Chow Factory, and Creek Factory adopted similar Westernized elements. These Westernized elements included arched gates, pilasters, semicircular window lintels on the 1st floor, and colonnades with architraves on the upper floors, establishing these as signature decorative elements. Meanwhile, the front colonnades of the British Factory and Dutch Factory were enlarged and adorned with Palladian motifs. However, Tongwen Hang, Taihe Hang, and Yen-tsze-chaou retained their native architectural façade elements.

Westernization of the Thirteen Factories reached its peak during 1822 – 1843 (Figure 9). During this period, façade Westernization continued with more intricate decorative details. For instance, the Old British Factory was remodeled in the Romanesque style, featuring triangular pediments and colonnades. The English Factory and Ji Yi Hang were merged to form a new English factory, which also adopted triangular pediments, arcades, and colonnades as decorative elements in its façade. In addition, the English and Dutch factories, while preserving their front porticos, transitioned from the Palladian style to neoclassicism, characterized by thick bases and Athenian capitals (Peng, 2014).

In summary, the transformation of the Thirteen Factories from native hangs to Western-style buildings reflected the continuous introduction of Western

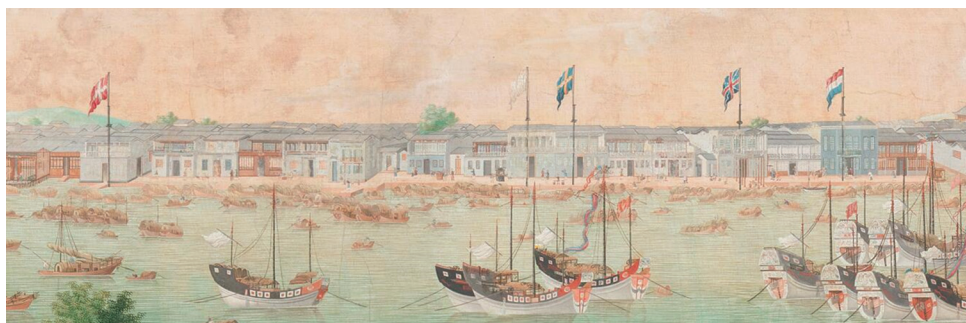


Figure 7. Thirteen Factories in Guangzhou, 1760 – 1770. Source: Rijksmuseum Amsterdam



Figure 8. Thirteen Factories in Guangzhou, 1788 – 1822. Source: Maritime Museum of Denmark



Figure 9. Thirteen Factories in Guangzhou, 1822 – 1843. Source: Swedish National Maritime and Transport Museum

architectural elements into Guangzhou. This architectural evolution illustrates the global mobility of architectural forms during the era of economic globalization. To meet functional needs, Western merchants not only modified the façades of the factories but also restructured their interior spaces.

4.2. Renovation of the interior spaces of the Thirteen Factories in Guangzhou

The spatial transformation of the Guangzhou factories is exemplified by the Spanish Factory, which was established in 1788 by the Royal Philippines Company. The company rented a hang, the layout of which was documented by Manuel de Agote in his diary (Figure 10). The factory featured a three-bay frontage and a depth of five halls. The first three halls were combined into a single zone for personnel to handle trading matters. The 2nd floor was designed as a single hall connecting the front and back (rooms Nos. 35 and 37), serving as a venue for banquets and public activities. In the fourth hall, rooms on the 1st floor (rooms Nos. 18 and 19) were arranged with a courtyard at the front, forming a garden suite. The 2nd and 3rd floors served as accommodations for the general staff.

The fifth hall functioned as a logistical area, including the kitchen. Factories were organized and numbered according to *jin* (进), a term denoting a specific section of the factory and serving as the spatial orientation for the work and daily lives of the staff in the factory (Figure 12). For example, in *The “Fan Kwae” at Canton Before Treaty Days, 1825 – 1844*, Hunter (1882) recorded that he worked and lived in No. 2 of the Sweden Factory, referring to its second *jin* or hall (Hunter, 1882).

Within the factories, the middle halls on the 1st floor were transformed into a spacious arched corridor running from front to back, serving as the core space for transportation and factory operations. This core space echoed Mediterranean prototypes, such as the *funduq* and the *fondaco*, as well as the inner courts of other factories along global shipping routes. While both the arched corridors in Guangzhou factories and the inner courts in other factories served as centers for cargo organization and transportation, the arched corridors were adapted to the constrained sites of native hangs, which were characterized by narrow widths and long depths. Therefore, the spacious inner courts of Western factories were compressed into

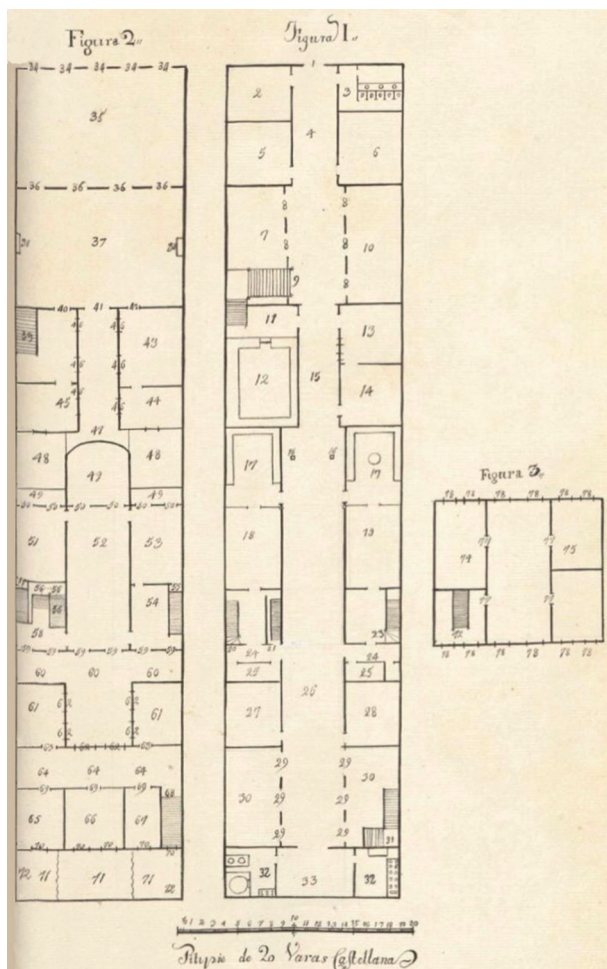


Figure 10. Plan of the Spanish Factory in 1789. Source: *Diario de Manuel de Agote*, R.631 (año 1789), p.95. Gordailua Centro de Colecciones Patrimoniales de Gipuzkoa. Diputación Foral de Gipuzkoa

long corridors in the Guangzhou factories, reflecting a fusion of exotic spatial forms with native architectural traditions. The habitable spaces were also reorganized to create apartments with garden entrances. William Hickey described his residence in the English Factory as being “in broad courts, having the sets of rooms on each side, every set having a distinct and separate entrance with a small garden, and every sort of convenience.” (Spencer, 1913, p. 202). In addition, the factories incorporated more office space than traditional hangs to meet the needs of their associated businesses.

By 1843, there were 12 foreign factories in Guangzhou that had undergone Westernization of their façades and interiors while still retaining some characteristics of the original hang buildings. What made Guangzhou’s factories unique was that all those established by Western countries were concentrated in the same section of the city, forming a distinct factory quarter. By contrast, most other factories

worldwide were built independently by individual trading powers and located in different areas. The emergence of this factory quarter in Guangzhou facilitated collective participation by Westerners in the construction of the Thirteen Factories, endowing the quarter with early “modern” characteristics.

5. Modern planning of the Thirteen Factories in Guangzhou

5.1. Emergence of the Thirteen Factories quarter

John Friedrich Dalman, a Swedish merchant who visited Guangzhou during the period 1747 – 1748, documented the distribution of factories along the river outside Guangzhou city on a map (Figure 11). The buildings of the hang merchants were primarily located along the commercial streets north of Factory Street and the riverfront areas south of it. In pre-modern Guangzhou, transportation relied heavily on waterways, making the river network the city’s lifeline for commercial development (Zheng *et al.*, 2023). Trading spaces were concentrated along the riverfront, especially the Pearl River. For foreign merchants, renting riverside hang buildings was the most convenient way to load and unload goods, reducing labor costs for transporting goods. This practicality led to a trend of building factories along the river.

In 1757, the Qing Court issued a decree stating that Western ships were permitted to “only be allowed to receive moorings in Guangzhou for trading, and prohibited to sail to Ningbo,” marking the beginning of the Guangzhou System. Two years later, this restriction was further tightened, accompanied by reforms regulating the residence of foreign merchants in Guangzhou factories. These changes prompted significant spatial transformations within the factory zone. To enforce the segregation of foreign merchants, the government opened Old China Street at the center of the area and stationed guards to confine foreign merchants within a designated space, prohibiting interaction with local residents (Xu, 1974). In addition, the Guangzhou authorities enforced a strict residential policy separating Chinese residents and foreigners. Foreign merchants were no longer allowed to rent houses freely in the western suburbs of Guangzhou; instead, they were required to rent factories along the riverside. Consequently, the factories relocated from the streets to the riverside, completely transforming the original residential area into a factory zone. From an urban planning perspective, this shift led to the establishment of the Thirteen Factories quarter, significantly stimulating the area’s development (Gu & Peng, 2023).

The emergence of the Thirteen Factories quarter holds unique historical significance. Unlike the castle-like

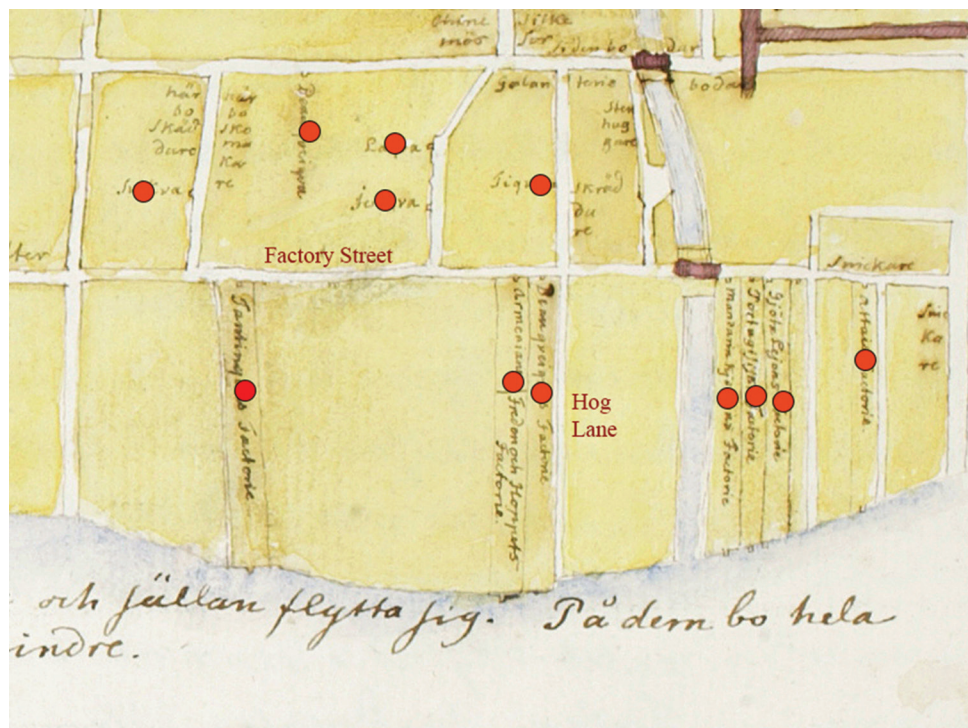


Figure 11. Distribution of factories in 1748 – 1749 (locations marked in red circles by the authors). Source: John Friedrich Dalman. *Dagbok under resån fran Giötheborg til Canton 1748 – 1749.*

factories that Western countries typically built along global shipping routes to address conflicts with competitors and local residents, the factories in Guangzhou were concentrated in a single area. This distinct arrangement resulted from strong local government control over foreign merchants, reflecting the dominant role of national will in regulating foreign trade. As a result, the development of the Thirteen Factories quarter contributed significantly to the district's distinctive development and planning.

5.2. Planning of The Thirteen Factories before the First Opium War (1839 – 1842)

The Thirteen Factories quarter was bounded by Factory Street to the north, West Moat to the east, Pearl River to the south, and Xinglong Street to the west. It consisted of 17 factories (hangs) and two commercial streets running east to west, including Creek Factory, Dutch Factory, Jiyi Hang, English Factory, and Hog Lane, followed by Chow-Chow Factory, Old English Factory, Swedish Factory, French Factory, Baoshun Factory, Wanyuan Hang, Guangyuan Hang, and Old China Street. These were further joined by Yen-tsze-chaou, Taihe Hang, Old Cohong, Spanish Factory, Tongwen Hang, and Danish Factory. Hog Lane, originally an old street created by the wharf leading to the Pearl River, was transformed into a commercial street after the quarter's establishment, featuring stores that provided daily necessities for Westerners. Old China Street was opened during the

quarter's formation, with shops on either side offering a wide range of exported goods. In November 1822, a fire destroyed all the factories and streets in the quarter. During reconstruction, New China Street and Lienhing Street were added as internal firebreaks. As a result, the rebuilt quarter consisted of 13 factories and four streets (Figure 12). Unlike the neighboring hang district, the Thirteen Factories quarter was deliberately planned to accommodate business needs and mitigate the risks of future fires.

Each hang in the Thirteen Factories quarter had a pier at its front to facilitate the transportation of goods. During the nearly century-long construction, Western merchants continued to use sediment from the Pearl River to reclaim land, creating additional space for their activities. They also displayed their national flags in front of their factories, symbolizing the establishment of trading posts by their respective countries. The space between the piers and the factories gradually evolved into a square, which served various purposes, including the transportation of goods, socializing, exercising, and leisurely activities. These squares also attracted city traders, who sold goods, introduced business opportunities, and provided various services. The square of the Thirteen Factories exhibited a distinctly public character, resembling city squares in the West. When the Thirteen Factories were rebuilt after the 1822 fire, one of the most striking changes was the

transformation of the square in front of the English Factory into a garden (Figure 12). This garden stretched from the gate of the English Factory to the Pearl River. It was enclosed by walls on either side, paved with gravel paths, and adorned with oval flowerbeds planted with verdant shrubs (Figure 13). This redesign laid the foundation for the complete transformation of the square into a garden after the First Opium War.

The Thirteen Factories quarter showcased spatial forms that were markedly different from those of the neighboring hangs, largely due to the direct interventions of Western merchants. From the formation of a closed quarter and the establishment of commercial streets to the emergence of squares and gardens, the quarter's spatial elements became increasingly diverse, incorporating public and recreational features. These developments can be seen as the introduction

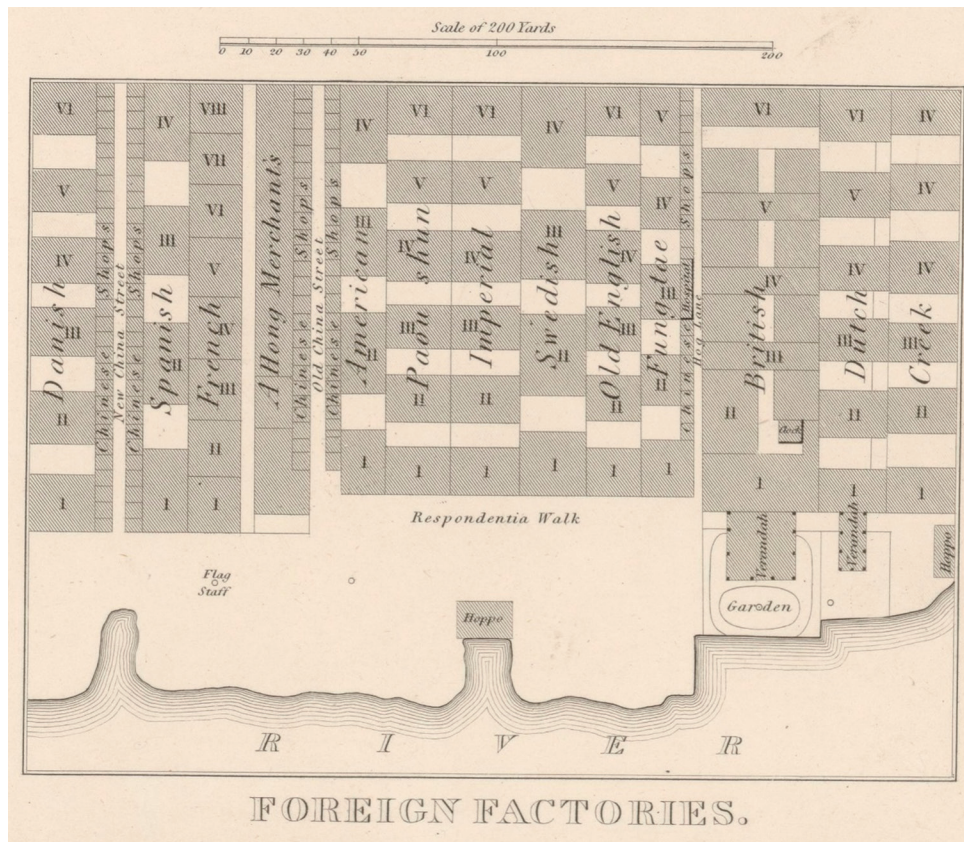


Figure 12. Plan of the Thirteen Factories, Guangzhou, 1840. Source: Bibliothèque nationale de France



Figure 13. The square and English garden in front of the Thirteenth Factories after 1822. Source: Swedish National Maritime and Transport Museum

a new factory on leased land, bypassing the layout of the original factories. The New English Factory featured two rows of buildings separated by streets and alleys. Its exterior embraced the veranda style, with an arcade on the 1st floor and colonnades on the 2nd and 3rd floors, topped by a four-pitched roof (Farris, 2007). On the western side of the Thirteen Factories, the Danish Factory, New China Street, Spanish Factory, and French Factory were rebuilt on their original sites, while squares in front of the Danish Factory, Spanish Factory, French Factory, and Mingquas' Hang were converted into additional factories (Figure 14).

Western merchants also built an American Garden in the square, featuring native plants and wide walkways, providing an outdoor space for foreign merchants to stroll, relax, and socialize. Adjacent to the garden, an ornate water club was established on the western side of the American Garden, serving as a library, billiard room, and venue for dances. An open boathouse for long paddle boats was located nearby (Figure 15). In 1849, a Gothic Revival church was built between the English Garden and the American Garden, becoming a landmark along the Pearl River. Behind the church, Log Lane was transformed into a parsonage. These developments marked the transformation of the Thirteen Factories quarter from a trading zone into a Western-style community.

After the First Opium War, the Thirteen Factories quarter gained various new spatial elements, including a church, a parsonage, gardens, a club, dockyards, a hospital, schools, and wharves, in addition to its factories and three commercial streets. Western concepts of healthcare, education, sports, entertainment, and engineering technology – symbols of “modernity” – first took root in the factories quarter and later spread to other parts of the city. The redevelopment of the Thirteen Factories quarter featured veranda-style architecture, landscaped district, improved community facilities, and landmark structures, exemplifying a “modern” cityscape along the Guangzhou riverside.



Figure 15. Thirteen Factories in 1856. Source: National Maritime Museum, Greenwich, London

In contrast to the concessions in Shanghai and other treaty ports, the Thirteen Factories quarter remained under the jurisdiction of the Guangzhou government. It served as a precursor to the concept of concessions, laying the groundwork for land lease agreements, construction regulations, and cooperative community development. In concessions, foreigners often gained administrative and judicial power, allowing for more extensive Western-style construction on a larger scale without interference or conflict from local governments and residents. However, after the Thirteen Factories quarter was destroyed during the Second Opium War in 1856, it was abandoned by foreigners, who relocated to the newly built Shamian Concession on an isolated human-made island, replacing the Thirteen Factories as their new base in Guangzhou.

The ruined site of the Thirteen Factories was later redeveloped into dense commercial streets in the late 19th century, featuring businesses specializing in tea, medicine, and porcelain, as well as a growing number of financial institutions and banks. In 1937, Japanese air raids devastated the area, leaving it in ruins on the west bund of the city. By 1951, this area was chosen for the Fair of Southern China Local and Special Products, where 12 new buildings were constructed to accommodate the event. The architects adopted a modernist approach in designing the exhibition halls, incorporating frame structures, free space, and clean façades. This design was regarded as a significant example of modernism in China (Yang, 2015). Following the fair, the exhibition area transitioned into Guangzhou Cultural Park, and several of the exhibition halls remain intact today. The area surrounding the park has since evolved into a bustling wholesale clothing market, trading with both inland provinces and foreign countries. This transformation marks a new phase in the globalization of Guangzhou's trade. In summary, the evolution of the Thirteen Factories—from an economic hub to exhibition halls, a cultural park, and a wholesale market—illustrates the enduring influence of modernity and globalization introduced by the Thirteen Factories centuries ago, which continue to shape Guangzhou's development today.

6. Conclusion

The Thirteen Factories in Guangzhou emerged from the interaction between economic globalization and China's foreign trade policies during the 18th century. Western countries established factories along global routes as trading posts, and the Qing government designated Guangzhou as a key port city for foreign trade – between 1757 and 1840, the sole port for such activity in China. Consequently, Guangzhou became a critical base for Western merchants to acquire Chinese goods for the global market. From a commercial perspective, the establishment

of the Guangzhou factories was itself a manifestation of globalization.

The concept of Western factories can be traced back to the *funduqs* and *fondacos*—commercial establishments in the Mediterranean world during the Middle Ages—which spread globally with Portuguese maritime expansion. These facilities served as marketplaces, warehouses, customs offices, defense points, and even government institutions. Successive maritime powers, including the Netherlands, England, and France, adopted this architectural and functional model for use in port cities worldwide.

In Guangzhou, the early factories similarly drew on local architectural styles, adapted to meet their functional requirements. Western merchants initially rented hang buildings in Guangzhou, which served as residences and warehouses. These structures, characterized by a three-bay width and multi-hall depth, were connected to piers and provided spaces for storing goods, living, and conducting trade. Over time, Westerners transformed these leased hangs into factories, changing both their external appearances and internal layouts to better suit their needs.

The transformation of the Thirteen Factories from native hangs to Western-style factories was accompanied by the gradual introduction of Western architectural elements into China. Early factories incorporated porticos and arcades, while later ones featured colonnades, triangular pediments, and Palladian motifs in the design of verandas. These elements demonstrate the influence of Western classical architecture and Renaissance styles in Guangzhou. One of the most notable changes in the spatial organization of the factories was the elimination of the ceremonial halls traditionally found on the central axis of the local hangs. These were replaced with arched corridors extending from the front to the back of each factory. These corridors became the central organizational features, facilitating the transportation of goods within each factory and redefining internal spaces. The design of the arched corridor retained the concept of the inner court found in a *fondaco*, but due to the elongated and narrow footprints of the local hang buildings, the inner court was compressed into a long and narrow corridor. Through this adaptation, the architecture evolved from hang to factory in both appearance and internal spatial layout, reflecting the global mobility of architectural styles driven by economic globalization. Furthermore, the Qing government's control over foreign merchants created a “closed” factory quarter. Unlike the independent factories found in other regions along global trade routes, the Thirteen Factories quarter in Guangzhou allowed Western merchants some influence over the planning of the district. The construction of commercial streets, squares, gardens, a church, a club,

and other spatial elements gave the quarter a distinctive character, incorporating early “modern” features into its design.

Globalization and modernization were key factors in shaping the development of the Thirteen Factories, fostering an open and inclusive spirit in Guangzhou. Even after their destruction in 1856, the area where the Thirteen Factories once stood was redeveloped to reflect global and modern practices in modern architectural design and the development of wholesale markets. Although the Thirteen Factories themselves no longer exist, their legacy of openness and inclusiveness endures in Guangzhou and will surely continue to influence the city's urban development in the future.

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Conflict of interest

The authors declare no competing interests.

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Not applicable.

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ORIGINAL ARTICLE

Disappearance of vernacular character in rural residences: An assessment of residents' requirements for rural residential façades and environments in Suzhou, Jiangsu, China

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Abstract

This study, framed within the context of the Harmonious and Beautiful Countryside policy, focuses on optimizing the living environment of rural housing by addressing the loss of diverse heritage in rural architecture and landscapes. Through fieldwork and importance-performance analysis methods, the research investigates the façades and environments of rural houses in Suzhou, Jiangsu, China. By incorporating the “vernacular” evaluation factors identified in previous studies, this study adopts a user-centered perspective to provide practical insights into rural cultural landscapes, thereby augmenting existing literature. The study reconstructs elements of rural residences and their environments to enhance residents' comprehension and yield more objective evaluation outcomes. Analysis reveals that both native and non-native residents share similar views on the importance and performance of various factors. Environmental quality and building functionality emerge as top priorities for residents, while Suzhou's efforts to preserve traditional architectural esthetics are notably effective. However, field observations also highlight urbanization's impact on rural housing, such as the use of non-native materials that compromise traditional rural architectural styles. To tackle these challenges, this study proposes the following strategies for rural regeneration: (i) permit integration of new materials, technologies, and spatial configurations with traditional rural architecture; (ii) incorporate historical context, cultural continuity, traditional materials, and lifestyle needs into building renovations; and (iii) establish a dynamic regulatory mechanism for rural residential architecture to aid residents in optimizing their buildings and surroundings. These strategies aim to mitigate the effects of excessive urbanization and provide a user-centered approach for future research on rural cultural landscapes.

Keywords: Rural regeneration; Importance-performance analysis; Rural living environment; Needs assessment

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1. Introduction

In the pursuit of harmonious development between humans and nature, rural areas have evolved into integrated spaces that combine natural and residential environments. This integration represents a comprehensive system encompassing

ecology, human habitation, society and culture, and sustainable development (Wang *et al.*, 2022). Since the beginning of China's reform and opening up, the pace of urbanization has accelerated significantly. However, this rapid urban development has inevitably introduced numerous challenges (Lv, 2018). The unique characteristics of rural areas are primarily reflected in the forms and spatial features of rural landscape elements and their interrelationships. Yuan & Lin (2018) argue that industrialization and urbanization are the primary drivers of rural landscape decline, resulting in a reduction of local characteristics and a loss of diversity. In addition, urbanization has caused a dramatic decrease in rural populations and accelerated aging among rural residents, both of which indirectly exacerbate rural decline (Kweon & Youn, 2021). Chen & Zhang (2021) observe that past rural planning in China often followed a standardized approach, with excessive imitation posing a significant issue. This standardization has dissolved much of the diverse heritage inherent to rural areas. Yuan *et al.* (2017) further emphasize that rural development characterized by urbanized landscape architecture but lacking essential infrastructure and public services has inflicted irreversible damage on traditional culture and the ecological environment. Consequently, China's rural development has suffered from a gradual erosion of traditional rural culture and its inherent diversity (Montalvo *et al.*, 2019), with rural issues becoming increasingly pronounced (Fu & Dai, 2016). Issues such as homogenization, superficiality, and depopulation have emerged (Wang, 2020), reflecting a progressive loss of rural vernacular identity (Wang, 2019).

In response to these issues, China has introduced several policies over the years, including the New Socialist Countryside Initiative in 2005, the Beautiful Countryside program in 2008, the Rural Revitalization Strategy in 2017, and the Harmonious and Beautiful Countryside policy in 2023. These top-down strategies aim to address the aforementioned challenges in rural development and revitalize rural areas.

Current rural planning approaches rely heavily on top-down constraints, such as regulations and controlled detailed planning, focusing primarily on the perspectives of designers or village-level administrators while often overlooking bottom-up evaluations and the residents' needs for rural housing. Present studies on rural identity predominantly center on historical and cultural heritage (Zhang *et al.*, 2022). In existing studies on rural façades and their relationship with the environment, Jiang & Zhang (2016) identified several issues contributing to the degradation of rural building façades and their surroundings. These include unauthorized structural additions to building façades, inconsistent details such as

air conditioning units and electrical boxes, haphazardly installed rain shelters, and disorganized routing of municipal pipelines, compounded by a lack of public facilities. They argue that rural façade renovation requires a holistic perspective, one that considers the unique natural, economic, and cultural contexts of the local environment.

Similarly, Lin (2016) highlights that during the rural modernization process, urban construction professionals often use reinforced concrete to build monotonous, uniformly aligned buildings. This approach replaces the original natural village environment and communal spaces with plazas, fountains, and landscaped vegetation, contributing significantly to the destruction of rural architecture and environmental character. Chen & Zhang (2021) underline that the improper use of vernacular elements is a primary factor in the loss of rural identity. Overuse of vernacular elements leads to visual chaos, neglect results in a loss of rural character, and a general lack of understanding and research exacerbates these issues. Yuan & Lin (2018) emphasize that enhancing the living environment, improving esthetic quality, and optimizing rural functions are the primary objectives of rural revitalization efforts. However, much of the existing research adopts a top-down perspective. Kosanović *et al.* (2019) advocate for rural housing preservation and regeneration strategies that prioritize collective regulation and stakeholder-driven design strategies. Architectural façades and their surrounding environments are key elements of rural esthetics, and these are areas where residents can play an active role. Residents' needs are pivotal in shaping the architectural façades and environments of rural areas (Figure 1). To explore the underlying reasons for the current state of rural residential façades and to identify priorities for future façade and environmental regeneration, it is essential to consider the needs of the local resident population in the respective areas.



Figure 1. The esthetic image of Suzhou's traditional villages. (A) Feng Menglong village. (B) Weng Xiang village. Source: (A) <https://www.gooood.cn/feng-menglong-academy-of-classical-learning-by-9-town-design-studio-for-urban-architecture.htm>; (B) <https://www.163.com/dy/article/J10AF82U052482RT.html>

In many rural areas, aging buildings have made residential housing regeneration an urgent priority. Suzhou, as a rapidly urbanizing new first-tier city, provides valuable insights that can guide future rural development efforts in other regions. Quantifying rural identity in a way that is both comprehensible to local residents and capable of accurate assessment remains a significant challenge. This study approaches rural architectural identity by evaluating both the “architectural ontology” (Zhang *et al.*, 2022) and user perceptions, focusing on the esthetic presentation of building façades and the residential environment. By examining façade renovations in Suzhou’s rural houses, this study explores users’ subjective evaluations of current façades and environments, identifies existing issues in façade modifications, and proposes future renovation paths. This practical approach bridges the significant gap between theoretical framework and applied rural cultural landscape design in contemporary China (Wang *et al.*, 2022). The significance of this study is threefold: (i) it quantifies residents’ needs by integrating rural attributes with actual residential functions; (ii) it examines residents’ evaluations, needs, and the underlying factors shaping Suzhou’s rural esthetic, addressing gaps in bottom-up assessment methodologies; and (iii) it provides practical recommendations on content, policies, and design strategies for future renovation of aged rural housing from a user-centered perspective.

2. Methodology

2.1. Research subjects

This study focuses on rural residences and environments in Suzhou, Jiangsu, China, chosen for several reasons.

First, Suzhou serves as a representative example of a densely urbanized area and a national pilot for rural–urban integration. Throughout its development, from rural industrialization to the Southern Jiangsu Model and subsequently to rural–urban integration, Suzhou’s rural areas have exemplified the transformation experienced by developed, densely populated regions (Zhou, 2022). Studying rural Suzhou, therefore, provides significant insights. Suzhou serves as a model case, demonstrating the shift from rural–urban separation to integration and the application of rationalized planning standards (Fan, 2015). Findings on Suzhou’s rural façades may offer guidance for rural development in other parts of China.

Second, Suzhou’s strong regional characteristics – including its traditional rural esthetics, architectural façades, and social customs – imbue the area with high cultural value and form a rich resource base for distinctive landscape characteristics (Fan, 2015). The façades and environments of Suzhou’s rural housing are thus well-suited for evaluation from a user-centered perspective.

Finally, Suzhou’s urbanization rate highlights its rapid transformation. Between the Sixth (2010) and Seventh (2020) National Censuses, the urbanization rate increased from 70.07 percent to 81.72 percent, an 11.65 percent rise. The permanent population grew from 10.45 million to 12.74 million, with the urban population increasing from 7.32 million to 10.41 million (Suzhou Bureau of Statistics, 2012; Suzhou Daily, 2021). As of 2023, Suzhou’s rural population totaled 2.27 million, accounting for 17.52 percent of the city’s total population (Suzhou Bureau of Statistics, 2024).

Given this high level of urbanization, exploring rural areas within this context adds valuable insights. According to *Suzhou Daily* (2023), population data released by Suzhou Public Security in mid-2023 indicated that Suzhou’s actual population reached 16.19 million. Among them, the registered household population was 7.81 million, accounting for only 48.22 percent, while the floating population totaled 8.39 million, comprising 51.78 percent (Suzhou Daily, 2023).

In addition, migrant population statistics reported by *Gusuwang* (2018) highlight that Suzhou ranks first in Jiangsu province in both its migrant population size and migrant population index, solidifying its position as the largest immigrant city in the province. Migrants, including registered non-native residents and floating residents, account for 63.6 percent of the population, whereas local residents with Suzhou lineage represent only 36.4 percent. These data underscore Suzhou’s status as a city deeply integrated with its migrant population (Gusuwang, 2018).

For the purposes of this study, residents born in Suzhou are defined as native residents. In contrast, non-native residents include those without Suzhou birthplaces but holding Suzhou household registrations, as well as floating residents such as adult college students and non-registered workers. Both groups are crucial to understanding Suzhou’s social dynamics and were explored in this research.

In analyzing Suzhou’s rural areas, the study expands its focus beyond native rural residents. With ongoing rural development, a significant portion of Suzhou’s rural areas now accommodates non-native residents, including rural renters and short-term visitors who are not originally from Suzhou’s rural areas. Addressing their needs is critical to guiding Suzhou’s rural revitalization efforts. Consequently, this study incorporates evaluations from both native residents born in Suzhou and non-native residents living in Suzhou’s rural areas.

2.2. Method

Current evaluation standards for rural housing façades and environments largely focus on structural and safety aspects.

However, comprehensive international standards for urban housing performance are often not directly applicable to rural living environments. In the previous studies, hierarchical analysis has been a common method for evaluating rural housing and environments, typically from the perspective of designers or experts. This approach, however, often overlooks the viewpoints of residents themselves (Zhang *et al.*, 2022). In contrast, researchers such as Kevin Lynch have emphasized the importance of user-focused studies based on human perceptions to guide design (Fu & Dai, 2016).

This study adopts a performance analysis approach to examine user feedback, aiming to identify the key areas of concern for residents. Data were collected through questionnaires, interviews, and field surveys to establish evaluation criteria and gather user assessments. Quantitative analysis was employed to capture direct feedback on the importance and performance of various factors, providing insights into the actual needs of residents in the context of rural regeneration.

To quantify the gap between the importance users assign to specific evaluation factors and the perceived performance of these factors, this study employs the importance-performance analysis (IPA) method (Kwon *et al.*, 2016). Originally introduced by Martilla & James (1977) to assess automotive dealerships, IPA has since gained widespread application due to its intuitive and easy-to-understand framework. Despite its versatility, the application of IPA in analyzing rural living environments remains limited.

In this study, an IPA matrix was constructed based on elements related to rural residential structures, including façades and surrounding environments. This analysis identifies critical factors for façade regeneration and evaluates performance levels from the user's perspective. The findings provide targeted recommendations for stakeholders involved in future rural housing revitalization efforts.

2.3. Construction of the evaluation index system

This study takes into account the current status, goals, and demands of rural landscape construction in Suzhou. Data collection included interviews, literature reviews, and field surveys, with expert opinions solicited from relevant fields. Widely recognized perception elements were selected, objectively summarized, and statistically processed. Field research was conducted in Huayewei village in Suzhou's high-tech district and Juliqiao village in Wujiang district. Based on comprehensive analysis, the study finalized the selection of elements and indexes (Table 1).

Traditional exterior indexes, such as form design and façade design, represent the most direct expressions of architectural style, embodying the vernacular identity of local architecture. In contrast, spatial layout and functional indexes

are more implicit, reflecting the spatial textures shaped by the living patterns and habits of Suzhou's residents. Rural residents engage with their environments through multidimensional perceptions – functionality, comfort, cultural identity, and a connection with nature – but often lack the terminology to articulate these experiences. Compared to the façades of rural dwellings, spatial layouts have a more direct impact on residents' quality of life and emotional connections, highlighting the unique heritage of rural environments. Recognizing that respondents are primarily non-design professionals, the study identified six key components for evaluation: entrance, wall, doors and windows, roof, details, and environment. This restructured framework facilitates better understanding among respondents. Based on user perspectives, the study developed a subjective perception model for rural building façades and environments in Suzhou, encompassing a total of 14 evaluation indexes (Table 2).

2.4. Sample size

The sample size for this study was determined based on the Kendall sample estimation method (Qian *et al.*, 2024). According to this method, the recommended sample size typically ranges from 5 to 10 times the number of variables. For this study, 17 index layers corresponding to 17 variables were established, leading to an initial sample size range of 85 to 170 participants. To account for potential dropouts, a 10 percent increase was applied, resulting in a final adjusted sample size range of 94 to 187 participants.

Using data from the Suzhou migrant population research report, it was observed that native residents comprise 36.4 percent, while non-native residents account for 63.6 percent of the population (Gusuwang, 2018). Based on these proportions, the sample size for native residents should range from 31 to 62 participants, and for non-native residents, from 54 to 108 participants. After considering a 10 percent attrition rate, the adjusted sample size range becomes 34 to 68 for native residents and 60 to 119 for non-native residents.

Suzhou comprises six districts (Gusu, Wuzhong, Xiangcheng, Huqiu, Suzhou Industrial Park, and Wujiang) and four county-level cities (Changshu, Zhangjiagang, Kunshan, and Taicang). Among these, Gusu district and Suzhou Industrial Park with their 100 percent urbanization rates, were excluded from the sampling framework. The remaining districts and cities were included, with survey sample sizes distributed according to the proportion of the rural population in each district (Table 3) (Zhang *et al.*, 2023). Accordingly, Kunshan and Changshu, which have the highest rural population proportions, require the largest sample sizes, while Xiangcheng and Huqiu districts, with the smallest rural populations, require the smallest sample sizes.

Table 1. Quantification of vernacular indexes for rural building façades and environments



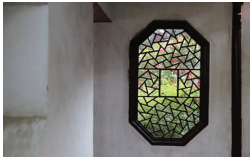

Hierarchical factors		Indexes	Source
Spatial layout		The entry is identifiable.	Fu & Dai, 2016; Yuan & Lin, 2018.
		Whether the indoor lighting condition is good?	Zhang <i>et al.</i> , 2023
		Whether the outdoor view of the rural building is good (whether the distance from the front building is sufficient)?	Zhang <i>et al.</i> , 2023
Structural form	Form design		Zhang <i>et al.</i> , 2022; Source of the reference image: https://www.sohu.com/a/822354254_420849 .
		Traditional local exterior wall forms are used.	
			Zhang <i>et al.</i> , 2022; Source of the reference image: https://www.pinterest.com/pin/11188699072433910/ .
		Traditional roof forms are used.	
Decoration and finishing	Exterior design	Doors and windows are made of excellent-quality materials and reflect local cultural characteristics.	Zhang <i>et al.</i> , 2022; Source of the reference image: http://www.360doc.com/content/23/1201/14/7654794_1105934212.shtml .
			
		Local traditional patterns, lines, or decorations (animal motifs, wall ornaments, etc.) are used.	Zhang <i>et al.</i> , 2022; Source of the reference image: http://www.360doc.com/content/22/0806/00/21414832_1042735145.shtml .
			
Functional indexes		Accessibility features and accessibility of the building (e.g., wheelchair ramps and handrails).	Fu & Dai, 2016
		The indoor temperature is suitable.	Zhang <i>et al.</i> , 2023
		No wet spots, water damage, or mildew inside the house.	Zhang <i>et al.</i> , 2023
Public space	Traditional public space (These are spaces formed throughout human history that serve as venues for collective activities and repositories of cultural memory. Such spaces are characterized by distinct regional, social, and cultural attributes.)	Is there any traditional public space around the building (ancestral hall, cultural wall, etc.)?	Fu & Dai, 2016; Yuan & Lin, 2018; Zhou <i>et al.</i> , 2021; Xiong <i>et al.</i> , 2022.
	Modern public space	Is there any modern public space around the building (chess room, fitness space, recreation space, etc.)?	Fu & Dai, 2016; Yuan & Lin, 2018; Zhou <i>et al.</i> , 2021; Xiong <i>et al.</i> , 2022.
		Whether the building is in harmony with its surroundings?	Xiong <i>et al.</i> , 2022
		Are the pipelines around the building in order (electrical wires, water pipes, TV telephone lines, etc.)?	Zhang <i>et al.</i> , 2023

Table 2. Reconstruction of evaluation indexes based on building façade components

Evaluation object	Elements	Indexes
Rural residential façades in Suzhou	1. Entrance	1. The entry is identifiable.
		2. Accessibility features and accessibility of the building (e.g., wheelchair ramps, handrails, etc.).
	2. Wall	3. The indoor temperature is suitable.
		4. Traditional local exterior wall forms are used.
		5. No wet spots, water damage, or mildew inside the house.
	3. Windows and doors	6. Whether the indoor lighting condition is good?
		7. Doors and windows are made of excellent-quality materials and reflect local cultural characteristics.
		8. Whether the outdoor view of the rural building is good (whether the distance from the front building is sufficient)?
	4. Roof	9. Traditional roof forms are used.
	5. Detail	10. Use the local traditional patterns, lines, or decorations (animal, wall decoration, etc.).
	6. Environment	11. Is there any traditional public space around the building (ancestral hall, cultural wall, etc.)?
		12. Is there any modern public space around the building (chess room, fitness space, recreation space, etc.)?
		13. Whether the building is in harmony with its surroundings?
		14. Are the pipelines around the building in order (electrical wires, water pipes, TV telephone lines, etc.)?

Table 3. Relationship between sampling spatial distribution and sampling quantities across Suzhou districts

District	Rural population (thousand people)	Percentage (%)	Sampling quantity (people)	
			Native residents	Non-native residents
Wuzhong	312.1	13.75	5 – 10	8 – 16
Xiangcheng	49.6	2.19	1	1 – 2
Huqiu	61.8	2.72	1	1 – 3
Wujiang	374.3	16.49	5 – 12	10 – 20
Changshu	432.7	19.06	7 – 13	12 – 23
Zhangjiagang	358.9	15.81	5 – 11	9 – 19
Kunshan	435.9	19.20	7 – 13	12 – 23
Taicang	244.6	10.78	3 – 7	7 – 13
Total	2,269.9	100	34 – 68	60 – 119

2.5. Questionnaire design and survey

The survey questionnaire for this study consists of two parts. The first section collects demographic data, including respondents' place of birth, age group, educational background, and other relevant personal details. The second section evaluates respondents' perceptions of the current state of rural house façades and environments in Suzhou. A five-point Likert scale was employed for evaluation, with importance categorized as "very unimportant," "unimportant," "neutral," "important," and "very important," corresponding to scores of 1 – 5. Similarly, performance was rated as "very dissatisfied," "dissatisfied," "neutral," "satisfied," and "very satisfied," also assigned scores from 1 to 5. Expert opinions were

solicited to refine the wording of the evaluation indexes, minimizing potential biases that could affect the results (Zhou *et al.*, 2024). Refer to [Appendix](#) for the details of the questionnaire.

The questionnaires were distributed through an online platform (SoJump), and by July 31, 2024, a total of 165 responses were collected. Of these, 65 responses were from native residents and 100 from non-native residents, satisfying the specified sample size criteria. The collected data were analyzed to calculate the average scores for the importance and performance of evaluation factors, which were then plotted on an IPA chart. This approach facilitated the IPA evaluation of rural house façade indexes in Suzhou (Wu *et al.*, 2023).

2.6. Evaluation factor reliability and validity testing

The reliability and validity of the scales used in this study were assessed to ensure their accuracy. Cronbach's alpha coefficient was calculated to assess the reliability of the importance and performance scales. Reliability and validity analyses were conducted using SPSS 27 on the 14 factors of importance and performance. The Cronbach's alpha values were 0.963 for the importance factors and 0.960 for the performance factors, both exceeding the threshold of 0.7, indicating high reliability for both scales. Furthermore, the Kaiser–Meyer–Olkin value was 0.810, exceeding the recommended threshold of 0.8, signifying that the data were suitable for factor extraction and demonstrated robust validity.

3. Results

3.1. Demographic characteristics of respondents

This study analyzed the demographic characteristics of the respondents to assess whether the sample composition accurately reflects the population characteristics (Kwon *et al.*, 2016). The effective sample population exhibits the following key characteristics:

First, 60.61 percent of respondents were non-local residents of Suzhou, reflecting the city's significant immigrant population. Suzhou's attraction as a destination for work or study enriches its diversity. This diversity enhances the comprehensiveness of the research findings, indicating that the conclusions drawn from this study may be applicable to rural areas in other regions. Furthermore, these insights provide valuable guidance for Suzhou's future development.

Second, respondents aged 18 – 30 years old constituted the largest group (63 respondents, or 38.18%). This age cohort represents a crucial demographic for rural revitalization efforts, as their perspectives are critical for effectively implementing changes in rural housing and community development. The second largest groups were those aged 30 – 40 (50 respondents, or 30.30%) and 40 – 50 (36 respondents, 21.82%). These age groups play a pivotal role in shaping the current state of rural residential development, as their needs significantly influence the appearance of rural house façades and environments (Table 4).

3.2. Importance and performance analysis

Based on the survey data, statistical values were compiled to assess the importance and performance of various elements as perceived by residents in Suzhou. The importance and performance rating was derived from the mean values of respective indexes (Table 5).

From the perspective of importance, the rankings of elements are as follows: Windows and doors > Wall

Table 4. Attributes of respondents

Situation	Type	Number of people	Percentage (%)
Birthplace	Native	65	39.39
	Non-native	100	60.61
Age	Under 18 years old	2	1.21
	18 – 30 years old	63	38.18
	30 – 40 years old	50	30.30
	40 – 50 years old	36	21.82
	Over 50 years old	14	8.49
Educational background	Junior high school and below	3	1.82
	Senior high school	3	1.82
	College degree and above	159	96.36

Table 5. Importance and performance analysis of elements

Elements	Importance	Performance	Importance-performance analysis
Entrance	4.08	3.56	0.52
Wall	4.21	3.78	0.43
Windows and doors	4.25	3.78	0.47
Roof	3.97	3.88	0.09
Detail	3.82	3.76	0.06
Environment	4.17	3.75	0.42
Overall mean values	4.08	3.75	0.33

> Environment > Entrance > Roof > Detail. The scores for these elements ranged from 3.82 to 4.25, with Windows and Doors, Wall, and Environment receiving significantly higher importance ratings. Conversely, the detail score was markedly lower than the other elements, indicating that residents prioritize functional aspects, such as walls, doors, and windows, over finer architectural details.

In terms of performance, the ranking is: Roof > Windows and doors = Wall > Detail > Environment > Entrance. Performance scores ranged from 3.56 to 3.88, with the Roof, Walls, and Windows and doors achieving the higher performance scores. Notably, Entrance had the lowest performance score.

A significant negative correlation was observed between the importance and performance of the Roof element, while Windows and doors and Wall elements exhibited positive correlations.

From the perspective of the mean importance scores of various indexes, the following aspects received high expectations from residents:

- 1. The entry is identifiable.
- 3. The indoor temperature is suitable.
- 4. Traditional local exterior wall forms are used.
- 5. There is no wet trace, water trace, or mildew inside the house.
- 6. Whether the indoor lighting condition is good.
- 8. Whether the outdoor view of the rural building is good (whether the distance from the front building is sufficient).
- 12. Is there any modern public space around the building (chess room, fitness space, recreation space, etc.)?
- 13. Whether the building is in harmony with its surroundings.
- 14. Are the pipelines around the building in order (electrical wires, water pipes, TV telephone lines, etc.)?

The mean scores for these eight indexes exceeded 4.14, indicating a high level of expectation among residents regarding these aspects.

In terms of performance scores, the following indexes achieved mean scores greater than 3.75:

- 1. The entry is identifiable.
- 4. Traditional local exterior wall forms are used.
- 7. Doors and Windows are made of excellent-quality materials and reflect local cultural characteristics.
- 8. Whether the outdoor view of the rural building is good (whether the distance from the front building is sufficient).
- 9. Traditional roof forms are used.
- 10. Use the local traditional patterns, lines, or decorations (animal, wall decoration, etc.).
- 12. Is there any modern public space around the building (chess room, fitness space, recreation space, etc.)?
- 13. Whether the building is in harmony with its surroundings.

The difference between mean importance and performance scores reflects relatively poor performance. Specifically, both elemental and index-level scores indicate that performance ratings fall short of perceived importance. This suggests that there is room for improvement in the quality of rural residential building façades and their integration with the surrounding environment in the Suzhou region (Tables 5 and 6, Figure 2).

Table 6. Importance and performance analysis of indexes

Indexes	Importance		Performance		Importance-performance analysis
	Mean value	Ascending means	Mean value	Ascending means	
1. The entry is identifiable.	4.15	9	3.82	5	0.33
2. Accessibility features and accessibility of the building (e.g., wheelchair ramps, handrails, etc.).	4.00	11	3.30	14	0.70
3. The indoor temperature is suitable	4.21	6	3.73	9	0.48
4. Traditional local exterior wall forms are used	4.18	8	4.00	1	0.18
5. There is no wet trace, water trace, or mildew inside the house	4.24	5	3.61	12	0.63
6. Whether the indoor lighting condition is good	4.39	1	3.73	9	0.66
7. Doors and windows are made of excellent-quality materials and reflect local cultural characteristics	4.09	10	3.85	4	0.24
8. Whether the outdoor view of the rural building is good (whether the distance from the front building is sufficient)	4.27	4	3.76	7	0.51
9. Traditional roof forms are used	3.97	12	3.88	3	0.09
10. Use the local traditional patterns, lines, or decorations (animal, wall decoration, etc.)	3.82	13	3.76	7	0.06
11. Is there any traditional public space around the building (ancestral hall, cultural wall, etc.)?	3.82	13	3.61	12	0.21
12. Is there any modern public space around the building (chess room, fitness space, recreation space, etc.)?	4.21	6	3.79	6	0.42
13. Whether the building is in harmony with its surroundings	4.30	3	3.94	2	0.36
14. Are the pipelines around the building in order (electrical wires, water pipes, TV telephone lines, etc.)	4.36	2	3.67	11	0.69
Overall mean values	4.14	-	3.75	-	0.40

When examining the responses of native and non-native residents separately, native respondents rated the following indexes higher in terms of importance:

- 4. Traditional local exterior wall forms are used.
- 5. There is no wet trace, water trace, or mildew inside the house.
- 6. Whether the indoor lighting condition is good.
- 8. Whether the outdoor view of the rural building is good (whether the distance from the front building is sufficient).

Conversely, non-native residents provided higher ratings for the following indexes (Figure 3):

- 1. The entry is identifiable.
- 2. Accessibility features and accessibility of the building (e.g., wheelchair ramps, handrails, etc.).
- 3. The indoor temperature is suitable.
- 7. Doors and windows are made of excellent-quality materials and reflect local cultural characteristics.
- 10. Use the local traditional patterns, lines, or decorations (animal, wall decoration, etc.).
- 11. Is there any traditional public space around the building (ancestral hall, cultural wall, etc.)?

- 12. Is there any modern public space around the building (chess room, fitness space, recreation space, etc.)?
- 13. Whether the building is in harmony with its surroundings.
- 14. Are the pipelines around the building in order (electrical wires, water pipes, TV telephone lines, etc.)?

In terms of performance, native residents rated higher on the following indexes:

- 1. The entry is identifiable.
- 3. The indoor temperature is suitable.
- 5. There is no wet trace, water trace, or mildew inside the house.
- 6. Whether the indoor lighting condition is good.
- 7. Doors and windows are made of excellent-quality materials and reflect local cultural characteristics.
- 9. Traditional roof forms are used.
- 11. Is there any traditional public space around the building (ancestral hall, cultural wall, etc.)?

In contrast, non-native residents rated higher on the following indexes (Figure 4):

- 2. Accessibility features and accessibility of the building (e.g., wheelchair ramps, handrails, etc.).
- 8. Whether the outdoor view of the rural building is good (whether the distance from the front building is sufficient).
- 10. Use the local traditional patterns, lines, and decorations (animal, wall decoration, etc.).
- 12. Is there any modern public space around the building (chess room, fitness space, recreation space, etc.)?
- 13. Whether the building is in harmony with its surroundings.
- 14. Are the pipelines around the building in order (electrical wires, water pipes, TV telephone lines, etc.)?

This differentiation highlights the varying perceptions and priorities of local and non-local residents regarding rural residential architecture in Suzhou.

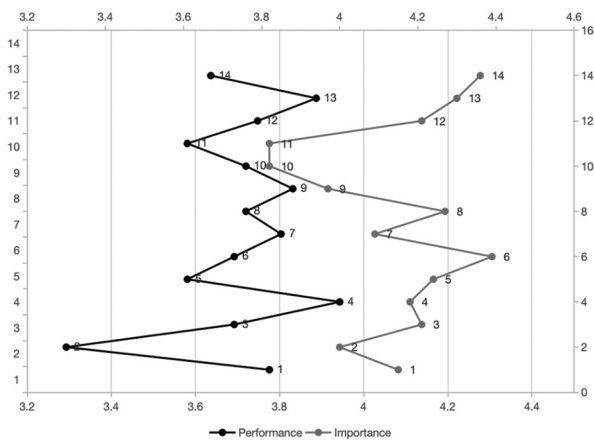


Figure 2. Comparison of importance and performance at index level. Source: Graph by the authors

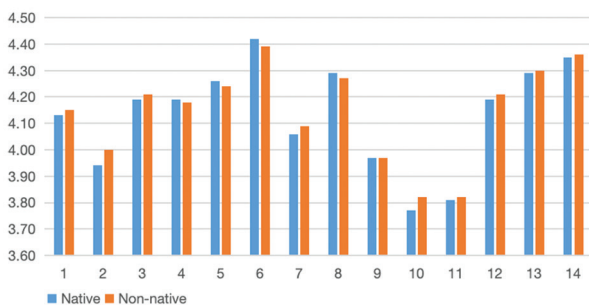


Figure 3. Comparison of importance between native residents and non-native residents. Source: Graph by the authors

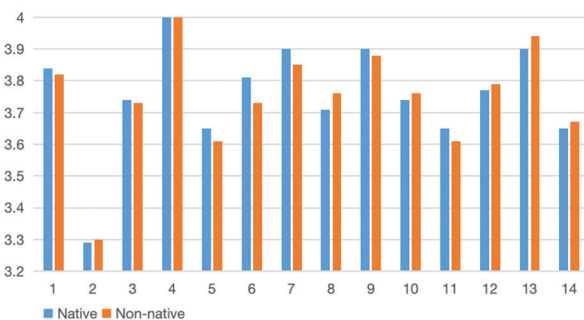


Figure 4. Comparison of performance between native residents and non-native residents. Source: Graph by the authors

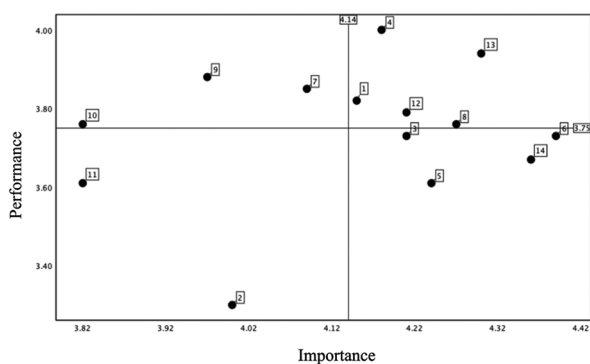


Figure 5. Importance-performance analysis of the indexes for all residents (the numbers correspond to the indexes). Source: Graph by the authors

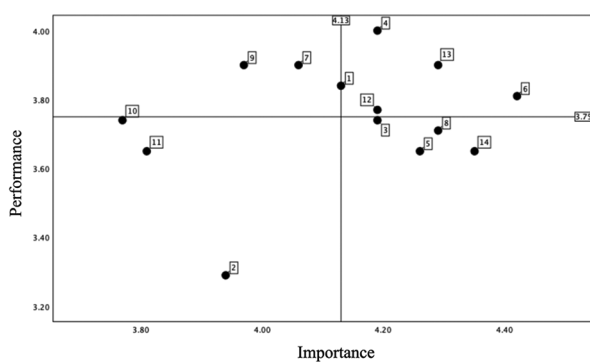


Figure 6. Importance-performance analysis of the indexes of native residents (the numbers correspond to the indexes). Source: Graph by the authors

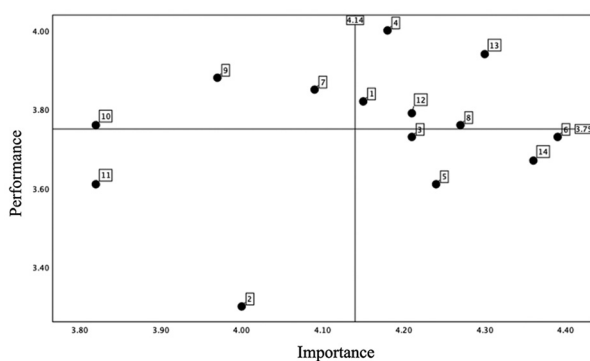


Figure 7. Importance-performance analysis of the indexes of non-native residents (the numbers correspond to the indexes). Source: Graph by the authors

Based on the above analysis of the importance and performance factors for rural house façades and environmental vernacularity, we conducted an IPA by setting importance as the horizontal axis and performance as the vertical axis. Using an overall mean of 4.14 for importance and 3.75 for performance as the quadrant intersection point, we constructed a two-dimensional, four-quadrant

coordinate graph. The mean values of importance and performance for each rural house façade evaluation factor were plotted as coordinates (X, Y) across the four quadrants, resulting in the IPA evaluation matrix (Figure 5). The IPA evaluation matrices for native and non-native residents (Figures 6 and 7) were constructed in the same way.

In this matrix, the first quadrant represents the “Continue to Maintain” area (Strength Zone), the second quadrant is the “Over-Emphasized” area (Maintenance Zone), the third quadrant is the “Low Priority” area (Expansion Zone), and the fourth quadrant is the “Urgent Improvement” area (Repair Zone) (Kim & Huh, 2019; Zhang *et al.*, 2023).

4. Discussion

In the matrix constructed based on the index assessments, the first quadrant, which indicates high importance and high performance, includes five indexes:

- 1. The entry is identifiable
- 4. Traditional local exterior wall forms are used.
- 8. Whether the outdoor view of the rural building is good (whether the distance from the front building is sufficient).
- 12. Is there any modern public space around the building (chess room, fitness space, recreation space, etc.)?
- 13. Whether the building is in harmony with its surroundings.

Among these, only Index 4 is explicitly related to exterior appearance. Field visits to various rural areas in Suzhou reveal that the characteristic white-wall appearance of Suzhou’s architecture is largely preserved, particularly in larger public buildings, such as the Suzhou Museum designed by I. M. Pei (1917 – 2019). The remaining indexes (1, 8, 12, and 13) are implicit, focusing more on functionality and residential comfort, which reflects a greater demand for functional comfort over esthetic appeal among residents. In the first quadrant, native residents and non-native migrants differ in their views on Indexes 6 and 8. Both indexes are rated as highly important and relate strongly to functionality, suggesting that issues such as view and lighting, stemming from locational or design limitations, align with the observed realities of rural areas in Suzhou. Therefore, in future revitalization efforts for rural residential buildings, prioritizing functional infrastructure and ensuring a livable environment will be essential (Figures 6 and 7).

The second quadrant, which reflects low importance but high performance, includes three variables:

- 7. Doors and windows are made of excellent-quality materials and reflect local cultural characteristics
- 9. Traditional roof forms are used.
- 10. Use the local traditional patterns, lines, or decorations (animal, wall decoration, etc.).

All three variables relate to traditional architectural forms. The characteristic white walls and dark tiles of traditional Jiangnan architecture are relatively well-preserved in Suzhou, and the overall rural appearance in most areas remains intact. However, field visits to two villages revealed that some buildings no longer retain these features. This observation aligns with data analysis showing low importance for traditional architectural details. While both native and non-native Suzhou residents recognize the unique cultural aspects of Suzhou's traditional architecture, functionality is prioritized over esthetic features. Urbanization has introduced a preference for functionality, practicality, and modern esthetics, which may lead to the perception that the characteristics of traditional rural dwellings are unnecessary or outdated. This city-centered value system has influenced the appearance of some rural residences in Suzhou, where traditional architectural features are often overshadowed by urban design trends.

The third quadrant, which indicates low importance and low performance, includes two variables:

- 2. Accessibility features and accessibility of the building (e.g., wheelchair ramps, handrails, etc.)
- 11. Is there any traditional public space around the building (ancestral hall, cultural wall, etc.)?

Field observations indicate that revitalization efforts for traditional Suzhou rural buildings seldom consider the provision of accessibility features, even in some renovated homestays. In addition, due to urbanization, cultural emphasis in southern Jiangsu differs from that in Lingnan, where ancestral halls are highly valued. The traditional “familiar society” is gradually being deconstructed, leading to a decline in collective spaces such as ancestral halls. This shift reflects the increasing individualism in rural areas and the diminishing role of collective traditions in daily life. In Suzhou, cultural significance is often more evident in building appearances rather than in dedicated spaces. With rural populations aging rapidly, ordinary residents have generally not considered age-friendly designs in rural homes, highlighting a critical need for integrated design planning and policy improvements to address accessibility and age-appropriate features in rural housing.

In the second and third quadrants, both native and non-native residents share similar perspectives, viewing traditional and culturally related indexes as relatively unimportant. This perspective reflects why the appearance of existing rural buildings has changed and appears less vernacular compared to the past. In actual rural façade renovation projects, residents tend to focus primarily on the technical and cost-related aspects of renovating older buildings. However, research shows that this purely technical and cost-focused approach can inadvertently reduce the vernacular character of rural houses.

A “familiar society” is characteristic of rural social relations, where social interactions are based on longstanding relationships rather than technical dependencies (Liu & Yan, 2022). This societal structure traditionally fostered similarity in living spaces, with residents constructing façades based on collectively passed-down experiences, forming locally distinctive vernacular styles. However, as urbanization and migration increase, the traditional familiar society, once bounded by rural areas, is gradually disintegrating. This breakdown has resulted in changes to traditional rural lifestyles and the erosion of the distinctiveness that once characterized rural façades and environments.

Traditional rural society is inherently static and locally bound (Fei, 2022), while modern society is highly fluid, leading to a phenomenon known as “flowing rurality” under the pressures of urbanization (Liu & Yan, 2022). Rural stakeholders are increasingly influenced by urban values, resulting in several trends: (i) a focus on functionality and (ii) the adoption of common building materials. When these urban-centric influences extend to rural façades, they often manifest as an overemphasis on functionality. This shift can result in disordered façade forms, inconsistent architectural spaces, altered environments, and the use of non-traditional building materials.

In the fourth quadrant, which reflects high importance but low performance, four variables are identified:

- 3. The indoor temperature is suitable.
- 5. There is no wet trace, water trace, or mildew inside the house.
- 6. Whether the indoor lighting condition is good.
- 14. Are the pipelines around the building in order (electrical wires, water pipes, TV telephone lines, etc.)?

These indexes are all implicit and relate to functionality and the living environment. Field visits reveal that as urbanization progresses, rural populations are aging rapidly, leaving many older homes vacant. This situation has led to an increase in deteriorated and even unsafe buildings. The poor living environment in these homes also detracts from the attractiveness of rural areas, making it challenging to retain or attract residents.

The data reveal that for both local and non-local residents, the functional and environmental needs of rural housing far outweigh esthetic and cultural demands. Traditional Suzhou rural dwellings, with their iconic white walls and dark tiles, are still preserved in many rural areas of Suzhou. However, field visits noted that some façades have been renovated with new materials, such as tiles replacing the original plaster (Figure 8). Therefore, rural house renovations should prioritize fundamental living environment improvements, including insulation,



Figure 8. Rural building façades and environments in (A) Huayewei village and (B) Jiuliqiao village in Wujiang district, Suzhou city, Jiangsu province, China. Source: Photos by Sucheng Yao (2023)

thermal resistance, and waterproofing. Addressing these basic needs is essential to attract more people back to the countryside or to encourage rural tourism.

At the same time, rural façades shaped by local lifestyles and cultural values are an integral part of the rural cultural landscape, combining practicality with vernacular esthetics. While functionality often involves quick solutions or the use of urbanized building materials, vernacular character requires the passage of time to develop organically. Each era expresses rural vernacular in different ways. According to Tomanović *et al.* (2019), incorporating contemporary lifestyles and modern architectural trends into traditional buildings can breathe new life into rural architecture.

From a historical perspective, the functionality of residential spaces is indispensable, while a good rural living environment should integrate both functionality (physical space) and esthetics (emotional connection). In the process of modern rural residential regeneration, preserving the esthetic elements of traditional dwellings not only helps maintain the continuity of traditional culture but also strengthens residents' sense of belonging and cultural identity.

In the case of Suzhou's rural residences and environment, this study, based on IPA results and surveys conducted in two rural areas of Suzhou, identifies four key elements that contribute to the retention and use of rural vernacular character: traditional roof forms, building colors, traditional materials, and public spaces. These elements help sustain both the functionality and vernacular character of Suzhou's rural dwellings. For example, traditional roof forms are an important cultural symbol in Suzhou's rural architecture, while also serving functional purposes such as waterproofing, insulation, and ventilation. The distinctive color scheme of Suzhou's rural dwellings (white walls and black tiles) reflects strong regional characteristics.

The use of traditional materials helps preserve the unique heritage of the space. While many commercial spaces adopt this approach to present traditional

esthetics, incorporating such materials into rural housing renovations must be cost-effective compared to the high investments typically seen in commercial projects. Using traditional and reclaimed materials in rural residential and environmental revitalization efforts can help manage costs more efficiently. In addition, public spaces that combine functional uses, such as drying grain, with recreational areas allow both native residents and non-native residents to experience the rural environment in diverse ways.

In the analysis (Figure 5-7), the three indexes representing spatial layout (1, 6, and 8) all fall within the high-importance area, indicating that rural residents consider the spatial layout of rural homes to be highly important. The diversity of spatial layouts reflects the variety of rural lifestyles, serving as a key factor in generating rural heritage. In addition, spatial layout directly manifests the optimization of the rural living environment.

On one hand, lifestyle, climate, and cultural traditions influence the spatial layout of rural homes. Layout changes according to family size, functional needs, and daily habits, while relationships among family members, age structure, and social roles are reflected in the residential space. Each space maintains a certain degree of privacy and social order, allowing the spatial layout to embody the traditional lifestyle and social structure of Suzhou's rural areas. On the other hand, the orientation and layout of rural homes are rooted in traditional inheritance. Although some cultural symbols of the countryside may have faded from the façades of rural homes in the current era, rural living habits continue to extend residents' connection to the land.

Differentiated optimization strategies for native residents and non-native residents can be applied in rural housing façade and environment revitalization efforts, as the needs and concerns of these two groups share commonalities but also exhibit differences. Overall, both groups tend to prioritize functionality and residential comfort, placing less emphasis on the esthetics and cultural expression of traditional architecture. For native residents, there is typically a deeper emotional connection to the overall rural environment and architectural

traditions. However, in actual renovation projects, they are more likely to approach improvements from a cost and technical perspective, prioritizing practical living issues such as natural daylight, ventilation, and waterproofing. In contrast, non-native residents, influenced by urban living habits, are more inclined toward the integration of modern functional amenities, such as higher-quality heating systems or enhanced public spaces.

Therefore, future renovation strategies should strike a balance between functionality and tradition:

- (i). The primary focus should be on meeting the residential functional needs, including improving indoor lighting, regulating temperature, enhancing waterproofing, and ensuring a rational layout of utility lines around the building to enhance the livability of the residential environment.
- (ii). It is equally important to preserve rural culture and architectural characteristics by incorporating local decorative elements and materials into façade designs and optimizing the traditional spatial layout using modern techniques to maintain the unique historical and cultural characteristics of rural areas for residents' memories.

Furthermore, to address the differing needs of native and non-native residents, a dynamic management mechanism can be implemented to flexibly adjust renovation strategies. This approach ensures that rural housing revitalization efforts not only meet the current living needs of residents but also protect the cultural and ecological diversity of rural areas.

Avoiding excessive adherence to tradition while iteratively updating façade treatments is another effective way to preserve rural architectural character.

In summary, the following strategies are proposed for maintaining vernacular attributes in future rural housing:

- (i). Necessary integration

Optimize traditional spatial layouts and incorporate new materials and construction techniques where appropriate (Shi *et al.*, 2024).

Traditional rural spatial layouts were typically designed to accommodate historical lifestyles and environmental conditions, such as the need for collective living and agricultural activities. However, modern rural residents require spaces that meet contemporary demands, including more integrated functional spaces (e.g., kitchens and bathrooms), higher levels of privacy, more efficient indoor-to-outdoor transitions, and multifunctional space designs (e.g., living rooms and lounges). Optimizing the spatial layout can enhance functionality by redesigning the interior structure. For example, transforming the

traditional entrance living room in Suzhou rural homes into an open-plan living space can improve space efficiency and living comfort while respecting the original spatial layouts.

The use of modern materials for updating traditional houses can significantly improve their durability, energy efficiency, and living comfort. For instance, adding insulation to walls and using high-performance exterior paints preserves the building's vernacular character while enhancing functionality. In addition, using lightweight, durable roofing tiles can improve insulation, while sustainable materials, such as permeable bricks instead of traditional stone, can reduce environmental impact while maintaining the architectural style of Suzhou's rural homes.

The integration of modern construction techniques can also make the renovation of rural buildings faster, safer, and more cost-effective. For example, prefabricated components allow for customized replication of traditional forms while ensuring structural integrity. Digital tools, such as building information modeling or drone surveying, can assist in documenting the existing structure with precision, facilitating targeted repairs and revitalization efforts that blend tradition with innovation. Furthermore, advancements such as 3D printing allow for the rapid production of traditional building components, while generative artificial intelligence offers efficient design solutions for rural façades and environments.

However, it is essential to prioritize the local cultural and natural context throughout the integration process. Actively involving stakeholders during planning and construction ensures that renovated buildings reflect vernacular traditions while balancing practicality.

- (ii). Localized research

Emphasizing localized research that integrates historical, cultural, and traditional contexts is crucial for effective reconstruction and renovation (Monterroso-checa *et al.*, 2020). This approach strengthens connections to local settings, cultural diversity, and unique identity, aligning with the "thousand villages, thousand faces" concept (Chen & Zhang, 2021; Pietta & Tononi, 2021).

Historical studies of local architectural styles can provide valuable insights into spatial layouts, building techniques, and decorative elements. For instance, understanding how past designs adapted to local climate conditions or agricultural practices can inform modern renovations. By referencing these historical elements, renovations can preserve traditional characteristics while introducing modern improvements.

The use of traditional materials, such as locally sourced wood, stone, or clay, supports environmental sustainability

and ensures esthetic harmony with existing buildings. When combined with modern construction methods, these materials enhance durability and functionality while maintaining the authentic character of rural architecture. Actively engaging local crafts workers and builders, who possess expertise in these materials, should be prioritized in both the construction and research efforts. Such collaboration not only preserves traditional artisanry but also facilitates the incorporation of innovative solutions for the future.

(iii). Dynamic management mechanisms

Post-construction, rural housing should be maintained through dynamic management systems that continuously identify and address emerging issues. Effective rural housing management must adapt to changing environmental conditions (such as extreme weather or climate change) as well as demographic changes (such as population aging). This adaptability may involve upgrading insulation systems to improve energy efficiency during both summer and winter, or installing accessible facilities in areas with a high concentration of elderly residents.

Establishing a feedback loop – through ongoing assessment of maintenance efforts and collection of resident input – ensures continuous optimization of the system. This iterative process helps maintain rural homes as livable, functional spaces aligned with the community's evolving needs and vision.

5. Conclusion

This study offers valuable insights from a user perspective for landscape designers, architects, and other professionals, presenting fresh approaches to rural housing and environmental improvements within the broader framework of rural revitalization. By understanding these user-centered aspects, rural decision-makers can better integrate user needs into planning processes. In addition, this research contributes to the practical discourse on rural cultural landscapes, advocating for a balanced approach to sustainable rural landscape planning.

However, the study has certain limitations:

- (i). Limited representation of elderly respondents: The proportion of respondents aged 65 and older is low. Challenges such as literacy barriers and a reluctance to complete paper surveys hindered the collection of effective data from elderly individuals during field visits.
- (ii). Subjectivity in quantitative survey indexes: The survey methodology retains an element of subjectivity, which may affect the reliability of results.

To address these issues, future research could adopt a mixed-methods approach, integrating qualitative and

quantitative methods to achieve more comprehensive data collection. For instance, semi-structured interviews could help gather more effective insights from older participants.

Another key area for future exploration lies in the preservation of traditional decorative patterns, such as murals, carvings, and “kissing beasts” (animal motifs used in rooftop construction). For rural housing, determining how to adapt and present these traditional elements in modern contexts remains a crucial challenge for designers. Safeguarding these patterns and crafts is essential, requiring their adaptation to evolving times to ensure they are showcased in ways that honor tradition while enhancing their relevance and appeal in contemporary design. Establishing a bottom-up feedback mechanism, grounded in existing practices and research, would complement top-down efforts to preserve the vernacular character of rural façades. Such an approach would facilitate the targeted allocation of policies and funding, thereby increasing the efficiency of rural development and preservation. Moreover, it would provide both theoretical and technical support for the practical study of rural living environments.

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Author contributions

Conceptualization: All authors

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Investigation: All authors

Methodology: All authors

Writing – original draft: Sucheng Yao

Writing – review & editing: Kanjane Budthimedhee

Ethics approval and consent to participate

Permission to participate in the study was obtained from each subject verbally.

Consent for publication

Not applicable.

Availability of data

Data will be made available from the corresponding author on reasonable request.

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Appendix

调查问卷 Questionnaire

尊敬的先生/女士:

您好,为了研究苏州地区乡村住宅与传统乡村记忆的关系,提高乡村人居环境,让居民可以“望得见山,看得见水,记得住乡愁”,因此制定此问卷。本次问卷为匿名调查,仅用于学术研究,请您根据自身体验进行填写,再次感谢。

Dear Madam / Sir:

Hello. In order to study the relationship between rural architecture and traditional rural memory in Suzhou, improve rural living environment, so that residents can "see mountains, see water and remember homesickness", so this questionnaire is formulated. It is anonymous and only used for academic research. Please fill it out according to your own experience. Thank you very much.

第一部分 基础信息

First part Basic Information

1.您的出生地?

a.本地人 b.非本地人

1.Your birthplace?

a.native b. non-native

2.您的年龄段?

a.18岁以内 b.18岁-30岁 c.30岁-40岁 d.40岁-50岁 e.50岁以上

2.Your age?

a.under 18 years old b.18 years old-30 years old c. 30 years old-40 years old d. 40 years old e. over 50 years old

3.您的学历?

a.初中及以下 b.高中 c.大专及以上

3.Your educational background?

a.junior high school and below b.senior high school c.college degree and above

第二部分 苏州乡村住宅外立面评价

Second part The Evaluation of Rural Residential Facade in Suzhou.

4.您对曾经去过/看过/居住过的苏州的乡村住宅入口区域的评价:

4.1 入口是否具有识别性

满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

4.2 进出口是否方便,住宅带无障碍设施(如:供轮椅推行的无障碍坡道、扶手等)

满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

4.Your evaluation of the rural residential entry you have ever gone to/ see / live in.

4.1The entry is identifiable

Satisfaction:a.very unsatisfied(one points) b.unsatisfied(two points) c.general (three points) d.satisfied(four points) e.very satisfied(five points)

Significance:a.very unimportant(one points) b.unimportant(two points) c.general(three points) d.important(four points) e.very important(five points)

4.2Accessibility, accessibility of the building (e.g. wheelchair accessible ramps, handrails, etc.).

Satisfaction:a.very unsatisfied(one points) b.unsatisfied(two points) c.general (three points) d.satisfied(four points) e.very satisfied(five points)

Significance:a.very unimportant(one points) b.unimportant(two points) c.general(three points) d.important(four points) e.very important(five points)

5.您对曾经去过/看过/居住过的苏州的乡村住宅的墙体评价:

5.1 室内温度适宜程度

满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

5.2 使用当地传统外墙形式 (图)



满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

5.3 房屋内部有无湿迹、水迹与发霉现象

满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

5>Your evaluation of the rural residential wall you have ever gone to/ see / live in.

5.1Thermal insulation performance of wall(whether it can keep warm in winter and it can keep cool in summer)

Satisfaction:a.very unsatisfied(one points) b.unsatisfied(two points) c.general (three points) d.satisfied(four points) e.very satisfied(five points)

Significance:a.very unimportant(one points) b.unimportant(two points) c.general(three points) d.important(four points) e.very important(five points)

5.2 Traditional local exterior wall forms are used

Satisfaction: a. very unsatisfied (one points) b. unsatisfied (two points) c. general (three points) d. satisfied (four points) e. very satisfied (five points)

Significance: a. very unimportant (one points) b. unimportant (two points) c. general (three points) d. important (four points) e. very important (five points)

5.3 There is no wet trace, water trace and mildew inside the house

Satisfaction: a. very unsatisfied (one points) b. unsatisfied (two points) c. general (three points) d. satisfied (four points) e. very satisfied (five points)

Significance: a. very unimportant (one points) b. unimportant (two points) c. general (three points) d. important (four points) e. very important (five points)

6. 您对曾经去过/看到过/居住过苏州的乡村住宅的门窗评价:

6.1 室内采光状况良好

满意度: a. 非常不满意 (1分) b. 不满意 (2分) c. 一般 (3分) d. 满意 (4分) e. 非常满意 (5分)

重要性: a. 非常不重要 (1分) b. 不重要 (2分) c. 一般重要 (3分) d. 很重要 (4分) e. 非常重要 (5分)

6.2 门窗材料优良且体现地方文化特色 (图)



满意度: a. 非常不满意 (1分) b. 不满意 (2分) c. 一般 (3分) d. 满意 (4分) e. 非常满意 (5分)

重要性: a. 非常不重要 (1分) b. 不重要 (2分) c. 一般重要 (3分) d. 很重要 (4分) e. 非常重要 (5分)

6.3 乡村住宅户外视野是否良好 (与前方住宅距离是否足够)

满意度: a. 非常不满意 (1分) b. 不满意 (2分) c. 一般 (3分) d. 满意 (4分) e. 非常满意 (5分)

重要性: a. 非常不重要 (1分) b. 不重要 (2分) c. 一般重要 (3分) d. 很重要 (4分) e. 非常重要 (5分)

6. Your evaluation of the rural residential windows and doors you have ever gone to / see / live in.

6.1 Whether the indoor lighting condition is good

Satisfaction: a. very unsatisfied (one points) b. unsatisfied (two points) c. general (three points) d. satisfied (four points) e. very satisfied (five points)

Significance: a. very unimportant (one points) b. unimportant (two points) c. general (three points) d. important (four points) e. very important (five points)

6.2 Doors and Windows of excellent materials and reflect local cultural

characteristics

Satisfaction:a.very unsatisfied(one points) b.unsatisfied(two points) c.general (three points) d.satisfied(four points) e.very satisfied(five points)

Significance:a.very unimportant(one points) b.unimportant(two points) c.general(three points) d.important(four points) e.very important(five points)

6.3Whether the outdoor view of the rural building is good (whether the distance from the front building is sufficient)

Satisfaction:a.very unsatisfied(one points) b.unsatisfied(two points) c.general (three points) d.satisfied(four points) e.very satisfied(five points)

Significance:a.very unimportant(one points) b.unimportant(two points) c.general(three points) d.important(four points) e.very important(five points)

7.您对去过/看到过/居住过的苏州的乡村住宅的屋面评价:

7.1 使用当地传统屋顶形式 (图)



满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

7>Your evaluation of the rural residential roof you have ever gone to/ see/ live in.

7.1Traditional roof forms are used

Satisfaction:a.very unsatisfied(one points) b.unsatisfied(two points) c.general (three points) d.satisfied(four points) e.very satisfied(five points)

Significance:a.very unimportant(one points) b.unimportant(two points) c.general(three points) d.important(four points) e.very important(five points)

8.您对去过/看到过/居住过的苏州的乡村的住宅立面细部评价:

8.1 采用当地传统图案、线条、小品装饰 (吻兽、墙面装饰等纹样)



满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

8. Your evaluation of the rural residential detail you have ever gone to/ see/ live in.

8.1 Use the local traditional patterns, lines, small decoration (animal, wall decoration, etc.)

Satisfaction: a. very unsatisfied (one points) b. unsatisfied (two points) c. general (three points) d. satisfied (four points) e. very satisfied (five points)

Significance: a. very unimportant (one points) b. unimportant (two points) c. general (three points) d. important (four points) e. very important (five points)

9.您对去过/看到过/居住过的苏州的乡村的住宅周边环境评价:

9.1 住宅周边是否有传统公共空间 (祠堂、文化墙等)

满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

9.2 住宅周边是否有现代公共空间 (棋牌室, 健身空间, 游憩空间等)

满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

9.3 住宅与周边的环境是否协调

满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分) e.非常重要 (5分)

9.4 住宅周边的管线是否整齐 (电线、水管、电视电话线等)

满意度: a.非常不满意 (1分) b.不满意 (2分) c.一般 (3分) d.满意 (4分) e.非常满意 (5分)

重要性: a.非常不重要 (1分) b.不重要 (2分) c.一般重要 (3分) d.很重要 (4分)
e.非常重要 (5分)

9. Your evaluation of the rural residential environment you have ever gone to/ see / live in.

9.1 Is there any traditional public space around the building (ancestral hall, cultural wall, etc.)?

Satisfaction: a. very unsatisfied (one points) b. unsatisfied (two points) c. general (three points) d. satisfied (four points) e. very satisfied (five points)

Significance: a. very unimportant (one points) b. unimportant (two points) c. general (three points) d. important (four points) e. very important (five points)

9.2 Is there any modern public space around the building (chess room, fitness space, recreation space, etc.)?

Satisfaction: a. very unsatisfied (one points) b. unsatisfied (two points) c. general (three points) d. satisfied (four points) e. very satisfied (five points)

Significance: a. very unimportant (one points) b. unimportant (two points) c. general (three points) d. important (four points) e. very important (five points)

9.3 Whether the building is in harmony with its surroundings?

Satisfaction: a. very unsatisfied (one points) b. unsatisfied (two points) c. general (three points) d. satisfied (four points) e. very satisfied (five points)

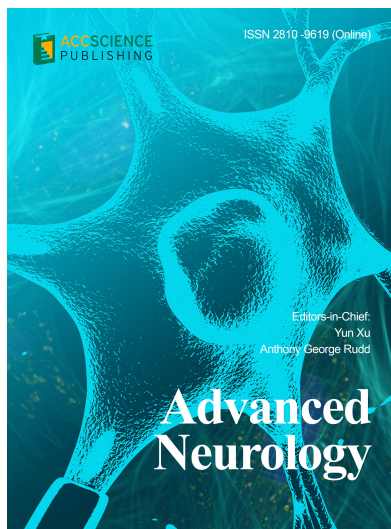
Significance: a. very unimportant (one points) b. unimportant (two points) c. general (three points) d. important (four points) e. very important (five points)

9.4 Are the pipelines around the building in order (electrical wires, water pipes, TV telephone lines, etc.)?

Satisfaction: a. very unsatisfied (one points) b. unsatisfied (two points) c. general (three points) d. satisfied (four points) e. very satisfied (five points)

Significance: a. very unimportant (one points) b. unimportant (two points) c. general (three points) d. important (four points) e. very important (five points)

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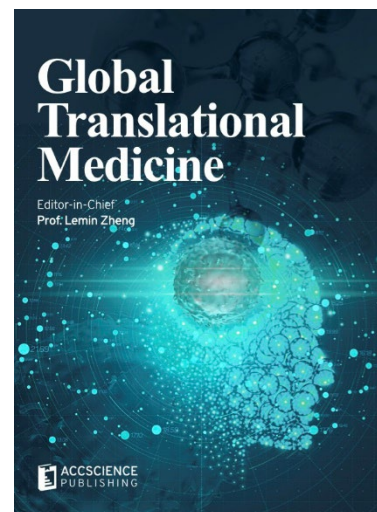
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- Computational modeling of nervous system

Global Translational Medicine is a quarterly journal that focuses on medicine, biological sciences, and biomaterials engineering. The goal of *Global Translational Medicine* is to provide a platform to researchers for showcasing their latest research works in translational medicine so as to advance the field towards the betterment of human health. Despite the advancement of omics and new technologies, the process of transforming these technologies and scientific research results into effective therapies and putting them into clinical use still has a long way to go. *Global Translational Medicine* provides a platform to fill the gaps in preclinical and inter-disciplinary research, to promote clinical translation of scientific research results, and to contribute to the conception of new and improved preventive measures as well as diagnostic and therapeutic techniques of diseases.

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