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Enhancing cultural heritage accessibility through space syntax: a case study of the archaeological site of the wooden water gate of southern Yue State

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ABSTRACT

The accessibility of heritage sites is essential for sustaining cultural vitality in urban environments. This study investigates the Wooden Water Gate of the Southern Yue State in Guangzhou, China, with the goal of improving its spatial accessibility and integration within the historic district. Using an integrated framework combining Space Syntax analysis, field surveys, and urban design strategies, spatial metrics such as connectivity, integration, choice, and total depth were evaluated to diagnose accessibility challenges. The analysis revealed fragmented spatial structures, weak topological connections, and excessive spatial depth that hinder visitor movement and disrupt historical continuity. Based on these findings, targeted interventions were proposed, including enhancing pedestrian linkages, activating public spaces, and creating a cultural heritage experience loop. The results demonstrate that combining spatial analysis with urban design offers an effective approach to optimizing heritage accessibility. While grounded in a case, the insights contribute to broader applications for heritage revitalization globally.

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Accessibility; cultural heritage; space syntax; urban design; historic district

1. Introduction

Accessibility plays a pivotal role in achieving sustainable urban development (Liu et al. 2025; Moreno et al. 2025), notably aligning with Sustainable Development Goal 11 (SDG 11), which emphasizes creating inclusive, safe, resilient, and sustainable cities and human settlements. As a key determinant of how people interact with the urban environment, accessibility serves as a bridge between spatial planning objectives and the lived urban experience. Urban design fundamentally shapes the functionality, inclusiveness, and spatial equity of cities through the dimension of accessibility. Ashrafi, Kloos, and Neugebauer (2021) emphasize that cultural heritage, as a vital part of urban areas, is crucial for reflecting historical evolution and sustaining the connection between past and future generations. Specifically, the accessibility of cultural heritage sites significantly influences their viability and societal relevance, thus directly affecting urban sustainability and cultural continuity. Therefore, optimizing the accessibility of heritage sites through urban design interventions not only enhances physical connectivity but also strengthens their integration into contemporary urban fabric, promoting both cultural preservation and dynamic urban development.

Furthermore, Twumasi-Ampofo, Opong, and Quagraine (2023) argue that integrating historic

buildings and sites into urban planning is essential for achieving sustainable development goals and preserving the identity of communities. Building on this perspective, enhancing urban design strategies for historic districts not only strengthens the sense of place among residents and visitors but also plays a critical role in effective placemaking, thereby contributing to the sustainable revitalization of heritage environments (D. Chen 2024). However, Tweed and Sutherland (2007) argue that while traditional heritage protection focuses on individual monuments and conservation areas, it often overlooks less tangible features such as street patterns, which are crucial in shaping a city's unique character and fostering a sense of belonging integral to cultural identity. Thus, optimizing the spatial configuration of historic districts becomes crucial for bridging tangible and intangible dimensions of heritage conservation.

As Yang et al. (2025) highlight, spatial accessibility is increasingly recognized as a critical component in urban landscape planning, reflecting its significance in urban heritage management. Heritage sites represent an integral component of the urban landscape, contributing not only to the spatial structure but also to the cultural identity and historical continuity of cities. Their preservation and integration within the broader urban fabric are

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essential for sustaining the social, cultural, and economic vitality of contemporary urban environments. Nevertheless, current accessibility to heritage sites faces numerous barriers, including traffic congestion (Moreno et al. 2025; Yang et al. 2025), inadequate infrastructure (Liu et al. 2025), and the inconvenience of pedestrian and cycling pathways (Moreno et al. 2025). These barriers not only restrict visitor mobility but also compromise the overall vitality and connectivity of heritage sites. Y. Chen et al. (2025) further emphasize that enhancing spatial connectivity and vitality within historical districts is essential for maintaining the authenticity and continuity of cultural heritage.

The archaeological site of the Wooden Water Gate of Southern Yue State (WWGSYS), located in Guangzhou, China, embodies these challenges vividly, facing pressing issues related to limited visitor accessibility and fragmented spatial connectivity, thereby underscoring the urgent need for informed spatial planning and design interventions to enhance its integration into the urban fabric and ensure its sustainable revitalization. This study aims to systematically evaluate and optimize accessibility at the archaeological site of WWGSYS through the application of Space Syntax methods. By quantitatively analyzing spatial configurations and their impacts on pedestrian movement and connectivity, the research intends to propose specific, actionable urban design strategies for enhancing heritage accessibility. The ultimate objective is not only to facilitate visitor access but also to activate and revitalize the site sustainably, ensuring its integration into broader urban contexts while preserving its cultural significance and authenticity.

Despite the recognized importance of enhancing accessibility in historical districts, there remains a notable research gap concerning the application of Space Syntax specifically aimed at optimizing the accessibility and activation of heritage sites within the Chinese context. This study hypothesizes that the current spatial configuration of the WWGSYS site critically impacts its accessibility within the surrounding urban context, and that spatial factors such as integration, connectivity, and visibility play a decisive role in shaping visitor access and movement patterns. It further posits that targeted spatial interventions, informed by space syntax analysis, can substantially enhance visitor accessibility, improve the experiential quality, and ultimately strengthen the site's vitality and sustainable development. Addressing this gap, the current research poses the following questions:

- How does the current spatial configuration of the WWGSYS site, as revealed through space syntax analysis, impact its accessibility and integration within the surrounding urban fabric?

- How can targeted space syntax-based interventions enhance the site's spatial accessibility and improve the visitor experience?

This study differs from previous research in three respects. First, rather than describing spatial patterns only, it operationalizes Space Syntax within a Chinese historic-district context to directly optimize heritage accessibility. Second, it triangulates syntactic indicators (connectivity, integration, choice, total depth) with on-site field observations and translates the diagnosis into implementable urban-design interventions. Third, it extends the analysis to policy-relevant recommendations within a transparent, stepwise procedure that enhances methodological replicability. By employing an integrated methodological approach combining space syntax analysis, field survey and the development of targeted urban design strategies, this study offers new insights and methodological frameworks for heritage accessibility enhancement and revitalization planning in China, thereby addressing an existing gap in current research.

2. Literature review

2.1. Accessibility and urban design

Accessibility, as conceptualized by Hansen (1959), is generally defined as the ease with which individuals can reach destinations or access services within a given spatial area. Building on this foundation, Garau, Annunziata, and Yamu (2020) refine the definition by emphasizing accessibility as the ability to benefit from opportunities in public spaces. It is closely tied to urban spatial configuration and land-use patterns. Yildiz Ozkan and Cekmis (2024) emphasize that spatial connectivity, especially through street networks, plays a critical role in regional spatial integrity. Street length and direction strongly influence accessibility performance. Additionally, Tian and Jiang (2025) underscore the importance of evaluating urban landscape accessibility to optimize public service facility distribution, thereby promoting spatial equity and contributing to more inclusive urban environments.

In heritage contexts, Aftabi and Bahramjerdi (2023) argue that sustainable urban planning should integrate strategies such as pedestrian-friendly routes and adaptive reuse of historic buildings. These measures improve accessibility, enhance resilience, and support cultural tourism. Moreover, Y. Chen, Zheng, and Yan (2023) propose that the application of parametric methods offers scientific and innovative frameworks for urban planning, effectively balancing spatial configuration optimization with historical and cultural preservation needs. These studies suggest that enhancing accessibility in heritage sites should be both analytical and context-sensitive, balancing cultural significance with functional integration.

From a practical urban design perspective, Deng et al. (2021) emphasize that urban design strategies, including the creation of permeable and legible urban forms and the provision of high-quality public spaces, are vital for enhancing spatial accessibility and supporting the sustainable revitalization of historic quarters. Similarly, Huang et al. (2023) demonstrate that improving accessibility to public amenities and developing pedestrian-oriented street networks significantly boosts street vitality and overall urban integration, leading to improved quality of urban life. Furthermore, Gospodini (2007) highlights that urban conservation enhances place identity by both preserving a city's historical and cultural heritage and creating distinct environmental images that attract and engage visitors. Taken together, these findings suggest that strategic interventions focusing on spatial accessibility not only strengthen heritage preservation but also foster dynamic and sustainable urban environments. To further support such spatial strategies with analytical precision, the following section introduces Space Syntax as a methodological framework for quantifying and optimizing urban accessibility. In summary, previous studies establish accessibility as a core component of sustainable urban design, yet few have systematically examined its role within heritage conservation.

2.2. Space syntax

Space Syntax, developed by Bill Hillier and Julienne Hanson at University College London in the late 1970s, is a powerful analytical method for interpreting urban space objectively (Önder and Gigi 2010). This method inherently recognizes a strong correlation between physical spatial arrangements and social structures. The analytical framework provided by Hillier and Hanson (1989), utilizing graph theory for street network analysis, has firmly established Space Syntax as an indispensable tool for urban spatial research. It translates complex urban networks into quantifiable and visual forms, providing a scientific basis for evaluating spatial accessibility in both contemporary and historical contexts. Du (2025) explicitly acknowledges the utility of Space Syntax in assessing the accessibility of urban landscapes, demonstrating its applicability in urban planning processes. This aligns with the growing recognition, as highlighted in Section 2.1, that accessibility is central to both spatial equity and urban vitality.

Building on this foundation, Space Syntax offers a set of spatial indicators that are particularly useful for evaluating street network structure and pedestrian behavior. Moreno et al. (2025) identify key metrics like integration and connectivity as essential for understanding the performance of urban street systems. These metrics are instrumental in identifying how

easily different parts of a city can be reached and how movement flows through a given spatial configuration. Integration, for instance, quantifies how accessible space is within the whole system, reflecting its centrality and attractiveness to pedestrians. As another important Space Syntax metric, choice assesses the extent to which a particular segment is likely to be used as a route between all possible origin-destination pairs, resembling the concept of betweenness in graph theory. Depth, also recognized as a core syntactic indicator, measures the number of steps or topological transitions required to reach a given space from all others in the network; higher depth values typically reflect more segregated or peripheral spaces, whereas lower values suggest greater accessibility and centrality. Yunitsyna and Shtepani (2023) further demonstrate that these indicators not only help predict pedestrian movement patterns but also support spatial interventions to enhance social and commercial interactions. Thus, Space Syntax serves as a critical link between spatial morphology and behavioral dynamics in urban environments.

Recent applications of Space Syntax further emphasize its utility in heritage revitalization and urban design. Xu et al. (2020) argue that Space Syntax analysis can inform urban design concepts that enhance sustainable heritage tourism, highlighting its capacity to guide culturally sensitive interventions. Celik and Yildirim (2025) apply Space Syntax specifically within historic urban districts, showing how spatial integration patterns can reflect and reshape the dynamics of heritage spaces. Similarly, Garau, Annunziata, and Yamu (2020) assert that incorporating Space Syntax into planning processes facilitates the identification of walkability barriers and enables targeted interventions to improve inclusivity and spatial usability. Moreover, Salah Ouf (2001) emphasizes that the historical identity of urban areas is often encoded in their spatial structures, particularly streets and built forms, suggesting that spatial coherence in historical districts can be enhanced by focusing on street network configuration.

Fan et al. (2024) further demonstrate the effectiveness of combining Space Syntax with GIS-based pedestrian analysis and urban design adjustments in George Town, Penang. Their study proposed micro-scale interventions such as the creation of pedestrian zones, addition of zebra crossings, and regulation of "five-foot ways" along traditional shophouses to enhance both accessibility and safety in a UNESCO-listed heritage city. This approach shares conceptual proximity with the present study, as both emphasize translating syntactic analysis into practical, culturally adaptive design strategies. However, while they focus primarily on safety and movement efficiency in George Town, the present research extends the method toward heritage accessibility and spatial integration in the Chinese

context, highlighting how syntactic metrics can guide design interventions for improving visitor experience and cultural continuity.

Taken together, these perspectives support the notion that Space Syntax not only deepens our understanding of urban form but also provides a robust analytical foundation for designing inclusive, walkable, and culturally resonant heritage spaces. In summary, Space Syntax provides measurable indicators that link spatial structure with social and behavioural patterns, forming a solid foundation for urban design research.

2.3. Study site

Guangzhou, located in southern China, is recognized today as one of the world's major megacities (Figure 1). Historically, however, it served as the capital of the Southern Yue State, reflecting its profound political and cultural significance. In 1982, the Chinese government established the "State-list Famous Historical and Cultural Cities" (*Guojia Lishi Wenhua Mingcheng*) mechanism, which marked a critical shift from the preservation of isolated monuments to the comprehensive conservation of larger urban historical spaces. Guangzhou was among the first cities to be designated under this new framework, emphasizing its importance as a cultural and historical hub. Benefiting from this policy, several historic districts within the ancient city boundaries of Guangzhou were identified for priority protection, among which the Beijing Road Historic District stands as a prominent example. This designation laid the groundwork for integrating heritage protection into broader urban renewal efforts, especially in relation to enhancing spatial accessibility and functional integration.

Recent urban planning and policy developments further underscore the importance of accessibility and spatial cohesion within Guangzhou's historic core. Lei and Xu (2024) highlight that Guangzhou, as a national central city, actively promotes high-quality urban renewal initiatives aimed at enhancing livability, resilience, and governance efficiency, thereby accelerating the transformation towards a more sustainable and inclusive urban development model. Fang and Wu

(2025) emphasize that while the city has proactively engaged in top-level cultural heritage protection through legislative frameworks, it continues to face challenges in revitalizing heritage buildings. These issues highlight the urgent need for more effective spatial and urban design strategies to enhance the accessibility and functional integration of heritage sites into the surrounding urban fabric. Xie et al. (2024) also point out that the Beijing Road commercial street has been recognized as a critical site for balancing heritage resource preservation with economic transition, stressing the value of integrated design approaches. Collectively, these insights underscore the importance of analytical tools such as Space Syntax in diagnosing spatial barriers and informing evidence-based design strategies for the revitalization of heritage environments.

The Beijing Road Historic District is a vibrant commercial zone layered with rich historical and cultural significance. In 2000, during urban development activities beneath Guangming Plaza on Beijing Road, archaeologists uncovered the archaeological site of WWGSYS (Figure 2). This site, dating back over 2000 years, is the earliest, largest, and best-preserved wooden sluice gate known globally. Functioning as part of the southern city wall of the Southern Yue capital, the water gate played critical roles in flood control, tidal defense, drainage, and military fortification. The discovery provides invaluable insights into ancient Chinese architecture, urban planning, and hydraulic engineering, shedding light on the political, economic, and cultural development of the Lingnan region during a formative period in Chinese history. In 2006, the site was designated as a national key cultural relics protection unit and was simultaneously included in UNESCO's Tentative List of China's World Cultural Heritage. Given the site's exceptional historical value and its current challenges in spatial integration, it offers an ideal case for applying the analytical and design frameworks discussed in Sections 2.1 and 2.2. The chosen research boundary encompasses a square area extending 1 kilometer in radius centred on Guangming Square. This clearly defined

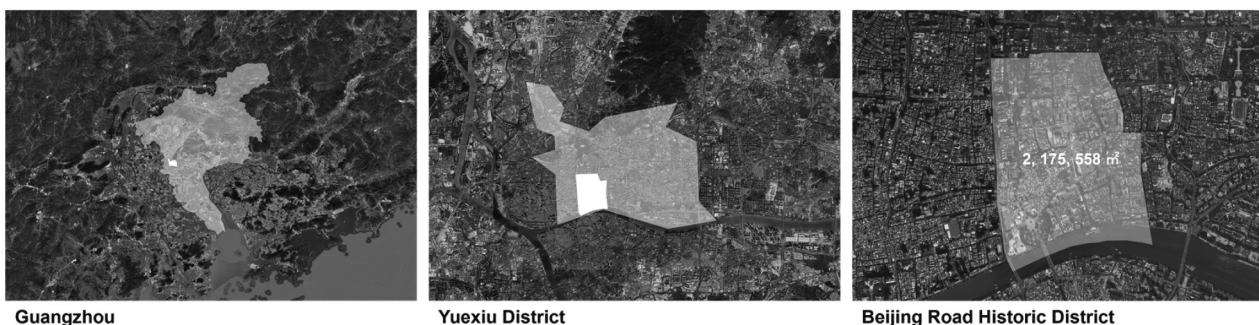


Figure 1. Location of the Beijing Road Historic District in Guangzhou. (Resource: authors).



Figure 2. The archaeological site of the Wooden Water gate of southern Yue State. (Resource: photograph by the authors, September 2024).

spatial scope facilitates an in-depth exploration of the factors influencing heritage accessibility and supports the detailed application of Space Syntax analysis to propose targeted urban design interventions. Overall, the Beijing Road Historic District exemplifies how historical heritage and modern urban systems intersect, providing a valuable foundation for testing accessibility-oriented design strategies.

3. Methodology

This research employs Space Syntax methodology, integrating it with field surveys to systematically evaluate and optimize the accessibility of heritage sites from an urban design perspective. According to Liu et al. (2025), pedestrian accessibility constitutes a fundamental component of urban design, emphasizing its crucial role in urban space planning and heritage site management. The methodological framework adopted herein specifically addresses how spatial configurations impact pedestrian movement, visitor interaction, and overall accessibility within heritage areas. Space Syntax, fundamentally grounded in topological analysis, provides a robust theoretical basis for examining spatial structures and their influence on pedestrian mobility and site accessibility. Tian and Jiang (2025) highlight that topological relationships underpin the analytical capabilities of Space Syntax, facilitating precise delineation of area boundaries and

internal spatial structures. Consequently, these analytical capacities are particularly useful in assessing heritage site layouts and their implications for visitor accessibility. Furthermore, Önder and Gigi (2010) validate the utility of Space Syntax as a method for evaluating the effectiveness of specific urban design interventions, underscoring its applicability in practical heritage planning contexts.

Space Syntax serves as an analytical tool aimed at uncovering underlying economic, cultural, and social logics embedded within urban spatial networks. Its analytical strength lies in providing an objective, quantifiable, and intuitive representation of spatial arrangements, beneficial for comprehensively addressing urban renewal and revitalization challenges. Specifically, its capacity to harmonize multi-functional assessments and unify local and global spatial analyses renders it highly suitable for evaluating and optimizing heritage site configurations. This comprehensive analytical capability enables detailed assessment and precise intervention planning to enhance the spatial integration, connectivity, and overall accessibility of heritage sites.

Complementing the Space Syntax analytical approach, field surveys are employed to gather empirical data on current pedestrian movement patterns, visitor behaviours, and site conditions at WWGSYS archaeological site. These observations facilitate validation and refinement of the Space Syntax analysis, providing nuanced insights into real-world

accessibility challenges and visitor interaction dynamics. In addition to quantitative analysis and field observation, this research also develops targeted urban design optimization strategies based on analytical findings. These strategies aim to address identified spatial shortcomings and propose actionable interventions to enhance the accessibility, connectivity, and experiential quality of the heritage site. The combination of rigorous quantitative analyses and detailed qualitative observations enables the formulation of targeted, context-sensitive urban design strategies aimed at optimizing heritage accessibility.

To enhance methodological transparency and replicability, the research process follows a systematic multi-stage procedure integrating quantitative spatial analysis with empirical fieldwork. The procedure consists of: (1) defining research problems and objectives related to accessibility and integration challenges at WWGSYS; (2) collecting baseline data, including the street network obtained from Tianditu (National Platform for Common Geo-Spatial Information Services) and base maps of the study area, as well as empirical information collected through on-site field surveys regarding pedestrian movement patterns, visitor behaviour, and physical spatial conditions; (3) pre-processing the Tianditu-derived street network through projection harmonization and topology cleaning, and generating an axial map using DepthmapX (version 0.8.0) to represent the topological configuration of the site; (4) computing key syntactic indicators to evaluate both local and global accessibility. The conceptual definitions and analytical interpretations of these four indicators are further elaborated in [Section 4](#) (Results), where each metric is discussed in relation to its spatial implications and analytical outcomes; (5) validating syntactic results through cross-referencing with field observations to identify potential mismatches between predicted and observed accessibility; (6) interpreting integrated findings to diagnose spatial constraints and propose targeted urban design interventions to enhance connectivity, legibility, and overall accessibility; and (7) formulating policy recommendations derived from the analytical findings to guide heritage management and urban planning practices, encouraging the integration of spatial accessibility assessment into evidence-based decision-making frameworks. While the proposed interventions are conceptual and not yet simulated through a secondary syntactic analysis, their formulation and policy implications are informed by the quantified accessibility patterns revealed in previous steps. This systematic procedure ensures the methodological clarity, reproducibility, and practical applicability of the study.

To visually clarify the analytical process and demonstrate how quantitative spatial analysis and empirical validation are integrated, [Figure 3](#) presents the

methodological framework adopted in this research. The diagram summarizes the three major stage, input, analytical & validation, and interpretation & output, highlighting the logical flow from data collection and preprocessing to the generation of accessibility maps and design recommendations.

4. Result

This section presents the combined analytical and empirical results of the study, organized into two complementary parts. The first part reports the results of the Space Syntax analysis, conducted using DepthmapX v0.8.0 based on the TianDitu street-network dataset, which quantifies key spatial indicators – connectivity, integration, choice, and total depth – to evaluate accessibility patterns within the Beijing Road Historic District and the WWGSYS site. The second part introduces the field study results, which include systematic on-site observations and photographic documentation, serving to validate and interpret the syntactic findings in relation to real-world pedestrian behaviour and environmental conditions.

4.1. Space syntax analysis results

4.1.1. Connectivity

Connectivity quantifies the immediate accessibility of a spatial unit, typically represented as street segments or axial lines, by counting the number of directly adjacent spatial units reachable within a single step. It serves as a direct measure of local accessibility. High connectivity values indicate that a spatial segment possesses numerous direct linkages within the local network, suggesting superior immediate accessibility. Streets exhibiting higher connectivity typically occupy densely arranged street networks or key intersections, allowing access to multiple potential routes within a short distance. Consequently, streets with high connectivity play a pivotal role in spatial cohesion and can enhance regional spatial integration by acting as central nodes within the urban fabric, thereby facilitating visitor accessibility.

The analysis indicates that the connectivity of Zhongshan Road and Jiefang Road within the research scope is the highest, followed by Beijing Road. Overall, the north-south road connectivity is higher, while the east-west road connectivity needs improvement, and the analysis results align with the actual situation ([Figure 4](#)).

4.1.2. Integration

Integration assesses the relative depth or accessibility of spatial units within the broader network. It comprises global integration and local integration, where global integration measures the centrality of a site within the entire urban network, indicating its ease of

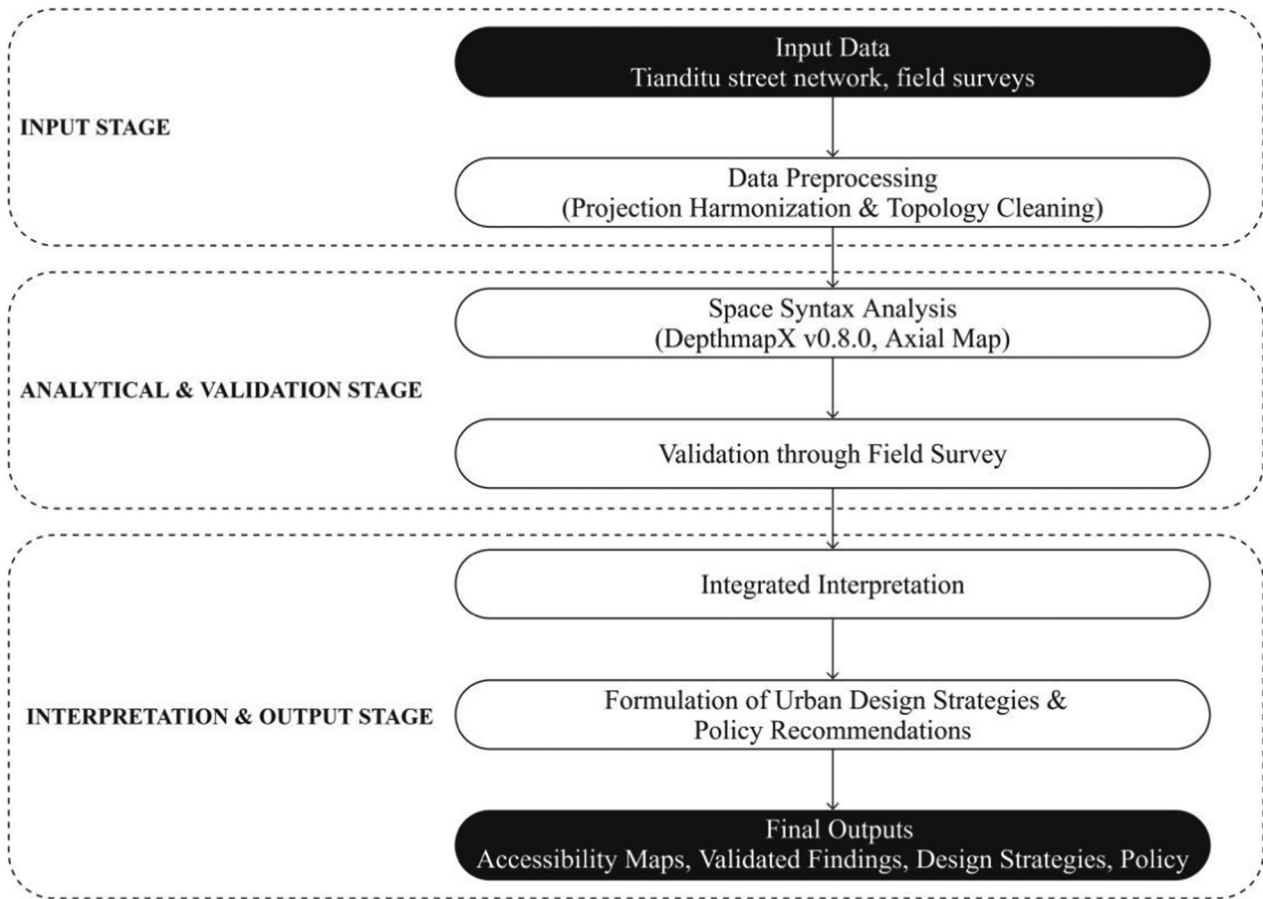


Figure 3. Methodological framework. (Resource: authors).

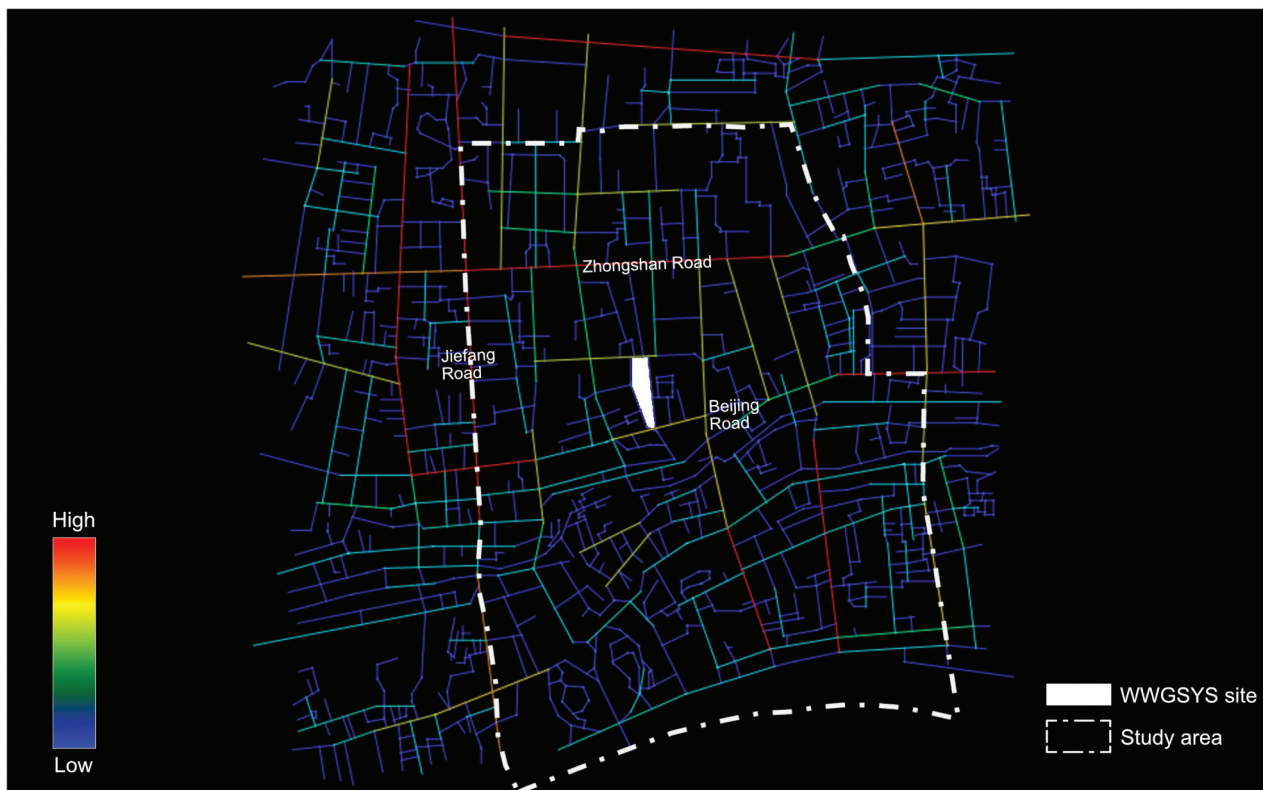


Figure 4. Connectivity analysis of the Beijing Road historic district. (Resource: produced by the authors using DepthmapX v0.8.0, based on street network data from Tianditu in 2024).

reach from the broader urban context. Conversely, local integration evaluates accessibility within limited radio, providing insights into the intermediate or micro-scale advantages of the heritage site's immediate surroundings. According to Önder and Gigi (2010), buildings and areas of significant cultural-historical value often exhibit low integration within their immediate network contexts. Integration values are crucial not just numerically but in interpreting the strategic position of heritage sites, informing urban design interventions aimed at increasing their spatial centrality and accessibility.

The integration map generated from the analysis illustrates that Zhongshan Road is the main axis of regional development. The northern area enclosed by the three transportation corridors of Jiefang Road-Zhongshan Road-Beijing Road serves as the primary commercial centre for the district, with a significantly higher level of integration compared to the southern area (Figure 5).

4.1.3. Choice

Choice, analogous to betweenness centrality, quantifies the frequency with which a spatial unit lies on the shortest paths connecting pairs of origin-destination nodes within a network. Streets or locations exhibiting high choice values represent critical passageways or essential routes, indicating significant potential for pedestrian or vehicular flow. For heritage sites, high choice values suggest enhanced visibility and visitor

attractiveness within the broader urban network, underscoring their strategic placement and potential for attracting spontaneous visitation or integrated movement patterns.

The analysis results of the Choice indicate that the road distribution within the research scope is relatively even, which can balance the traffic flow in the area (Figure 6).

4.1.4. Total depth

Total depth measures the cumulative steps or distances from a particular node or a set of nodes to all other nodes within the network. Typically expressed through metrics like average or maximum depth, it indicates the overall accessibility or remoteness of the site from essential urban nodes such as transit hubs, commercial centres, and metro stations. High total depth values suggest relative isolation or difficulty in accessibility, indicating peripheral positioning within the urban spatial system. In contrast, lower total depth values reflect central positioning and superior overall network accessibility, emphasizing efficient connectivity and proximity to major urban infrastructure and amenities.

The total depth analysis results indicate that the connectivity and convenience in the northern part of the study area are generally higher than in the southern part, centred around Zhongshan Road, showing a radial distribution trend (Figure 7).



Figure 5. Integration analysis of the Beijing Road Historic District. (Resource: produced by the authors using DepthmapX v0.8.0, based on street network data from Tianditu, 2024).



Figure 6. Choice analysis of the Beijing Road Historic District. (Resource: produced by the authors using DepthmapX v0.8.0, based on street network data from Tianditu, 2024).



Figure 7. Total depth analysis of the Beijing Road historic district. (Resource: produced by the authors using DepthmapX v0.8.0, based on street network data from Tianditu, 2024).

4.1.5. Summary of spatial indicators

The findings from this spatial syntax analysis clearly demonstrate specific strengths and weaknesses of WWGSYS's current spatial configuration. Connectivity and integration analyses revealed that enhancing local linkages and global accessibility can significantly increase visitor flow and heritage site vitality. Choice and total depth metrics emphasized the need for strategic infrastructural enhancements, such as better pedestrian pathways and clearly defined access routes, to elevate the site's visibility and attractiveness within the urban network. These insights collectively provide a detailed framework for targeted design interventions aimed at optimizing heritage accessibility and sustaining cultural vitality.

To synthesize the results of the Space Syntax analysis, Table 1 summarizes the comparative outcomes of the four key spatial indicators across the main corridors and nodes within the Beijing Road Historic District. This synthesis clarifies the relative spatial roles and accessibility hierarchies of each area, providing a concise basis for subsequent design discussion.

4.2. Field study results

Complementing the Space Syntax analysis, the field study involved direct on-site observations and photographic documentation to validate syntactic findings and assess real-world accessibility conditions. The survey confirmed several analytical findings, for instance, segments with low integration and connectivity values corresponded to underutilized alleyways, poorly maintained pavements, and visual obstructions (Figure 8). Conversely, areas with high syntactic centrality displayed greater pedestrian activity, active street frontage, and commercial density (Figure 9). A notable finding concerns the entrance to the WWGSYS site, which is located on the basement level of Guangming Square, a large commercial complex. This

vertical separation between the street-level urban fabric and the underground heritage entrance contributes to its poor visibility and weak spatial integration (Figure 10). Despite its cultural importance, the entrance is neither intuitively located nor clearly marked from surrounding public spaces, resulting in limited pedestrian flow and missed opportunities for engagement. These field observations highlight the importance of combining structural and perceptual design interventions to improve accessibility and site vitality.

5. Discussions

The connectivity values along the north-south streets adjacent to Guangming Square are lower than the average for the district, indicating a weaker topological structure within the alleyway network and a limited capacity to support effective pedestrian dispersal. Furthermore, the gradual decline in integration values from north to south suggests poor accessibility in the northern sectors and an over-concentration of pedestrian flow in the southern areas, hindering efficient dispersal and reducing the overall visitor experience.

While Beijing Road exhibits the highest integration and choice values within the district, acting as a strong attractor of pedestrian flow, the adjacent Xihu Road shows a significant drop in both integration and choice values. This sharp contrast results in a "trunk siphon effect", weakening the attractiveness and accessibility of Xihu Road's public facilities.

Additionally, the streets surrounding Guangming Square and Dafosi Temple exhibit significantly higher total depth values compared to neighboring areas, indicating weaker spatial linkages and a degree of spatial fragmentation relative to the surrounding Beijing Road Historic District. This fragmentation undermines the continuity and integrity of the district's overall historical and cultural narrative.

Table 1. Comparative summary of space syntax indicators and spatial characteristics of key corridors in the Beijing road historic district. (Resource: authors).

Corridor/Area	Connectivity	Integration	Choice	Total Depth	Key spatial characteristics
Beijing Road	High	Very High	Very High	Low	Main pedestrian and commercial corridor
Zhongshan Road	Very High	Very High	Very High	Low	Major east-west transport corridor enhancing regional accessibility and integration
Wenming Road	Moderate	Moderate	Moderate	Moderate	Transitional street linking core and periphery; moderate accessibility and mixed land use
Xihu Road	Moderate	Moderate	Moderate	Moderate	Limited public attraction and lower integration with main pedestrian flows
Guangming Square Area	Low	Moderate	Low	Moderate	Fragmented alley network
Gongyuanqian Station Area	High	High	Very High	Low	Major transport hub with strong spatial integration and movement potential
Beijing Road Station Area	Moderate	High	Very High	Low	Interchange node enhancing accessibility along the southern axis



Figure 8. The segment with low connectivity value. (Resource: photograph by the authors, December 2023).



Figure 9. The segment with high connectivity value. (Resource: photograph by the authors, December 2023).

To spatially project the proposed design procedures derived from the spatial analysis, a series of schematic maps (Figures 11–13) illustrate how analytical findings are translated into site-specific urban design strategies.

These visual representations link the analytical results with the proposed interventions, ensuring spatial clarity and practical applicability. In response to the identified issues, a comprehensive strategy based on



Figure 10. The entrance of the Wooden Water gate of southern Yue State. (Resource: photograph by the authors, September 2024).

cultural leadership, organic renewal, and integrated enhancement is proposed.

5.1. Activating the historic commercial axis and enhancing spatial permeability

Beijing Road functions as the district's primary pedestrian corridor, connecting Zhongshan Road to the north and the Pearl River waterfront to the south. In contrast, the surrounding roads near Guangming Square are of lower hierarchy, with the northern Shuyuan Street block yet to be developed, and the southern edge terminating at Wenming Road with only minor alleyways.

Thus, optimization strategies are proposed in two directions centred around Guangming Square (Figure 11):

- (1) Northward: Enhance direct pedestrian connections to the undeveloped Shuyuan Street block and optimize the exit connections to the underground space, thereby strengthening links to major transportation nodes. This intervention would increase Guangming Square's attractiveness as a destination, boost the axial permeability of Beijing Road, and reinforce its role in concentrating cultural and commercial activities. In addressing similar issues, Önder and Gigi (2010) suggest that providing direct pedestrian entries from adjacent sub-regions into the

target area can significantly enhance pedestrian connectivity and accessibility, particularly by linking entrances to urban open spaces.

- (2) Southward: Improve the eastern frontage of Guangming Square by integrating paving designs that embed cultural imprints of the WWGSYS, creating a shaded historical walkway. Incorporate rest areas, artistic displays, and scenic spots into the design to immerse visitors in the history and culture as they stroll. According to (Yildiz Ozkan and Cekmis 2024), direct pedestrian connections are vital for urban vitality and appeal. By upgrading the existing corridors, considering pedestrian needs and walking safety, designing a clear road signage system, and establishing a direct walking connection with Wenming Road, this aims to enhance the permeability of the streets and the vitality of the city, promote communication and interaction between Guangming Square and the southern area, and provide more space and opportunities for commercial and cultural activities in the area.

5.2. Creating a public service vitality corridor and restructuring spatial nodes

Strengthening key nodes is crucial for enhancing their competitiveness and significance within the urban network (Y. Chen et al. 2025). Although Xihu Road is positioned as a major public space along

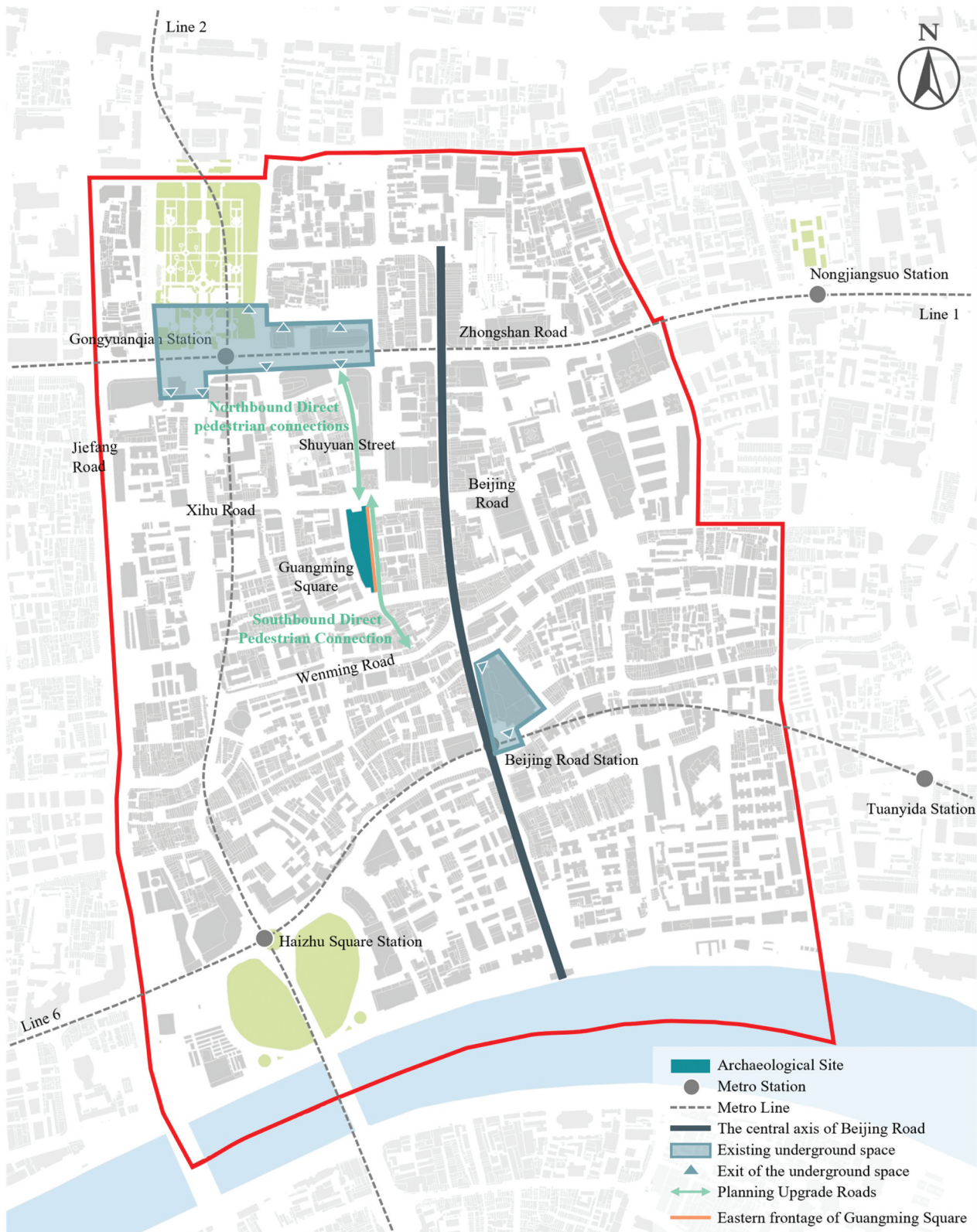


Figure 11. Strategy 1: multi-directional activation of the historical commercial axis to enhance spatial permeability. (Resource: authors).

Beijing Road, it currently lacks strong pedestrian attraction. Enhancing the emotional ambiance of public spaces can significantly boost user participation, visitation frequency, and social interaction (Zou et al. 2023).

It is proposed to deploy 3D projection systems under the arcade structures along Xihu Road to project “Southern Yue State Splendor” light shows during the night, complemented by interactive information screens in public spaces to diversify

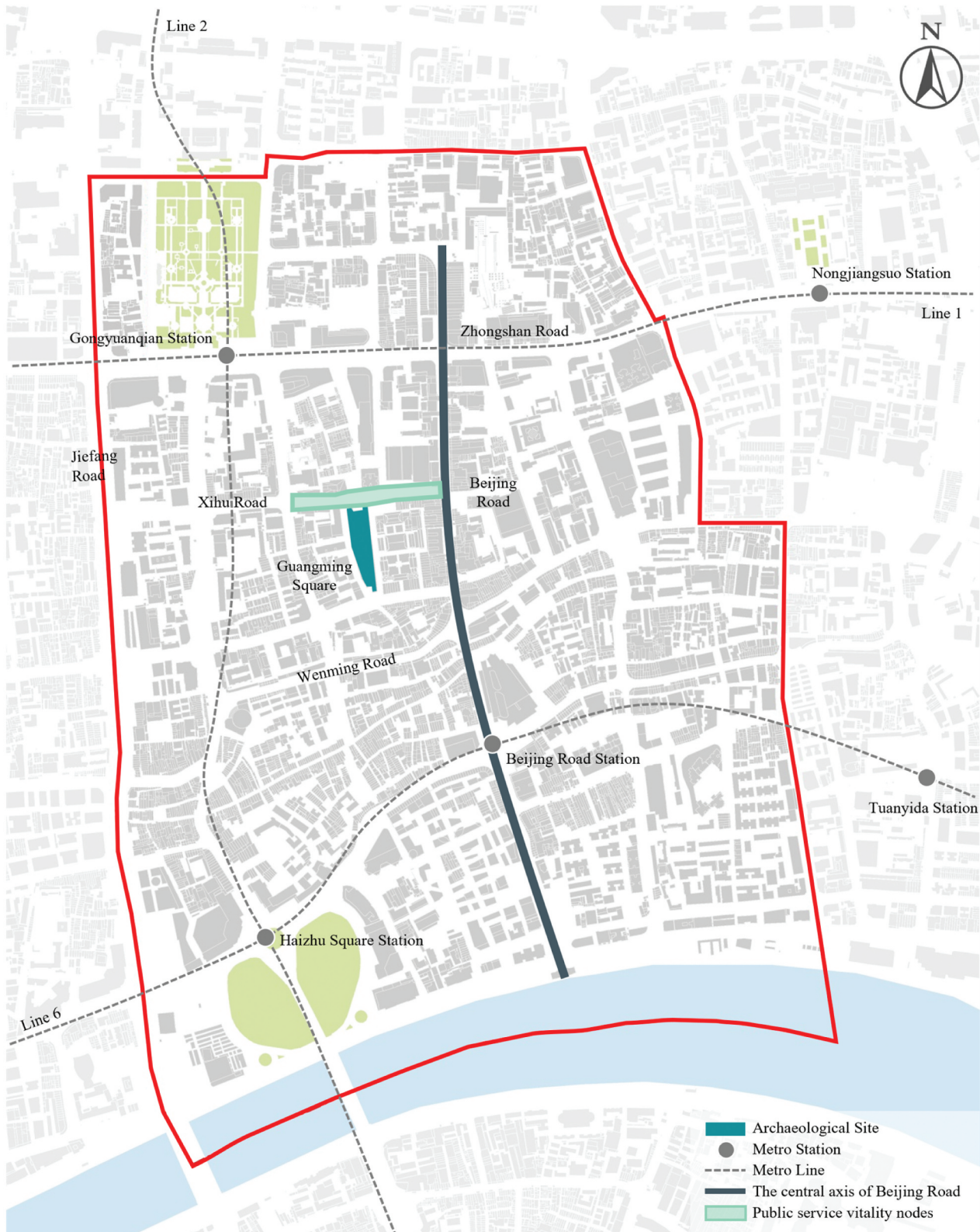


Figure 12. Strategy 2: creating a public service vitality corridor to restructure spatial nodes. (Resource: authors).

cultural activities. Additionally, a “Southern Yue Impressions” sculpture embedded with LED displays showcasing archaeological documentaries should be installed at the northern entrance of Guangming Square on Xihu Road to strengthen place identity and enhance the attractiveness of the WWGSYS site (Figure 12).

In the broader context of promoting spatial equity, Moreno et al. (2025) highlight that the concentration of cultural and heritage sites in central urban areas exacerbates spatial access inequalities. They advocate establishing satellite cultural centres and repurposing vacant spaces in peripheral areas to promote a fairer distribution of cultural resources. Incorporating such

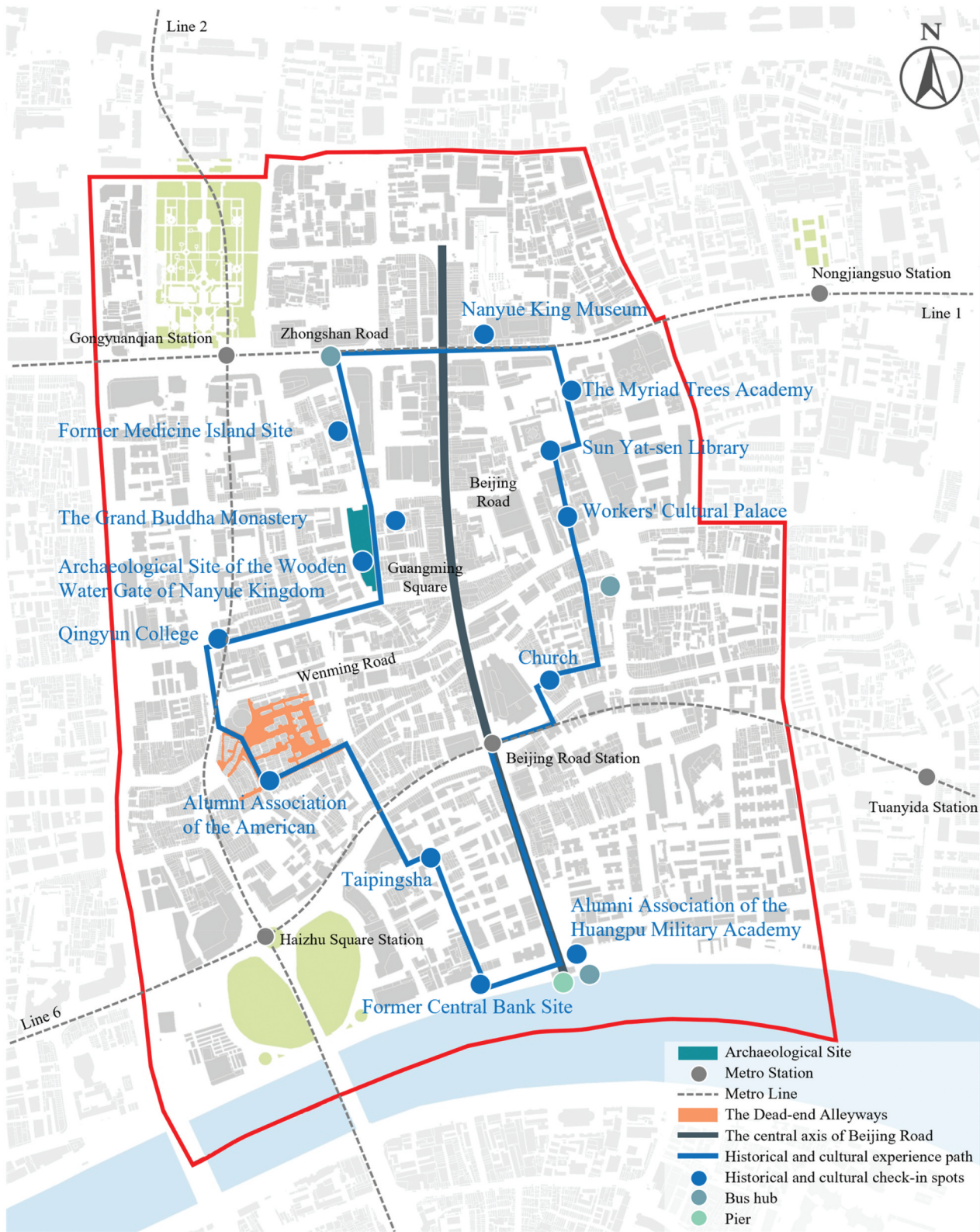


Figure 13. Strategy 3: developing a cultural experience route around Beijing Road to establish an integrated experiential network. (Resource: authors).

decentralized strategies into the Beijing Road Historic District holds practical significance. On the one hand, it can break the excessive concentration of cultural resources at the Nanyue King Museum central axis area of Beijing Road, radiating and spreading cultural

vitality to the surrounding areas. On the other hand, by optimizing the overall layout of the heritage landscape, it further enhances accessibility, allowing more visitors to conveniently access and experience the rich historical culture.

5.3. Establishing a Beijing Road heritage experience loop and a comprehensive interaction network

Leveraging the distribution of surrounding historical landmarks and transport hubs, paths with deeper total depth values are selected to form a cultural heritage experience loop encircling Beijing Road. Buragohain et al. (2024) highlight that enhancing accessibility is fundamental to democratizing cultural heritage experiences, ensuring that heritage sites are no longer limited to those with physical or economic means to travel, but can be accessed widely through strategic technological or spatial interventions.

Integrating public transportation with urban development (Li et al. 2024), this experiential loop connects docks, metro stations, and bus terminals to facilitate seamless, multi-modal access for citizens and visitors.

The route (Figure 13) will feature distinctive paving, iconic signage, and navigation aids to improve way-finding efficiency and spatial recognition, enhancing overall accessibility and visitor experience (Celik and Yildirim 2025). Furthermore, recognizing that excessive spatial depth can diminish accessibility, it is recommended to eliminate “dead-end” alleyways and link them to streets with lower topological depth, thereby reducing unnecessary turns and lowering spatial depth across key sectors. Such measures align to improve overall network integration and reinforce visitor mobility throughout the heritage district. Additionally, by integrating historical and cultural elements to narrate the Nanyue story, creating distinctive themed activities. By assigning visitors historical identities and embedding role-playing characters, check-in missions and narrative-driven activities can be strategically designed along heritage experience loops. This approach not only enhances visitors’ engagement and enriches the visitation experience (Campos, Guerreiro, and Beevor 2025). but also elevates the recognizability, utilization efficiency, and global visibility of the WWGSYS site.

6. Conclusions

This study investigated the accessibility challenges of the WWGSYS site within the Beijing Road Historic District, employing Space Syntax analysis, field surveys, and urban design strategies. Through this research, the questions raised in the introduction regarding the site’s spatial configuration, accessibility, and potential for design-based improvement were systematically addressed. The results reveal that fragmented connectivity, uneven integration patterns, and excessive spatial depth significantly hinder visitor accessibility and weaken the site’s integration with the surrounding urban fabric.

Based on these findings, targeted urban design interventions were proposed, including enhancing pedestrian linkages, activating key public spaces, and establishing a cultural heritage experience loop. These strategies aim to improve spatial permeability, reinforce site vitality, and restore the continuity of the historical and cultural landscape.

Although this study focuses on a single heritage site in China, the integrated methodological framework and findings offer broader insights applicable to heritage sites worldwide. Many historical urban areas across different countries face similar challenges of fragmented spatial structures, limited accessibility, and declining cultural vitality. The approach of combining quantitative spatial analysis with context-sensitive urban design interventions can serve as a replicable model for improving accessibility, enhancing visitor experience, and fostering the sustainable revitalization of heritage environments globally.

Moreover, the findings provide policy-relevant insights, suggesting that spatial accessibility analysis should be incorporated into heritage management and urban planning processes to support evidence-based decision-making and ensure more inclusive, sustainable revitalization practices.

Distinctive findings of this study include a pronounced “trunk-siphon effect”, where Beijing Road’s very high integration and choice values suppress pedestrian flow on adjacent Xihu Road; fragmented connectivity and high total depth around Guangming Square indicating spatial segmentation; and an accessibility deficit caused by the underground entrance to the WWGSYS site. Scientifically, the study contributes:

- a transparent, stepwise analytical-to-design procedure linking syntactic diagnosis to practical interventions and policy guidance.
- an indicator-to-intervention mapping that can be adapted to other heritage districts.
- empirical cross-validation of Space Syntax predictions with field observations in a Chinese historic-district context.

However, this research has certain limitations. It primarily analyses static spatial configurations without incorporating dynamic pedestrian flow simulations or long-term behavioural data, which could further enrich the understanding of temporal movement patterns and visitor behaviours. Future research should integrate dynamic simulation models to validate and extend the accessibility framework proposed in this study, complementing the static analysis with behavioural dynamics. Moreover, as a case-specific study, contextual differences across global heritage sites may influence the direct applicability of the proposed strategies. To further verify

the practicality of the proposed urban design strategies, future research could conduct a secondary Space Syntax analysis after simulated or implemented street adjustments, thereby testing their effectiveness in improving accessibility and spatial integration. Practically, these limitations can be addressed by post-intervention syntactic re-analysis, agent-based pedestrian simulations, and comparative multi-case benchmarking to test transferability and long-term effectiveness.

Author contributions statement

Conceptualization, Dingran Chen and Runqi Wang; methodology, Dingran Chen and Yang Xiao; software, Dingran Chen; validation, Dingran Chen and Runqi Wang; investigation, Dingran Chen and Runqi Wang; resources, Runqi Wang; data curation, Dingran Chen and Runqi Wang; writing – original draft preparation, Dingran Chen and Runqi Wang; writing – review & editing, Dingran Chen, Runqi Wang and Yang Xiao; visualization, Dingran Chen and Runqi Wang. All authors have read and agreed to the published version of the manuscript.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

References

- Aftabi, P., and S. F. N. Bahramjerdi. 2023. "Developing a Decision-Making Framework Within the Management of Historical Cities: Towards Integrated Conservation and Development of the Roudaki Neighbourhood." *Land Use Policy* 129:106653. <https://doi.org/10.1016/j.landusepol.2023.106653>
- Ashrafi, B., M. Kloos, and C. Neugebauer. 2021. "Heritage Impact Assessment, Beyond an Assessment Tool: A Comparative Analysis of Urban Development Impact on Visual Integrity in Four UNESCO World Heritage Properties." *Journal of Cultural Heritage* 47:199–207. <https://doi.org/10.1016/j.culher.2020.08.002>
- Buragohain, D., Y. Meng, C. Deng, Q. Li, and S. Chaudhary. 2024. "Digitalizing Cultural Heritage Through Metaverse Applications: Challenges, Opportunities, and Strategies." *Heritage Science* 12 (1): 295. <https://doi.org/10.1186/s40494-024-01403-1>
- Campos, A. C., M. M. Guerreiro, and M. C. Beevor. 2025. "Storytelling in Heritage Tourism: An Exploration of Co-Creative Experiences from a Tourist Perspective." *Museum Management and Curatorship* 40 (2): 225–250. <https://doi.org/10.1080/09647775.2023.2230194>
- Celik, E., and O. C. Yildirim. 2025. "Wayfinding in Historical Urban Landscapes: Unraveling the Spatial-Behavioral Dynamics in Eskisehir's Odunpazari." *Journal of Asian Architecture and Building Engineering*: 1–20. <https://doi.org/10.1080/13467581.2025.2490298>
- Chen, D. 2024. "Examining Urban Design Strategies in Historic Districts: A Systematic Literature Review." *Proceedings of the Institution of Civil Engineers-Urban Design and Planning* 177 (4): 232–239. <https://doi.org/10.1680/jurdp.24.00046>
- Chen, Y., J. Xu, H. Xiang, Z. Huang, Z. Lin, and S. Lu. 2025. "Construction of a Public Space Network Connectivity and Vitality Optimization System in Historical Districts of Southwestern China: Guiyang Case Study." *Ain Shams Engineering Journal* 16 (3): 103304. <https://doi.org/10.1016/j.asej.2025.103304>
- Chen, Y., L. Zheng, and L. Yan. 2023. "Research on the Intelligent Generation of the Spatial Form of the Island City Historic District Based on Parameterization: Taking Macau Taipa Village as an Example." *Journal of Asian Architecture and Building Engineering* 23 (3): 1094–1125. <https://doi.org/10.1080/13467581.2023.2257274>
- Deng, Z., D. Chen, X. Qin, and S. Wang. 2021. "Comprehensive Assessment to Residents' Perceptions to Historic Urban Center in Megacity: A Case Study of Yuexiu District, Guangzhou, China." *Journal of Asian Architecture and Building Engineering* 20 (5): 566–580. <https://doi.org/10.1080/13467581.2021.1942000>
- Du, H. 2025. "Urban Landscape Accessibility Evaluation Model Based on GIS and Spatial Analysis." *Results in Engineering* 25:103723. <https://doi.org/10.1016/j.rineng.2024.103723>
- Fan, M., M. Hedayati Marzbali, A. Abdullah, and M. J. Maghsoodi Tilaki. 2024. "Using a Space Syntax Approach to Enhance Pedestrians' Accessibility and Safety in the Historic City of George Town, Penang." *Urban Science* 8 (1): 6. <https://doi.org/10.3390/urbansci8010006>
- Fang, K., and Y. Wu. 2025. "Key Barriers and Decision Supports in Revitalizing Heritage Buildings from Investors' Perspective in China: A Case Study in Guangzhou, China." *PLOS ONE* 20 (1): e0311757. <https://doi.org/10.1371/journal.pone.0311757>
- Garau, C., A. Annunziata, and C. Yamu. 2020. "A Walkability Assessment Tool Coupling Multi-Criteria Analysis and Space Syntax: The Case Study of Iglesias, Italy." *European Planning Studies* 32 (2): 211–233. <https://doi.org/10.1080/09654313.2020.1761947>
- Gospodini, A. 2007. "Urban Morphology and Place Identity in European Cities: Built Heritage and Innovative Design." *Journal of Urban Design* 9 (2): 225–248. <https://doi.org/10.1080/1357480042000227834>
- Hansen, W. G. 1959. "How Accessibility Shapes Land Use." *Journal of the American Institute of Planners* 25 (2): 73–76. <https://doi.org/10.1080/01944365908978307>
- Hillier, B., and J. Hanson. 1989. *The Social Logic of Space*, 82–142. Cambridge, UK: Cambridge University Press.
- Huang, J., X. Hu, J. Wang, and A. Lu. 2023. "How Diversity and Accessibility Affect Street Vitality in Historic Districts?" *Land* 12 (1): 219. <https://doi.org/10.3390/land12010219>
- Lei, B., and P. Xu. 2024. "The Remodeling of Urban Functions by Urban Renewal—Take Guangzhou as an Example." *Journal of Civil Engineering and Urban Planning* 6:62–70. <https://doi.org/10.23977/jceup.2024.060209>
- Li, Z., J. Tang, W. Zhang, Y. Ji, L. Cui, C. Hu, and C. Zhao. 2024. "Exploring the Association Between Multi-Mode Transport

- and the Built Environment: A Comparative Study of Metro, Bus, Taxi, and Shared Bike Use." *Sustainable Cities and Society* 114:105789. <https://doi.org/10.1016/j.scs.2024.105789>
- Liu, J., Z. Liang, Y. Huai, and H. K. Lo. 2025. "Investigating Utility-Based Walking Accessibility: New Versus Old Development Areas in Hong Kong." *Transport Policy* 165:97–106. <https://doi.org/10.1016/j.tranpol.2025.02.004>
- Moreno, C., C. Gall, J. Woo, D. Lee, and M. Bencekri. 2025. "Assessing Accessibility of Cultural Sites Through the 15-Minute City Framework in Seoul." *International Journal of Urban Sciences* 29 (1): 8–39. <https://doi.org/10.1080/12265934.2025.2462820>
- Önder, D. E., and Y. Gigi. 2010. "Reading Urban Spaces by the Space-Syntax Method: A Proposal for the South Haliç Region." *Cities* 27 (4): 260–271. <https://doi.org/10.1016/j.cities.2009.12.006>
- Salah Ouf, A. M. 2001. "Authenticity and the Sense of Place in Urban Design." *Journal of Urban Design* 6 (1): 73–86. <https://doi.org/10.1080/13574800120032914>
- Tian, Y., and Y. Jiang. 2025. "Research on Urban Landscape Accessibility Assessment Model Based on GIS and Spatial Analysis." *Geojournal* 90 (2): 67. <https://doi.org/10.1007/s10708-025-11310-y>
- Tweed, C., and M. Sutherland. 2007. "Built Cultural Heritage and Sustainable Urban Development." *Landscape and Urban Planning* 83 (1): 62–69. <https://doi.org/10.1016/j.landurbplan.2007.05.008>
- Twumasi-Ampofo, K., R. A. Oppong, and V. K. Quagraine. 2023. "Awareness of Preservation of Historic Buildings and Sites in Ghana: The Case of Residents in Kumasi." *Journal of Cultural Heritage Management and Sustainable Development* 13 (1): 185–200. <https://doi.org/10.1108/JCHMSD-06-2020-0094>
- Xie, Q., L. Hu, J. Wu, Q. Shan, W. Li, and K. Shen. 2024. "Investigating the Influencing Factors of the Perception Experience of Historical Commercial Streets: A Case Study of Guangzhou's Beijing Road Pedestrian Street." *Buildings* 14 (1): 138. <https://doi.org/10.3390/buildings14010138>
- Xu, Y., J. Rollo, D. S. Jones, Y. Esteban, H. Tong, and Q. Mu. 2020. "Towards Sustainable Heritage Tourism: A Space Syntax-Based Analysis Method to Improve Tourists' Spatial Cognition in Chinese Historic Districts." *Buildings* 10 (2): 29. <https://doi.org/10.3390/buildings10020029>
- Yang, L., Y. Lu, M. Cao, R. Wang, and J. Chen. 2025. "Assessing Accessibility to Peri-Urban Parks Considering Supply, Demand, and Traffic Conditions." *Landscape and Urban Planning* 257:105313. <https://doi.org/10.1016/j.landurbplan.2025.105313>
- Yildiz Ozkan, D., and A. Cekmis. 2024. "The Impact of Passages on Street Connectivity in Commercial Areas: The Case of Beşiktaş Market Area in Istanbul." *ACE: Architecture, City and Environment* 18 (54): 12088. <https://doi.org/10.5821/ace.18.54.12088>
- Yunitsyna, A., and E. Shtepani. 2023. "Investigating the Socio-Spatial Relations of the Built Environment Using the Space Syntax Analysis—A Case Study of Tirana City." *Cities* 133:104147. <https://doi.org/10.1016/j.cities.2022.104147>
- Zou, Y., Y. Yang, Y. Li, J. Liao, and H. Xiao. 2023. "How Do Tourists' Heritage Spatial Perceptions Affect Place Identity? A Case Study of Quanzhou, China." *Journal of Hospitality and Tourism Management* 55:460–470. <https://doi.org/10.1016/j.jhtm.2023.05.018>