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Walkability Evaluation of Historical and Cultural Districts Based on Multi-Source Data: A Case Study of the Former Russian Concession in Hankou

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Abstract: With the rapid development of urban motorized transportation, the narrow and aging streets in historical and cultural districts can no longer meet modern traffic demands. The development of pedestrian systems and the improvement in street walkability have become important issues in the preservation and renewal of these districts. Although walkability research has established a relatively systematic theoretical framework and technical methods, current studies predominantly focus on modern urban roads due to limited attention to the unique characteristics of streets within historical and cultural districts. As a mixed-use area integrating residential, commercial, and tourism functions, the former Russian concession in Hankou features diverse street types and a rich spatial texture, making it a representative case for walkability research in historical districts. This study aimed to construct a walkability evaluation framework suited to the characteristics of such districts. First, relevant literature was reviewed and combined with the actual conditions of streets in the study area to select evaluation indicators and reconstruct the framework. Second, based on multi-source data, a comprehensive evaluation was conducted using spatial syntax, semantic segmentation, and GIS spatial analysis. The results show that streets with high walkability scores are mainly concentrated in the core tourism area and are strongly associated with the distribution of historical buildings. Finally, based on the evaluation results, three groups of representative streets were compared to analyze differences in pedestrian environments. Key issues such as low spatial quality and functional disorder were identified, and targeted optimization strategies are proposed. The findings provide useful references for the future preservation and sustainable renewal of historical and cultural districts.

Keywords: the former Russian concession in Hankou; historical and cultural districts; walkability; comprehensive evaluation

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1. Introduction

Rapid socioeconomic development has driven the expansion and upgrading of urban roads, which, while enhancing transportation efficiency, has also posed significant challenges to the preservation and renewal of historical and cultural districts. Historical and cultural districts were formed a long time ago, and their internal street networks are mostly small-scale systems built to meet traditional societal needs, making them difficult to adapt to the rapid development of modern motorized transportation. Large-scale road widening

not only leads to the forced demolition of some historical buildings, thereby affecting the coordination of the district's historical character [1], but also destroys the traditional street fabric and architectural layout, resulting in a fragmentation of cultural memory and weakening the overall cultural value. Additionally, excessive motorization leads to the issue of imbalanced road space allocation in historical and cultural districts, further compressing pedestrian space and affecting the daily mobility of residents and tourists. This also leads to air and noise pollution, negatively impacting the living environment and cultural atmosphere of these districts [2].

Optimizing the pedestrian system in historical and cultural districts allows for better adaptation to the small-scale street spaces within the area, which helps to preserve the traditional street fabric, maintain the historical character, and enhance the cultural atmosphere, thereby providing better mobility experiences for both residents and visitors. Secondly, the development of pedestrian transportation can reduce carbon emissions, improve air quality, enhance urban landscapes, and promote the sustainable development of historical and cultural districts [3]. Lastly, through proper pedestrian system planning, creative industries and cultural enterprises can be encouraged to settle, striking a balance between historical preservation and modern functions and thus revitalizing the district [4]. The former Russian concession in Hankou—characterized by its integration of residential, commercial, and tourism functions, as well as its diverse street types and rich spatial texture—was selected as the research area. This study focused on evaluating street walkability in historical and cultural districts using streets as the core analytical unit to identify spatial factors that hinder the walking experience. Based on the findings, targeted optimization strategies are proposed to support the development of a more refined pedestrian system and to offer both theoretical and practical guidance for the preservation and renewal of historical and cultural districts.

In recent years, the continuous development of big data and information technologies has provided new perspectives and revolutionary changes in data collection, utilization, analysis, and research. The abundance of urban data has driven walkability research to develop in more diversified, multi-dimensional, and visualized directions [5]. Although traditional methods have been improved by employing multi-source data, previous walkability studies have mainly focused on urban roads, with insufficient attention given to streets within historical and cultural districts [6]. To address this gap, a walkability evaluation framework was constructed in this study based on a systematic review of existing literature and the spatial characteristics of streets in the former Russian concession in Hankou. The framework integrates multiple data sources and is tailored to the specific features of historical and cultural districts. Spatial syntax, semantic segmentation, and GIS-based spatial analysis were subsequently applied to conduct a comprehensive evaluation of street walkability within the study area. Based on the evaluation results, three representative groups of streets were selected for comparative analysis to examine differences in pedestrian environments, identify existing spatial issues, and propose targeted optimization strategies. These efforts aim to provide useful references for the sustainable development of historical and cultural districts.

2. Literature Review

In recent years, with the development of urban management refinement and multi-source data integration technologies, street walkability evaluation methods based on geographic information system (GIS) platforms have gradually evolved towards comprehensiveness, intelligence, and multi-dimensionality. In early research, scholars used GIS databases and traditional data such as population data, land use data, service facility data, street fabric data (including intersection number and density), sidewalk data (such as

length and width), and street safety data (such as crime rates) to replace labor-intensive neighborhood audits for measuring street walkability [7–9]. To overcome the limitations of traditional data in terms of timeliness, perception, and social dimensions, recent studies have begun incorporating multi-source big data and emerging technologies to expand evaluation dimensions. These new data types include real-time traffic data, POI (point of interest) business-type data, street view image data, Weibo posts, and check-in data, among others. Combined with methods such as machine learning, deep learning, spatial syntax, and spatial data network analysis (SDNA) and supported by multidisciplinary theories from urban planning, transportation engineering, landscape ecology, and sociology, a more explanatory measurement system for the built environment's walkability has been formed [10–17].

In addition, the development of the walk score evaluation method has further propelled the shift of walkability research from static physical space to dynamic social space. Relevant studies have integrated various data sources, including census data [18], social media data [19], public health data [20], street environmental factors [21], street attribute factors [17,22], population distribution [23], POI distribution [24], and demographic characteristic data [25], to construct a multi-dimensional, multi-scale, and multi-variable coupled comprehensive evaluation model. This model is used to assess street walkability levels, environmental quality, social equity, and walkability.

Looking at the current mainstream research paths, walkability evaluation based on multi-source data typically uses GIS as the data integration platform, supplemented by field surveys, street view image collection, and questionnaires. Emerging technologies and built environment audit tools, along with subjective perception evaluations, are used to construct a multi-dimensional, comprehensive evaluation system. The evaluation targets cover various urban spatial types, including central urban areas, ordinary residential communities, and historical and cultural districts. As early as 2011, Duncan et al. [26] began attempting to assess neighborhood walkability through GIS combined with the walk score method, although the data primarily consisted of traditional indicators such as facility density and road network density. Later, Dong Shiyong (2015) [27] combined GIS with fuzzy comprehensive evaluation methods to evaluate neighborhood walkability using both objective data and subjective perceptions. Bai Yuanjun (2017) [28] constructed an evaluation indicator set and adjusted indicator weights through a questionnaire survey, conducting walkability research on historical districts. Cao Zhejing (2018) [13] and Yao Yiting (2019) [29] used open data for walkability evaluation, enriching and diversifying data sources. In 2019, Su S. et al. [15] integrated big data with spatial syntax, GIS spatial analysis, and mathematical modeling methods to construct an evaluation model for street walkability and social equity. That same year, Yang Junyan [30] used deep learning algorithms to perform semantic segmentation on street view images, extracting visual perception dimension variables such as green view index (GVI) and sky view factor (SVF), further enriching the measurement methods for street perception dimensions. Liu Bingqian (2021) [31] combined street view images, road networks, POI distribution, nighttime illumination data, and sidewalk facility satisfaction questionnaire results, integrating semantic segmentation, spatial syntax, and mathematical modeling methods to build a composite evaluation system covering spatial material, behavioral perception, and social characteristics. In recent years, Qin J. et al. [32] further optimized the indicator weight structure in the evaluation system by combining entropy weight (EW) and an analytic hierarchy process (AHP), making the logical structure of the multi-source data model more rigorous and scientific.

From the perspective of the indicator system, the current walkability evaluation indicators based on multi-source data have transitioned from a single built environment variable to a multi-dimensional integration of material–perception–behavior–social factors.

Generally, these can be categorized into two major groups: physical street factors and spatial perception factors, with sub-indicators classified into four basic dimensions: connectivity, convenience, safety, and comfort. However, the walkability evaluation of streets in historical and cultural districts has certain specificities, requiring the integration of regional contextual characteristics. It is essential to consider factors such as municipal facilities, wayfinding signage, street interfaces, and the coordination with the district' s historical character. Therefore, this study synthesizes previous research on walkability evaluation indicators and categorizes them into five dimensions: connectivity, convenience, safety, comfort, and coordination (Table 1).

Table 1. Summary of street walkability evaluation indicators.

Evaluation Dimension	Evaluation Indicator
Connectivity	1. Intersection density; 2. Street network density; 3. Linearity of walking routes; 4. Pedestrian accessibility; 5. Global integration; 6. Local integration; 7. Mean depth value; 8. Choice; 9. Pedestrian continuity; 10. Relative walking width; 11. Average pedestrian segment length; 12. Network legibility; 13. Block betweenness centrality; 14. Entrance and exit convenience
Convenience	1. Functional density; 2. Functional mix; 3. Functional accessibility; 4. Functional completeness; 5. Functional satisfaction; 6. Public transport convenience; 7. Linearity of walking routes; 8. Signage and wayfinding; 9. Parking facility density; 10. Crossing facility density; 11. Potential destination density
Safety	1. Motorized traffic impact; 2. Nighttime illumination; 3. Pedestrian safety; 4. Pedestrian density; 5. Proportion of high-risk buildings; 6. Pedestrian crossing facilities; 7. Accessibility facilities; 8. Sidewalk encroachment ratio; 9. Presence of sidewalks; 10. Accident rate; 11. Urban road signage and markings; 12. Street security
Comfort	1. Green view index; 2. Sky view factor; 3. Street height-to-width ratio; 4. Building alignment ratio; 5. Air quality; 6. Street gradient; 7. Facade transparency; 8. Facade complexity; 9. Pavement comfort; 10. Environmental noise; 11. Resting space density; 12. Environmental satisfaction
Coordination	1. Proportion of historical facade interfaces; 2. Municipal facility incongruity; 3. Wayfinding signage uniqueness; 4. Street furniture coordination; 5. Street color coordination; 6. Coordination of advertising and promotional facilities

3. Materials and Methods

3.1. Study Area

We focused on the former Russian concession in Hankou as our study area. Located within the historical concession district of Hankou in Wuhan, Hubei Province, the area is bounded by Hezuo Road, Zhongshan Boulevard, Chezhan Road, and Yanjiang Boulevard. To ensure the integrity of the urban form and street network, the extended segments of Huangxing Road, Yuefei Street, Shengli Street, Chezhan Road, and Zhongshan Boulevard—although partially located outside the former Russian concession—were also included in the study area (Figure 1). According to the Planning System for Historical and Cultural Districts and Streetscape Zones in Wuhan's Main Urban Area [33], the former Russian concession in Hankou contains diverse land uses, including residential streets such as Tongxing neighborhood and Taixing neighborhood, mixed-use streets along Zhongshan Boulevard and Yanjiang Boulevard, and tourism district streets centered around the Site of the August 7th Conference, Bagong House, and Luojiashan Street. The richness of functional composition has resulted in a variety of street environments within the study area, and such diversity leads to differences in walking experiences among both visitors and residents. By comparing the internal streets of the district, the impact of street environments

on walkability can be revealed, demonstrating the representativeness of the former Russian concession as a case study for evaluating walkability in historical and cultural districts.

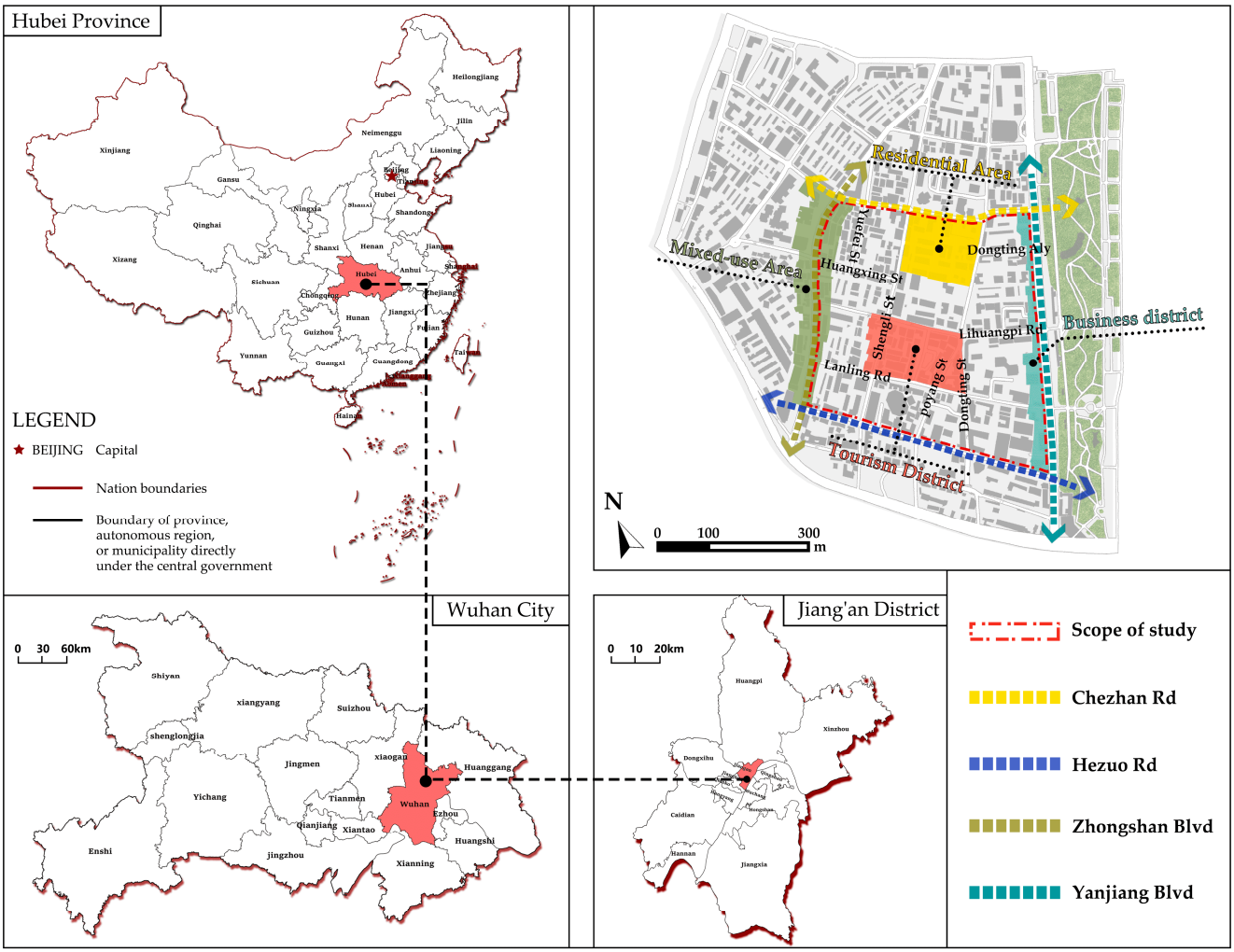


Figure 1. Scope of the street walkability study.

3.2. Research Framework

We first reviewed previous literature to organize and summarize walkability evaluation indicators. Then, based on the current spatial characteristics of streets in the former Russian concession in Hankou, 19 indicators were selected and their quantitative methods were defined, forming the foundation for the construction of a walkability evaluation framework. Second, following the defined quantitative methods, four data acquisition approaches—OpenStreetMap, AMap, on-site collection, and on-site measurement—were used to obtain road network data, POI data, street view image data, and other physical spatial data of streets. Methods such as spatial syntax, GIS spatial analysis, semantic segmentation, and mathematical calculation were then applied to calculate the values of all 19 indicators. Third, the calculated results were normalized and combined with the respective indicator weights to obtain the comprehensive walkability evaluation results for the streets. Finally, based on these results, several representative streets were selected for comparative analysis of pedestrian environment differences, common walkability issues were identified, and targeted optimization strategies were proposed accordingly (Figure 2).

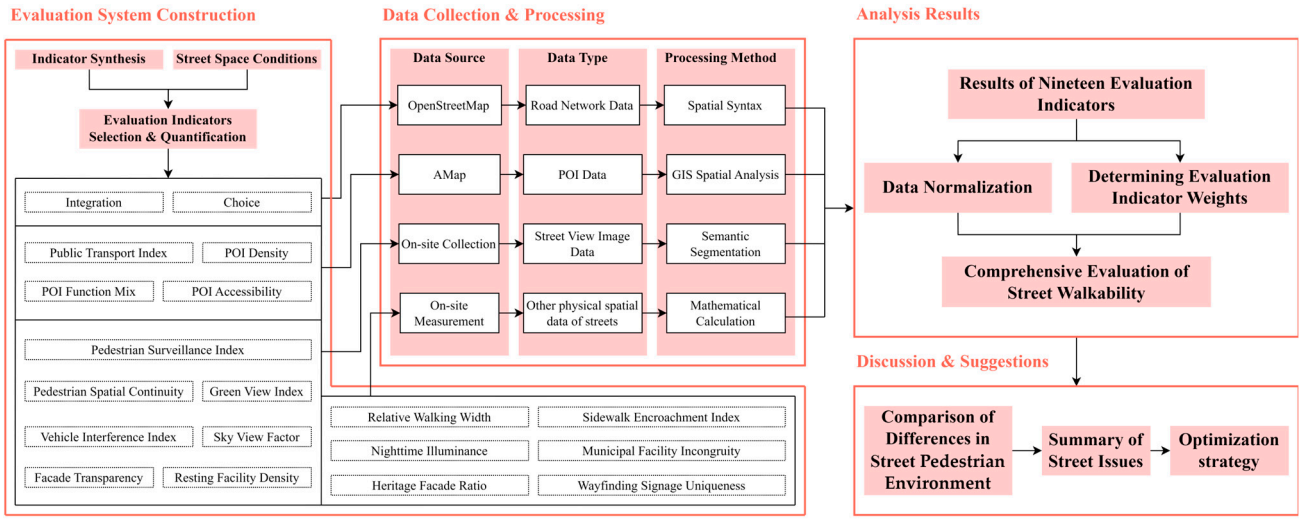


Figure 2. Research framework.

3.3. Evaluation Indicator Extraction and Calculation

Based on multiple rounds of field investigation in the former Russian concession in Hankou, the existing issues within its street space can be summarized into four main aspects: imbalanced right-of-way allocation, spatial disorder, functional dislocation, and fragmentation of historical context.

1. Imbalance in Right-of-Way Allocation

The imbalance in right-of-way allocation is the result of multiple overlapping conflicts. First, the rapid growth of motorized traffic has occupied already narrow street spaces, with insufficient provision for non-motorized lanes and sidewalks, forcing pedestrians to share the roadway with vehicles. Some streets lack proper parking planning and suffer from weak traffic regulation, resulting in vehicles being parked arbitrarily and significantly reducing the effective width available for pedestrian movement. Second, the absence of street safety barriers has led to frequent instances of non-motorized vehicles encroaching on pedestrian space, causing intensified pedestrian–vehicle conflicts. Moreover, outdoor commercial displays and mobile vendors further encroach upon sidewalk space, disrupting the continuity of pedestrian pathways. Lastly, the original street fabric of the historical and cultural district is insufficient to accommodate modern motorization demands. When combined with the surging foot traffic during peak tourist periods, these issues further reduce circulation efficiency and make balanced right-of-way allocation increasingly difficult to achieve.

2. Spatial Disorder

Spatial disorder is also the result of multiple interrelated issues. In terms of historical character preservation, unauthorized additions and excessive commercial modifications to the facades of historic buildings in the former concession have damaged the original texture of the street interface. The coexistence of faux-historic elements in public facilities with modern concrete utility boxes has further fragmented the visual landscape. In terms of functional layout, the unregulated overlap of residential, commercial, and tourism functions has led to the intertwining of pedestrian and logistics flows, the fragmentation of public space, and intensified activity conflicts between residents and tourists. From a management perspective, ambiguous property rights have given rise to unauthorized constructions, the expansion of outdoor displays by internet-famous shops, and the occupation of pedestrian space by mobile vendors. Additionally, repeated excavation caused by aging underground

infrastructure has damaged traditional pavement materials. These factors collectively contribute to the problem of spatial disorder within the district.

3. Functional Dislocation

Functional dislocation is reflected in three main areas. First, the mixed use of space and lack of effective zoning management have resulted in the unregulated overlap of residential, commercial, cultural tourism, and administrative functions. Second, there is a serious shortage of public facilities, with inadequate tourism services: notably, areas lacking resting facilities often coincide with areas where tourists tend to stay for extended periods. Finally, cultural experiences are superficial: exhibitions of historical and cultural buildings rely primarily on static displays, lacking interactive narratives, making it difficult for visitors to engage deeply with the historical and cultural essence of the district.

4. Fragmentation of Historical Context

The fragmentation of historical context is also manifested in three ways. In terms of spatial structure, traditional historical interfaces of the concession—such as continuous arcades and vaults—have been disrupted by motorized traffic lanes or newly added commercial buildings, which in turn has fractured the continuity of the street's historical fabric. In terms of cultural symbols, Russian-style cast iron streetlamps have been replaced by modern stainless steel LED fixtures, while fluorescent lightbox advertisements have been installed next to historical address plaques, resulting in a cluttered pedestrian visual experience. In terms of place-based cultural expression, historic street-corner plazas—such as the front yard of the Bagong House—have become popular photo spots on social media, yet they lack basic amenities such as resting benches and contextual interpretive installations. As a result, visitor engagement with the site tends to be superficial and transient, characterized mainly by "stop-and-shoot" behavior rather than meaningful cultural interaction.

Based on the synthesis of street walkability indicators and the existing spatial problems identified in the streets of the former Russian concession in Hankou, this study adopted five key dimensions: connectivity, convenience, safety, comfort, and coordination. A total of 19 evaluation indicators commonly used in previous studies were selected and analyzed within this framework. The specific indicators and their quantitative methods are shown in Table 2.

Table 2. Street walkability evaluation index system.

Analysis Dimension	Evaluation Index	Quantitative Method	Metric Attributes	Formulas	Formula Explanation
Connectivity	Integration (INT)	Space Syntax	Positive	$INT = \frac{\sum_{j=1}^{n} d(i,j)}{n-1}$	i is the current spatial unit; n is the total number of spatial units; $d(i, j)$ is the shortest path distance from spatial unit i to j
	Choice (Ch)	Space Syntax	Positive	$Ch = \sum_{j \neq i} \frac{1}{d(i,j)}$	i is the current spatial unit; j is another spatial unit; $d(i, j)$ is the shortest path distance from spatial unit i to j
	Relative Walking Width (RWW)	Mathematical Calculation	Positive	$RWW = \frac{Sn}{L}$	Sn is the actual walkable area available to pedestrians; L is the total length of the street
	Pedestrian Spatial Continuity (PSC)	Semantic Segmentation	Positive	$PSC = \frac{1}{\sigma_w}$	σ_w is the standard deviation of the proportion of sidewalk pixels in all street view images within the street coverage area

Table 2. *Cont.*

Analysis Dimension	Evaluation Index	Quantitative Method	Metric Attributes	Formulas	Formula Explanation
Convenience	Public Transport Index (PTI)	GIS	Positive	$PTI = \frac{L}{\sum_{i=1}^{n} t_i * l_i}$	L is the total length of the street; t_i is the time cost required to reach a public transportation station from the i-th street segment; l_i is the length of the i-th street segment
	POI Density (PD)	GIS	Positive	$PD = \frac{Npoi}{L}$	$Npoi$ is the number of POIs within the street buffer zone; L is the total length of the street
	POI Accessibility (PA)	GIS	Positive	$PA = \min \sum_{i=1}^{n} w_i$	min is the minimum (shortest) path distance; w_i is the length of each segment in the road network; n is the total number of segments in the path
	POI Function Mix (PFM)	GIS	Positive	$PFM = -\sum_{i=1}^{n} (P_i \times \ln P_i)$	n is the category of service facilities on the street; P_i is the proportion of a specific type of POI on the street relative to the total number of POIs on that street
Safety	Vehicle Interference Index (VII)	Semantic Segmentation	Negative	$VII = \frac{\sum Vi}{An}$	$\sum Vi$ is the total number of pixels corresponding to vehicles (including cars, motorcycles, and bicycles) in the image; An is the total number of pixels in the n-th image
	Nighttime Illuminance (NI)	Mathematical Calculation	Positive	$NI = \frac{\sum_{i=1}^{n} E_i}{n}$	n is the number of sampling points; E_i is the nighttime illuminance value at the i-th sampling point
	Sidewalk Encroachment Index (SEI)	Mathematical Calculation	Negative	$SEI = \frac{Le}{L}$	Le is the length of the encroached sidewalk; L is the total length of the street
	Pedestrian Surveillance Index (PSI)	Semantic Segmentation	Positive	$PSI = \frac{Pn}{An}$	Pn is the number of pedestrian pixels in the n-th image; An is the total number of pixels in the n-th image
Comfort	Green View Index (GVI)	Semantic Segmentation	Positive	$GVI = \frac{Gn}{An}$	Gn is the number of vegetation pixels in the n-th image; An is the total number of pixels in the n-th image
	Sky View Factor (SVF)	Semantic Segmentation	Positive	$SVF = \frac{Sn}{An}$	Sn is the number of sky pixels in the n-th image; An is the total number of pixels in the n-th image
	Facade Transparency (FT)	Semantic Segmentation	Positive	$FT = \frac{Bn}{Wn}$	Bn is the number of building pixels in the n-th image; Wn is the number of wall pixels in the n-th image
	Resting Facility Density (RFD)	Semantic Segmentation	Positive	$RFD = \frac{Rn}{An}$	Rn is the number of resting facility pixels in the n-th image; An is the total number of pixels in the n-th image
Coordination	Heritage Facade Ratio (HFR)	Mathematical Calculation	Positive	$HFR = \frac{Lhf}{L}$	Lhf is the length of street interfaces that conform to the historical character of the district; L is the total length of the street
	Municipal Facility Incongruity (MFI)	Mathematical Calculation	Negative	$MFI = \frac{Nmf}{L}$	Nmf is the number of municipal facilities that do not conform to the historical character of the district; L is the total length of the street
	Wayfinding Signage Uniqueness (WSU)	Mathematical Calculation	Positive	$WSU = \frac{Nws}{L}$	Nws is the number of wayfinding signs that conform to the historical character of the district; L is the total length of the street

3.4. Data Collection and Processing

3.4.1. Data Collection Methods

Street spatial data for the former Russian concession in Hankou were obtained through two main sources: on-site measurement and open online platforms. The data types collected include road network data, POI data, street view image data, nighttime illumination data, and other types of physical spatial data related to the street environment. The specific data collection methods are as follows:

(1) Road Network Data: Road network data covering the study area and its surrounding region were obtained from the OpenStreetMap (OSM) open data platform. These data served as the foundation for subsequent spatial syntax modeling and GIS network analysis.

(2) POI Data: POI data for the study area and its surrounding region were obtained using web crawler tools through the AMap API.

(3) Street View Image Data: To better capture the influence of street environments on pedestrian experience during walking activities and to address the limitations of using Baidu panoramic static image APIs—such as outdated imagery and missing segments—this study employed a self-collected street view image approach. Sampling points were set every 10 to 15 m along the streets. At each point, two images were taken (one facing forward and one facing backward) using a smartphone camera held at eye level, in order to simulate the pedestrian visual experience during actual walking. To ensure consistency in pedestrian activity, image collection was conducted between 9:00 and 11:00 a.m. in May 2024. Additionally, since this study focused on the physical spatial characteristics of streets. Holidays and other special periods were avoided during data collection to minimize visual obstruction caused by crowd gatherings.

(4) Nighttime Illumination Data: Sampling points were set at 10 m intervals along the streets within the study area. At each point, nighttime illumination data were collected using a digital lux meter to measure the illuminance level. (5) Other Physical Spatial Data of Streets: Sidewalk width and the length and width of public facilities were measured on-site using a laser rangefinder. The quantities of public facilities along the streets—such as streetlights, traffic signals, fire hydrants, trash bins, and public benches—were obtained through manual counting.

3.4.2. Data Processing

1. Road Network Data Processing

Studies have shown that 30 min is the upper threshold for walking distance [34]. Based on an average pedestrian speed of 4.8 km/h, the maximum walking distance is approximately 2.4 km. Therefore, this study took the former Russian concession in Hankou as the origin point and used GIS tools to calculate a 2.4 km walking range, which served as the basis for delineating the extended study area (Figure 3a). To establish a complete road network system and ensure the accuracy of subsequent analyses, the extended study area included several road segments that fall outside the 30 min walking distance. In addition, since the southwestern boundary of the study area is separated by the Yangtze River and pedestrians cannot cross the river on foot, road segments located in Wuchang District were excluded from the extended study area.

The raw data obtained from the OSM open-source map contained a large number of non-pedestrian street types, such as railways, expressways, and elevated roads. To ensure the accuracy and completeness of the pedestrian network, this study refined the OSM-based road network data by referencing real-world maps. On this basis, a spatial syntax axial model of the extended study area was constructed (Figure 3b).

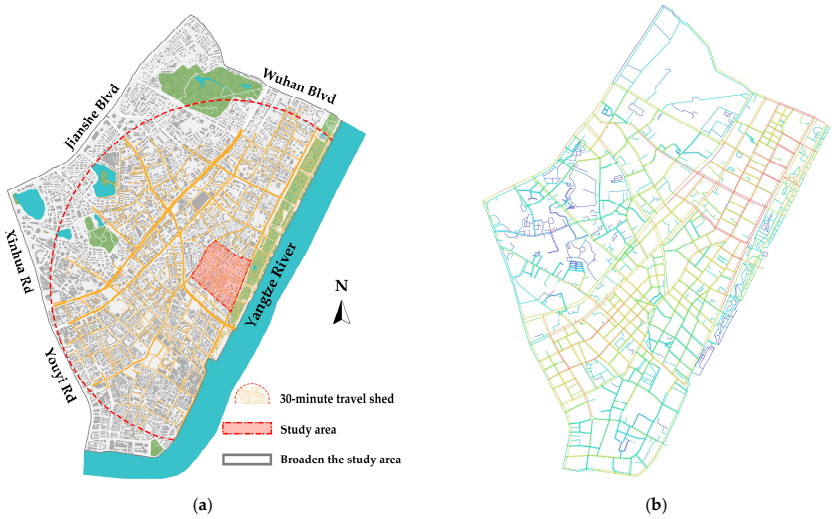


Figure 3. (**a**) Broadened study area; (**b**) space syntax axial model.

2. POI Data Processing

Through comparative analysis, this study categorized POI data based primarily on the classification of daily service facilities in the Urban Residential Area Planning and Design Standards [35] and the Guidelines for Building Complete Communities [36], supplemented by classifications found in relevant literature on street walkability and daily service facilities [37–39]. The collected POI data were divided into seven major categories—public service facilities, commercial service facilities, transportation stations, basic supporting facilities, medical service facilities, scenic and cultural sites, and public administrative facilities—which were further subdivided into 34 subcategories (Table 3). A preliminary screening of POI data was conducted using ArcGIS, resulting in 18,721 POI points in the extended study area and 667 POI points within the core study area.

Table 3. POI classification.

Facility Category	Facility Subcategory
Public Service Facilities	1. Secondary school; 2. Primary school; 3. Kindergarten; 4. Sports venue or national fitness center; 5. Mother-and-baby room; 6. Elderly care home; 7. Cultural activity center; 8. Community service center
Commercial Service Facilities	1. Fresh food market; 2. Shopping mall or supermarket; 3. Convenience store; 4. Catering facilities; 5. Bank branch; 6. Telecommunications service outlet; 7. Postal service outlet; 8. Beauty and hair salon; 9. Laundry shop; 10. Repair station; 11. Leisure and entertainment facilities
Transportation Hubs	1. Rail transit station; 2. Bus stop; 3. Parking lot
Basic Supporting Facilities	1. Public toilet; 2. Charging facility; 3. Emergency shelter facility
Medical Service Facilities	1. General hospital; 2. Specialized hospital; 3. Clinic; 4. Pharmacy
Scenic Spots and Historic Sites	1. Park; 2. Public square; 3. Historical and cultural site
Public Administration Facilities	1. Government agency; 2. Social organization

3. Street View Image Data Processing

With the continuous advancement of computer science and technology, deep learning techniques have been widely applied in image processing and computer vision. As a key technology in this domain, semantic segmentation has been extensively used in the quantitative analysis of urban spaces. In this study, the Mask2Former model and the ADE20K dataset were adopted for semantic segmentation of street view images. Mask2Former is a highly efficient model that leverages the powerful capabilities of transformer encoders and learns mask representations to adapt to various segmentation paradigms. It has demonstrated excellent performance in semantic segmentation, instance segmentation, and panoptic segmentation tasks. The ADE20K dataset contains a total of 27,574 images and is capable of recognizing 150 categories of elements, addressing the limited-scene issue

present in datasets such as Cityscapes. From the segmentation results, 18 key elements were selected for evaluating the walkability of streets in the historical and cultural district (Figure 4).

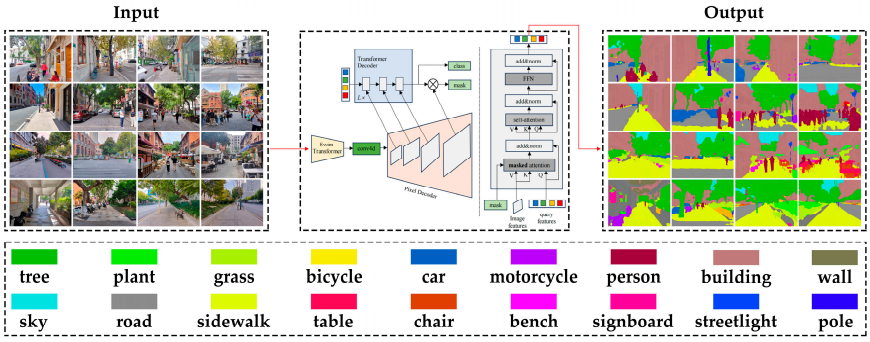


Figure 4. Street view image data processing.

4. Results

4.1. Results of Nineteen Evaluation Indicators

First, the streets with high connectivity in the study area were Yanjiang Boulevard, Zhongshan Boulevard, Lihuangpi Road, and Luojiashan Street. Among these, Yanjiang Boulevard and Zhongshan Boulevard are classified as urban secondary roads and occupy relatively important positions within the urban road network. These roads are connected to a larger number of adjacent streets, resulting in higher values for integration (INT) and choice (Ch). In contrast, Lihuangpi Road and Luojiashan Street are located within the core tourism zone, where vehicular access is generally restricted to improve the pedestrian experience. This traffic control policy reallocates more street space to pedestrians. Consequently, these two streets perform notably better in terms of relative walking width (RWW) and pedestrian spatial continuity (PSC).

Second, in terms of street convenience, the streets with high values vary across the four relevant indicators. The public transport index (PTI) is influenced by the distribution of public transport stations and generally exhibits a pattern of higher values at the outer edges and lower values in the central area of the study region. High-PTI segments are mainly located in the four corners of the study area, while the internal segments show relatively lower PTI values. POI accessibility (PA) presents a southwest-high and northeast-low spatial trend. The study found that the PA values of streets are not only affected by the POI density within the study area but are also strongly influenced by the POI density center of the extended area, which happens to be located in the Jianghan Road area to the southwest of the core region. Theoretically, a higher POI density (PD) is more likely to contribute positively to the POI function mix (PFM). However, in the study area, many streets with high PD values actually exhibit low PFM values. Further analysis of POI types along these high-PD streets revealed that they are predominantly occupied by small and densely distributed food and beverage services, leading to high density, but low diversity, reflecting a significant degree of commercial homogeneity within the study area.

Third, in terms of street safety, Yanjiang Boulevard and Zhongshan Boulevard, which have higher road classifications, are equipped with more complete street lighting facilities; therefore, both roads exhibit higher values of nighttime illuminance (NI). A higher road classification also means that these two roads are required to accommodate greater traffic volumes, which increases the likelihood that pedestrian walking activity will be affected by motor vehicles. However, analysis results showed that both Yanjiang Boulevard and Zhongshan Boulevard have relatively low vehicle interference index (VII) values. On the eastern segments of Zhongshan Boulevard, due to the absence of green buffer systems

separating motor vehicle lanes from sidewalks, the impact of motor vehicles on pedestrians is more pronounced. Areas with high pedestrian surveillance index (PSI) values largely overlap with the core tourism zone, where the dense distribution of historic buildings attracts more pedestrian presence and encourages lingering, which significantly increases PSI values along those streets.

Fourth, in terms of street comfort, streets with high green view index (GVI) values and those with high sky view factor (SVF) values tend to exhibit a degree of spatial opposition, indicating that GVI is an important factor influencing SVF in the study area. In actual street environments, both excessively high GVI and SVF can reduce comfort levels. An overly high GVI may cause pedestrians to feel oppressed or anxious due to excessive enclosure in the walking space, while an overly high SVF can lead to increased solar radiation and noticeable wind amplification effects, resulting in a lack of shading during hot summer conditions and intensified wind chill during cold winter days. Therefore, achieving a proper balance between GVI and SVF is crucial for improving street comfort. In addition, both facade transparency (FT) and resting facility density (RFD) are generally low across the study area. Notably, only Luojiashan Street shows a high RFD value. This scarcity of resting facilities has had a significant negative impact on pedestrian comfort in the district.

Finally, in terms of street coordination, streets with high heritage facade ratio (HFR) values and low municipal facility incongruity (MFI) values largely overlap with the core tourism zone, indicating a relatively high level of coordination within streets in this area. In contrast, streets outside the core tourism zone still require improvement in both HFR and MFI performance. According to the analysis, wayfinding signage uniqueness (WSU) is generally low throughout the study area, including streets within the tourism core. This widespread lack of distinctive signage significantly reduces overall street coordination, highlighting the urgent need for wayfinding system improvements (Figure 5).

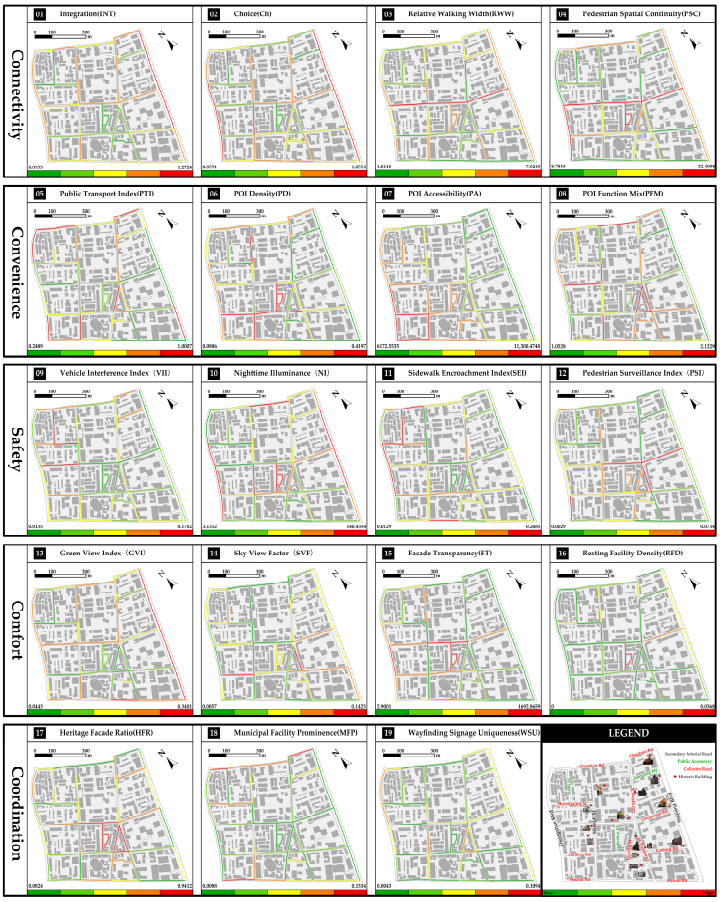


Figure 5. Results of nineteen evaluation indicators.

4.2. Analysis of Comprehensive Street Walkability

1. Data Normalization Processing

The range normalization method was used to eliminate dimensional differences and magnitude effects among the results of the 19 evaluation indicators [40]. Positive and negative indicators were normalized separately, with the normalization formula for positive indicators shown in Equation (1) and that for negative indicators in Equation (2).

$$x' = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{1}$$

$$x' = \frac{x_{max} - x}{x_{max} - x_{min}} \tag{2}$$

2. Determining Evaluation Indicator Weights

The analytic hierarchy process (AHP) was used to assign weights to each indicator. Due to the large computational load involved in pairwise comparisons, Yaahp (Yet Another AHP) software (version V10.3) was used to model and calculate the judgment matrix. A pairwise comparison questionnaire was designed and distributed to 11 experts from relevant fields, including architecture and urban planning, to independently assess the importance of the criterion layer and indicator layer [41]. The expert scores were input into Yaahp, and after consistency testing (consistency ratio, CR < 0.1), the group decision module was used to integrate the judgments of the 11 experts, resulting in the determination of the evaluation indicator weights (Table 4).

Table 4. Distribution of evaluation indicator weights.

Goal Layer	Criterion Layer	Weight	Indicator Layer	Weight
Street walkability assessment	Connectivity	0.2054	Integration (INT)	0.1821
			Choice (Ch)	0.2507
			Relative Walking Width (RWW)	0.2254
			Pedestrian Spatial Continuity (PSC)	0.3418
	Convenience	0.1988	Public Transport Index (PTI)	0.3395
			POI Density (PD)	0.1589
			POI Accessibility (PA)	0.3361
			POI Function Mix (PFM)	0.1655
	Safety	0.2515	Vehicle Interference Index (VII)	0.3237
			Nighttime Illuminance (NI)	0.2843
			Sidewalk Encroachment Index (SEI)	0.2966
			Pedestrian Surveillance Index (PSI)	0.0954
	Comfort	0.2111	Green View Index (GVI)	0.2241
			Sky View Factor (SVF)	0.3619
			Facade Transparency (FT)	0.1028
			Resting Facility Density (RFD)	0.3112
	Coordination	0.1332	Heritage Facade Ratio (HFR)	0.5961
			Municipal Facility Prominence (MFP)	0.1907
			Wayfinding Signage Uniqueness (WSU)	0.2132

3. Comprehensive Walkability Evaluation of Streets

The normalized scores of each indicator were multiplied by their respective weights to obtain the final scores for each indicator. The sum of the final scores of all indicators represents the comprehensive walkability score of the street, with positive indicators being added and negative indicators subtracted. The calculation methods are shown in Equations (3) and (4).

$$S_i = R_i \times w_i \tag{3}$$

$$S_t = \frac{S_1 + S_2 + \ldots + S_i}{i} \tag{4}$$

In the equations, S_i is the final score of each indicator, R_i is the normalized score of each indicator, w_i is the respective weight of each indicator, S_t is the comprehensive score of each indicator, and i is the total number of indicators.

From the comprehensive walkability analysis map of streets (Figure 6), it can be observed that there is a certain correlation between the distribution of high-walkability streets and the distribution of historic buildings within the study area. Specifically, the core tourism zone, which is densely populated with historic buildings, has surrounding streets with relatively high walkability. Yanjiang Boulevard, as an urban secondary road, is also home to many historic buildings. Its wide roads and well-developed pedestrian facilities significantly enhance its walkability. In contrast, streets such as Chezhan Road, Hezuo Road, and Huangxing Street exhibit lower walkability. These streets primarily serve residential functions and are influenced by factors such as road width, traffic control, and the availability of facilities, which result in lower walkability. Overall, the streets within the study area can be ranked by walkability from high to low based on spatial location as follows: tourism district streets, business district streets, mixed-use streets, and residential streets.

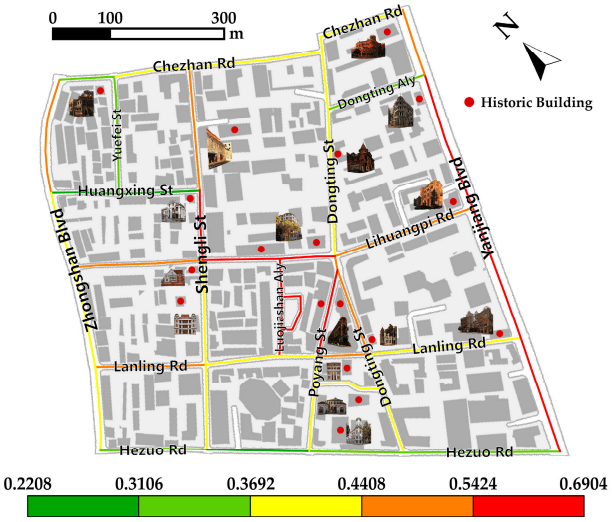


Figure 6. Comprehensive walkability analysis map of streets.

5. Discussion

To identify the unfavorable factors affecting walkability in street environments, we integrated the results of walkability evaluations with on-site street characteristics and conducted a comparative analysis of typical pedestrian environments. According to the 13th Five-Year Plan for Urban Road Construction in Jiang'an District [42], roads within the study area are mainly classified into three types: urban secondary roads (e.g., Yanjiang Boulevard), branch roads (e.g., Lihuangpi Road), and public pathways (e.g., Luojiashan Street). Considering the inherent physical spatial differences among roads of different classifications (such as street width), this analysis focuses on three pairs of streets with the same classification, conducting pairwise comparisons to explore differences in pedestrian environments. The selected street pairs are as follows: urban secondary roads: Yanjiang Boulevard and Zhongshan Boulevard (from Chezhan Road to Hezuo Road; for clarity, the following text refers to them simply as Yanjiang Boulevard and Zhongshan Boulevard); branch roads—Chezhan Road and Hezuo Road (from Yanjiang Boulevard to Zhongshan Boulevard); and branch roads: Lihuangpi Road and Lanling Road (from Yanjiang Boulevard to Zhongshan Boulevard; see Figure 7).

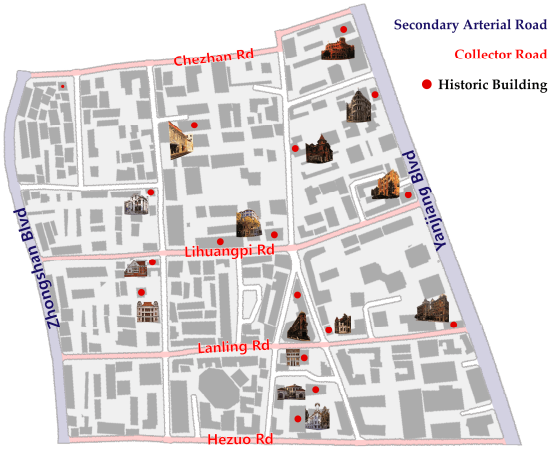
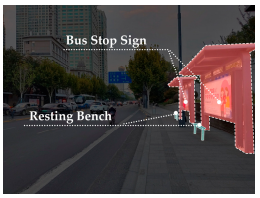
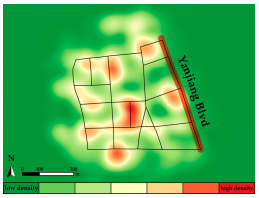
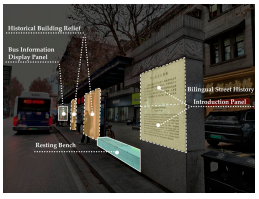
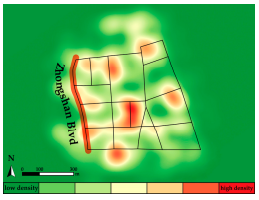


Figure 7. Street location map.

5.1. Comparison of the Differences in Pedestrian Environments Between Yanjiang Boulevard and Zhongshan Boulevard

Yanjiang Boulevard and Zhongshan Boulevard are both classified as urban secondary roads and carry a relatively high volume of motorized traffic. A comparison of the walkability evaluation results for these two streets reveals significant differences across multiple indicators. Therefore, based on actual street conditions, the following section explores how variations in the pedestrian environment influence street walkability (Table 5). To better highlight differences between indicators, the comparison is based on raw indicator values without normalization. In addition, since each street typically consists of three to four segments, the average value across segments was used for indicator comparison.

Table 5. Yanjiang Boulevard and Zhongshan Boulevard.

Street Name	Pedestrian Environment	Sidewalk	Municipal Facilities	Service Facilities
Yanjiang Blvd				
	GVI = 0.3185 VII = 0.0509	RWW = 5.8951 PSC = 16.9022	MFI = 0.0479	PD = 0.1205 PA = 6872.6125
Zhongshan Blvd				
	GVI = 0.2207 VII = 0.1655	RWW = 4.4389 PSC = 12.8409	MFI = 0.0299	PD = 0.3094 PA = 10,517.6925

First, the green view index (GVI) of Yanjiang Boulevard is 0.3185, and its vehicle interference index (VII) is 0.0509. The GVI is significantly higher than that of Zhongshan Boulevard (GVI = 0.2207), while the VII is lower than that of Zhongshan Boulevard (VII = 0.1655). Therefore, in terms of the pedestrian environment, Yanjiang Boulevard is clearly superior to Zhongshan Boulevard. A comparison of on-site conditions revealed that Yanjiang Boulevard features a greening system composed of trees, shrubs, and vertical greenery, which not only enhances the green view index but also effectively buffers pedestrians from the influence of motor vehicles. In contrast, the greening system along Zhongshan

Boulevard consists of only a single row of trees, making it noticeably less substantial. The lower GVI reflects this deficiency. Furthermore, the wide spacing between street trees prevents the greenery from effectively separating pedestrian space from vehicular lanes, resulting in a higher vehicle interference index.

Second, the relative walking width (RWW = 5.8951) and pedestrian spatial continuity (PSC = 16.9022) of Yanjiang Boulevard are both higher than those of Zhongshan Boulevard (RWW = 4.4389; PSC = 12.8409). Based on an on-site comparison, it was observed that the traffic infrastructure along Yanjiang Boulevard is well organized, with clearly separated pedestrian lanes, non-motorized lanes, and motor vehicle lanes. In addition, the building setbacks on both sides of the boulevard are more reasonable, providing wider pedestrian space. These conditions contribute to the higher relative walking width observed along Yanjiang Boulevard. Furthermore, traffic regulation is more strictly enforced on Yanjiang Boulevard. In contrast to Zhongshan Boulevard—where illegal vehicle parking often blocks pedestrian space—vehicles along Yanjiang Boulevard are parked in an orderly fashion without encroaching on the sidewalks, leading to a higher degree of pedestrian spatial continuity.

Third, Zhongshan Boulevard outperforms Yanjiang Boulevard in terms of the coordination of municipal facilities. Its municipal facility incongruity (MFI) is 0.0299, significantly lower than that of Yanjiang Boulevard (MFI = 0.0479). Taking bus stops as an example, those along Zhongshan Boulevard are more harmonious with the overall historical character of the area in terms of form and materials. In addition to standard amenities such as benches and real-time bus information displays, they also incorporate bilingual street introductions and historical building relief elements that align with the cultural identity of the district. These features help pedestrians and visitors intuitively understand the historical background of the area. In contrast, the bus stops on Yanjiang Boulevard lack these contextual design elements, and the resting benches are relatively narrow and insufficient to meet pedestrian needs.

Finally, both the POI density (PD = 0.1205) and POI accessibility (PA = 6872.6125) of Yanjiang Boulevard are lower than those of Zhongshan Boulevard (PD = 0.3094; PA = 10517.6925). The calculated number of POIs within the buffer zone of Zhongshan Boulevard is 170, while Yanjiang Boulevard, despite its longer length, contains only 84 POIs. The east side of Yanjiang Boulevard is adjacent to the Yangtze River, with sparse building development and limited potential for the concentration of service facilities. This contributes to its lower POI density and also negatively impacts its POI accessibility. As a traditional commercial street, Zhongshan Boulevard has a dense and evenly distributed pattern of services, resulting in higher PD and PA values.

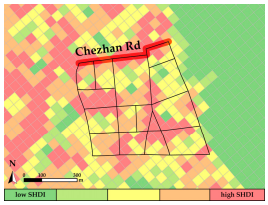
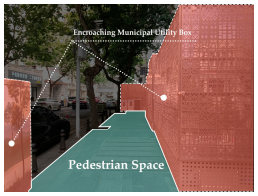
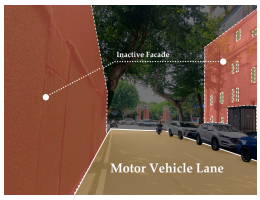
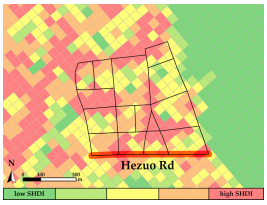
5.2. Comparison of the Differences in Pedestrian Environments Between Chezhan Road and Hezuo Road

Both Chezhan Road and Hezuo Road are classified as branch roads. While these streets primarily exhibit characteristics of residential streets, certain segments feature a large number of ground-floor commercial establishments. Unlike the previous group of streets, the indicator values for Chezhan Road and Hezuo Road generally do not show significant differences. Instead, they often share similarly high or low values, yet the underlying causes are entirely different (Table 6).

First, compared with other streets in the study area, both Chezhan Road and Hezuo Road perform poorly on three key indicators: relative walking width (RWW), pedestrian spatial continuity (PSC), and sidewalk encroachment index (SEI). However, on-site investigation revealed that the reasons behind these lower scores vary between the two streets. Based on on-site comparison, the low RWW and PSC values of Chezhan Road are primarily due to the disorderly parking of non-motorized vehicles (including shared bikes and e-

bikes), as well as outdoor stall extensions or merchandise displays spilling into pedestrian space from ground-floor shops. These issues contribute to a significantly higher SEI, as the walking space becomes heavily compressed. In contrast, the low RWW and PSC values and the elevated SEI of Hezuo Road are not caused by vehicle encroachment or vendor activity. Instead, they result mainly from a large number of municipal installations—such as utility boxes, trash bins, and wayfinding signs—being placed directly on the sidewalk, occupying the already narrow pedestrian space.

Table 6. Chezhan Road and Hezuo Road.

Street Name	Sidewalk	Street Facade	Service Facilities
Chezhan Rd	  RWW = 2.2364; PSC = 11.6901; SEI = 0.3922	 FT = 44.4532 NI = 60.6157	 PD = 0.2011 PFM = 1.8142
Hezuo Rd	  RWW = 1.9897; PSC = 10.9271; SEI = 0.4134	 FT = 27.5362 NI = 26.5543	 PD = 0.2945 PFM = 1.4998

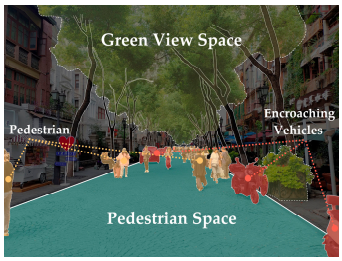
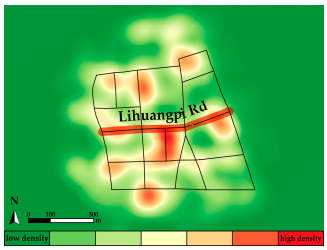
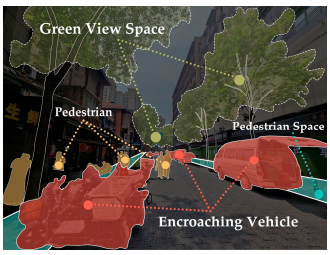
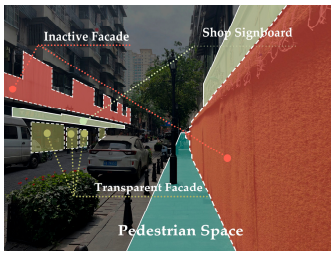
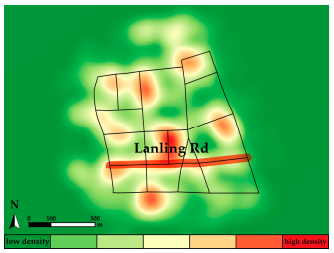
Second, Chezhan Road has a facade transparency (FT) of 44.4532 and a nighttime illuminance (NI) of 60.6157, both significantly higher than those of Hezuo Road (FT = 27.5362; NI = 26.5543). It was observed that many ground-floor commercial spaces along Chezhan Road use glass curtain walls, creating a relatively open street-level facade. In contrast, certain sections of Hezuo Road are under construction, with one side of the street fully enclosed by temporary fencing, resulting in large areas of inactive facades. In addition, the buildings along Hezuo Road have relatively small windows, making it difficult to form a transparent street interface. Higher facade transparency not only encourages pedestrians to linger but also positively contributes to nighttime illumination. Field investigation shows that the street lighting infrastructure on both roads is comparable; however, the stronger auxiliary lighting effect from ground-floor commercial activities along Chezhan Road—attributed to its higher facade transparency—results in a higher level of nighttime illuminance than on Hezuo Road.

Finally, although the POI density (PD = 0.2011) of Chezhan Road is lower than that of Hezuo Road (PD = 0.2945), its POI function mix (PFM) is higher. The analysis shows that while Chezhan Road has fewer overall service facilities compared to Hezuo Road, it is located in an area with a high Shannon diversity index (SHDI). In contrast, the SHDI value in the area surrounding Hezuo Road is relatively low. This finding is consistent with the results of the on-site investigation, which revealed that 27 categories of daily service facilities are distributed along Chezhan Road, significantly more than the 19 categories found along Hezuo Road.

5.3. Comparison of the Differences in Pedestrian Environments Between Lihuangpi Road and Lanling Road

Lihuangpi Road and Lanling Road are both classified as branch roads and share many similarities in terms of form and function. Both streets have undergone pedestrian-oriented pavement upgrades, replacing the original asphalt surfaces with brick paving. However, since its pedestrianization renovation in 2016, the central and eastern sections of Lihuangpi Road have been designated a pedestrian street, with strict traffic control measures in place that in principle prohibit motor vehicle access. In contrast, although Lanling Road has adopted a similar paving treatment, it does not restrict motorized traffic and continues to serve vehicular flows to some extent. This key difference in traffic regulation has led to a noticeable disparity in walkability between the two otherwise similar streets (Table 7).

Table 7. Lihuangpi Road and Lanling Road.

Street Name	Pedestrian Environment/ Sidewalk	Street Facade	Service Facilities
Lihuangpi Rd	 GVI = 0.3125; PSI = 0.0453 RWW = 6.6777; PSC = 19.6991	 FT = 158.1606	 PD = 0.2384
Lanling Rd	 GVI = 0.1162; PSI = 0.0258 RWW = 3.3451; PSC = 13.5388	 FT = 86.5397	 PD = 0.3357

First, in terms of the pedestrian environment, Lihuangpi Road has a higher green view index (GVI = 0.3125) and pedestrian surveillance index (PSI = 0.0453) than Lanling Road (GVI = 0.1162; PSI = 0.0258). Based on on-site comparison, the street trees on both sides of Lihuangpi Road are denser and have broader canopies than those along Lanling Road. This is the primary factor contributing to the difference in GVI between the two streets. In addition, evenly distributed planter boxes along Lihuangpi Road further enhance its greenery, widening the gap in overall greening quality between the two streets. Moreover, the implementation of stricter traffic control on Lihuangpi Road ensures that pedestrians are not disturbed by motorized traffic while walking. The comfortable walking environment has attracted more pedestrians, thereby increasing the PSI value and further improving pedestrian safety along Lihuangpi Road.

Second, the decision to restrict motor vehicle access has resulted in an impressive relative walking width (RWW) of 6.6777 for Lihuangpi Road—nearly twice that of Lanling Road (RWW = 3.3451). With no vehicular interference, the pedestrian spatial continuity (PSC) of Lihuangpi Road also increased to 19.6991, greatly enhancing the street's pedestrian connectivity.

Third, in some segments of Lanling Road, the transparent ground-floor facades originally formed by small-scale units have been replaced by large construction enclosures due to ongoing renovation work, resulting in a facade transparency of only 86.5397. In contrast, Lihuangpi Road features more transparent and interactive ground-floor interfaces. Although its upper building facades also contain large-scale modules, their visual monotony is mitigated through the use of finely divided fenestration and integrated greenery. As a result, Lihuangpi Road outperforms Lanling Road in both facade transparency and visual richness.

Finally, the POI density (PD) of Lanling Road (PD = 0.3357) is higher than that of Lihuangpi Road (PD = 0.2384). A comparison of the POI density heatmaps reveals that the mid and eastern sections of the two streets have comparable densities of service facilities, while a significant difference is observed in the western section. According to the raw POI data, the number of service facilities in the western segment of Lanling Road is 63, whereas Lihuangpi Road has only 22 facilities in the same segment. Wuhan Traditional Chinese Medicine Hospital is located along the western section of Lihuangpi Road, occupying approximately three-fifths of the entire segment. In contrast, the western section of Lanling Road primarily consists of small and densely distributed commercial service facilities. Therefore, when viewed in its entirety, the overall POI density of Lihuangpi Road is lower than that of Lanling Road.

5.4. Summary

Based on the above analysis of the differences in pedestrian environments across the three groups of streets, the following four common spatial issues have been identified.

1. Insufficient Effective Walking Width

The effective walking width of a street is influenced by three key indicators: relative walking width (RWW), pedestrian spatial continuity (PSC), and the sidewalk encroachment index (SEI). Based on the comparative analysis of pedestrian environments, the causes of insufficient effective walking space can be summarized into the following four factors.

The first factor is the disparity in sidewalk width. Urban secondary roads (e.g., Yanjiang Boulevard) typically have wider sidewalks, whereas sidewalks on internal branch roads tend to be narrower. When sidewalks are occupied by illegally parked vehicles or municipal facilities, even the relatively wide sidewalks along urban secondary roads may fail to meet pedestrian demand, while the walking space on internal branch roads becomes even more constrained.

The second factor is the limitation imposed by historical context and street functions. Historical and cultural districts were not originally designed to accommodate modern motor vehicle traffic, resulting in many older streets having limited width. As motorization has increased, pedestrian space in these areas has been progressively compressed. In particular, under the premise of preserving the integrity of historical street fabric, the ability to expand street width is significantly constrained, further worsening the pedestrian environment.

The third factor is institutional barriers caused by insufficient interdepartmental coordination. Sidewalk facilities fall under the jurisdiction of multiple departments, including transportation, housing and urban development, and utilities. A lack of coordination among these agencies has led to the redundant installation of municipal infrastructure. Moreover, because earlier street planning did not reserve adequate space for such facilities, some of them have been installed directly on sidewalks, thereby further encroaching upon pedestrian space.

The fourth factor is the lack of adequate traffic control measures. The level of traffic regulation has a significant impact on the quality of the pedestrian environment. On streets with strict traffic control, the likelihood of pedestrian space being encroached upon is

relatively low and the walking environment tends to be better. In contrast, on streets with lax regulation, motorized and non-motorized vehicles frequently encroach upon pedestrian space, thereby reducing both pedestrian safety and street connectivity.

2. Poor Quality of Street Space

The quality of street space is influenced by multiple indicators, including the green view index (GVI), sky view factor (SVF), facade transparency (FT), and nighttime illuminance (NI), all of which are interrelated. Studies have shown that a GVI between 25% and 40% is considered optimal [43]. An appropriate GVI value can enhance pedestrian comfort through visual exposure to natural elements, thereby increasing the willingness to walk. In addition, tree canopies can provide shade and help improve the local microclimate. However, both excessively high and low GVI values can have an impact on SVF. When streets are narrow and the canopies of street trees are overly large, GVI tends to be too high and SVF becomes too low, which may trigger feelings of claustrophobia and anxiety among visitors. Conversely, when GVI is too low, SVF may become excessively high, leading to increased solar radiation and intensified wind tunnel effects [44]. On-site investigation revealed that most streets in the former Russian concession have relatively uniform building heights, making GVI the primary factor influencing SVF. Therefore, balancing GVI and SVF is a critical approach to improving the spatial quality of streets.

3. Disordered Street-Level Service Functions

Although the Wuhan Central Urban Area Historical and Cultural District and Urban Character Conservation Plan clearly outlines a "one core, four zones" planning framework centered on the Site of the August 7th Conference—defining tourism, business, residential, and mixed-use zones—walkability analysis and on-site investigation within the former Russian concession reveal that some streets still exhibit a blurred functional orientation, where cultural, commercial, and residential functions coexist in a disorganized manner. The misalignment between modern urban demands and the traditional spatial structure has led to the hollowing out of ground-floor commercial spaces in some areas, with a high rate of shop vacancies—for example, along the northern section of Zhongshan Boulevard.

Comparative analysis of street convenience indicators reveals that although certain roads have relatively high service facility density and accessibility, their POI function mix remains low. This reflects a common issue of homogeneous commercial types along many streets. On-site investigations indicate that a large number of ground-floor shops are concentrated in low-end, short-term profit-oriented sectors, such as snack retail and budget food and beverage outlets, with minimal connection to the historical context of the former concession. The development of cultural IP derivatives is also limited to low-value-added products such as postcards, with a noticeable absence of high-end cultural consumption and creative industries. As a result, the cultural identity of the district remains underdeveloped and difficult to articulate.

4. Distortion of Historical Features of the Neighborhood

According to the Standards for the Evaluation of Historical and Cultural Districts and Historic Buildings, the total length of continuous facades consistent with the overall character of a historical district should account for more than 60% of the total street length within the core protection area, and the continuity of historical building facades along the street should not be less than 70%. However, analysis results reveal that fewer than 20% of the streets within the study area meet this standard, indicating that the preservation of historical spatial fabric is facing severe challenges. On-site investigation shows that the facade styles of some non-historic buildings differ significantly from those of the surrounding historic architecture, particularly in terms of materials and colors,

greatly undermining the visual integrity of the streetscape. For instance, on Shengli Street, several newly constructed commercial buildings have adopted extensive glass curtain walls, creating an abrupt visual transition when juxtaposed with adjacent red-brick arcade-style historic buildings, thereby disrupting the original rhythm of the street facade.

In addition to building facades, municipal elements within the district—such as utility boxes, bus stops, wayfinding signage, and lighting systems—are often inconsistent with the overall historical character of the area. Most utility boxes are made of reflective metallic materials, which starkly contrast with the coarse-textured exterior finishes of the historic buildings. With the exception of Zhongshan Boulevard, bus stop designs on other streets generally fail to harmonize with the district's architectural style. Similarly, most wayfinding signs are conventional blue direction boards. Aside from a few signs in the core tourism zone, the materials and forms of most signage do not align with the visual and historical character of the district.

6. Proposed Guidelines

Based on the analysis of pedestrian environment differences across the selected typical streets, this study proposes targeted strategies for enhancing the walkability of streets within the former Russian concession in Hankou. The strategies focus on four key aspects: expanding effective walking width, improving the spatial quality of streets, optimizing street service functions, and harmonizing the historical character of the district.

6.1. Expanding Effective Walking Width

Based on the analysis results, six major types of issues contributing to insufficient effective walking width were identified. Targeted optimization strategies have been proposed for each issue in order to expand the effective pedestrian space. The specific strategies are presented in Table 8.

Table 8. Strategies for expanding effective pedestrian width.

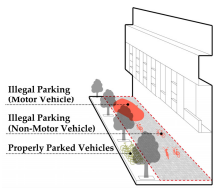
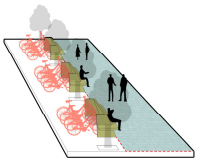
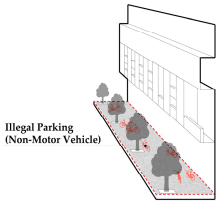
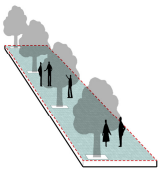
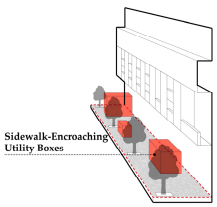
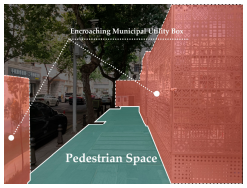
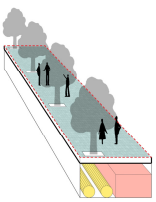
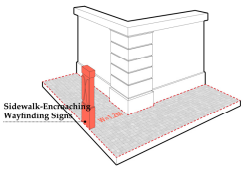
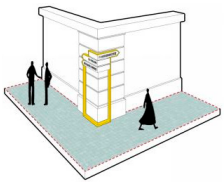
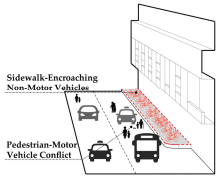
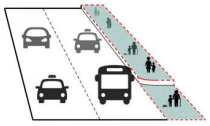
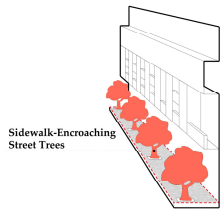
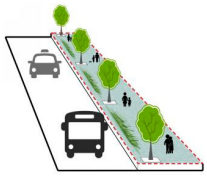
Problem Illustration	Street View	Problem Description	Optimization Strategy Illustration	Optimization Strategy
		Illegal vehicle parking on sidewalks		Integrate seating with bike parking to regulate disorderly parking and prevent vehicle encroachment
		Sidewalk too narrow for non-motor vehicle parking		Implement traffic control to restrict non-motor vehicle parking and restore pedestrian space
		Redundant municipal utility boxes on sidewalks		Relocate utility boxes and pipelines underground to free sidewalk space

Table 8. *Cont.*

Problem Illustration	Street View	Problem Description	Optimization Strategy Illustration	Optimization Strategy
		Wayfinding signage occupying the sidewalk		Move signage to facades to free sidewalk space
		Discontinuous sidewalks with non-motor vehicle encroachment and pedestrian–motor vehicle conflict		Use tidal lane management to temporarily convert part of the motor vehicle lane into pedestrian space during peak non-motor traffic hours
		Street trees encroaching on pedestrian space		Replace large-diameter trees with hierarchical greening to reduce motor vehicle impact on pedestrian activity without lowering GVI

6.2. Improving the Spatial Quality of Streets

Based on the analysis results, street space quality issues within the study area are categorized into five types. Specific strategies for improving street space quality are summarized in Table 9.

Table 9. Strategies for improving street space quality.

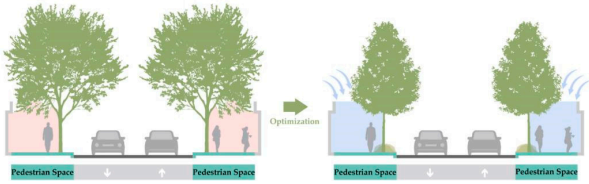
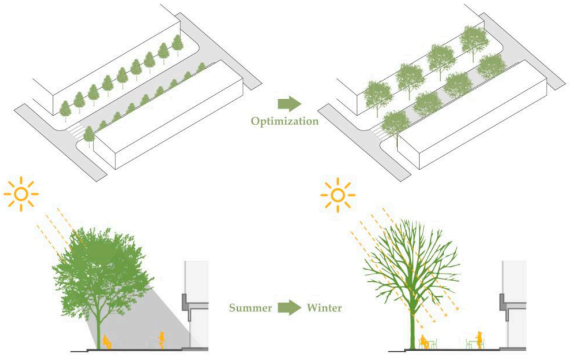
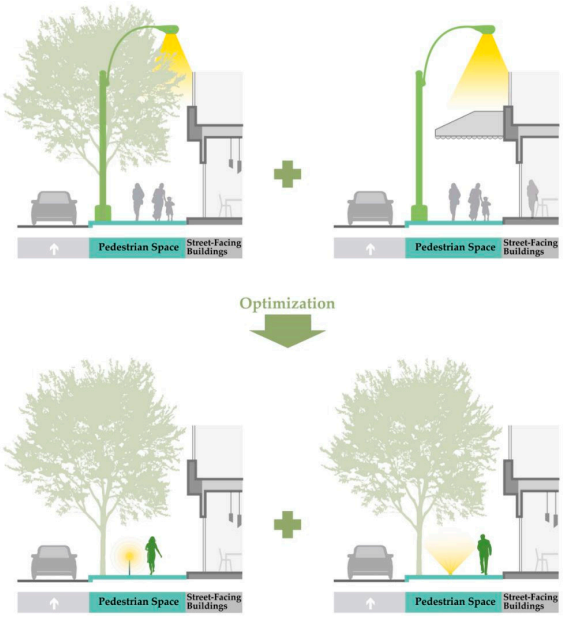
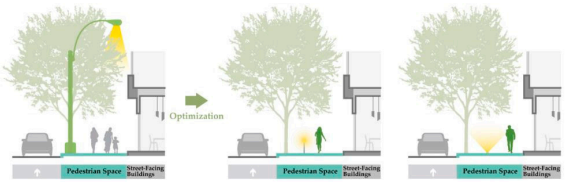
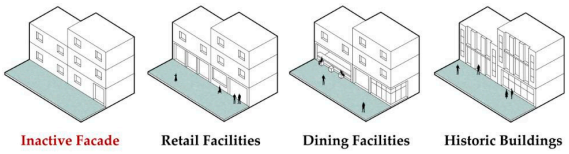
Problem Description	Diagram of Issues and Strategies	Optimization Strategy
Excessive GVI and low SVF		Replace large-canopy trees with a greening system of small trees, shrubs, and groundcover to maintain an appropriate GVI while improving SVF
Excessive SVF and low GVI		Replace small high-density trees with large low-density trees (e.g., plane trees) to provide summer shade and allow winter sunlight in pedestrian spaces

Table 9. *Cont.*

Problem Description	Diagram of Issues and Strategies	Optimization Strategy
Excessive GVI and low NI		Tree canopies and awnings block lighting; low-mounted fixtures help restore nighttime illumination
Low FT and NI		Closed facades and high windows limit indoor light spill; open ground-floor interfaces enhance street illumination
Low FT		Shops, supermarkets, and restaurants can enhance facade transparency through glass curtain walls, while historic buildings can reduce inactive facades by refining facade details

6.3. Optimizing Street Service Functions

Although the planning structure of the study area has been clearly defined in the Planning System for Historic and Scenic Districts in Wuhan's Central Urban Area, field investigations and the Wuhan City Master Plan Map (Figure 8) reveal that several streets within the district still exhibit a high degree of functional disorder. To enhance the district's walkability, optimization strategies for street-level service functions are proposed from two perspectives: the rational distribution of commercial types and the improvement of functional diversity along the streets.

1. Rational allocation of commercial functions based on existing cultural and tourism resources

Develop a distinctive commercial service route by leveraging the existing cultural and tourism resources within the study area:

- The building fabric along Zhongshan Avenue has been relatively well preserved, with the northern section retaining a large number of arcade buildings. By drawing on the cultural legacy of this century-old commercial street, it is possible to develop a distinctive arcade-style commercial corridor;
- Lihuangpi Road and Luojiashan Street have undergone pedestrianization, resulting in pedestrian spaces that are free from motorized traffic interference and suitable for the development of pedestrian commercial routes.

- Yanjiang Avenue is built along the river and benefits from a prime geographical location, making it suitable for the development of a riverside business route.
- A large number of historic and cultural buildings are preserved along the central section of Shengli Street, as well as Poyang Street and Dongting Street. These resources should be reasonably utilized to develop a cultural experience route supported by relevant cultural industries, in order to highlight the cultural identity of the district.

2. Enrich street-level service facilities and enhance functional diversity

Service facility types should be appropriately diversified based on actual street conditions to enhance street-level convenience:

- The ground floors of buildings within residential land use areas can accommodate daily service facilities such as clinics, fruit-and-vegetable markets, repair stations, and convenience stores to meet residents' everyday needs.
- Large supermarkets should be uniformly located on one side of the block to meet the needs of the ten-minute living circle, while avoiding damage to the overall street fabric of the historical and cultural district.
- On streets with a high concentration of historic buildings, cultural facilities should be prioritized. Other types of daily service facilities may be added where appropriate, as long as they do not compromise the overall cultural atmosphere of the street.

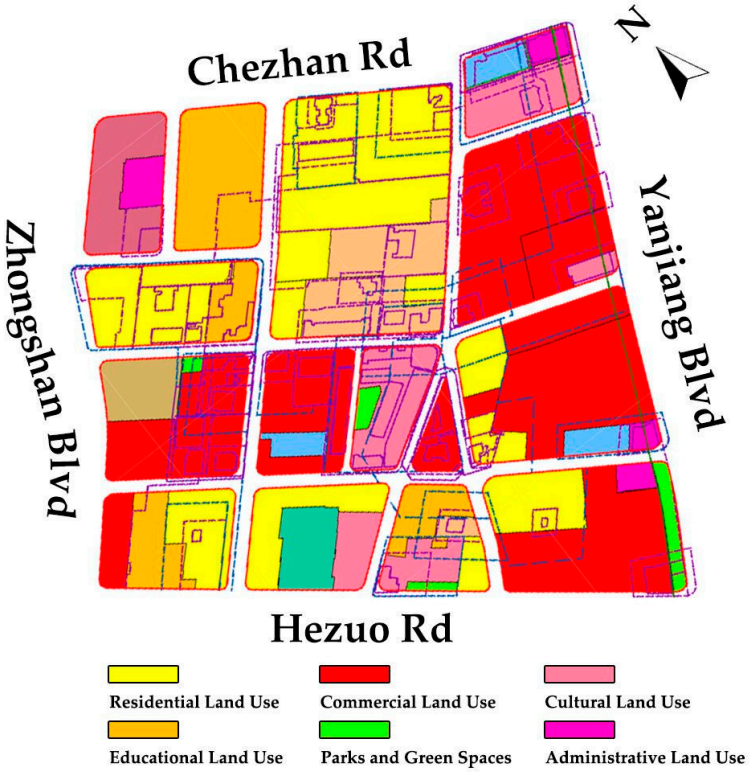


Figure 8. Current land use classification within the study area.

6.4. Harmonizing the Historical Character of the District

Based on the results of the quantitative analysis, the former Russian concession in Hankou exhibits a serious loss of historical character continuity. This is reflected in the stylistic disparity between certain buildings and the facades of adjacent historic structures, resulting in severe visual fragmentation along the streets. In addition, the design of municipal facilities on some streets is inconsistent with the overall historical appearance of the district. To improve the visual coherence and stylistic harmony of the district, two strategies are proposed: repairing fragmented urban fabric and introducing cultural symbols.

1. Repairing Fragmented Urban Fabric

- Unified facade renovation: Employ materials, colors, window types, and other design elements that are compatible with the surrounding historic architecture to reduce stylistic conflicts and ensure the continuity of the historical atmosphere.
- Transitional design: Introduce gradual visual transitions between historic and modern buildings. For example, commercial structures can adopt materials and decorative details similar to those found in adjacent historical buildings to avoid abrupt stylistic breaks.
- Enhanced facade detailing: Modern buildings may incorporate traditional architectural elements—such as porches, arches, or cornices—into their facades to strengthen overall visual consistency along the street.
- Color palette coordination: Apply color schemes commonly found in the historical district or use natural and muted tones to unify the visual appearance of the area and minimize perceptual dissonance.

2. Introducing Cultural Symbols

- Wayfinding signage enhancement: Install wall-mounted directional signs that align with the architectural texture of historic buildings, improving visual coordination while freeing up pedestrian space.
- Utility box improvement: Use perforated aluminum panels or graphic wraps that incorporate local historical and cultural elements to visually integrate utility boxes with the surrounding environment.
- Bus stop design optimization: Design bus stops using forms and materials compatible with the historical character of the district. In addition to standard signage, consider integrating relief sculptures, historical narratives, or other localized cultural elements into the design.
- Lighting facility enhancement: Select lighting fixtures whose forms and materials reflect the historical identity of the street. Beyond conventional forms, consider embedded lighting systems that incorporate cultural motifs to enhance both function and aesthetic continuity.

7. Conclusions and Future Work

This study developed a street walkability evaluation framework tailored to historical and cultural districts by integrating multi-source data and applied it to the former Russian concession in Hankou. The framework was used to systematically assess the walkability levels of streets within the study area. The results indicate that highly walkable streets are primarily concentrated in the core tourism zone and show significant spatial overlap with the distribution of historical buildings. Streets of higher classification also exhibit relatively high walkability due to well-developed infrastructure and strong network connectivity. In contrast, residential streets located deeper within the district generally demonstrate lower walkability, mainly due to narrow spatial layouts, inadequate facilities, and imbalanced right-of-way allocation. Based on the evaluation results, three representative street pairs were selected for comparative analysis. Four common issues were identified: insufficient effective walking width, poor quality of street space, disordered street-level service functions, and distortion of historical features of the neighborhood. Corresponding optimization strategies were proposed to address these problems, aiming to provide valuable references for the preservation and renewal of historical and cultural districts.

Despite the above contributions, this study still has certain limitations. First, the evaluation framework primarily focuses on the physical characteristics of street spaces and has not yet fully incorporated social attributes that may influence walking behavior—

such as the needs of specific groups (e.g., people with disabilities), income levels, and educational backgrounds. Second, although self-collected street view imagery was used to compensate for the limitations of open-source data—such as low timeliness and missing segments—the requirements related to equipment and image precision have constrained the scalability of data collection. Third, in terms of measurement methods, conventional semantic segmentation models are designed for standard urban street environments and have difficulty adapting to the complex street-level spatial environments of historical and cultural districts, which affects recognition accuracy.

Future research could incorporate more diverse social dimension data, such as mobile signaling and social media data, to enhance the equity and responsiveness of walkability evaluations. The quality of street view data can also be improved by integrating image sources like Flickr. Furthermore, a dedicated AI-based semantic recognition platform tailored to the spatial characteristics of historical and cultural districts could be developed to advance street walkability assessment toward higher precision, greater intelligence, and increased systematization.

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