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Multi-level Tourism Spatial Structure and Its Coupling with Transportation Accessibility in Wuhan

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KEYWORDS

Tourist Attractions;
Spatial Structure;
Public Transport Accessibility;
Multi-Tiered Tourism Structure;
Comparative Analysis

ABSTRACT

The hierarchical structure and functional types of urban tourist attractions are fundamental to shaping tourism spatial organization, while public transport accessibility determines service efficiency and spatial equity. This study investigates the coupling between tourism spatial patterns and public transport accessibility in Wuhan, China, focusing on Grade A and popular unrated attractions. Using a GIS-based framework integrating origin–destination (OD) cost matrix modeling and non-parametric statistical tests, we examine spatial distribution and accessibility differences from both rating and functional perspectives. Results show that: (1) Grade A attractions are largely located in suburban areas with low accessibility, whereas popular attractions cluster in central districts with superior transit, forming a “high-grade–low-accessibility, low-grade–high-accessibility” mismatch; (2) popular attractions leverage metro and bus networks to create multiple high-accessibility cores with concentrated and stable accessibility; (3) natural attractions exhibit the weakest accessibility due to dispersed locations and limited transport connectivity, in contrast to cultural and urban leisure attractions. These findings reveal a grade-oriented planning pattern that induces transport service imbalance. A transportation-adaptive strategy is recommended to enhance suburban high-grade accessibility and improve overall system performance. Policy implications include bridging suburban transit gaps, strengthening rail and transfer connectivity for central Grade A attractions, and developing function-specific transport strategies to promote coordinated evolution of urban tourism and transport systems.

INTRODUCTION

In recent years, against the backdrop of insufficient global economic recovery momentum and accelerated regional industrial transformation, tourism has emerged as a key engine for stimulating consumption, promoting employment, and boosting domestic demand. Governments worldwide have successively introduced policies to support the recovery of local tourism markets and strengthen the service linkage between transportation systems and tourist attractions. For example, the United Kingdom implemented the *Tourism Recovery Plan*,

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which emphasizes the integration of transport with landmark attractions, the issuance of tourism passes and discounts, and tax incentives to accelerate the return of international visitors. Australia has promoted the recovery of the tourism industry through fiscal subsidies and strategic planning, with a particular focus on improving regional tourism infrastructure and fostering the development of innovative experiential products.

In China, the Wuhan Municipal Bureau of Culture and Tourism released the *Measures to Further Stimulate Tourism Consumption Potential and Promote the Recovery and Development of the Tourism Industry in Wuhan*, proposing measures such as financial support, tourism-benefit activities for citizens, optimization of tourism product supply, strengthening the intermediary role of travel agencies, and developing core tourism brands.

As a national central city and a comprehensive transportation hub in Central China, Wuhan possesses abundant tourism resources and a stable tourist flow. Its coordination between tourism spatial structure and the transportation system is regionally representative. In this context, tourism accessibility has gradually become a critical indicator for evaluating the efficiency of tourism resource utilization and the supporting capacity of transportation systems, directly influencing tourists' travel efficiency, destination choice preferences, and tourism satisfaction (Wang Yajuan, 2022; Li et al., 2022). Nevertheless, current research still exhibits limitations in integrating the spatial structure of attractions, transportation accessibility, and typological differentiation, indicating the necessity of a multi-dimensional and systematic investigation to provide practical guidance for urban tourism spatial optimization and transport resource allocation.

LITERATURE REVIEW

Research on the spatial distribution and transportation accessibility of tourist attractions mainly falls into three major areas:

Spatial Structure of Tourist Attractions

Existing studies generally recognize that urban tourist attractions demonstrate significant spatial agglomeration, especially high-grade scenic spots, which often form a "core–periphery" pattern along urban development axes, historical and cultural cores, or transportation nodes. Xie Shuangyu et al. (2019) analyzed the distribution of attractions in central Wuhan and found that lifestyle and cultural attractions are highly concentrated in the urban core, forming dense clusters. Liu Min and Hao Wei (2020) observed that high-grade attractions in Shanxi Province are mostly located in peripheral areas rich in cultural or ecological resources, whereas medium- and low-grade attractions are distributed around urban functional zones. Fan et al. (2016) applied road network analysis to evaluate the accessibility of urban green spaces, expanding the methodological framework for spatial landscape analysis. Widely used spatial analysis methods include kernel density estimation, nearest neighbor index (Zeng et al., 2019; Wang et al., 2017), and Ripley's K function (Xu et al., 2017), which effectively capture multi-scale clustering characteristics (Zheng et al., 2016).

Tourism Accessibility Research

Accessibility is a key indicator for evaluating the level of transport services and spatial efficiency in tourist destinations, and it represents a core topic in both urban transportation planning and tourism geography (Pan Jinghu et al., 2014). Domestically, Li Shengchao and Huang Hua (2023) examined the role of Xi'an's metro system in improving the accessibility of tourist attractions and concluded that the density of transport nodes significantly enhances public transportation service levels in the urban core. Ye Tong (2024) integrated origin–destination (OD) data to reveal the coupling mechanism between the accessibility of commercial centers and urban spatial structure in Nanjing. Internationally, Aranburu et al. (2016) highlighted that the centrality of tourist resources and urban accessibility jointly influence tourists' spatial behavior and destination perception, while Chen et al. (2020) employed complex network models to analyze the Guizhou expressway system, revealing the potential coupling between service areas and tourism spaces.

Interactions Between Attraction Type and Accessibility

Li Weiwei et al. (2023) emphasized that transportation accessibility is a decisive factor in attracting visitors to urban attractions. Wang Yongming et al. (2025) proposed that tourist spaces should be optimally configured from the perspective of the coordinated evolution of hierarchy, type, and transportation systems. Li Li et al. (2020), based on Chengdu POI data, revealed that commercially oriented leisure attractions tend to form large-scale clusters, whereas natural attractions are more spatially dispersed due to site selection constraints. Similarly, Sun et al. (2024) found in Qingdao that natural attractions suffer from poor accessibility due to weak transportation coverage, whereas dining-related attractions achieve efficient accessibility by leveraging dense public transit networks.

In summary, while substantial progress has been made in understanding the spatial distribution characteristics of tourist attractions, accessibility assessment, and typological differences, three main gaps remain:

1) Research scope bias: Most studies focus on Grade-A attractions while neglecting the role of popular non-rated attractions within the urban tourism network;
2) Dimensional limitation: Spatial structure analyses are often single-dimensional, lacking systematic exploration of the "grade–type–transportation" triadic relationship;
3) Mechanism insufficiency: Investigations into the matching mechanisms between attraction types and accessibility remain largely descriptive, with limited quantitative comparisons and conceptual framework construction.

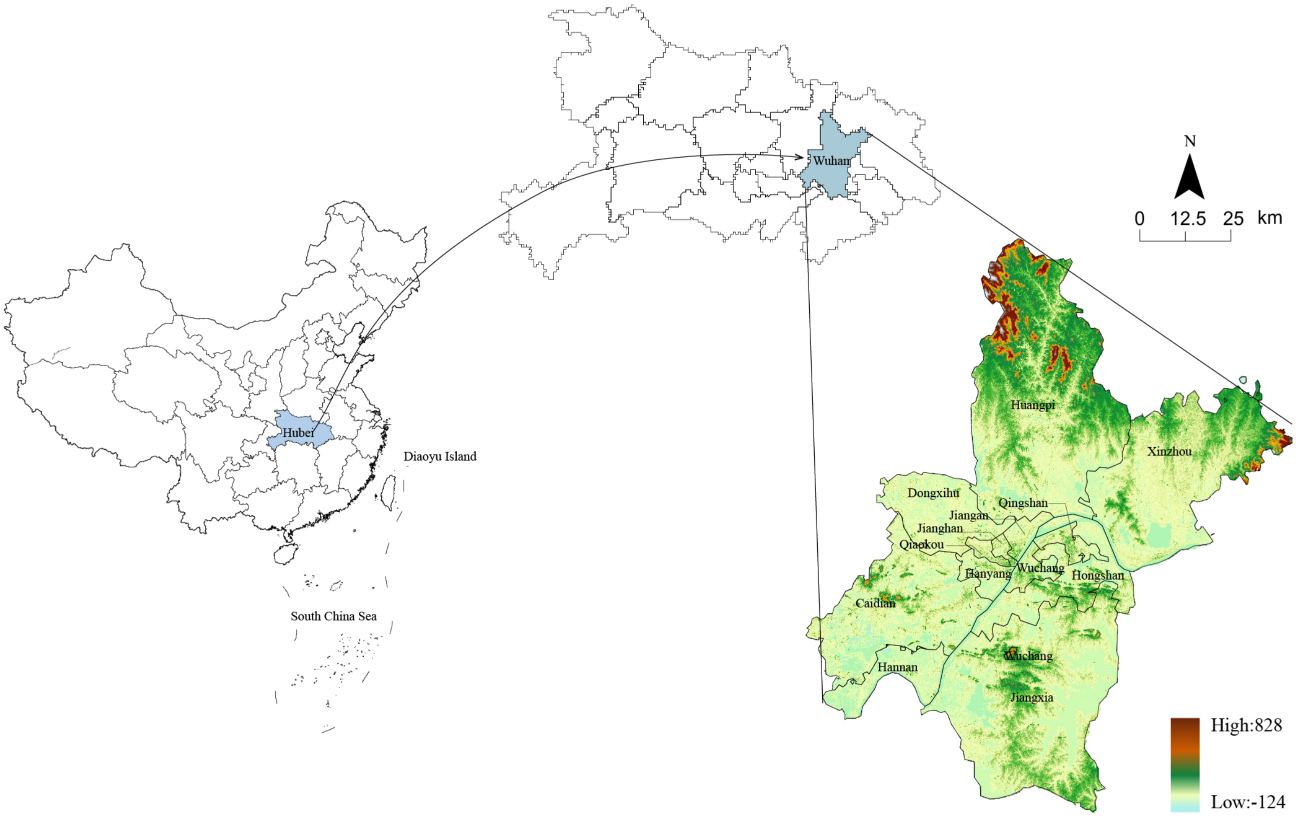

Figure 1 I Geographical Location of Wuhan

To address these gaps, this study takes Wuhan as the case area, integrating the dual perspectives of attraction grade and functional type. A multi-level analytical framework of urban tourism spatial structure is constructed, combining OD-based accessibility modeling and non-parametric statistical tests to systematically examine the spatial distribution and accessibility differentiation of attractions across grades and types, thereby providing a scientific reference for urban tourism spatial optimization and transport resource allocation.

STUDY AREA AND METHODOLOGY

Overview of the Study Area

Wuhan City is located in central China (**Figure 1**), serving as one of the core cities of the Yangtze River Midstream Urban Agglomeration and a major national comprehensive transportation hub and tourist destination. The city administers 13 administrative districts, with seven districts—Jiang'an, Jianghan, Qiaokou, Hankou, Wuchang, Qing Shan, and Hong Shan—forming the urban core area. By 2025, Wuhan will have 57 Grade A tourist attractions, as well as numerous unrated popular tourist spots that are widely visited by tourists but have not received official ratings (hereinafter referred to as "popular spots"), whose spatial distribution is shown in the map at (**Figure 2**). In terms of public transportation, Wuhan has constructed 12 subway lines and 592 bus routes, forming a multi-tiered public transportation network that integrates subways and buses (**Figure 3**). Wuhan Station, Hankou Station, Wuchang Station, and Tianhe International Airport, among other major comprehensive transportation hubs, collectively form the city's primary gateways for tourism, supporting interregional passenger flow and enhancing tourism travel efficiency.

Data Sources

The scenic spot data used in this study includes two categories: Grade A scenic spot data is sourced from the official websites of the Hubei Provincial Department of Culture and Tourism and the Wuhan Municipal Bureau of Culture and Tourism; popular scenic spot data is collected from the Dianping platform, with data retrieval time set to January 2025, and the screening criteria being a total of over 1,000 user reviews. Python was used to obtain relevant POI data within the Wuhan City area. After manual verification, deduplication, and spatial positioning, a total of 45 valid popular scenic spots were ultimately identified. All scenic spot spatial data were obtained via the Gaode Maps API in WGS-84 coordinates, imported into the ArcGIS platform for spatial encoding and database creation. The classification of attractions was based on the "Classification, Survey, and Evaluation of Tourism Resources" (GB/T 18972-2017) (2017) and related research findings (Huang Zhenfang et al., 2011). Considering the attraction names, Dianping tags, and actual functions, they

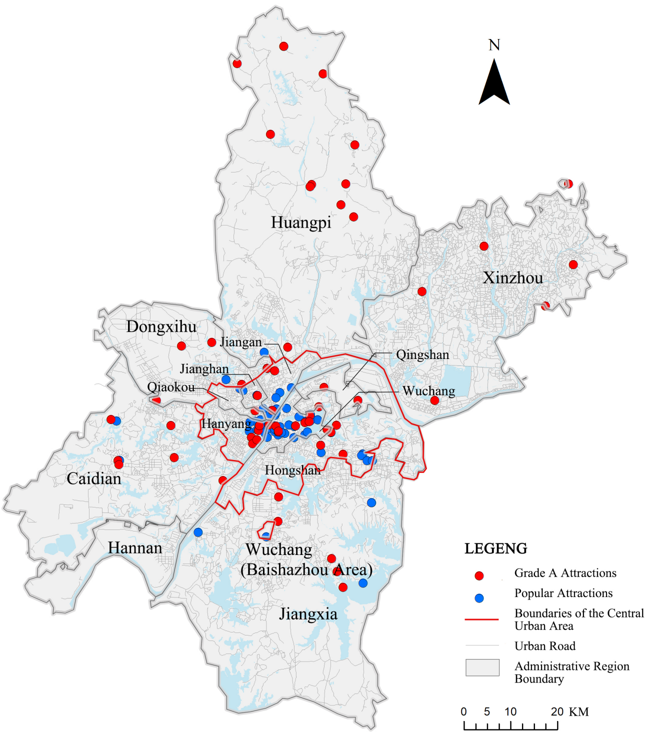

Figure 2 | Administrative Districts and Spatial Distribution of Tourist Attractions in Wuhan

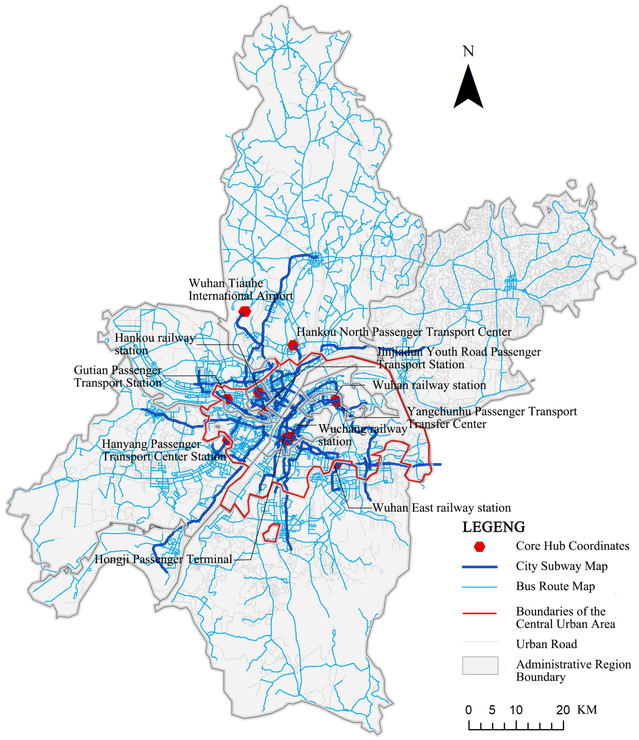

Figure 3 | Wuhan Public Transport Network and Major Transportation Hubs

were categorised into four types: cultural, natural, urban leisure, and miscellaneous.

Transportation data includes Wuhan rail transit line data sourced from the Wuhan Metro Group, bus route data from the 8684 Bus Network, and basic road network data from the OpenStreetMap official website, with data retrieval conducted in January 2025. After data format conversion and topological error correction, the data were uniformly imported into an ArcGIS network dataset. The study selected major transportation hubs such as Wuhan Station, Wuchang Station, Hankou Station, Wuhan East Station, and Tianhe Airport as starting points for travel, and constructed a tourist transportation network based on multiple public transportation modes.

Research Methods

To explore the relationship between the spatial structure of tourist attractions and public transport accessibility, this study employs spatial analysis to identify the distribution characteristics of attractions, applies OD accessibility models and non-parametric statistical tests to analyse accessibility patterns, and quantifies differences in grades and types. At the spatial scale, the analysis is conducted at two levels: the metropolitan area and the central urban area, taking into account both overall trends and core area details. At the structural dimension, starting from attraction ratings and functional types, the spatial distribution differences are examined to further reveal the transportation service mismatches caused by different structural characteristics.

Spatial Pattern Analysis

Based on GIS, kernel density estimation (KDE) can be used to analyse the spatial aggregation intensity of scenic spots, with the calculation formula as follows:

$$f(x) = \frac{1}{nh^2} \sum_{i=1}^{n} K\left(\frac{d(x,\ x_i)}{h}\right) \tag{1}$$

Where $f(x)$ denotes the kernel density value at location x, n is the total number of sample points; h is the bandwidth, K is the kernel function, and $d(x, x_i)$ represents the distance between location x and the sample point x_i .

Additionally, the average nearest neighbour index (ANN) is used to measure the spatial clustering degree, with the formula:

$$R = \frac{\overline{r}_{obs}}{\overline{r}_{exp}}, \quad \overline{r}_{exp} = \frac{1}{2\sqrt{\lambda}} \tag{2}$$

Where $\overline{r}_{obs}$ denotes the observed average nearest-neighbor distance denotes the observed average nearest-neighbor distance, $\overline{r}_{exp}$ is the expected distance under a random distribution, and λ represents the point density. If R = 1, the points exhibit a random distribution; if R > 1, the points tend to be uniformly dispersed; if R < 1, the points tend to be clustered.

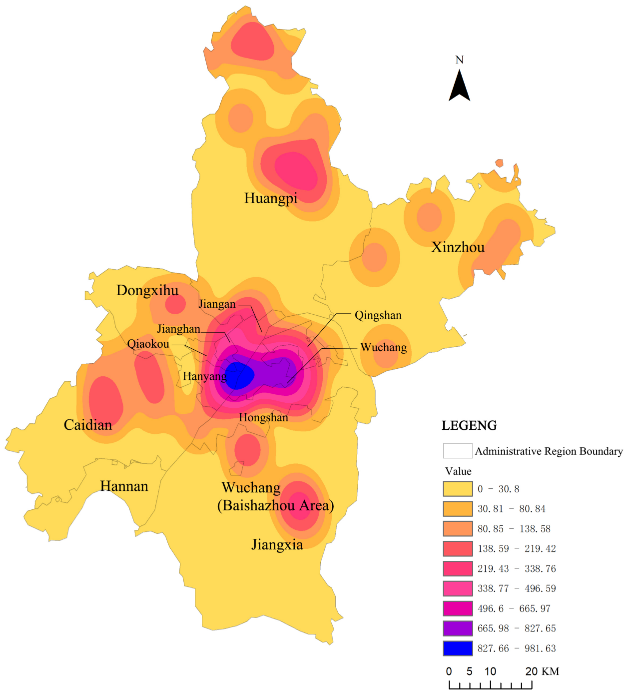

Figure 4 l Kernel Density Distribution of A-Level Tourist Attractions in Wuhan

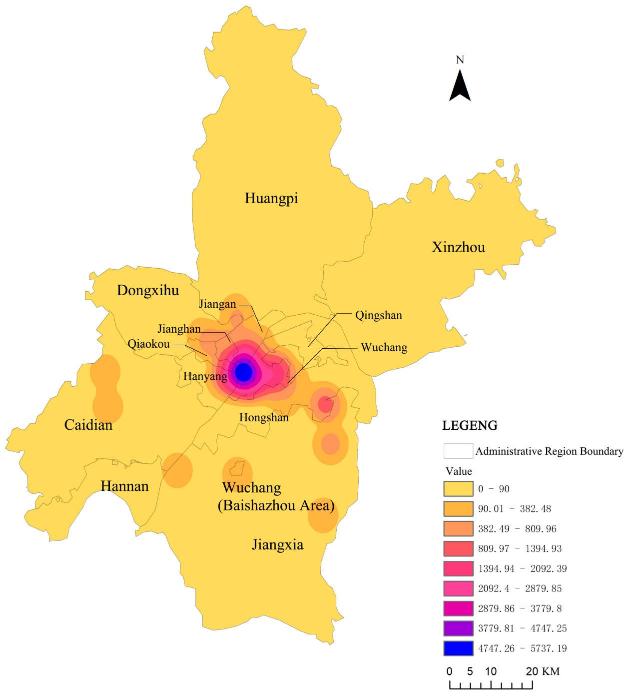

Figure 5 l Kernel Density Distribution of Popular Tourist Attractions in Wuhan

Public Transportation Accessibility Model

The public transport accessibility is calculated using the OD cost matrix model based on ArcGIS Network Analyst, with major transportation hubs in Wuhan as the starting points and tourist attractions as the destinations. The model integrates the metro, bus, and shared bicycle networks, assigning corresponding travel speeds to different transport modes (metro: 35 km/h, bus: 18 km/h, shared bicycle: 12 km/h), and optimises the route planning based on the shortest travel time. To simplify the model, transfer penalties (Wang Lian-zhen et al., 2025), waiting times, and walking transfer times were not considered, reflecting the ideal state of public transport travel costs. The results are closer to an objective estimate of structural differences. The formula for the shortest public transport travel time is as follows:

$$T_{sj} = \min\left(\sum\nolimits_{k \in R_{sj}} t_k\right) \quad (3)$$

Where T_{sj} represents the shortest public transportation travel time from transportation hub s to tourist attraction j, R_{sj} denotes the set of all available public transportation paths, and t_k represents the travel time for path segment k.

Non-Parametric Statistical Analysis

To verify the statistical significance of differences in accessibility between different grades and types of scenic spots, the Mann-Whitney U test and Kruskal-Wallis H test were introduced. The former was used to compare the accessibility time differences between two categories of grades (Grade A and popular), while the latter was used for inter-group accessibility analysis among multiple types of scenic spots. All tests were conducted at a significance level of 0.05, and data analysis was implemented using Python.

RESULTS ANALYSIS

Citywide Spatial Distribution and Accessibility Differences of Tourist Attraction Grades

At the city scale, tourist attractions in Wuhan exhibit distinct spatial hierarchical differentiation characteristics. The results of the kernel density analysis, as shown in **Figure 4** and **Figure 5**, indicate that popular attractions are highly concentrated and clustered in the central urban area, while A-level and above attractions are more widely distributed in the peripheral areas, such as Huangpi District, Jiangxia District, and Xinzhou District, with relatively dispersed spatial distribution.

The nearest neighbour index analysis further validates the results. **Table 1** shows that the R value for popular tourist attractions is 0.664 and the Z value is -5.186, indicating significantly higher clustering than Grade A tourist attractions (R = 0.810, Z = -2.788). This reflects that popular tourist attractions tend to cluster within the city, while Grade A tourist attractions are often dependent on natural resources or historical sites and have a more dispersed layout. This distribution structure reveals a hierarchical spatial structure characterised by "higher-level spillover and lower-level cohesion."

In addition, the analysis results of the number and grade distribution of scenic spots in each administrative district (**Figure 6**) show that the main urban areas such

Table 1 | Spatial Proximity Index of Grade A and Popular Tourist Attractions in Wuhan

Sightseeing Spot Type	Proximity Index (R)	Z-test Value	Distribution Type
Grade A Scenic Spots	0.81	-2.788	Significant clustering
Popular tourist attractions	0.664	-5.186	Significant clustering

Note: A nearest neighbour index (R value) less than 1 indicates a spatial distribution with a clustering trend; the larger the absolute value of Z, the more significant the clustering trend.

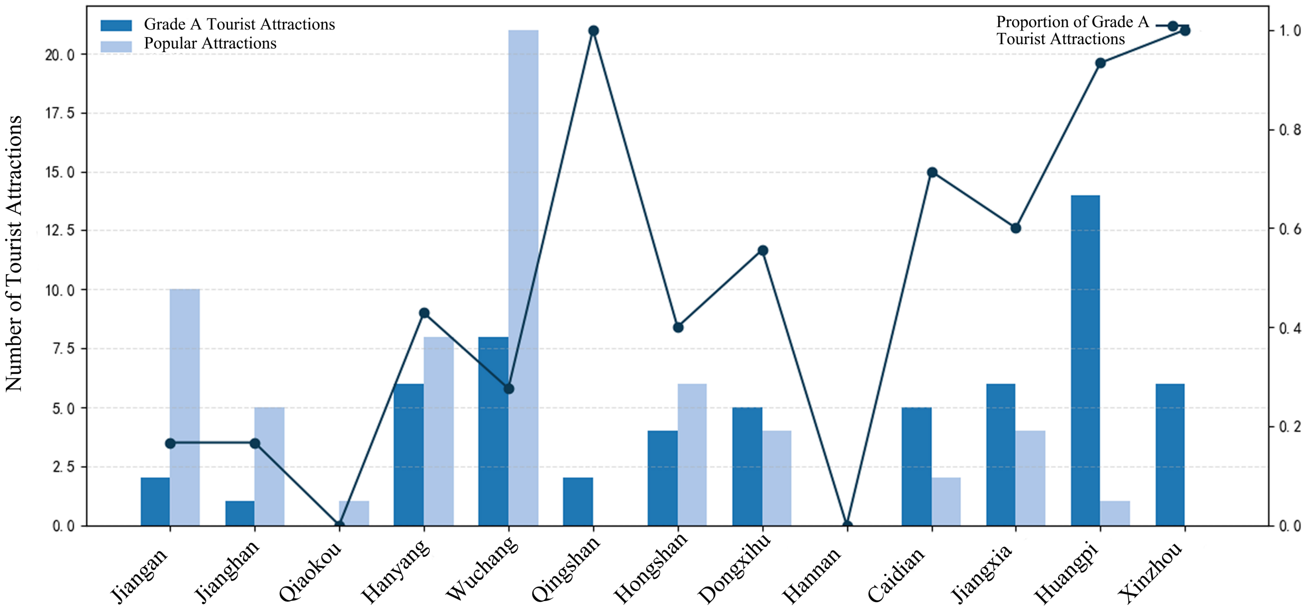

Figure 6 I Number of Tourist Attractions and Proportion of Grade A Sites by Administrative District in Wuhan

as Wuchang, Jiang'an, and Hanyang are dominated by popular scenic spots, with the proportion of Grade A scenic spots accounting for less than 40%; while the outer areas such as Huangpi, Jiangxia, and Xinzhou have a proportion of Grade A scenic spots generally exceeding 60%. This indicates that the main urban districts prioritise meeting residents' micro-tourism and daily leisure needs, forming a "lifestyle-oriented" tourism network centred around popular attractions; whereas the outlying areas serve the city's overall tourism image and brand functions, concentrating A-level and above attractions such as Mulan Mountain and Mulan Rose Garden.

Taking major transportation hubs in Wuhan as starting points, this study integrates various transportation modes such as metro, bus, and shared bicycles. Using ArcGIS's origin-destination (OD) cost matrix analysis, the shortest travel times to Grade A and non-Grade A scenic spots were calculated. The natural neighborhood method was then employed to generate a spatial distribution map of public transportation accessibility. **Figure 7** and **Figure 8** show that in terms of accessibility, popular scenic spots generally have higher accessibility, shorter travel times, and more compact spatial distribution; while Grade A scenic spots have overall poor accessibility and significantly longer travel times, especially in outlying areas such as Huangpi, Xinzhou, and Jiangxia, where weak transportation connectivity has formed large-scale low-accessibility zones. Conversely, popular attractions exhibit a "high accessibility" distribution pattern centred around the urban core. This spatial differentiation reflects the mismatch between the layout of attractions in Wuhan and its public transport network: high-grade attractions are located in remote areas with inadequate transport services, while popular attractions rely on rail and bus networks, giving them significant accessibility advantages. Box-and-whisker plots and histograms (**Figure 9** and **Figure 10**) show that the accessibility distribution of popular tourist attractions is concentrated with low variance, indicating strong support from public transportation in the central urban areas. In contrast, certain Grade A tourist attractions situated in remote suburban areas, or characterized by a high degree of spatial enclosure, exhibit low operational efficiency and limited visitor mobility.

Coupling Analysis of Attraction Grades and Public Transport in the Central Urban Area

Based on the city-wide analysis, we further focused on the grade differences within the central urban area and used the natural neighborhood interpolation method to draw accessibility spatial distribution maps. This method is suitable for scenarios with unevenly dis-

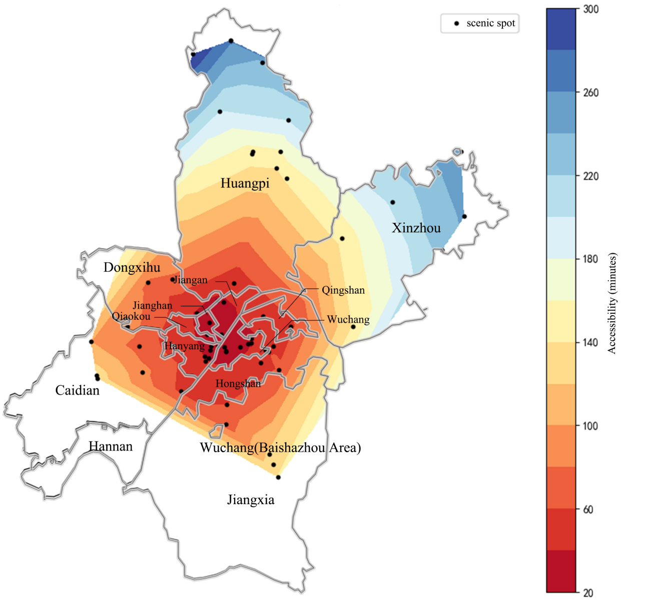

Figure 7 | Interpolated Public Transport Accessibility of A-Level Tourist Attractions in Wuhan

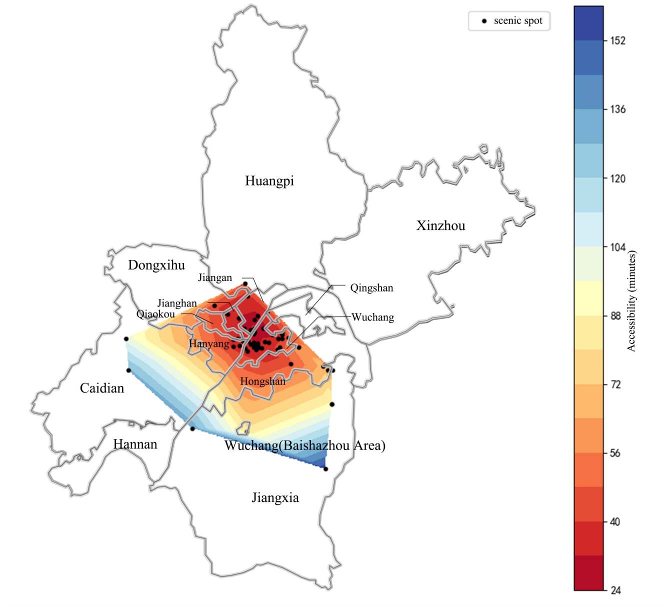

Figure 8 | Interpolated Public Transport Accessibility of Popular Tourist Attractions in Wuhan

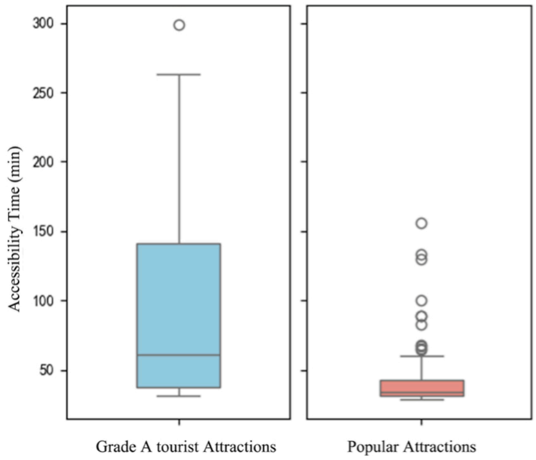

Figure 9 | Boxplot of Public Transport Accessibility by Tourist Attraction Grade

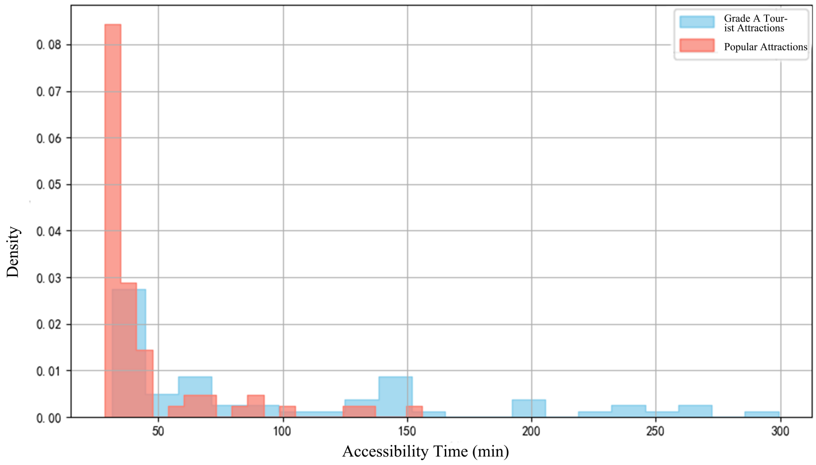

Figure 10 | Histogram of Public Transport Accessibility by Tourist Attraction Grade

tributed data points, as it can more accurately reflect local spatial trends and avoid the over-reliance on spatial autocorrelation intensity inherent in the Kriging method.

The accessibility distribution of Grade A tourist attractions is shown in **Figure 11**. Overall, it presents a "point-axis" pattern, dominated by rail transit and bus trunk lines, exhibiting high accessibility. Among them, Grade A tourist attractions in the Wuchang central area and around Jianghan Road are mostly within a 30-minute travel time zone; however, in areas with insufficient rail coverage, such as the southern part of Hongshan, travel times are relatively longer, resulting in significantly reduced accessibility. The accessibility distribution of popular tourist attractions, as shown in **Figure 12**, indicates that most are located in areas with high rail transit coverage, forming multiple "high accessibility core zones", with overall accessibility superior to that of Grade A tourist attractions.

To quantitatively compare the accessibility differences between the two types of tourist attractions, **Figure 13** The box plot shows that the median accessibility time for popular tourist attractions is 32 minutes, with an interquartile range (IQR) of 10 minutes, few outliers, and a concentrated distribution; for Grade A tourist attractions, the median accessibility time is 36 minutes, with an IQR of 14 minutes, and multiple high-value outliers, indicating greater variability in their transportation accessibility. Significance tests indicate a statistically significant difference between the two groups (Mann-Whitney $U = 979.000$, $p = 0.008$). This phenomenon may be attributed to three factors: first, popular attractions are often located near residential areas and are significantly influenced by high-coverage rail and bus networks;

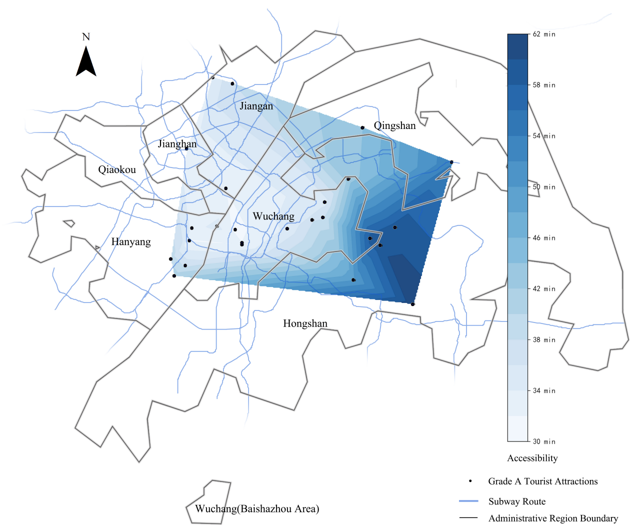

Figure 11 I Interpolation Map of Public Transport Accessibility for A-Level Tourist Attractions in the Central Urban Area of Wuhan

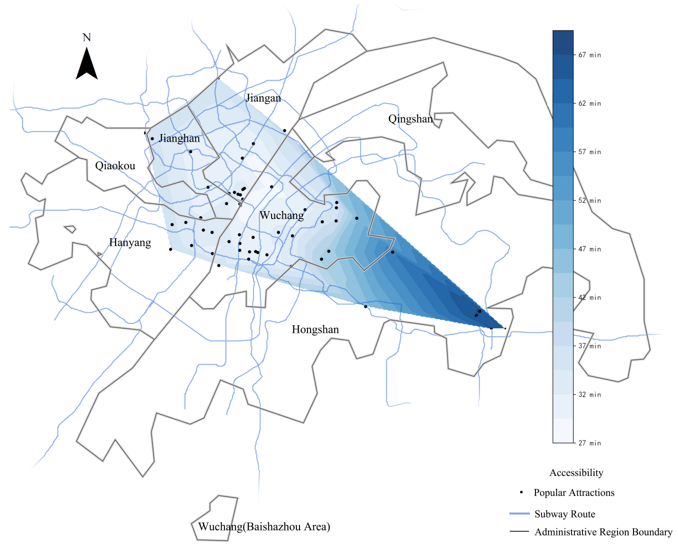

Figure 12 I Interpolation Map of Public Transport Accessibility to Popular Scenic Spots in Wuhan's Central Urban Area

Note: The scenic spots in the Bashazhou area of Wuchang District were excluded from the central urban area interpolation analysis due to their peripheral location and limited number.

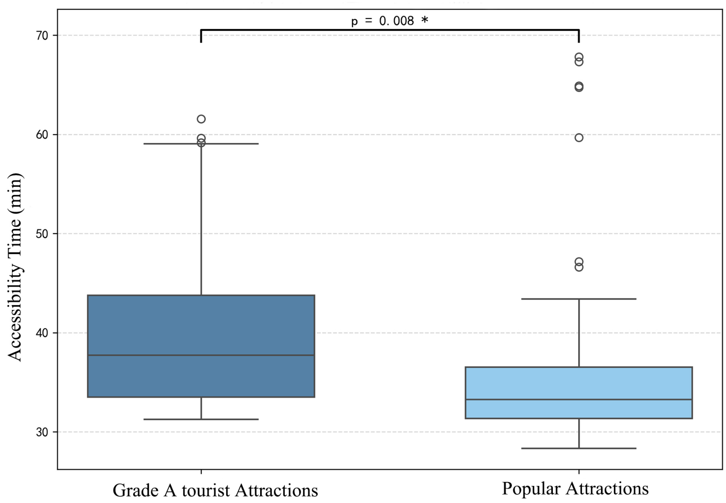

Figure 13 I Box Plot of Public Transport Accessibility by Tourist Attraction Grade in Wuhan's Central Urban Area

Table 2 | Summary Table of Mann-Whitney U Test Results for Public Transportation Accessibility of Different Grade Scenic Spots in Wuhan

Indicator	Scenic spots of Grade A and above	Popular Scenic Spots
Average (minutes)	37.7	33.29
Median (minutes)	36.00	32.00
Standard deviation	7.21	9.82
Minimum value (minutes)	26.00	15.00
Maximum value (minutes)	57.00	64.00
Mann-Whitney U value	979.000	—
p-value	0.008	—

Note: Data are based on the shortest travel time calculated using the OD cost matrix (unit: minutes). According to the Mann-Whitney U test, the differences in travel time between the two types of attractions are statistically significant ($p < 0.01$).

Table 3 | Descriptive Statistics of Public Transport Accessibility by Scenic Spot Type

Sightseeing Spot Type	Sample Size	Average (minutes)	Median (minutes)	Standard Deviation	Minimum	Maximum
Cultural	39	61.55	33.67	61.30	28.33	263.29
Comprehensive or other categories	10	38.72	35.71	10.80	28.34	64.74
Natural Sciences	54	86.64	60.60	67.49	28.91	299.26
Urban leisure	20	64.89	36.49	54.79	31.32	236.24
Kruskal-Wallis H test						
H = 11.00, p = 0.012						

Note: Data are based on the OD cost matrix model to calculate the optimal travel time (unit: minutes). H values and p values are derived from the Kruskal-Wallis H test, used to determine overall differences between different types of attractions.

Table 4 | Mann–Whitney U Test of Public Transport Accessibility by Tourist Attraction Type

Group 1	Group 2	U value	p-value	Significance
Natural	Cultural	1410	0.0054	**
Natural Sciences	General or other	404	0.0136	*
Nature	Urban Leisure Category	667	0.1236	ns
Urban Leisure Category	General or Other Category	121	0.3671	ns
Urban Leisure Category	Cultural	446	0.3742	ns
Cultural	General or other category	194	0.9901	ns

*Note: The test examines the differences in accessibility between pairs of attractions of the same type. * indicates $p< 0.05$, ** indicates $p< 0.01$, and ns indicates no significant difference. The significance level is set at 0.05.*

second, most are distributed around commercial centres or transportation hubs, which are inherently high-accessibility areas; third, public transportation planning prioritises densely populated areas, objectively improving their accessibility efficiency.

In summary, there is a clear inverse relationship between the grade of tourist attractions and public transport accessibility in the central urban area. The study suggests that tourism transportation planning should break away from the traditional logic of focusing on tourist attraction ratings, emphasize the value of popular tourist attractions as everyday tourism resources, and simultaneously improve transportation services in areas with weak infrastructure around some Grade A tourist attractions to enhance the balance and adaptability of the public transport network (**Table 2**).

Spatial Distribution Patterns and Accessibility Characteristics of Tourist Attractions by Type in Wuhan

In addition to grade factors, the functional type of attractions also significantly influences their public transport accessibility. **Table 3** shows that natural attractions have the weakest accessibility, with an average accessibility time of 86.64 minutes, a median of 60.60 minutes, and a standard deviation of 67.49, indicating a dispersed distribution and uneven transportation access conditions. Cultural and urban leisure attractions have median accessibility times of 33.67 minutes and 36.49 minutes, respectively, with some individual high values but overall good accessibility. Comprehensive or other attractions have the shortest accessibility times and the smallest standard deviation, with their spatial distribution more concentrated in areas with convenient transportation.

The results of the Kruskal–Wallis H test (**Table 3**) indicate that there are statistically significant differences in travel times among different types of tourist attractions (H = 11.00, p = 0.012). Further Mann–Whitney U tests (**Table 4**) reveal that the differences between natural attractions and cultural attractions (p = 0.001), as well as natural attractions and comprehensive attractions (p = 0.035), are significant. The latter two types are mostly located in central urban areas with extensive rail coverage, resulting in higher public transport accessibility. Differences among other types are not statistically significant, although variations in the shape of their accessibility distributions can still be observed.

Overall, natural attractions are mostly located on the outskirts of cities, with poor connectivity and significantly weaker accessibility; urban leisure attractions rely on public transport and rail networks, resulting in higher accessibility levels; comprehensive attractions are concentrated around transportation hubs, offering clear advantages; and cultural attractions fall in the middle. **Figure 14** shows that urban leisure attractions have a concentrated accessibility distribution with peaks occurring earlier, indicating overall good accessibility; natural

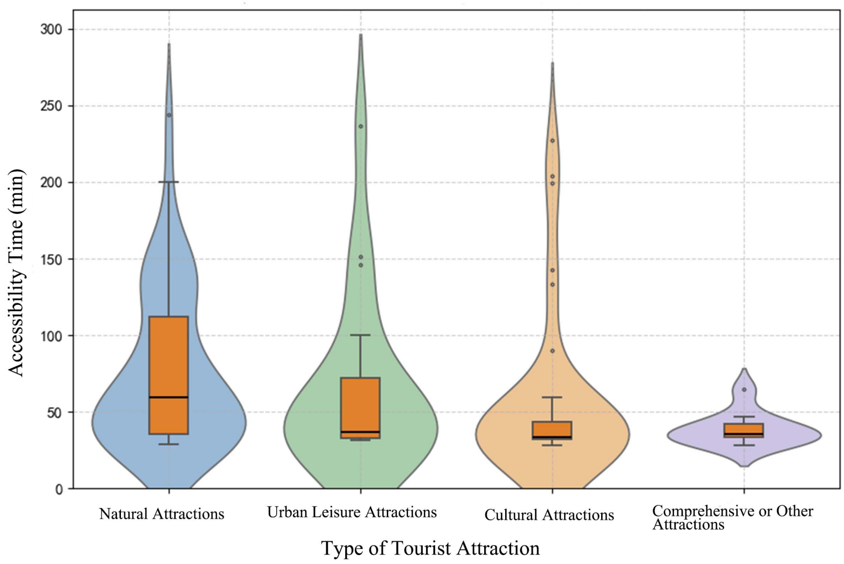

Figure 14 I Distribution of Public Transport Accessibility by Tourist Attraction Type

attractions are more dispersed, with obvious accessibility disadvantages; comprehensive or other types of attractions have a relatively concentrated accessibility distribution, primarily concentrated within 30 minutes, demonstrating certain accessibility advantages. Cultural attractions are at an intermediate level, with moderate accessibility, overall exhibiting a differentiated characteristic of "better accessibility for urban-type attractions and weaker accessibility for suburban attractions."

DISCUSSION

This study analysed the structural differences in public transport accessibility among tourist attractions in Wuhan from two dimensions: attraction rating and functional type. The results indicate that there is a significant mismatch between attraction ratings and transport accessibility in Wuhan's tourist space, manifested as a "higher-rated attractions with lower accessibility and lower-rated attractions with higher accessibility" paradox. Compared with Xie Shuangyu et al. (2019), who focused on the agglomeration characteristics of scenic spots in the urban core area, this study extends the analysis scale to the city level. It not only reveals the "grade mismatch" problem, where A-grade scenic spots expand to the periphery but their accessibility decreases, but also points out that popular non-A-grade scenic spots form multiple "highly accessible core areas" supported by the transportation network. In terms of transportation service analysis, Zhang Qi et al. (2015) emphasised that some high-grade tourist attractions in Wuhan exhibit a deviation between geographical accessibility and cognitive experience. This study uses an accessibility model based on OD cost-time to validate the spatial mechanism of this deviation: namely, that attractions' distance from major transportation arteries or lack of transfer support is the primary cause of their accessibility disadvantages. In terms of typological differentiation, the study found that urban leisure and commercial attractions, which rely on rail and bus trunk lines, have stronger accessibility stability; natural attractions, however, are at a disadvantage due to their dispersed distribution and weak transfer connections.

It should be noted that to simplify the calculation process, the OD accessibility model does not include transfer penalties, actual waiting times, or walking transfer durations. The results primarily reflect the structural accessibility costs under the theoretically optimal path. This may lead to an overestimation of accessibility in some areas with dense transportation nodes.

CONCLUSIONS

This study uses "scenic spot rating–functional type–transport accessibility" as the core analytical dimension, combining GIS spatial analysis, OD cost measurement, and non-parametric statistical methods to systematically explore the compatibility characteristics between scenic spot spatial distribution and transport services. From a multi-scale perspective, this study reveals the accessibility differences between scenic spots of different grades and types. Compared with previous studies that focused on a single grade or lacked type differentiation, this study further highlights the structural characteristics and type-oriented mechanisms of accessibility differences, providing a reference for improving urban tourism spatial organisation and public transport coordination.

This study draws the following conclusions: **(1)** There is a significant mismatch between scenic spot ratings and accessibility. High-grade scenic spots are predominantly located at the urban periphery, with generally low accessibility; popular scenic spots are concentrated in the central urban area with good rail transit coverage, exhibiting higher accessibility, forming a structural contradiction of "high grade—low accessibility, low grade—

high accessibility," reflecting spatial mismatches between the current scenic spot rating system and transportation services. **(2)** Spatial hierarchical differences exacerbate the uneven distribution of services. Within the municipal area, public transportation coverage is insufficient in peripheral regions, with prominent shortcomings in transportation services for high-grade attractions in distant urban areas; meanwhile, the central urban area forms multiple high-accessibility zones with dense distributions of popular attractions and superior transportation conditions, illustrating structural inconsistencies between tourism spatial organisation and the transportation system. **(3)** Functional types significantly influence transportation compatibility. Natural attractions, due to their remote locations and weak connections, exhibit significant fluctuations in accessibility; cultural and urban leisure attractions, which rely on the main urban transportation system, offer higher accessibility. Comprehensive attractions, which are often located near transportation hubs, have the best accessibility. Accessibility is not only influenced by grade but is also closely related to functional positioning and locational characteristics.

In response to the above issues, the following recommendations are proposed: **(1)** Address transportation shortcomings in high-grade scenic spots in outlying areas. It is recommended to introduce customised bus services, optimise public transport connections, and moderately extend rail lines in areas such as Mulan Mountain and Liangzi Lake to enhance rapid connectivity with the city centre. **(2)** Strengthen transportation infrastructure for Grade A tourist attractions in the central urban area. The southern part of Hongshan District faces issues such as gaps in rail coverage and inconvenient transfers. It is recommended to integrate urban renewal and district renovation to increase public transportation coverage density and transfer convenience, thereby enhancing service accessibility and spatial radiation capacity. **(3)** Differentiate and optimise transportation service strategies for different types of tourist attractions. Natural attractions should strengthen bus connectivity with peripheral nodes and promote integration with green travel systems (e.g., slow-moving transport, customised bus services); Cultural attractions should focus on enhancing the efficiency of connections between metro networks and pedestrian systems to improve visitor flow and overall accessibility. Urban leisure attractions should be incorporated into the “living-circle” public transport system to achieve better integration between daily commuting and leisure travel, thereby improving the convenience and attractiveness of urban tourism. Comprehensive attractions, which already possess significant accessibility advantages, should concentrate on strengthening the integrated utilization and operational resilience of surrounding transport hubs, enhancing both the carrying capacity and the flexibility of the local transport network. Through these differentiated strategies, transportation services can be better aligned with the functional characteristics of various tourist attraction types, promoting a more balanced and efficient urban tourism transportation system.

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References

1. Aranburu, I., Plaza, B., & Esteban, M. (2016). Sustainable Cultural Tourism in Urban Destinations: Does Space Matter? *Sustainability*, *8*(8), 699. https://doi.org/10.3390/su8080699
2. Chen, S., Xi, J., Liu, M., & Li, T. (2020). Analysis of Complex Transportation Network and Its Tourism Utilization Potential: A Case Study of Guizhou Expressways. *Complexity*, *2020*, 1–22. https://doi.org/10.1155/2020/1042506
3. Fan, Y., Zhao, M., Ma, L., & Zhao, L. (2016). Research on the accessibility of urban green space based on road network: A case study of the park green space in the city proper of Nanjing. *Journal of Forest and Environmental Science, 32(*1), 1–9. https://doi.org/10.7747/JFES.2016.32.1.1
4. General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China. (2017). *GB/T 18972—2017 Classification, Survey, and Evaluation of Tourism Resources*. Beijing: China Standards Press
5. Huang Zhenfang, Zhu Ye, Yuan Linwang, Hu Xiaohai, & Cao Fangdong. (2011). The connotation, classification, and evaluation of leisure tourism resources: A case study of Changzhou City, Jiangsu Province. Geographical Research, *30*(9), 1543–1553.
6. Li Li, Hou Guolin, Xia Siyou, & Huang Zhenfang. (2020). Spatial Distribution Characteristics and Influencing Factors of Leisure Tourism Resources in Chengdu City. Journal of Natural Resources, *35*(3), 683–697.
7. Li, J., Guo, X., Lu, R., & Zhang, Y. (2022). Analysing Urban Tourism Accessibility Using Real-Time Travel Data: A Case Study in Nanjing, China. *Sustainability*, *14*(19), 12122. https://doi.org/10.3390/su141912122
8. Li Shengchao & Huang Hua. (2023). The Impact of Rail Transit on the Public Transportation Accessibility of Tourist Attractions: A Case Study of Xi'an City. Modern Urban Research, *4*, 74–81.
9. Li Weiwei, Cui Ting, Ma Xiaolong, & Zhang Xiyue. (2023). Spatial Pattern and Causes of Attractiveness of Tourist Attractions in Hangzhou City. Tourism Science, *37*(2), 19–39. https://doi.org/10.16323/j.cnki.lykx.2023.02.005
10. Liu Dajun, Hu Jing, & Chen Junzi. (2014). Spatial Structure and Differences of Leisure Tourism Destinations in Wuhan City. Economic Geography, *34*(3), 176–181. https://doi.org/10.15957/j.cnki.jjdl.2014.03.028
11. Liu Min & Hao Wei. (2020). A Study on the Spatial Distribution Factors of National A-Level Tourist Attractions in Shanxi Province. Acta Geographica Sinica, *75*(4), 878–888.
12. Pan Jinghu & Li Junfeng. (2014). Spatial Distribution Characteristics and Accessibility of A-Level Tourist Attractions in China. Journal of Natural Resources, *29*(1), 55–66.
13. Wang Hongqiao, Yuan Jiadong, & Meng Xiangjun. (2017). Spatial Distribution Characteristics and Influencing Factors of A-Level Tourist Attractions in Northeast China. Geographical Science, *37*(6), 895–903. https://doi.org/10.13249/j.cnki.sgs.2017.06.011
14. Wang Lianzhen, Du Yifei, Liu Kiyi, Zhou Ming, & Xue Shuqi. (2025). Optimisation of Bus-to-Subway Transfer Route Networks Considering Station Transfers. Journal of Beijing Jiaotong University, *49*(4), 41–51.
15. Wang, Y. J. (2022). Improving the coupling efficiency between transportation accessibility and tourism resource supply and demand: A case study of the Yangtze River Delta. Journal of Business Economics, *11*, 155–158.
16. Wang Yongming, Tian Jingxian, Jiang Lingling, Gong Chao, & Fan Min. (2025). The Multi-Layer Structure and Mechanism of the Tourism Scenic Area Network in the Yangtze River Economic Belt. Acta Geographica Sinica, *80*(4), 1103–1120.
17. Sun, F., Xu, M., Li, Z., Zhang, W., & Yang, Y. (2024). Spatial Distribution, Accessibility, and Influencing Factors of the Tourism and Leisure Industry in Qingdao, China. *Sustainability, 16(*16), 6961. https://doi.org/10.3390/su16166961
18. Xie Shuangyu, Zhang Qi, Gong Jian, Han Lei, & Wang Xiaofang. (2019). Construction and Application of a Comprehensive Evalu-

ation Model for the Accessibility of Urban Tourist Attractions: A Case Study of the Central Urban Area of Wuhan. Economic Geography, *39*(3), 232–239. https://doi.org/10.15957/j.cnki.jjdl.2019.03.028

19. Xu Dongdong, Huang Zhenfang, Sun Huangping, Shi Xueying, Liu Huan, & Tan Linjiao. (2017). Spatial Characteristics and Influencing Factors of Leisure Tourism Resources in Nanjing City. Journal of Nanjing Normal University (Natural Science Edition), *40*(1), 127–133.
20. Ye Tong. (2024). Evaluation of Public Transportation Accessibility in Commercial Centres of Nanjing City Based on Integrated Travel OD. 13, 514–526. https://doi.org/10.26914/c.cnkihy.2024.034874
21. Zhang Qi, Xie Shuangyu, Wang Xiaofang, Jiang Lili, Gu Hengyu, & Liu Dajun. (2015). Evaluation of the accessibility of tourist attractions in Wuhan based on spatial syntax. Economic Geography, *35*(8), 200–208. https://doi.org/10.15957/j.cnki.jjdl.2015.08.029
22. Zheng, Q., Kuang, Y., & Huang, N. (2016). Coordinated development between the urban tourism economy and transport in the Pearl River Delta, China. *Sustainability*, *8*(12), 1338. https://doi.org/10.3390/su812133
23. Zeng Xuan, Cui Haishan, & Liu Zhigen. (2019). Distribution characteristics and influencing factors of restaurants in Guangzhou. Economic Geography, *39*(3), 143–151. https://doi.org/10.15957/j.cnki.jjdl.2019.03.017