Journal of Sustainable Built Environment

press

Case Study

https://doi.org/10.70731/2v33yh55

Study on the Cultural and Tourism Enhancement Effect of Urban Rail Transit Coupled with the Wilson Model Based on GIS: A Case Study of Wuhan

Ruiping Zhu [a,b], **Haojie Chen** [a,b], **Ran Peng** [a,b,*]

[a] *Wuhan Red Culture Research Center, Wuhan 430056, China*
[b] *School of Civil Engineering and Architecture, Wuhan Institute of Technology, Wuhan 430074, China*

KEYWORDS

Sustainable Development;
Urban Rail Transit;
Cultural and Tourism Synergy Development;
GIS Technology;
Wilson Model

ABSTRACT

As a well-known tourist destination in China, Wuhan's tourism industry has faced sustainable development challenges in recent years. Regional development imbalance, insufficient transportation accessibility, and limited tourism capacity have become the core constraints to its high-quality sustainable development. This paper focuses on the synergistic enhancement effect of Wuhan's rail transit and urban cultural tourism. Based on GIS geographic information data support, the Wilson model is constructed to systematically calculate the tourist transportation network attraction and analyze spatial autocorrelation, combined with empirical research to explore the path for overcoming bottlenecks. The survey results show: 1) The subway helps to promote urban tourism transportation; 2) The subway serves residents' daily life more than it develops tourism; 3) The subway's role in promoting urban tourism is greater than its role in scenic area tourism. Based on the above results, the findings of this study provide theoretical support and practical paradigms for government departments in formulating sustainable development strategies for metro tourism transportation planning, construction, and operational management decisions and practices.

INTRODUCTION

With the increasingly improved urban transportation network in China, transportation plays a significant role as the foundational support for socioeconomic development, with a strong driving force in urban growth. Under the development background of the intersection and integration of transportation and tourism, there are still some shortcomings in existing related research. Firstly, in the current studies, there is a lack of in-depth analysis of the attraction models for existing metro systems, leading to the insufficient transformation of theoretical potential into practical application. Secondly, the reshaping effect of metro construction on the tourism spatial pattern, attraction threshold, and differentiation characteristics still lacks quantitative evidence supported by refined data.

Therefore, this study takes the Wuhan metro as a case, integrating GIS spatial analysis, the tourism attraction model, and tourism spatial theory. It focuses on the impact of metro tourism transportation attraction on

* Corresponding author. E-mail address: pengran@wit.edu.cn

Received 15 December 2025; Received in revised from 20 December 2025; Accepted 22 January 2026; Published online 31 January 2026.

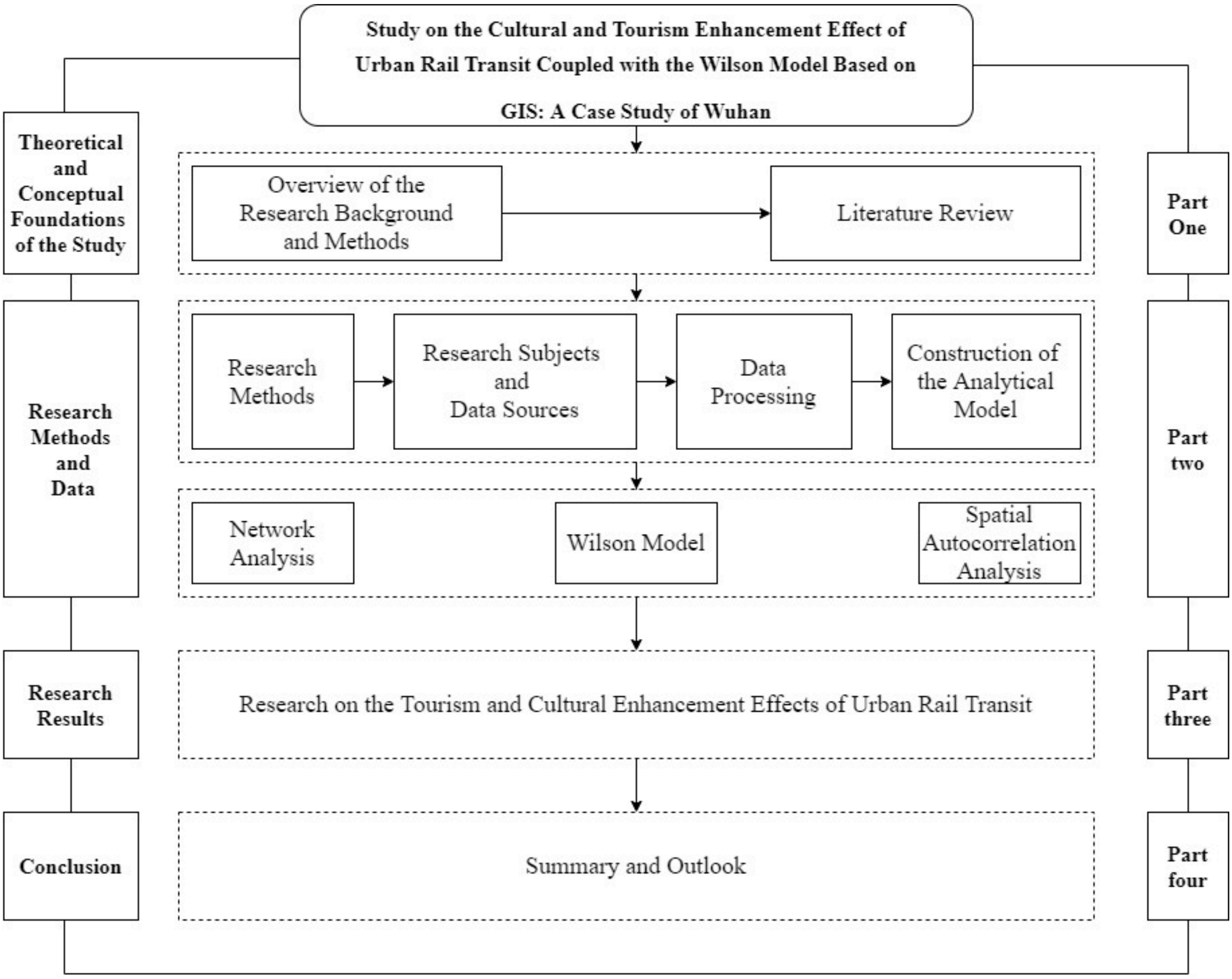

Figure 1 | Research framework

tourism appeal and regional spatial structure. A "rail-tourism" coupling research framework is constructed to systematically analyze the role of the metro network in the aggregation and diffusion of tourism elements. This research not only supports the further development of tourism gravity model theory but also holds significant practical value: it helps promote the development of Wuhan's tourism industry and activates the economic benefits of the metro, while also providing a practical basis for optimizing metro route planning and station layout in Wuhan.

In the field of transportation and urban development research, Guo Peng et al. [1], based on the gravity model, incorporated travel time into the analysis of urban gravity fields, revealing the intrinsic relationship between rail transit and urban development. Xu Lu [2], using Shanghai as a benchmark, applied the gravity model to simulate the evolution of urban spatial morphology in Nanjing from 2005 to 2014, confirming the significant impact of rail transit on its evolution and extracting patterns of influence.

In the field of tourism spatial connection research, Yang Zhongyuan et al. [3], relying on the Wilson model, coupled GIS with spatial autocorrelation techniques to analyze the tourism spatial relationships in 17 cities in Anhui Province. The study found that the overall regional connection is weak, with local clustering, and identified Chaohu and Chuzhou as cold spots, highlighting intercity differences. The research pointed out that tourist flow is the core indicator for the development of tourism, and enhancing reception capacity and strengthening supply-side capabilities are key to increasing tourism attractiveness.

In the intersection of transportation and tourism, Wang Degen et al. [4] focused on the interaction between rail transit and tourism destinations, empirically illustrating the impact mechanism of high-speed rail on tourist travel resistance, and revealing the role of factors such as tourism resource endowment in tourism attractiveness. Tang Qianyu et al. [5], based on the Wilson model, used GIS to analyze the spatial correlation between 33 metro stations (Lines 1 and 2) and 291 tourism facility points in Luoyang. They categorized the stations into nine functional types and constructed a three-level structural system.

Internationally, GIS technology has been deeply integrated into the field of tourism spatial planning and management. In the 1940s, Zipf [6] and Stewart [7,8] improved the Newtonian gravity model, with Crampon [9] being the first to apply it to tourism research. In the 1960s, Wilson A.G. [10] and others used the Wilson gravity model to analyze tourism flows, and the proposed maximum entropy model promoted the development of tourism attraction models. Farsari [11] and Sabou G.C. [12], relying on this technology, respectively carried out urban tourism spatial research and cultural heritage tourism layout optimization practices.

In summary, with the expansion of the application of gravity models, technological iteration, and the enhancement of GIS system functions, research on urban regional spatial relationships increasingly relies on the gravity model method and has attracted widespread attention in fields such as regional planning, tourism, and real estate. Existing studies have laid the theoretical and practical foundation for the fields of transportation and urban development, tourism spatial connections, and the intersection of transportation and tourism. However, they also highlight the research gaps mentioned earlier, providing an entry point for the development of this study.

RESEARCH METHODS AND DATA

Research Methods

This study employs the following two core research methods:

Firstly, Data Analysis Method. Based on the Wilson model, combined with network analysis techniques, this method quantifies the transportation attraction of various metro stations in Wuhan to nearby tourist attractions. The stations that have a significant impact on tourism transportation are selected through ranking and screening.

Secondly, Spatial Analysis Method. Using the ArcGIS platform, spatial correlation analysis is conducted to explore the spatial connection characteristics between metro stations and representative tourist attractions. On this basis, the research findings are integrated to carry out a comprehensive analysis of Wuhan's tourism industry development, providing targeted recommendations for the high-quality development of Wuhan's tourism industry (**Figure 1**).

Research Subjects and Data Sources

Research Subjects

Wuhan Metro The development process of the Wuhan Metro from its establishment in 2004 to 2023 is shown in **Table 1**. The data used in this paper are sourced from the authoritative releases by the National Development and Reform Commission (NDRC) and the Wuhan Municipal Development and Reform Commission, and are regularly updated by the Wuhan Metro Group up to December 31, 2023. The key development stages are summarized as follows:

1) 1984: Wuhan organized relevant departments and experts to discuss the feasibility of metro construction.
2) 2000: The China Railway Fourth Survey and Design Institute finalized the preliminary design for rail transit. In December, the construction of the first phase of Wuhan Metro Line 1 began.
3) 2006: The trial section of Phase I of Wuhan Metro Line 2 started construction.

Table 1 | The development history of Wuhan Metro lines and mileage

Year	Line	Total Line Length	Annual Line Length
2004	Line 1 Phase I	10	10
2010	Line 1 Phase II	19	29
2012	Line 2 Phase I	28	57
2013	Line 4 Phase I	16	73
2014	Line 1 Phase III	6	79
2014	Line 4 Phase II	17	96
2015	Line 3 Phase I	30	126
2016	Line 2 Phase II	19	145
2016	Line 6 Phase I	36	181
2017	Line 1 Phase IV	4	185
2017	Line 8 Phase I	17	202
2017	Line 21 Phase I	35	237
2018	Line 7 Phase I	31	268
2018	Line 11 Phase I	20	288
2018	Line 7 Phase II	17	305
2019	Line 2 Phase III	12	317
2019	Line 4 Phase III	15	332
2019	Line 8 Phase III	5	337
2021	Line 8 Phase II	15	352
2021	Line 11 Phase II	4	356
2021	Line 5 Phase I	35	391
2021	Line 6 Phase II	7	398
2021	Line 16 Phase I	37	435
2022	Line 7 Phase III	21	456
2022	Line 16 Phase II	4	460
2023	Line 5 Phase II	3	463
2023	Line 19 Phase I	23	486
2024	Line 7 Phase II	15	501
2024	Line 11 Phase II	12	513
2024	Line 11 Phase III	40	553

Table 2 | Wuhan metro line mileage table

Line	Length	Stations	Transfer Stations
Line 1	37.936	32	7
Line 2	60.304	38	12+1
Line 3	29.660	24	7+2
Line 4	49.693	37	7
Line 5	37.216	27	2+1
Line 6	42.537	32	9+1
Line 7	67.853	33	8+2
Line 8	38.197	26	5+2
Line 11	24.300	14	2
Line 16	36.458	14	2
Line 19	23.300	7	1
Line 21	34.575	16	2

Table 3 | Mileage density of administrative districts in Wuhan City

Administrative District	Line	Line Density (km/ 10,000 km^2)
Jianghan District	1、2、3、6、7	10004
Jiang'an District	1、2、3、6、7、8、21	7055
Wuchang District	2、4、5、7、8	5037
Qiaokou District	1、2、3、6、7	4892
Hanyang District	3、4、6、16	3256
Hongshan District	2、4、5、7、8、11、19	1735
Dongxihu District	1、2、3、6、7、8	797
Caidian District	3、4、6、16	388
Huangpi District	1、2、7、21	203
Jiangxia District	2、7、8、11	164
Xinzhou District	21	79

Table 4 | Top 10 single - day subway passenger flows in Wuhan in 2023

Ranking	Metro Passenger Flow (10,000 passengers)	Date
1	521.45	2023.09.28
2	519.01	2023.04.30
3	509.53	2023.12.31
4	506.04	2023.04.29
5	495.74	2023.05.01
6	494.91	2023.04.28
7	472.43	2023.06.21
8	466.92	2023.04.01
9	464.98	2023.10.27
10	461.95	2023.03.31

4) 2015: The "Wuhan Metro Phase III Construction Plan (2015-2021)" was approved by the National Development and Reform Commission.
5) 2018: Wuhan Metro added 51 km of new tracks, bringing the total length to 288 km, surpassing cities like Shenzhen, ranking fifth in the country.
6) 2021: Phase II of Metro Line 8 and Phase III of Line 11's Gedian section were simultaneously opened, covering the Qingshan and Hannan districts, achieving full coverage of the metro network across the city.

According to the approved Phase IV construction plan, Wuhan is set to complete metro projects, including Line 19, by the end of 2024, forming a 606-kilometer network with 14 operational lines, thus achieving the goal of "connecting the main city and new cities."

The **Table 2** shows the current line mileage and transfer stations of the Wuhan Metro. In the table, transfer stations labeled as "x+y" indicate that there are x stations for two-line transfers and y stations for three-line transfers. Based on this, the longest line in terms of mileage is Line 7, while the line with the most stations and transfer stations is Line 2.

Table 3 shows that Jianghan District, Jiang'an District, Wuchang District, Qiaokou District, and Hanyang District have the highest metro line density in Wuhan, while Xinzhou District, Jiangxia District, Huangpi District, and Caidian District have relatively low line density. This indicates that there is a significant disparity in the completeness of the metro network across different administrative districts in Wuhan, with an uneven distribution.

As of December 31, 2023, Wuhan Metro's daily ridership exceeded 4 million passengers on 88 days, indicating that there were 88 days in 2023 when the metro was operating under high load conditions. **Table 4** shows that the top six entries in the daily ridership ranking are all during medium and small holidays such as Labor Day (May 1), National Day (October 1), and New Year's Day, indicating that Wuhan Metro faces tremendous passenger flow pressure during holiday tourism peaks.

Wuhan Tourist Attractions According to the "2023 Government Work Report," Wuhan received 333 million tourists in 2023, a year-on-year increase of 62.4%, firmly ranking among the top ten most popular tourist cities in China. E-commerce transaction volume exceeded 1.7 trillion yuan, and total retail sales increased by 8.6% year-on-year. Among the 15 sub-provincial cities, Wuhan ranks in the first tier for tourism comprehensive competitiveness and has risen to the top spot. It ranks first in terms of current competitive strength, and its potential competitiveness and development environment competitiveness have both improved, while the quality of tourism development has significantly increased, and the city's cultural tourism brand image continues to stand out.

Research shows that the development of Wuhan's rail transit still faces two major prominent issues:

The first issue is the insufficient scientific planning of rail transit. Wuhan has excellent and widely distributed tourism resources, with the outer districts gathering high-quality cultural and tourism resources. However, the coordination between the rail transit planning and the layout of tourism resources is relatively low. Early planning focused on overall coverage efficiency, resulting in an imbalance in the line network's capacity. Existing lines are overloaded, while newly constructed lines have low passenger capacity. At the same time, the metro density in the outer districts is insufficient, and the accessibility of tourist attractions by public transport is poor. This leads to high travel costs and poor experiences for tourists, restricting the development and utilization of quality attractions. In addition, some attractions' transport planning has not been adapted to the growing demand from tourists, further exacerbating the capacity gap.

The second issue is the limited capacity of rail transit. During tourism peak periods, the number of tourists increases sharply, and rail transit becomes the preferred mode of transportation for tourists. The highest daily ridership on the metro reached 5.2145 million passengers, with Line 2 accounting for a significant share of the ridership, putting pressure on the line's capacity. The continuous growth in the number of tourists further exacerbates the rail congestion problem, not only degrading the travel experience for tourists and interfering with citizens' daily commuting but also creating safety risks. This leads to passenger flow diversion, increasing the overall traffic burden in the city. Adapting to tourists' travel needs and improving the quality of rail transit services has become a core challenge that Wuhan's rail transit development urgently needs to address.

Data Sources

The core components of the tourism system include tourist origin areas, tourism corridors, and tourist destinations. Based on the actual needs of tourism resource development in Wuhan and the requirements of this study, the specific data acquisition process is as follows:

1) Use OpenStreetMap (OSM) technology to acquire a map of Wuhan's administrative districts and define the spatial boundaries of the study.
2) Select 300 metro stations and 77 famous tourist attractions in Wuhan as the core study subjects for targeted analysis.
3) Rely on the Gaode Map API to obtain urban rail transit data, using four filtering techniques: keyword search, nearby search, polygon area search, and ID exact match. Metro station data is efficiently retrieved using the polygon search function to obtain all metro POI (Point of Interest) data within the city's range.

Data Processing

This study focuses on the two core aspects of tourist attractions and internal urban transportation. Multiple technical methods are used to systematically analyze the tourism functional system in Wuhan. The data processing steps are as follows:

1) Mars Coordinate Conversion using Map Location: Since Gaode Map data is based on the Mars coordinate system, a conversion is required to meet research needs. Based on the sample size and analysis needs, the Map Location tool is used for batch coordinate conversion. A sample is manually extracted through Gaode satellite imagery for coordinate picking, followed by accuracy verification and correction.

2) Spatial Correlation Analysis between Operational and Planned Rail Transit and Urban Tourism: The GIS software is used to add and edit data on the existing map for this purpose.
3) Data Format Conversion and Preprocessing: The geographical coordinates, path segments, and administrative area polygons acquired are converted into a projection coordinate system based on the internationally recognized WGS_1984_PDC_Mercator coordinate system (based on Gauss-Kruger) for the subsequent in-depth spatial correlation analysis.

Construction of the Analytical Model

Network Analysis

Social network theory [13, 14] defines society as a network structure composed of multiple nodes and complex relational chains. This theory can be extended to the tourism field to analyze the diverse network connections within the tourism space. In a tourism space network, metro stations can be seen as core "nodes," and the centrality of these nodes is a key indicator for evaluating their core position within the network. This study constructs a centrality evaluation model based on social network theory to assess the centrality of 300 metro stations in Wuhan. The core objective is to identify effective paths between metro stations and tourist attractions, eliminate redundant line interference, and construct an efficient connection for the Wuhan tourism transportation network.

To achieve this goal, the study adopts a three-step analysis strategy:

1) Effective Path Identification: Define the optimal path determination criteria. The potential paths between metro stations and attractions are diverse. This study uses the minimum travel ratio as the core criterion and defines the shortest time-consuming path as the optimal effective path. The "optimal" core evaluation dimension is the time span (not the physical spatial distance), similar to the "shortest path" identification logic in social network analysis.
2) Traffic Time Calculation: Quantify the time distance between nodes. Accurately quantifying the time distance between nodes is the core premise for constructing effective paths. Since GIS software can only directly obtain complete road length data, this study introduces a breakpoint cut-line function to finely segment each node, achieving automated calculations of road segment length and travel time. This allows for the precise acquisition of actual running time between nodes, providing reliable data support for path optimization.
3) Effective Path Screening: Extract core modeling data. GIS technology is used to calculate the potential paths between 77 tourist attractions and 300 metro stations in Wuhan. After eliminating irrelevant paths, the shortest travel time from each station to each attraction is extracted accurately, providing core data for in-depth modeling.

Wilson Model Calculation

Compared to the classic Newtonian gravitation model, the Wilson model has significant advantages in analyzing interactions between regions [15]. Based on existing research, Li Shan et al. [16] simplified the urban tourism space interaction model and derived a concise expression for tourism transportation interactions:

$$Tir = \exp(-Bri) \tag{1}$$

In the formula, T_{ix} represents the tourism transportation attraction between the origin and the destination, p is the spatial damping coefficient, and T_{ix} is the shortest transportation distance. In this study, as the scale of the tourism domain expands, β shows a decreasing trend, and the data obtained using three different methods all fall within the range of 0.002 to 0.005. Referring to existing empirical data, the middle value of 0.0032 can be selected as the reference [16].

After calculation, the point-to-point transportation attraction between the 300 metro stations and 77 tourist attractions in Wuhan was obtained, and the average value was further calculated to precisely quantify the attraction of each station to each attraction. The calculation formula used is as follows:

$$W_j = \frac{1}{n}\sum_{k}^{n} \exp(-\beta r_{jk}) \tag{2}$$

In this formula, W is the regional tourism transportation attraction of metro station j; n is the number of tourist attractions, which in this study is 77. Among the 300 metro stations selected for this study, the majority not only perform excellently in terms of centrality but also bear a high density of tourism transportation attraction.

Spatial Autocorrelation Analysis

This project plans to use methods such as global spatial autocorrelation and local spatial autocorrelation to conduct an in-depth spatial autocorrelation analysis of the tourist attraction at each metro station along the Wuhan Metro lines. The aim is to reveal and explore the potential spatial correlation patterns of tourist attraction between stations.

The concept of global spatial autocorrelation [17] aims to uncover the spatial correlation characteristics between attribute values across the entire study area [18]. This global spatial autocorrelation can be measured using various statistical indices, such as the global Moran's I index, global Geary's C coefficient, and global Getis-Ord G statistic [19, 20]. In this study, the global Moran's I index is selected as the evaluation tool.

The calculation formula for the global Moran's I index is:

$$I = \frac{n\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\left(x_i-\bar{x}\right)(x_j-\bar{x})}{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\sum_{i=1}^{n}(x_i-\bar{x})^2} = \frac{\sum_{i=1}^{n}\sum_{j\neq i}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{S^2\sum_{i=1}^{n}\sum_{j\neq i}^{n} w_{ij}} \quad (3)$$

In this model, n represents the sample size (i.e., the number of spatial locations studied); W_{ij} measures the relative proximity between spatial locations i and j , representing the strength of their relationship: when i and j are adjacent, the value is 1, indicating a close connection; when they are not adjacent, the value is 0, indicating no direct spatial correlation.

When exploring spatial autocorrelation, the Moran's index is a key tool, which is effectively tested through the standardized statistic . The calculation formula for this index is concisely expressed as:

$$Z = \frac{I - E(I)}{\sqrt{VAR(I)}} \quad (4)$$

In this model, $E(I)$ represents its theoretical expected value, while $VAR(I)$ represents the theoretical variance of the model.

When the Z's value is positive and its absolute value is large, there is a significant positive spatial correlation, meaning similar observations (whether high or low) tend to cluster in space. When the Z's value is negative and its absolute value is large, there is a negative spatial correlation, and similar observations tend to be dispersed. When the Z is 0, the observations are independently and randomly distributed, with no significant spatial correlation.

Meanwhile, this project plans to use the metro tourism transportation and tourist attractions as the core research subjects, employing global spatial autocorrelation analysis, and further exploring its local spatial autocorrelation characteristics.

First, the local Moran's index is based on the coordinates n, and its calculation steps can be summarized as follows:

$$I_n = \frac{(X_n - \bar{x})}{S^2}\sum_{j} w_{nj}(X_j - \bar{x}) \quad (5)$$

The standardized statistic for the local Moran's index test is:

$$Z(I_n) = \frac{I_n - E(I_n)}{\sqrt{VAR(I_n)}} \quad (6)$$

$E(I_n)$ is the theoretical expected value for point n, and $VAR(I_n)$ is the theoretical variance for point n.

If $I_n > Z(I)$, it confirms the existence of local spatial correlation; if $I_n < Z(I)$, it confirms a negative correlation.

RESEARCH ON THE TOURISM AND CULTURAL ENHANCEMENT EFFECTS OF URBAN RAIL TRANSIT

Section 2.4 above primarily explained the analytical model constructed in this study. Based on this, the following conclusions are drawn:

After completing the three-step analysis of network analysis, a total of 23,100 route information was obtained for the 300 metro stations to 77 tourist attractions. Given Wuhan's compact geographical layout and the densely covered metro network, most tourist attractions can be conveniently reached through a "metro + walking" mode. This result confirms the core role of the Wuhan metro system in linking urban transportation and tourism resources, thus boosting the development of urban tourism.

After solving the Wilson model, the tourism transportation attraction index for 300 stations was ranked, and the top 20 results are shown in **Table 1**. The tourism transportation attraction of each metro station is intuitively displayed through the differences in color depth (**Figure 3**), and the statistical ranking of the average tourism transportation attraction for each administrative district station is shown (**Figure 4**).

1) From **Table 5**, it can be seen that Jianghan Road Station has the strongest tourism transportation attraction. This station is located in the core business district of Jianghan District and serves as a transfer hub for Line 2 and Line 6. With a high daily passenger load, it has significant transportation attraction to tourist attractions. Huangpi Square Station has the lowest tourism transportation attraction. It is located in the northern extension of Line 7 in Huangpi District, far from the city center and most popular tourist

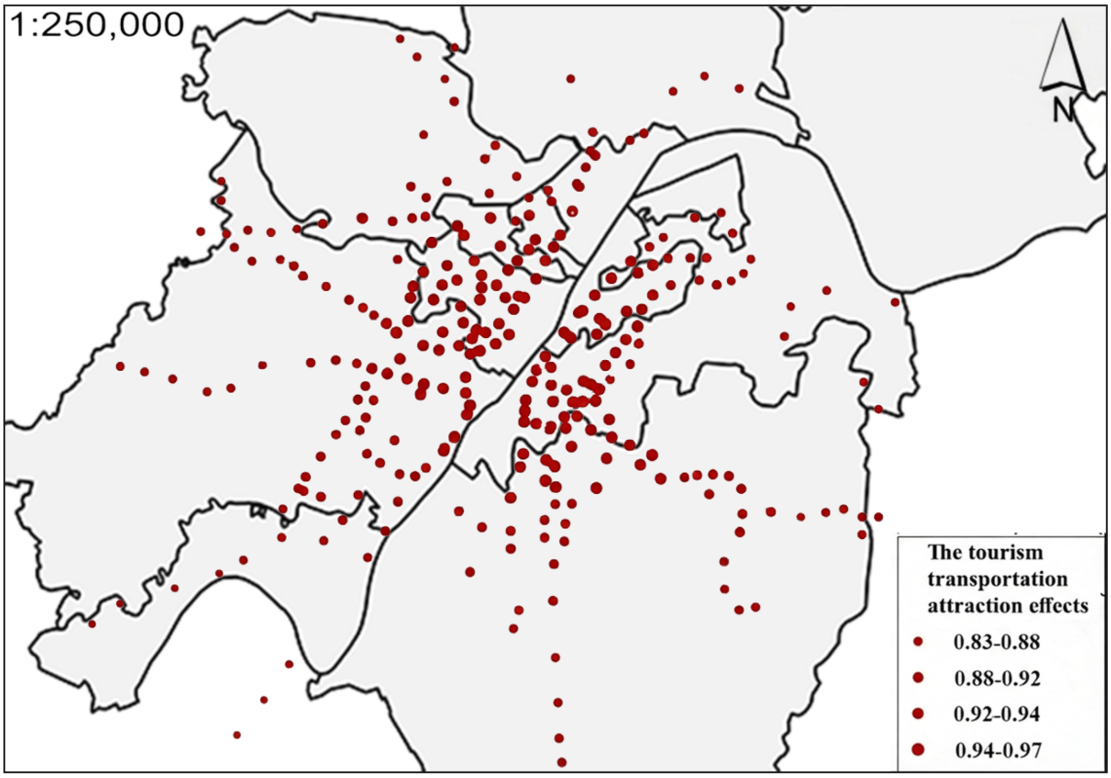

Figure 2 | Dot distribution of tourism and transportation attraction values of Wuhan subway stations

Table 5 | Ranking list of tourism and transportation attractiveness of Wuhan Metro (1 - 20)

Serial Number	Station Name	Belonging Line	Tourism Transportation Attraction
1	Jianghan Road	Line 2, Line 6	0.962961276
2	Jiyu Bridge	Line 2, Line 5	0.962866483
3	Xunlimen	Line 1, Line 2	0.962306107
4	Tanhualin	Line 5	0.961646754
5	Crab Cape	Line 2, Line 7	0.961490953
6	Dazhi Road	Line 1, Line 6	0.961460932
7	Simenkou	Line 5	0.961350019
8	Pengliuyang Road	Line 5	0.961195414
9	Fuxing Road	Line 4, Line 5	0.961117628
10	Xingsheng Road	Line 5	0.961014482
11	Shouyi Road	Line 4	0.960646468
12	Wuchang Railway Station	Line 4, Line 7, Line 11	0.960618738
13	Xiaodongmen	Line 7	0.960607673
14	Xiaoguishan	Line 2	0.960505066
15	Liuduqiao	Line 6	0.960276668
16	Sanyang Road	Line 1, Line 7	0.960071885
17	Hongshan Square	Line 2, Line 4	0.960005843
18	Zhongnan Road	Line 2, Line 4	0.95986735
19	Miaoli Road	Line 6	0.959826211
20	Youyi Road	Line 1	0.959769857

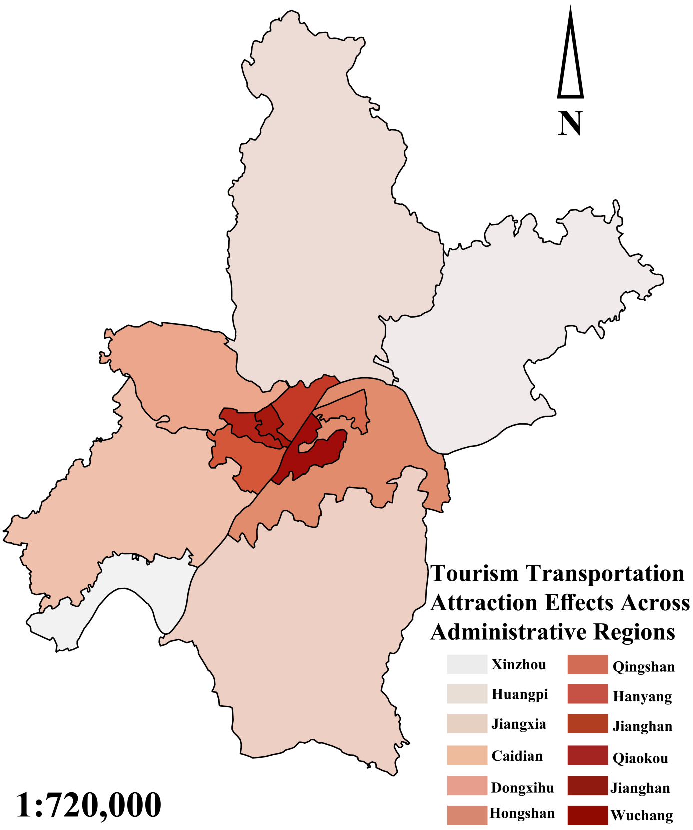

Figure 3 | Distribution map of the zoning of tourism and transportation attraction values in each administrative region

attractions.This study's tourism transportation attraction calculation takes into account both popular attractions and locally unique, lesser-known attractions that are waiting to be discovered, focusing on transportation connectivity to achieve seamless integration across all city attractions. Stations with higher attraction are at the core of the tourism network and are crucial for improving the efficiency of tourism transportation. If planning focuses only on popular tourist attractions, it can lead to overcrowding of attractions in the city center, overlooking the value of lesser-known attractions, which not only fails to address the imbalance in the popularity of attractions but also hinders balanced and high-quality development of regional tourism.

2) From the data in **Table 5** and **Figure 2**, it can be seen that the tourism transportation attraction effects along Wuhan Metro Lines 1, 2, 4, and 5 are the most significant. As the core lines of the urban rail transit network, these lines have a wide coverage and excellent accessibility, with strong passenger flow capacity. Additionally, the tourist attractions along these lines are densely distributed, and the number of visitors is relatively high. This not only reflects the compatibility between metro line planning and tourist attraction distribution but also achieves a synergistic effect between rail transit and tourism development, demonstrating a "1+1>2" cumulative effect.
3) Regional Comparison (**Figure 3**) shows that the tourism transportation attraction of metro stations in Wuchang, Jianghan, Qiaokou, and Jiang'an districts is relatively high, benefiting from their geographical advantages, which create significant transportation attraction to most tourist attractions. In Hanyang, Qingshan, Hongshan, and Dongxihu districts, the attraction is moderate, with regional tourism resources providing support to station attraction. The attraction in Caidian, Jiangxia, Huangpi, and Xinzhou districts is the lowest, attributed to their distance from the city center, low metro network coverage, as well as fewer and more singular tourism resources.
4) Although Wuchang District is a tourism hotspot with high tourist concentration, the tourism transportation attraction of its metro stations has not reached the optimal level. The core attraction comes from the abundance of tourism resources. Increasing the number of tourists is the core research direction, and

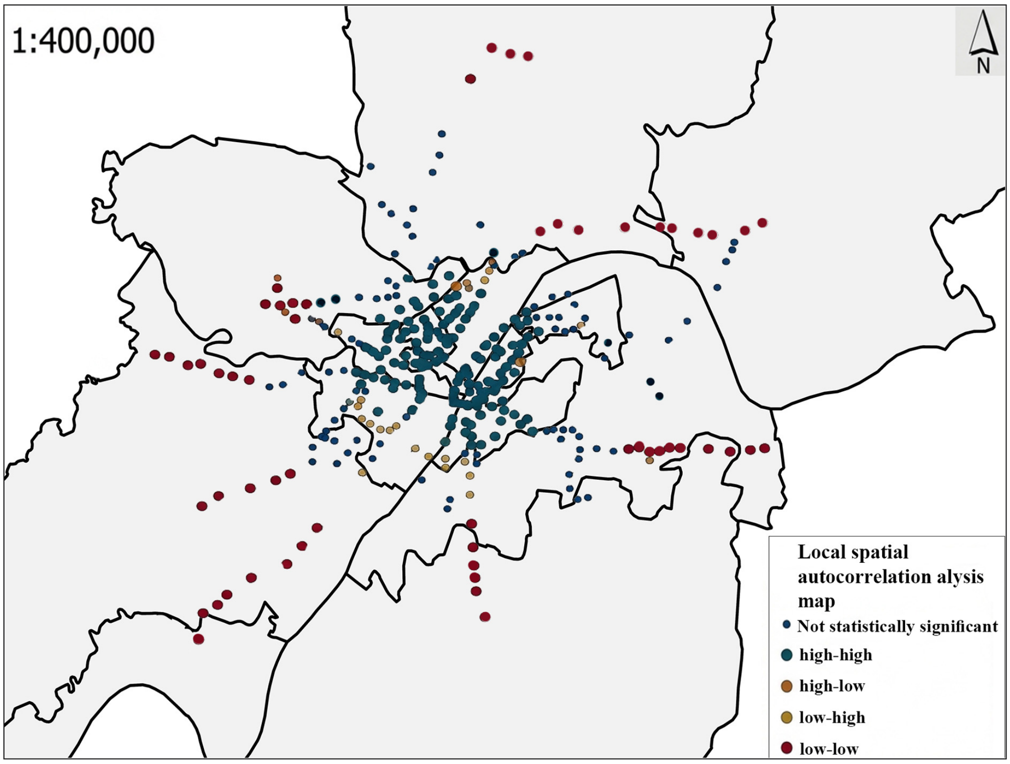

Figure 4 I Local spatial autocorrelation analysis map of tourism and transportation attraction of Wuhan subway stations

convenient transportation is the key path, which is also the core significance of this study.

Based on the analysis above, the research conclusions are consistent with the predictions of the Wilson model. The tourism transportation attraction of urban rail transit essentially reflects the centrality of metro stations, representing their core influence on tourism transportation. The tourism transportation attraction of Wuhan Metro varies significantly across different lines and administrative districts, indicating that its potential to promote the tourism industry has not been fully realized. To explore its underlying causes, this study will conduct a station centrality correlation analysis from a geographical spatial perspective. By comparing the alignment between metro line layout and tourist attraction locations, it will identify whether there are specific spatial patterns rather than random distribution.

This study plans to verify the correlation between urban tourism and rail transit in Wuhan. Based on the ArcGIS platform, a local spatial autocorrelation analysis [21, 22] will be conducted to verify whether there are significant spatial hot spots with strong influences, as well as whether spatial heterogeneity exists. Furthermore, it will analyze whether these factors affect or provide supplementary insights into the overall spatial correlation conclusions between the two.

The local spatial autocorrelation curve analysis in **Figure 4** shows that the central area of Wuhan exhibits significant HH clustering features, while peripheral areas such as Caidian, Jiangxia, Huangpi, and Xinzhou show LL clustering distribution. In the boundary areas between the center and the periphery, most metro stations have weak tourism transportation attraction, presenting spatially uncorrelated characteristics. Only a few stations exhibit an alternating high-low clustering pattern. Based on this, the following conclusions can be drawn:

1) The results of global and local spatial positive correlation broadly confirm the global positive correlation feature of the research elements. Both high and low clustering areas locally validate the existence of positive correlation. Local negative correlation does not contradict the global autocorrelation conclusion, and the central urban area's local positive correlation is significant, marking strong influence points with notable clustering effects.
2) Local autocorrelation analysis indicates that metro stations in Wuchang, Jianghan, Qiaokou, and Jiang'an districts have strong tourism transportation

attraction correlations between adjacent stations, forming a mature metro tourism transportation system.

3) Under the context of global positive correlation, the tourism transportation attraction of metro stations in the central urban area exhibits local associations, with an overall hierarchical feature of "inward clustering, outward diffusion." This reflects that the metro network planning has uneven regional distribution, leading to an imbalance in tourism contribution.

In conclusion, the local spatial autocorrelation analysis shows that the spatial correlation between rail transit and tourist attractions in the central and peripheral areas is significant. The boundary areas show no clear positive or negative correlation, and the impact of rail transit on tourist attractions in these areas is not prominent.

CONCLUSION AND OUTLOOK

This study focuses on the relationship between the metro system, urban tourism, and residents' daily life. By using network analysis methods to reveal core patterns, the following conclusions are drawn: **1)** The metro system has a significant role in driving urban tourism development. Based on the network analysis, a total of 23,100 multi-transport optimal time route plans between tourist attractions and metro stations have been constructed. These plans effectively improve the operational efficiency of the urban road network and travel convenience, enrich travel route options, and provide strong support for the advancement of tourism transportation. At the same time, the study finds that differences in metro lines and administrative district attributes significantly impact station-attraction attractiveness, deepening the understanding of the urban transportation system layout and providing scientific basis for optimizing tourism transportation resources. **2)** The metro's role in serving residents' daily life outweighs its tourism service function. There is a significant spatial positive correlation between the Wuhan metro and tourist attractions, showing an inward-to-outward clustering-diffusion effect and a layered passenger flow pattern. However, the metro line layout does not match the distribution of tourist attractions, making it difficult to fully meet tourists' travel needs. Notably, early metro lines (such as Line 1 and Line 2) were originally designed to focus on community layouts and residents' daily commuting rather than tourism services. As a result, there is a planning gap in adapting to current tourism needs, which urgently requires optimization and upgrading. **3)** The metro system's overall impact on urban tourism is greater than its direct impact on individual attractions. The Wuhan metro has weak spatial connections to most urban tourist destinations, resulting in remote, high-quality attractions like the Mulan Scenic Area not fully benefiting from metro passenger flow effects. Supplementary strategies are needed. However, from the perspective of the urban tourism landscape, the metro system, as a key element of tourism transportation, is a crucial link connecting tourists, attractions, and commercial districts. It also plays a central role in driving regional economic prosperity through tourism. Therefore, its overall impact is significantly greater than its direct effect on dispersed attractions.In summary, this study clarifies the multi-functional positioning of the metro and its boundaries of influence, providing important theoretical reference and practical guidance for optimizing metro planning and layout, balancing residents' commuting and tourism service demands, and improving the quality of urban tourism development.

Although this study provides theoretical and practical insights for tourism transportation policy formulation, it has significant time-related limitations and needs to be continuously refined in line with contemporary trends. Looking to the future, urbanization will further expand the space for metro-based tourism development. Various departments need to collaborate and integrate resources to create a comprehensive tourism experience product. To address issues such as the mismatch between metro lines and tourism needs and the weak traffic linkage to remote attractions, focus should be given to enhancing the quality of attractions. Tourists should have deep experiences of local culture and tourism, integrating into local communities to gain a sense of belonging and novelty, deepening their understanding and appreciation of Wuhan's unique charm, improving tourism satisfaction, and contributing to the high-quality development of all-area tourism.

Funding by Wuhan Red Culture Research Center (Key Research Base of Humanities and Social Sciences in Hubei Province Universities) Open Fund Projects (WHHS20252002), Hubei Cultural and Creative Industry Industrialization Design Research Center Open Fund (HBCY25Y01)

References

1. Guo Peng, Xu Ruihua. The correlation between urban rail transit and urban development based on the gravity model. Systems Engineering, 2006, 24(1): 36-40. (in Chinese)
2. Xu Lu. A study on the correlation between rail transit and urban spatial morphology based on gravity field analysis. Modern Urban Research, 2012(12): 48-52. (in Chinese)
3. Yang Zhongyuan, Lu Song, Jin Xiulong. Analysis of the spatial correlation of urban tourism in Anhui Province based on GIS technology. Resource Development and Market, 2012, 28(4):

310-313. (in Chinese)
4. Wang Degeng, Niu Yu, Wang Li. The impact of high-speed rail on tourist destination selection—A case study of the Beijing-Shanghai high-speed rail. Geographical Research, 2015, 34(9): 1770-1780. (in Chinese)
5. Tang Qianyu, Liu Yijiang, Liu Jia. Identification of metro station types in Luoyang from a tourism perspective. Land and Natural Resources Research, 2018(1): 66-71. (in Chinese)
6. Zipf G. K. The P_1P_2/D Hypothesis: On the Intercity Movement of Persons[J]. American Sociological Review, 1946, 11(6), 677-686. DOI: 10.2307/2087063.
7. Stewart J. Q. Empirical Mathematical Rules Concerning the Distribution and Equilibrium of Population[J]. Geographical Review, 1947,37(3), 46-66.
8. Stewart J. Q. Suggested Principles of "Social Physics"[J]. Science, 1947,106(2748), 179-180. DOI: 10.1126/science.106.2748.179.
9. Crampon L. J. Gravitational model approach to travel market analysis[J].Joumal of Marketing， 1966， 30(2):27-31.
10. Wilson A G.A statistical theory of spatial distribution models[J].Transportation Research， 1967， 1(3): 253-269.
11. Farsari I Prastacos P.GIS applications in the planning and management of tourism[M]. A Companion to Tourism Blackwell Publishing Ltd， 2004.
12. Sabou G C.GIS Applications for an Effective Heritage Tourism Management in Romania[J].International Journal of Economic Practices & Theories 52015， 5(2):136-141.
13. Zhu Qinghua, Li Liang. Social network analysis method and its application in information science. Information Theory and Practice, 2008, 31(2): 179-183. (in Chinese)
14. Wang Jun, Xu Jinhai, Xia Jiechang. Research on the spatial correlation structure and effects of regional tourism economy in China—Based on social network analysis. Tourism Tribune, 2017, 32(7): 15-26. (in Chinese)
15. Chen Yangguang, Liu Jisheng. Urban spatial cross-correlation and power spectrum analysis based on the gravity model: Theoretical proof, function extension, and application examples of the gravity model. Geographical Research, 2002, 21(6): 1-11. (in Chinese)
16. Li Shan, Wang Zheng, Zhong Zhangqi. The gravity model of tourism spatial interaction and its application. Acta Geographica Sinica. (in Chinese)
17. Meng Bin, Wang Jinpeng, Zhang Wenzhong, et al. Study on regional differences in China based on spatial analysis methods. Geographical Sciences, 2005(4): 11-18. (in Chinese)
18. Wang Jun, Xu Jinhai, Xia Jiechang. Research on the spatial correlation structure and effects of regional tourism economy in China—Based on social network analysis. Tourism Tribune, 2017, 32(7): 15-26. (in Chinese)
19. Bai Yancheng, Li Xin, Feng Xuezhi. Spatial data analysis and spatial models. Geographical Research, 1999(2): 74-79. (in Chinese)
20. Bryan K.E.Covariances among join-count spatial autocorrelation measures[J].Theor Popul Biols2003， 64(l): 81-87.
21. Meng Bin, Wang Jinpeng, Zhang Wenzhong, et al. Study on regional differences in China based on spatial analysis methods. Geographical Sciences, 2005(4): 11-18. (in Chinese)
22. Wang Lei, Duan Xuejun. Research on urban spatial expansion in the Yangtze River Delta region. Geographical Sciences, 2010(5): 702-709. (in Chinese)