

A Study on the Spatial Distribution Characteristics of Tourist Attractions in Nanjing and the Optimisation of Tourism Strategies Based on POI Data Analysis

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Abstract:

This study analyzes the spatial distribution of tourist attractions in Nanjing using Amap Points of Interest (POI) data and spatial statistical methods, including the Average Nearest Neighbor index, Kernel Density Estimation, and Standard Deviational Ellipse. The results reveal a clustered pattern characterized by a “core leadership with multi-district linkage.” Xuanwu, Qinhuai, and Gulou districts form high-density cores ($ANN = 0.31$, $p < 0.01$), while the outer suburbs exhibit a more dispersed distribution. Scenic spots are concentrated along the Zhongshan Mountain–Xuanwu Lake corridor, whereas temples show a northeast–southwest axial expansion. The analysis further indicates that traditional attractions are widely distributed, while modern attractions are primarily concentrated in the main urban area. In line with Nanjing’s cultural and tourism policies, we propose a development strategy focused on “enhancing core areas, strengthening suburban connections, and highlighting local distinctiveness.” The findings provide valuable insights for tourism planning in Nanjing and other similar cities.

Keywords:

POI Data, Tourism Strategy, Spatial Distribution, Nanjing

1. Introduction

The tourism industry is a major driver of China’s economic growth, contributing significantly to the national economy. Studying the spatial distribution of tourist attractions—key components of the tourism sector—and the factors that influence them is highly valuable. Such research helps optimize the allocation of tourism resources, improve regional tourism offerings, enhance a city’s image, and support high-quality urban development [1]. Nanjing, a renowned historical and cultural city and a national model for tourism consumption, has seen rapid growth in its tourism sector, supported by both policy and economic factors. In 2023, the city received over 200 million visitors, and in the first half of 2025, it ranked as the fourth most popular travel destination in China.

Advances in big data within Geographic Information Systems (GIS) have introduced new research approaches. Among these, Point of Interest (POI) data analysis is widely used because it provides more accurate, comprehensive, and timely information than traditional data sources [2]. Research outside China often examines spatial patterns at multiple scales, while studies within China tend to focus on specific cities, using methods such as kernel density analysis to understand how tourism spaces are organized. This study uses POI data for tourist attractions in Nanjing. Through quantitative analysis, it aims to uncover the spatial distribution and clustering patterns of these attractions. The results are expected to offer practical insights for tourism planning in Nanjing, serve as a reference for similar cities, and support smarter and more sustainable tourism development.

2. Study Area and Data Sources

2.1. Study Area Overview

This study focuses on Nanjing, the capital city of Jiangsu Province. Situated on the southern bank of the lower Yangtze River, Nanjing spans latitudes $31^{\circ}14' - 32^{\circ}37' N$ and longitudes $118^{\circ}22' - 119^{\circ} E$. It borders Zhenjiang to the east, Xuancheng (Anhui Province) to the south, Ma'anshan to the west, and Chuzhou to the north. The city comprises 11 administrative districts and benefits from a well-developed transportation network, including metro lines, public buses, expressways, and Nanjing Lukou International Airport, ensuring convenient internal and external connectivity (Figure 1).



Figure 1. Study area extent



Figure 2. Spatial distribution of tourist attractions in Nanjing

Known as the “Ancient Capital of Six Dynasties,” Nanjing possesses a profound historical and cultural heritage, featuring numerous cultural relics and natural landscapes. At the same time, modern commercial complexes and entertainment

facilities contribute to the city's vitality, catering to diverse tourism needs. The integration of historical and modern elements, along with the coexistence of cultural and natural resources, characterizes Nanjing's tourism offerings, providing a rich basis for this study (Figure 2).

2.2. Data Sources

Points of Interest (POI) refer to specific geographic locations that reflect the spatial distribution and structure of features of interest. As fundamental spatial big data, POI effectively represent the spatial morphology and organization of study subjects [4]. In this research, POI data were primarily obtained from the Amap Open Platform. Using Python programming, we comprehensively crawled POI data for tourist attractions in Nanjing in July 2024. A total of 5,083 valid records were collected, including key attributes such as name, coordinates, and category, forming the primary dataset for analysis. Supplementary data included vector datasets of Nanjing's administrative boundaries, digital elevation models (DEM), road networks, and water systems.

2.3. Data Processing

After acquiring the raw POI data, we categorized the tourist attractions into nine types based on the Amap POI classification standards, popular attraction rankings from platforms such as Meituan, Ctrip, and Douyin, and insights from the Nanjing Cultural and Tourism Consumption Big Data Report—which includes annual visitor statistics, origin market analysis, and consumption trends for popular scenic spots—as well as relevant literature. The nine categories are as follows: scenic areas, city squares, parks, churches, memorial halls, temples and Taoist shrines, zoos, botanical gardens, and aquariums.

3. Research Methods

3.1. Average Nearest Neighbor

The Average Nearest Neighbor (ANN) index serves as an effective spatial statistical method for quantitatively assessing the proximity between point features and identifying their spatial distribution patterns [4]. The calculation formulas are as follows:

$$ANN = \overline{D_0} / \overline{D_E} \quad (1)$$

$$\overline{D_0} = \sum_{i=1}^n d_i / n \quad (2)$$

$$\overline{D_E} = 0.5 / \sqrt{n/A} \quad (3)$$

In the formulas (1–3), ANN represents the Average Nearest Neighbor index, $\overline{D_0}$ represents the mean observed distance, $\overline{D_E}$ denotes the expected mean distance, n indicates the number of features, and A refers to the area of the study region. The ANN value is derived by comparing the average distance between each tourist attraction and its nearest neighbor with the theoretical mean distance under complete spatial randomness. An ANN value less than 1 indicates that the actual distance between attractions is shorter than the theoretical expectation, suggesting a clustered distribution. Conversely, an ANN value greater than 1 implies a more dispersed or uniform distribution. This study employs the ANN index to assess the spatial

clustering characteristics of tourist attractions in Nanjing, providing a quantitative basis for understanding their distribution patterns [5].

3.2. Kernel density analysis

Kernel density analysis is a non-parametric estimation method employed to reflect the spatial clustering patterns of point features within a geographical context. This approach calculates density values for each grid cell, thereby providing a visual representation of the spatial aggregation of tourism features. The greater the density of feature points, the higher the kernel density value, indicating stronger feature clustering. [6] The formula for kernel density analysis is as follows:

$$f(x) = \sum_{i=1}^n \frac{1}{r^2} k\left(\frac{x - x_i}{r}\right) \quad (4)$$

In Equation (4), $f(x)$ denotes the kernel density value at the study point, n represents the number of feature points within a distance $\leq r$, k is the spatial weighting value, and r is the distance decay threshold. Its spatial geometric significance lies in the kernel density value of tourism feature x_i being most ANN at the core feature x_i , gradually decreasing as the distance from the core feature x_i increases, and falling to zero when the distance reaches the threshold r . This study employs KDA to not only visually depict hotspot areas of tourist attractions but also identify potential tourism corridors and underutilised zones within Nanjing, providing spatial visualisation support for tourism planning and management. By adjusting the kernel bandwidth, we optimised analytical precision, ensuring result sensitivity and stability to deeply uncover subtle spatial patterns and characteristics of Nanjing's tourist attractions. [7.]

3.3. Standard Deviation Ellipse

The Standard Deviation Ellipse (SDE) is a significant geographical research methodology that quantitatively describes the concentration, dispersion, and directional trends of geographical features using fundamental parameters such as the standard deviations of the major and minor axes, the ellipse centre, and the azimuth. It enables an objective representation of the global characteristics of the spatial patterns of geographical features. It is currently applied in studies concerning scenic area location, tourism development patterns, and the network attention of tourism elements. Its advantage lies in precisely and effectively revealing the spatial distribution characteristics of geographic elements, intuitively demonstrating the centrality and extensibility of spatial distribution. Its calculation formulae are as follows:

Mean Centre:

$$\bar{X}_w = \sum_{i=1}^n \omega_i x_i / \sum_{i=1}^n \omega_i, \bar{Y} = \sum_{i=1}^n \omega_i y_i / \sum_{i=1}^n \omega_i \quad (5)$$

Ellipse Azimuth:

$$\tan \theta = (A + B) / C, \quad (6)$$

$$A = \left(\sum_{i=1}^n \omega_i^2 \tilde{x}_i^2 - \sum_{i=1}^n \omega_i^2 \tilde{y}_i^2 \right), \quad (7)$$

$$B = \sqrt{\left(\sum_{i=1}^n \omega_i^2 \tilde{x}_i^2 - \sum_{i=1}^n \omega_i^2 \tilde{y}_i^2 \right)^2 + 4 \sum_{i=1}^n \omega_i^2 \tilde{x}_i^2 \tilde{y}_i^2}, \quad (8)$$

$$C = 2 \sum_{i=1}^n \omega_i^2 \tilde{x}_i \tilde{y}_i, \quad (9)$$

Standard deviation on the X-axis:

$$\rho_x = \sqrt{\sum_{i=1}^n (\omega_i \tilde{x}_i \cos \theta - \omega_i \tilde{y}_i \sin \theta)^2 / \sum_{i=1}^n \omega_i^2}, \quad (10)$$

Standard deviation on the Y-axis:

$$\rho_y = \sqrt{\sum_{i=1}^n (\omega_i \tilde{x}_i \sin \theta - \omega_i \tilde{y}_i \cos \theta)^2 / \sum_{i=1}^n \omega_i^2}. \quad (11)$$

Where: $(\bar{X}_w, \bar{Y}_w)$ denotes the mean centre of spatial elements; represents the weight at spatial element i ; (x_i, y_i) are spatial coordinates; and denote the standard deviations of the x-axis and y-axis respectively; is the azimuth of the ellipse; and denote the deviations of the spatial coordinates of the study object from the mean centre coordinates.

4. Results and Discussion

4.1. Overall Spatial Distribution Characteristics

The nearest neighbour index (ANN) for Nanjing's tourist attractions is 0.319 ($P < 0.01$), indicating a significantly clustered spatial distribution pattern (report file link: file:///C:/Users/Administrator/Documents/ArcGIS/%E6%9C%80%E9%82%BB%E8%BF%91%E6%B3%95%E7%BB%93%E6%9E%9C_11056_20224_.html). The overall pattern exhibits a 'single core-multiple nodes' clustering characteristic, centred on Xuanwu Lake-Purple Mountain in Xuanwu District. This forms a high-density cluster encompassing key attractions such as the Sun Yat-sen Mausoleum and the Ming Xiaoling Mausoleum. Qinhuai and Gulou districts constitute secondary clusters radiating from the core area (Figure 3).

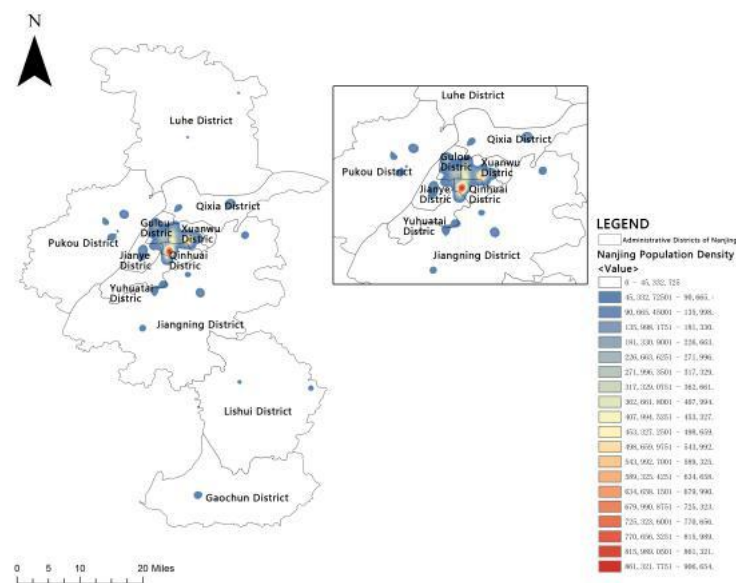


Figure 3. Nuclear Density Analysis of Tourist Attractions in Nanjing.

Beyond the central urban zone, multiple intermediate-density centres (as shown in Figure 4) are distributed along the urban periphery and in suburban tourism hubs. These secondary clusters in Nanjing predominantly develop around core scenic areas, exhibiting a ‘core attraction + supporting sites’ distribution pattern.

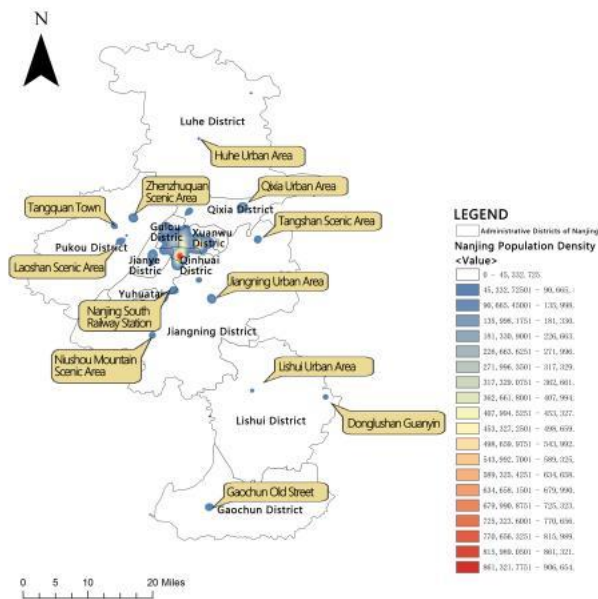


Figure 4. Example of Core Typical Areas with POI Density for Tourist Attractions in Nanjing.

4.2. Spatial Distribution Characteristics of Tourist Attractions

At the spatial scale of Nanjing City, each popular tourist attraction occupies a very small proportion of the geographical area. Consequently, each attraction can be represented as a discrete spatial point feature. [8] The nearest neighbour index (Table 1) reveals a pronounced clustering pattern across the city's tourist attractions (ANN=0.31, $z=-88.35$, $p=0$). Xuanwu District (ANN=0.38), Qinhuai District (ANN=0.40) and Gulou District (ANN=0.49) form a high-density core zone, exhibiting significantly shorter observation distances than expected and a marked clustering effect. Suburban districts such as Gaochun District (ANN=0.53), Lishui District (ANN=0.59), and Jiangning District (ANN=0.52) exhibit fewer attractions and relatively dispersed distributions, yet still demonstrate a degree of clustering.

Table 1. Nearest Neighbour Index of Tourist Attraction Distribution Across Districts of Nanjing City.

Citywide	Average observation distance (m)	Expected average distance (m)	Proportion of nearest neighbours	z	p	Spatial istribution
Citywide	288.22	927.4	0.31	-88.35	0	Significant clustering
Gaochun District	555.2	1040.58	0.53	-12.61	0	Clustering—random distribution
Gulou District	85.51	173.49	0.49	-21.38	0	Significant clustering
Jianye District	197.09	356.8	0.55	-11.89	0	Clustering—random distribution
Jiangning	601.29	1154.59	0.52	-21.16	0	Clustering—

District						random distribution
Lishui District	921.84	1541.64	0.59	-9.75	0	Clustering—random distribution
LuHe District	866.77	1767.97	0.49	-13.92	0	Significant clustering
Pukou District	473.16	940.96	0.50	-18.46	0	Clustering—random distribution
Qixia District	468.08	1135.45	0.41	-16.13	0	Significant clustering
Qinhuai District	70.59	175.26	0.40	-30.69	0	Significant clustering
Xuanwu District	64.95	168.18	0.38	-39.78	0	Significant clustering
Yuhuatai District	211.00	488.71	0.43	-17.56	0	Significant clustering

Analysis of kernel density and standard deviation ellipses for various tourist attractions in Nanjing reveals significant typological differences in their spatial distribution. Kernel density analysis indicates that parks, scenic spots, and urban squares form a high-density core within the central urban area. Cultural attractions such as memorial halls, churches, and temples exhibit distinct historical orientation in their distribution, with temples displaying a ‘dual-core’ pattern. Specialised attractions like zoos are highly concentrated in Xuanwu District, dependent on urban public service infrastructure.

Standard deviation ellipse analysis further reveals (Table 2): temples and Taoist shrines exhibit the widest distribution range (3,247.17 km²), extending along a northeast-southwest axis consistent with traditional mountain-oriented site selection; parks and scenic spots align east-west with the Ming Dynasty city walls and urban development axes; memorial halls are most concentrated (1,220.06 km²), clustered in the central Republican-era cultural zone; Churches exhibited a north-south orientation, reflecting modern road planning history. Overall, traditional-type attractions covered a larger spatial extent than modern-type attractions.

Ellipse shapes identified three spatial patterns: axially extended (e.g., temples), core-clustered (e.g., memorial halls), and transitional-hybrid (e.g., parks). Compared to similar cities, Nanjing’s attraction distribution demonstrated stronger directionality, closely linked to its natural topography and historical spatial accumulation.

Table 2. Standard Deviation Ellipse Parameters for Different Types of Tourist Attractions in Nanjing.

Name	Centre Coordinates	Long semi-axis/m	Short semi-axis/m	Azimuth	Area/km ²
Temples and Taoist shrines	118°51'21.25", 31°45'51.68"	20289.7	50948.9	164.20	3247.17
Parks	118°51'21.25", 32°01'09.70"	17457.8	29594.1	166.67	1622.95
Scenic spots	118°48'43.93", 32°00'01.65"	16469	28660.3	161.39	1482.73
Memorial halls	118°48'43.93",	14392.7	26986.2	153.66	1220.06

	32°00'01.66"				
Churches	118°48'43.93", 32°00'01.67"	21186.8	35723.6	178.83	2377.56
Aquariums	118°48'43.93", 32°00'01.68"	12960.8	29536.1	166.04	1202.53
Town squares	118°48'43.93", 32°00'01.69"	16970.6	30878.3	164.74	1646.19
Zoos	118°48'43.93", 32°00'01.70"	13459.3	28383.2	177.13	1199.99
Botanical gardens	118°48'43.93", 32°00'01.71"	11411.7	20908.3	164.03	749.49
Nanjing City	118°48'43.93", 32°00'01.72"	15503.9	31082.4	165.32	1513.86



Figure 5 . Analysis of Nuclear Density for Various Attractions in Nanjing.

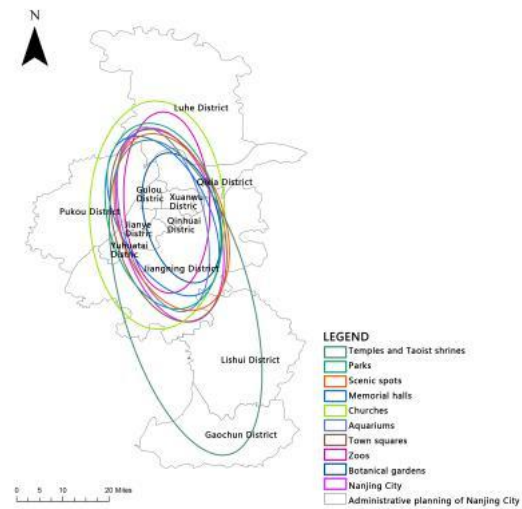


Figure 6. Standard Deviation Ellipses for Various Attractions in Nanjing.

5. Conclusions and Discussion

5.1. Conclusions

This study systematically elucidates the spatial organisation patterns of Nanjing's tourist attractions by employing geospatial analysis techniques—including the average nearest neighbour index, kernel density analysis, and standard deviation ellipses—based on point-based POI data of the city's tourist sites. Key findings are summarised as follows: (1) Nanjing's tourist attractions exhibit a spatial structure characterised by 'core-led, multi-district coordination' centred on Qinhuai, Gulou, and Xuanwu districts. Attractions are highly clustered, forming a pronounced central-radiating pattern; (2) Significant disparities exist in attraction distribution across administrative regions. Xuanwu District hosts the densest concentration of attractions with the highest proportion, whereas peripheral areas like Lishui District exhibit relatively sparse distribution; Xuanwu District exhibits the highest proximity index, indicating close distances and high clustering among attractions, whereas districts like Jiangning District show lower proximity indices, reflecting more dispersed distribution. (3) Among existing attraction types in Nanjing, scenic spots closely follow natural topography; temples and Taoist shrines are evenly distributed across multiple urban areas; memorial halls demonstrate high concentration, primarily clustered in areas of significant historical or academic value.

5.2. Discussion

This study utilises POI data from AutoNavi Maps to provide an intuitive representation of the distribution characteristics of tourist attractions within Nanjing, fully demonstrating the application potential of big data in micro-level tourism research. Findings reveal that Nanjing's tourist attractions exhibit a spatial pattern characterised by 'core-led development with multi-district coordination', though distribution remains uneven across regions. The types of attractions are closely correlated with regional resource endowments. In light of Nanjing's current scenic spot distribution characteristics and relevant policy documents—including the 14th Five-Year Plan for Cultural and Tourism Development, the Nanjing Tourism High-Quality Development Action Plan, and the Measures for Promoting High-Quality Development of Service Consumption in Nanjing—the following optimisation recommendations are proposed for each district's tourism development.

(1) Core Leadership Districts (Xuanwu District, Qinhuai District, Gulou District)

As Nanjing's core tourism development area, Xuanwu District exhibits the highest density index, with attractions highly concentrated (proximity index >1). This forms a high-density tourism belt centred on Zhongshan Scenic Area and Xuanwu Lake, though some sites approach saturation capacity. Recommendations include: - Strengthening development of the 'Purple Mountain-Xuanwu Lake' National Tourism Resort - Promoting smart management systems within scenic areas - Optimising visitor distribution mechanisms Qinhuai District, centred on the Confucius Temple-Laomen Dong Historical and Cultural Quarter, enjoys high tourism popularity but faces issues of business homogenisation and insufficient visitor immersion. The district must deepen the preservation and revitalisation of its historical quarters, introducing high-quality cultural tourism offerings such as intangible cultural heritage experiences. Gulou District boasts abundant modern architectural resources yet underdeveloped tourism functions. Addressing these issues, it should leverage

university resources to develop distinctive tourism products combining Republican-era architecture with academic research tours, while improving its pedestrian guidance systems.

(2) Suburban Potential Areas (Jiangning District, Qixia District, Yuhuatai District)

These areas possess significant tourism development potential. Jiangning District has numerous attractions but suffers from scattered distribution (proximity index <1). Resources like Niushan Mountain and Tangshan lack synergistic effects. Therefore, Jiangning should strengthen transport links between attractions, leverage resources such as Niushan and Tangshan to create a 'peripheral leisure belt', enhance scenic area connectivity, introduce themed combined tickets, and address the shortfall of spatial dispersion. Qixia District centres on Qixia Mountain, exhibits pronounced seasonal tourism patterns, and lacks adequate surrounding amenities. It should bolster the 'Autumn Foliage Festival' brand, introduce high-end cultural tourism facilities to extend visitor dwell times, develop year-round tourism products, and explore a 'Zen culture + wellness retreat' model. Yuhuatai District possesses both revolutionary tourism and ecological resources, though product integration remains low. It could combine revolutionary education with Jiangjunshan's ecological leisure resources to develop composite 'revolutionary education + nature study tours' products, utilising digital technology to enhance interactive experiences.

(3) Emerging Development Zones (Jianye District, Jiangbei New Area)

Nuclear density analysis indicates these areas possess low tourist attraction density but robust modern service industry foundations. Jianye District, with premium resources like the Youth Olympic venues and International Expo Centre, should vigorously develop 'MICE tourism' by attracting high-value projects such as international conferences and developing riverside cultural tourism initiatives. As a national-level new district, Jiangbei New Area possesses robust technological industry foundations. It should promote the integration of 'technology + cultural tourism,' establishing innovative formats like themed science museums, and develop micro-vacation products leveraging Laoshan's ecological resources.

(4) Peripheral Character Enhancement Zone (Pukou District, Liuhe District, Lishui District, Gaochun District)

These areas possess relatively fewer attractions (e.g., Lishui District has the lowest attraction density), yet exhibit distinct ecological and cultural characteristics. Pukou District should delve into the cultural essence of the Yangtze River, leveraging resources like Laoshan and Tangquan to forge a distinctive 'Yangtze River Culture + Ecological Leisure' brand. It should prioritise developing specialised products such as riverside ecological sightseeing and hot spring wellness tourism, creating a uniquely characteristic Yangtze River cultural experience zone. Hexi District should strengthen its 'Jasmine Painting Village' IP, promote agri-cultural-tourism integration, and elevate the quality of rural tourism. Lishui District should leverage its health industry strengths to build wellness tourism destinations with supporting medical rehabilitation facilities. Gaochun District must emphasise its 'International Slow City' positioning, optimise rural landscape corridors, and develop low-carbon tourism.

Nanjing's tourism optimisation should adhere to the principles of 'enhancing core areas, coordinating suburban regions, and developing peripheral distinctiveness'. By guiding balanced resource allocation through spatial planning, and integrating TOD development models with regional transport coordination concepts, the following

strategy framework is proposed to advance high-quality development of Nanjing's holistic tourism:

(1) Nanjing's tourism development should establish a transport-oriented spatial optimisation system. Key efforts should focus on developing TOD tourism hubs such as Nanjing South Railway Station and Xinjiekou Station, forming a three-tier tourism service system; Launch a Purple Mountain–Niushan Mountain–Laoshan Mountain tourist rail loop, enhancing the 'rail + dedicated lines + micro-circulation' transfer network. This transport optimisation is projected to increase scenic area rail coverage from 42% to 75%, significantly strengthening interconnectivity between tourism zones.

(2) Spatial planning requires differentiated tiered development strategies. The core zone within the Ming City Wall will strengthen cultural heritage preservation, while the near-suburban zone within the ring expressway will cultivate cultural-tourism integration demonstration areas. The far-suburban zone will develop three major thematic landscape corridors. Concurrently, promote functional integration by embedding cultural performance spaces in commercial districts like Xinjiekou and establishing a 'technology + cultural tourism' innovation park in Jiangbei New Area. This spatial restructuring will promote balanced tourism resource allocation, increasing the proportion of cross-district tourist routes from 15% to 35%.

(3) Brand synergy and institutional safeguards are pivotal to high-quality development. Cross-regional thematic tourism routes should be designed, alongside the development of the 'Nanjing Cultural Tourism Cloud' digital platform and the establishment of a visitor flow early-warning system. Institutional support for strategy implementation will be provided by integrating tourism planning into the 'single map' of territorial spatial planning, piloting a 'tourism development rights trading' system, and formulating unified service standards. This suite of measures is projected to extend the average visitor stay to 3.2 days, achieving high-quality development in all-for-one tourism.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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