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Study on the Distribution Characteristics of Tourism Elements in the Grand Canal Cultural Belt of Cangzhou City

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Abstract: This article focuses on the cultural belt of the Grand Canal in Cangzhou City, analyzing the spatial distribution and correlation of its tourism elements. Based on a total of 14,192 Points of Interest (POI) data collected through the Gaode Map Application Programming Interface (API), the study employs spatial analysis methods such as spatial syntax analysis, kernel density estimation, average nearest neighbor analysis, global spatial autocorrelation test, and bivariate spatial autocorrelation test. These methods reveal the spatial patterns and interdependencies of the six core tourism elements: food, accommodation, transportation, tourism, shopping, and entertainment. The results indicate significant agglomeration in the spatial distribution of various tourism elements, accompanied by distinct characteristics of differentiation among them. This research provides valuable insights and references for the reconstruction of tourist spaces and the coordination of functional areas within the cultural belt of the Grand Canal in Cangzhou City.

Keywords: Grand Canal; POI; Distribution characteristics

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1. Introduction

In June 2019, the President of the CCP emphasized that the Grand Canal is a precious heritage left by ancestors, representing a flowing culture that must be protected, inherited, and utilized in a coordinated manner. Following this, the Central Committee of the Communist Party of China and the State Council issued a plan, identifying the construction of the Grand Canal Cultural Tourism Belt as a key task in the "14th Five-Year" cultural and tourism plan. The plan aims to promote regional coordination through culture, with cities as the unit of layout. In 2022, taking advantage of hosting the 6th Hebei Provincial Horticultural Exposition, Cangzhou City advanced 18 key projects (with a total investment of 22.5 billion yuan) to develop the Grand Canal cultural protection zone, ecological landscape belt, and cultural tourism belt. Recently, Cangzhou City formulated the "Implementation Plan for High-Quality Integrated Development of Culture and Tourism in Cangzhou City (2024–2025)." This plan integrates cultural tourism projects along the Grand Canal in the central city, aiming to create a 5A-level scenic area by improving landscapes, services, and environmental quality. The goal is to establish the Grand Canal Cultural Tourism Belt as the preferred weekend destination for tourists from Beijing and Tianjin. Simultaneously, the plan aims to enhance the cultural tourism scene in the main city area, improve the service level of dining, accommodation, and transportation, develop branded cultural tourism products, enhance public services and infrastructure, optimize the environment, shape the "Cangzhou Cultural Tourism" brand, and enhance tourism attractiveness and service quality. Given this context, exploring the distribution characteristics and agglomeration status of cultural tourism resources along the Grand Canal in Cangzhou City is of great significance. It will help to clearly grasp the spatial distribution pattern of local cultural tourism resources, scientifically guide industrial integration and coordinated development, effectively update tourism products and service content, and reasonably transform tourist attractions and surrounding environments.

The tourism industry encompasses six elements: attractions, dining, accommodation, shopping, entertainment, and transportation. It is characterized by inclusivity, wide coverage, and strong correlation, spatially manifested as a combination of point and linear elements. Each type of tourism industry has its own spatial distribution, and there are rich associations among the various tourism industries [1]. In recent years, domestic experts have focused their research on the spatial pattern of tourism, drawing on and improving foreign tourism location theories while considering the actual situation of China's tourism industry. The research has primarily concentrated on the distribution of tourism resources, the spatial pattern of tourism-related single business formats, and the evolution of tourism elements [2–10]. However, there has been relatively little research on the distribution pattern of tourism at the micro level of cities, which limits the understanding and grasp of the overall development of urban tourism to some extent. In studies aiming at spatial layout, Points of Interest (POI) data stand out due to their wide distribution, abundant information, and low acquisition threshold, making them highly applicable in research on the spatial layout of elements at various scales and regions. Foreign scholars have achieved remarkable results in POI data research, primarily focusing on identifying urban hotspots, analyzing macro spatial patterns, and exploring behavioral patterns among different populations [11–13]. These studies lay a foundation for researching the spatial characteristics and optimization of tourism formats. In comparison, domestic scholars have also made considerable progress in POI big data applications, particularly in studying tourism spatial patterns, primarily concentrating on leisure tourism and scenic spots [14–18]. However, there are still few research results on the spatial distribution and spatial correlation characteristics of the six elements of tourism (food, accommodation, transportation, tourism, shopping, and entertainment).

In summary, this article conducts an in-depth study on the POI data of tourism elements in Cangzhou City, analyzing the spatial distribution patterns and characteristics of the city's tourism elements. The aim is to provide a scientific basis for resource allocation and related industrial layout planning in urban tourism development strategies.

2. Data sources and research methods

2.1. Overview of the study area

Cangzhou City is located in the southeast of Hebei Province, bordering Bohai Sea in the east, Tianjin in the north, Baoding in the west, and Dezhou and Binzhou in Shandong Province in the south. It is situated in the central and southern plain of Hebei and is an important part of the Beijing-Tianjin-Hebei city cluster. With convenient transportation, it is integrated into the "one-hour transportation circle" of Beijing-Tianjin-Hebei, facilitating connections with surrounding cities and scenic spots. The Beijing-Hangzhou Grand Canal passes through the city. In recent years, in response to national policies, multiple canal attractions have been developed, driving an increase in local residents' tourism demand and an influx of tourists from the Beijing-Tianjin-Hebei region. This study focuses on the enclosed area formed by four expressways, G307, Xin'an Avenue, Bohai Road, and Jingba Road, in the main urban area of Cangzhou City.

2.2. Data sources

This study utilizes the Gaode Map API to collect POI (Point of Interest) data and road network data for tourism elements in Cangzhou in February 2025. The data includes key information such as the name, category, longitude, and latitude of each POI. Subsequently, based on the characteristics of the study subject, referencing POI classification systems from previous studies, and according to the "National Tourism and Related Industries Statistical Classification (2018)" standard published on the Statistics Bureau website, POI data involving tourism elements such as dining, accommodation, transportation, travel, shopping, and entertainment were precisely filtered, totaling 14,192 data entries (**Table 1**).

Table 1. Types and quantities of POI data for tourism elements in Cangzhou City

Tourism element	Secondary classification	Quantity	Proportion
Dining (Food)	Chinese restaurants, food-related venues, fast food restaurants, beverage shops, pastry shops, foreign restaurants, cafes, dessert shops, casual dining venues	8,554	60.27%
Accommodation (Lodging)	Hotels, guesthouses/lodges	647	4.56%
Transportation (Travel)	Parking lots, bus stops, long-distance bus stations, ferry terminals, train stations	1,592	11.22%
Sightseeing (Touring)	Parks/plazas, scenic spots, museums	34	0.24%
Shopping (Purchasing)	Convenience stores, supermarkets, specialty stores, shopping malls, markets, specialty commercial streets	2,102	14.81%
Entertainment (Recreation)	Spa/massage facilities, entertainment venues, sports facilities, leisure venues, sports & recreation services, theaters/cinemas	1,263	8.90%
Total		14,192	100%

2.3. Research methods

2.3.1. Space syntax

Space syntax is a quantitative analysis method for spatial structure based on topological networks. This study applies space syntax to three travel scales: walking, non-motorized vehicles, and motorized vehicles [19]. Using the axis analysis method, global integration and local integration are employed to quantify the accessibility of roads in Cangzhou City. The higher the integration value, the stronger the road accessibility, and the local accessibility can be visually judged by the axis color on the local integration axis map.

Integration is an indicator used to quantify the accessibility between a spatial unit and other spatial units in a spatial system. The calculation formula for integration is as follows:

$$I_i = \frac{n[log_2(\frac{n+2}{3} - 1)] + 1}{(n - 1(MD_i - 1))}$$

Among them, I_i represents the integration of the *i*th spatial unit, *n* is the total number of spatial units, and MD_i is the average depth of the *i*th spatial unit.

2.3.2. Kernel density

Kernel density analysis is a non-parametric estimation method used to evaluate the density of points around each sample location. It involves placing a kernel function (usually a smooth curve) at each sample point and then stacking the values of these kernel functions to generate a density surface. The calculation formula is as follows:

$$f(x) = \frac{1}{n \cdot h} \sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right)$$

2.3.3. Average nearest neighbor

The average nearest neighbor is an important indicator used in spatial analysis to quantify the distribution characteristics of point patterns. By comparing the actual observed values with theoretical random distribution values, it determines whether the point set is clustered, dispersed, or randomly distributed. The formula is as follows:

$$\bar{d} = \frac{1}{n}\sum_{i=1}^{n} d_i\,, \bar{d}_{random} = \frac{0.5}{\sqrt{\lambda}}, R = \frac{\bar{d}}{\bar{d}_{random}}$$

Where $\bar{d}$ is the distance from a point to its nearest neighbor, d_i is the average nearest neighbor distance of all points, n is the total number of points, $\bar{d}_{random}$ is the theoretical average nearest neighbor distance, λ is the number of points per unit area, and R is the nearest neighbor index. R < 1 indicates a clustered distribution, R = 1 indicates a random distribution, and R > 1 indicates a uniform distribution.

2.3.4. Spatial autocorrelation

Global spatial autocorrelation is a statistical indicator that measures the similarity or correlation of variable values distributed spatially in spatial data. In this study, Moran's I index is used to quantify the spatial distribution, thereby assessing the spatial clustering characteristics of point coordinates. The calculation formula is as follows:

$$I = \frac{N}{W} \cdot \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} \omega_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

Where is the total number of spatial units, is the sum of all spatial weights ω_{ij}, ω_{ij} is the spatial weight matrix, representing the spatial relationship between spatial units i and j, x_i and x_j are the attribute values of spatial units i and j, and $\bar{x}$ is the average attribute value of all spatial units. Moran's I > 0 indicates that adjacent units have similar attributes (positive correlation), I < 0 indicates significant differences (negative correlation), and I ≈ 0 indicates no significant spatial autocorrelation.

2.3.5. Bivariate spatial autocorrelation

Unlike traditional spatial autocorrelation analysis, which focuses on a single variable, bivariate spatial autocorrelation further reveals the spatial dependency relationships between different types of elements. The formula is as follows:

$$I_{XY} = \frac{n}{\sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij}} \cdot \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} \omega_{ij} (X_i - \overline{X})(Y_j - \overline{Y})}{\sqrt{\sum_{i=1}^{n} (X_i - \overline{X})^2} \sqrt{\sum_{j=1}^{n} (Y_j - \overline{Y})^2}}$$

where n is the number of spatial units, x_i and Y_j representing the X value of unit i and the Y value of unit j, respectively, and ω_{ij} represents the Queen contiguity weight matrix.

3. Distribution characteristics of tourism elements in Cangzhou City

3.1. Accessibility analysis

Using Depthmap software and adopting a multi-scale integration system, the accessibility of transportation in the study area was evaluated (**Figure 1**). The integration colors gradually increase from cold to warm, indicating that accessibility gradually improves as the color tone becomes warmer. Topological steps are denoted by R: for tourist walking, R=3 is chosen to reflect the walking activity status of tourists; considering that tourists often have stronger touring needs or tend to use non-motorized transportation, R=7 is extended to reflect the characteristics of medium and long-distance activities; the global integration R=n is introduced to study the accessibility of tourist driving activities and conduct a comprehensive analysis of the accessibility of the region.

Conducting a horizontal analysis with the Grand Canal in the city center as the core, it can be seen that spatial accessibility presents significant differences under different topological scales. When R=3, multiple locally accessible cores are formed along the canal, mainly concentrated in iconic cultural tourism nodes such as the Garden Expo Park, People's Park, South Lake Park, and Nanchuan Tower. The color gradient analysis shows that these areas exhibit high integration characteristics, confirming that tourists can reach nearby areas on foot. As the topological steps expand to 7, accessibility demonstrates broader connectivity. The color gradient transition indicates that the distribution of road integration tends to be more balanced. Originally isolated hotspots further extend to surrounding areas, and the distribution of road integration becomes more uniform. The radiation range of integration extends along the canal axis into the hinterland, indicating that tourists have a strong desire or ability to expand their range of activities with the help of non-motorized vehicles and other transportation means. When integration R=n, the road integration around the Grand Canal in the city center exhibits distinct high-value areas. The red core area and the orange expansion area form a multi-center collaborative transportation network, reflecting that when tourists travel by car, they can quickly and easily reach various major attractions and functional areas of the city, indicating high overall accessibility of the city.

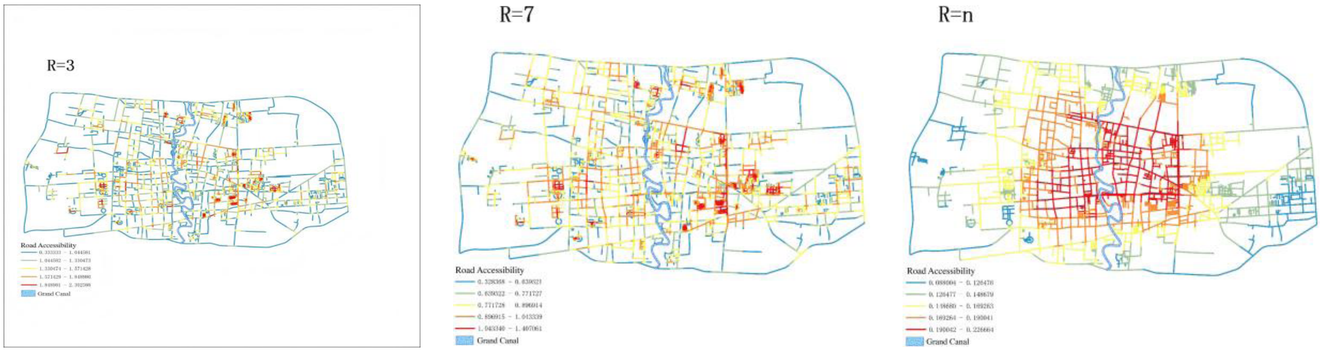

Figure 1. Integration of roads in the Cangzhou urban area

3.2. Kernel density analysis

The kernel density distribution analysis of various tourism POIs in the main urban area of Cangzhou City enables a comparison of spatial layout differences among different POI categories, revealing their inherent spatial correlations (**Figure 2**). In the center of the city, there is a region where various POIs are distributed in a red circular high-density pattern, indicating that the tourism supporting facilities in this area are well-developed and comprehensive. Further analysis shows that the spatial distribution of tourism dining, accommodation, transportation, and shopping is more widespread than that of sightseeing and entertainment, with a higher number of high-density areas. Specifically, although the clustering of tourism dining POIs is relatively weak, they are widely distributed in various corners of the main urban area. Tourism accommodation POIs have formed a distinct clustering area in the west of the main city, which is highly consistent with the actual situation, considering its proximity to the high-speed rail station. Additionally, tourism transportation POIs are more evenly distributed with a higher overall density, which is conducive to the development of Cangzhou's cultural tourism industry. Tourism sightseeing POIs are significantly clustered only on both sides of the Beijing-Hangzhou Grand Canal, forming a narrow, high-density distribution belt from north to south. The western clustering area mainly includes cultural attractions such as the Cangzhou Museum and Shicheng Park. The distribution of tourism shopping POI is mainly concentrated in commercial areas with high economic levels and strong consumption capabilities, and the phenomenon of distribution along the city's main transportation routes is also typical. On the other hand, tourism entertainment POIs are relatively concentrated, with lower kernel density values on the east and west sides of the central city, indicating poor spatial matching between entertainment elements and other types of tourism elements in these areas, which needs further optimization and improvement in the future.

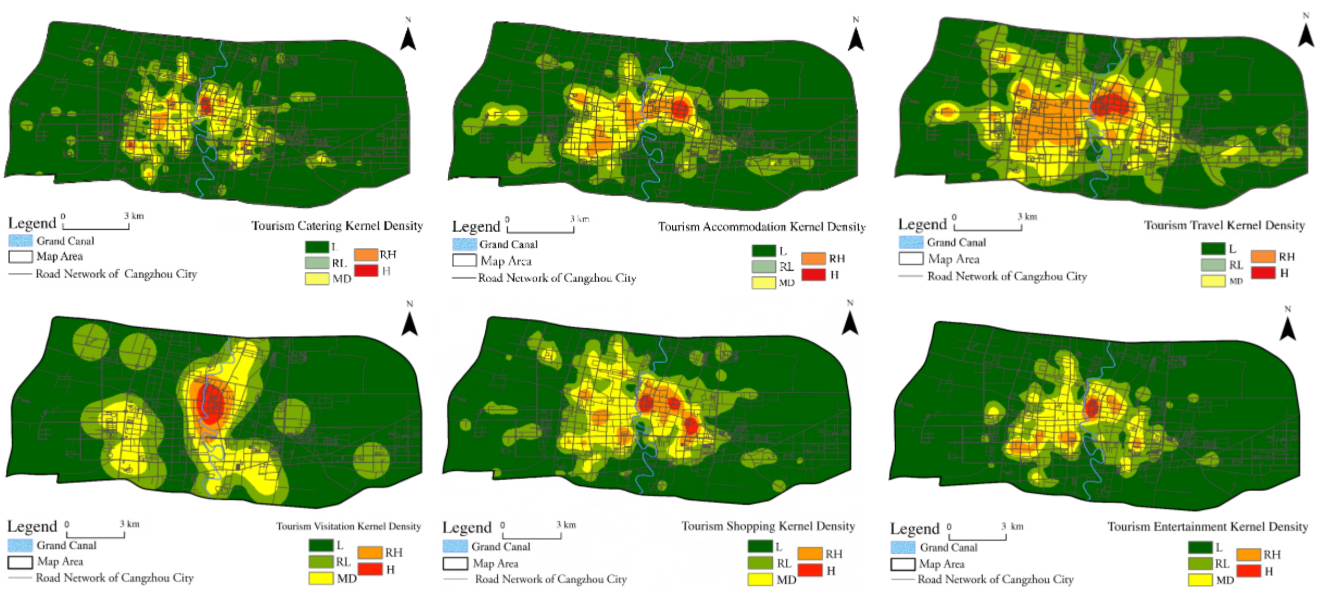

Figure 2. Kernel density of tourism elements in the Cangzhou urban area

3.3. Average nearest neighbor

Spatial analysis based on the six tourism elements of "food, accommodation, transportation, sightseeing, shopping, and entertainment" POI in the main urban area of the Grand Canal cultural belt in Cangzhou City shows that the overall tourism elements and the five categories of dining, accommodation, transportation, shopping, and entertainment all exhibit significant spatial agglomeration distribution (**Table 2**). The R-index of overall tourism elements is 0.38, which is similar to the agglomeration degree of accommodation (R=0.44) and shopping (R=0.48) elements, reflecting that the tourism service system in the main urban area is highly concentrated in several core areas. The spatial agglomeration intensity of each element, from high to low, is: dining (R=0.28) > accommodation (R=0.44) = entertainment (R=0.44) > shopping (R=0.48) > transportation (R=0.59) > sightseeing (R=0.87). The highest concentration of the dining industry is mainly due to the highly concentrated distribution of industrial clusters such as snack streets and food cities. The high agglomeration of accommodation and shopping elements stems from their rigid demand attributes as basic tourism facilities. Especially in the context of consumption upgrading, the shopping function has evolved from a single demand to a composite experience carrier, further driving its spatial agglomeration. The spatial agglomeration of entertainment and transportation elements is moderate. Entertainment demands are usually met after dining, accommodation, and shopping, while transportation elements mainly undertake the function of connecting other types of tourism functional areas. The sightseeing element has the lowest agglomeration degree, and its spatial distribution is relatively the most dispersed.

Table 2. Nearest neighbor index and spatial structure type of tourism elements in Cangzhou City

Category	Mean observed distance (m)	Mean expected distance (m)	z-score	*P*-value	R-index	Distribution type
Overall	20.92	50.96	-141.18	0.00	0.38	Clustered
Dining	20.14	78.81	-126.69	0.00	0.28	Clustered
Accommodation	112.63	255.65	-27.41	0.00	0.44	Clustered
Transportation	96.75	164.11	-31.33	0.00	0.59	Clustered
Sightseeing	976.43	1122.97	-1.45	0.15	0.87	Random
Shopping	67.94	142.82	-45.98	0.00	0.48	Clustered
Entertainment	81.52	184.25	-37.91	0.00	0.44	Clustered

3.4. Spatial autocorrelation analysis

Using GeoDa software and based on a 500m×500m grid, the number of POIs within each unit was counted. A spatial weight matrix was constructed using the queen contiguity principle, and a global spatial autocorrelation analysis was conducted for various tourism elements. The analysis results showed that the spatial agglomeration of dining elements was the most significant, with a Moran's I index of 0.45, indicating a high degree of positive spatial autocorrelation (**Table 3**). Shopping elements (Moran's I = 0.42) and entertainment elements (Moran's I = 0.40) also demonstrated strong spatial agglomeration characteristics, typically concentrated in commercial centers or specific blocks. Although the agglomeration degree of accommodation elements (Moran's I = 0.33) and travel elements (Moran's I = 0.32) was relatively lower, there was still a significant positive spatial autocorrelation, indicating their clustered distribution in space. In contrast, the spatial autocorrelation of sightseeing elements was the weakest, with a Moran's I index of only 0.05. This result might be related to the linear geographical constraints of the canal: although cultural attractions were mainly distributed along the canal corridor, their narrow morphological characteristics and limited number of elements resulted in significantly larger point spacing between attractions than other types of elements, making the spatial agglomeration less prominent.

Table 3. Spatial autocorrelation analysis table of tourism element POIs in Cangzhou City

Element	Moran's I	*P*-value	Z-score
Dining	0.45	0.005	36.0
Accommodation	0.33	0.005	27.9
Transportation	0.32	0.005	30.1
Sightseeing	0.05	0.005	4.6
Shopping	0.42	0.005	34.0
Entertainment	0.40	0.005	34.7

3.5. Bivariate spatial autocorrelation analysis of tourism elements

According to the results of the bivariate spatial autocorrelation analysis, tourism elements such as dining, accommodation, travel, shopping, and entertainment within the Grand Canal cultural belt of Cangzhou City showed a certain degree of positive correlation (**Table 4**). Among them, the correlation between dining elements and other elements was more significant, with the highest correlation of 0.41 with shopping elements. This indicated a strong consistency in the spatial distribution of dining and shopping elements, which often clustered together. Additionally, the correlation between dining elements and accommodation and travel elements reached 0.30 and 0.40, respectively, demonstrating the synergy in their spatial distribution. The correlation between accommodation and travel elements was 0.30, suggesting a certain spatial association between them, possibly concentrated around transportation hubs or tourist attractions. The correlation between shopping elements and travel elements was 0.36, which might imply mutual coordination in the layout of shopping venues and transportation facilities, facilitating travel and shopping for tourists. The correlation between entertainment elements and shopping elements was 0.38, indicating a strong interrelationship between entertainment facilities and shopping venues, typically clustered near commercial centers. In contrast, the correlation between sightseeing elements and other elements was generally low, with correlations below 0.08 for dining, accommodation, travel, shopping, and entertainment elements. This suggested that the spatial distribution of sightseeing elements was relatively independent of other tourism elements, showing weaker synergy with them.

Table 4. Bivariate spatial autocorrelation analysis table of tourism element POIs in Cangzhou City

Element	Dining	Accommodation	Transportation	Sightseeing	Shopping	Entertainment
Dining	-					
Accommodation	0.30	-				
Transportation	0.40	0.30	-			
Sightseeing	0.07	0.30	0.08	-		
Shopping	0.41	0.31	0.36	0.05	-	
Entertainment	0.42	0.29	0.36	0.07	0.38	-

4. Conclusion and discussion

This study relies on POI data obtained from the Gaode Map API and employs spatial analysis techniques to investigate the spatial distribution patterns and intrinsic connections of tourism elements in the core area of the

Grand Canal cultural belt in Cangzhou City. The analysis results show that the tourism elements in the study area exhibit significant spatial agglomeration characteristics: the catering elements have the highest degree of agglomeration, mainly due to the dense layout of specialized dining areas such as snack streets and food cities; accommodation and shopping elements also have significant agglomeration, reflecting their rigid demand characteristics as tourism infrastructure. Under the trend of consumption upgrading, the shopping function has transformed from a single consumption place to a composite experience space, further strengthening the spatial agglomeration effect. The agglomeration intensity of entertainment and travel elements is at a moderate level, while the agglomeration of touring elements is the lowest, and their discrete distribution state is closely related to the linear geographical constraints of the Grand Canal corridor.

Spatial correlation analysis reveals a positive spatial correlation between various elements. The spatial synergy of catering elements is most prominent, and its correlation strength with shopping elements reaches 0.41 (Moran's I), indicating a high degree of overlap in their spatial distribution, often forming functionally complementary agglomeration areas. Accommodation and travel elements also show clear spatial correlation characteristics, manifesting as a coordinated distribution around transportation hubs and scenic areas. Touring elements exhibit spatial independence, with correlation strengths with other elements all below 0.08. This characteristic is mainly influenced by the dual factors of natural landscape distribution and geographical location.

This study reveals the distribution characteristics of tourism elements through empirical analysis, providing a theoretical basis for regional tourism planning. With the continuous development of the tourism industry in Cangzhou City, the spatial configuration of tourism elements should be further optimized, strengthening the synergy between various elements and enhancing the overall competitiveness of the tourism industry. In subsequent research, more data sources and analysis methods, such as tourist behavior data and social media data, can be considered to provide a scientific basis for sustainable development.

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