POI-based Analysis of Spatiotemporal Evolution in the Accommodation Industry and Its Spatial Association with Tourist Attractions (Postprint)

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Abstract

This study examines accommodation POIs (Points of Interest) in Urumqi City (2012 and 2018), employing kernel density method and standard deviational ellipse method to investigate the spatiotemporal evolution characteristics of accommodation facilities. From the perspective of tourism regional system, it further utilizes fractal dimension model and related statistical analysis methods to measure the spatial coupling between accommodation facilities and tourist attractions, aiming to provide scientific reference for urban accommodation and tourism space optimization. The results show: (1) Accommodation facilities in the main urban area are generally distributed along major transportation routes such as Hetan Road and Altay Road, with notable quantitative growth, and areas such as Midong New District demonstrate a tendency to develop into peripheral agglomeration centers. (2) Accommodation facilities have generally moved toward the northeast direction, shifting from axial agglomeration to discrete distribution. In 2012, various types showed significant differences in spatial distribution direction and scope, while in 2018, three-star and budget types exhibited the most pronounced trend of spatial discretization. (3) Ordinary accommodation facilities evolved from an isolated kernel pattern to a belt-shaped multi-core pattern, demonstrating a clear central agglomeration-peripheral diffusion trend; budget hotels transformed from point agglomeration to belt-shaped agglomeration. (4) The spatial coupling between accommodation facilities and tourist attractions is relatively high, exhibiting strong spatial coordination within the buffer zones of major roads. The tourism regional system is in the primary stage of single-center agglomeration development, and its fractal structure requires optimization.

Full Text

Spatial and Temporal Evolution of the Accommodation Industry and Its Spatial Association with Tourist Attractions Based on POI Data

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Abstract: This study examines accommodation facilities in Urumqi from 2012 to 2018 using kernel density estimation and standard deviational ellipse analysis to investigate spatiotemporal evolution patterns. From the perspective of tourism regional systems, we employ fractal dimension models and spatial statistical methods to measure the spatial coupling between accommodation facilities and tourist attractions, aiming to provide scientific references for optimizing urban accommodation and tourism spatial structures. The results show that: (1) The number of accommodation facilities in the main urban area increased significantly, generally distributed along major transportation routes such as Hetan Road and Altay Road. The Midong New District and other areas show potential to become peripheral agglomeration centers. (2) Accommodation facilities overall shifted toward the northeast, transitioning from axial aggregation to discrete distribution. The spatial distribution directions and ranges of different types varied considerably between 2012 and 2018. Three-star and budget accommodations showed the most pronounced trend toward spatial dispersion. (3) Ordinary accommodations evolved from an isolated core pattern to a belt-shaped multi-core pattern, exhibiting a clear central agglomeration-peripheral diffusion trend. Budget hotels transformed from point agglomeration to belt agglomeration. (4) The spatial coupling between accommodation facilities and tourist attractions is relatively strong, with notable spatial coordination within main road buffer zones. The tourism regional system is in the primary stage of monocentric agglomeration development, and its fractal structure requires optimization.

Keywords: POI; accommodation industry; tourist attractions; aggregation fractal; Urumqi

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1. Introduction

The spatial distribution pattern of accommodation facilities represents the projection of the accommodation industry onto urban social space. Studying the spatiotemporal evolution of accommodation can reveal spatial distribution characteristics and patterns, thereby optimizing the accommodation industry struc-

ture. Among numerous influencing factors, tourist attractions exert significant influence on accommodation facility distribution. GUTIERREZ et al.' s study of Barcelona found that local hotel layouts primarily leveraged locational advantages near major tourist attractions rather than clustering among similar hotels. Related research originated in the 1990s, with foreign scholars providing scientific theories and paradigms regarding hotel macro/micro-location selection, spatiotemporal evolution of accommodation, and distribution influencing factors. However, in previous studies, whether in traditional regional tourism competitiveness evaluation or accommodation industry distribution factor system construction, the two elements were treated as evaluation factors affecting each other, lacking empirical research on their spatial distribution relationship and pattern summarization. In other words, how can we explain the spatial relationship between regional accommodation facilities and tourist attractions?

A tourism regional system is an open, self-organizing complex system composed of tourist attractions and service facilities. From a systems perspective, accommodation facilities and tourist attractions can be viewed as subsystems of the tourism regional system. Their spatial layout relationship and coupling determine the structure and function of the tourism regional system, consequently affecting regional tourism development and service levels. Current literature on tourist attractions often focuses on A-level scenic spots as study objects, neglecting ordinary attractions, which is clearly unfavorable for government and enterprise decision-makers to grasp urban tourism structures at the macro level. Ordinary attractions provide more leisure and recreation choices for citizens and tourists and should be included in the tourism subsystem. Moreover, current location-based big data (POI) can be conveniently obtained, further deepening understanding of the macro pattern of tourism regional systems.

Existing case studies predominantly concentrate on eastern and central Chinese cities or urban agglomerations, with scarce research on accommodation spatiotemporal patterns and tourism regional system analysis for large western cities like Urumqi. Therefore, this paper selects Urumqi as a case study. Many scholars have considered Urumqi as a distribution center for Xinjiang tourism, often overlooking the distribution of internal tourist attractions and related service facilities. In recent years, as the capital city, Urumqi has continuously developed characteristic tourism products, improved tourism service functions, and strengthened its "destination" function while weakening its "distribution center" function under government policy guidance. In 2017, Urumqi received 46.24$\times$10^{6}$ tourists (a 10.5% increase), generating tourism revenue of 71.5 billion yuan (a 14.6% increase), accounting for 24.3% of Xinjiang' s total tourism revenue. Tourism has become a strategic pillar industry in Urumqi. This study uses accommodation POI data (2012-2018) and tourist attraction POI data (2018) as foundational data, treating urban accommodation facilities and tourist attractions as two major elements of the tourism regional system. It systematically examines the spatiotemporal pattern evolution of Urumqi' s accommodation industry and the internal coordination and coupling of the tourism regional system under current conditions, aiming to provide sci-

entific references for rational tourism service facility layout and orderly urban development.

1.1 Study Area and Data Sources

Urumqi is the political, economic, and cultural center of Xinjiang Uygur Autonomous Region, with over 3,000 accommodation facilities ranging from low-end to high-end, including hotels, guesthouses, budget hotels, chain hotels, and star-rated hotels. Since suburban areas are still transitioning from rural to urban with extensive farmland and desert, this study selects Urumqi's main urban area as the case, covering areas within the ring expressway, including Xinshi District, Toutunhe District, Tianshan District, Shayibake District, Shuimogou District, and Midong District. The area comprises 78 subdistricts with a population of 1.8836$×10^{6}$, representing the most densely populated and economically active zone in Urumqi.

Accommodation and tourist attraction data were obtained from Gaode Electronic Maps. After deduplication, correction, and processing, POI data containing name, classification, and coordinate information were used to establish a spatial attribute database for tourism regional subsystems using ArcGIS 10.2. The database includes 3,123 accommodation facilities of various types and 1,056 tourist attractions (parks, resorts, gardens, mosques, ecological parks, etc.). Following previous research and classification standards from Meituan and Qunar, we categorize accommodations as: ordinary type (hotels, guesthouses, social hostels, family hostels), economic type (chain hotels like Home Inn, 7 Days, GreenTree Inn, Hanting, Jinjiang Inn), three-star, and four-star and above (based on official ratings or historical evaluation data).

1.2 Methods

1.2.1 Standard Deviational Ellipse Standard deviational ellipse (SDE) is a spatial statistical method for quantitatively describing geographic feature distribution, measuring ellipse center, major axis, minor axis, azimuth, and other parameters. The center represents the relative location of spatial distribution, the major axis indicates distribution direction, the minor axis represents distribution range, and greater flatness indicates more obvious directionality. This study uses SDE in ArcGIS 10.2 to measure the spatial evolution direction of various accommodation facilities in 2012 and 2018.

1.2.2 Kernel Density Analysis Kernel density analysis applies the first law of geography and spatial interpolation principles to conduct spatial statistics, assigning higher weights to elements closer to sample centers and lower weights to distant elements, thereby revealing agglomeration degrees. The calculation formula is:

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

where x_i represents a point in space, K denotes the kernel function, h is the bandwidth defining the radius range, d is data dimension, and n represents the number of points within the bandwidth. This study uses kernel density estimation to measure accommodation industry agglomeration centers in the main urban area.

1.2.3 Aggregation Fractal Dimension Calculation Tourist attractions and accommodation facilities form under combined natural, human selection, and socio-economic factors, evolving from disorder to order and new order, exhibiting infinite nesting and self-similarity characteristics. Therefore, fractal theory effectively 刻画 tourism regional system coupling states. Assuming various elements (accommodation facilities, tourist attractions) in the tourism regional system constitute aggregation fractal systems, the tourism regional system' s aggregation fractal dimension is the geometric mean of each element' s aggregation dimension:

$$D_d = \sqrt[N]{\prod_{i=1}^{N} D_i}$$

where D_i represents the aggregation dimension of each element system in the tourism regional system, and D_d represents the tourism regional system' s aggregation dimension, characterizing the agglomeration effect around tourism poles. In this study, D_1, D_2, and D_d represent accommodation, tourism, and tourism regional system aggregation dimensions, respectively. Subsystem aggregation dimensions are calculated using the formula:

$$\ln N(r) = A - D \ln r$$

where $N(r)$ is the number of elements within radius r, D is the aggregation dimension, and A is a constant.

2. Results and Analysis

2.1 Overall Pattern Changes of Accommodation Facilities Accommodation facility numbers increased significantly (Figure 1 [Figure 1: see original paper]), growing from 915 in 2012 to 3,123 in 2018—a 3.4-fold increase. All accommodation types showed growth trends, with increases decreasing as star rating increased. Ordinary type showed the largest increase, adding 1,507 facilities, while four-star and above showed the smallest increase, adding only 23 facilities. From the standard deviational ellipse perspective (Figure 2 [Figure

2: see original paper]), the overall distribution trend in 2012 was north-south along Altay Road and Hetan Road. Urumqi is an arid oasis valley city where urban development is significantly influenced by terrain, water sources, and transportation arteries, resulting in a north-south distribution pattern. However, the 2018 standard deviational ellipse shifted noticeably northward with significantly expanded geographic coverage, beginning to spread to peripheral areas. The ellipse azimuth rotated northeast, and the accommodation facility centroid shifted northeast, indicating that the Midong New District urban cluster experienced far greater accommodation growth than other urban clusters. The minor axis increased by 10 km, showing east-west expansion, indicating that accommodation facilities in peripheral areas like the high-speed rail station district and Bagang District also increased, expanding the minor axis length. Although the accommodation industry remains distributed along major urban transportation routes, a trend toward intensified dispersion has emerged.

2.2 Spatial Structure Evolution by Accommodation Type The distribution and evolution trends of various accommodation types in the main urban area differed significantly (Figure 3 [Figure 3: see original paper]). In 2012, economic and four-star+ hotels were mainly distributed along Hetan Road with obvious axial layout, while three-star and ordinary types showed discrete, relatively balanced distribution. By 2018, all types except ordinary showed significant changes in distribution direction and dispersion trends. Three-star and economic types showed intensified discrete expansion and weakened axial trends. The former shifted from northeast-southwest to northwest-southeast distribution, attributed to transportation industry development in the northwest high-speed rail district driving related hotel accommodation growth. The latter' s ellipse spatial range increased, representing strengthened discrete distribution and weakened axial trends, mainly because economic hotels have smaller scales and "chain operation" concepts, making spatial expansion more market-rational while avoiding blind over-agglomeration and vicious market competition.

2.3 Agglomeration Characteristics Analysis To explore spatial agglomeration characteristics of four accommodation types (ordinary, economic, three-star, four-star+), kernel density analysis was conducted (Figure 4 [Figure 4: see original paper]). Ordinary type evolved from multiple isolated cores to a more concentrated belt-shaped multi-core pattern with significantly increased kernel density levels. In 2012, main agglomerations were in the southern Changjiang Road and Nanhu Subdistricts, and northern Ergong and Gumudi West Subdistricts. By 2018, distribution agglomeration features became more pronounced, with new high-density areas in Erdaoqiao, Pingdingshan, Yingbin Road, and Qidaowan subdistricts. Simultaneously, isolated island-shaped centers formed in peripheral areas with obvious diffusion trends, showing a clear central agglomeration-peripheral diffusion pattern.

Economic hotels transformed from point agglomeration to belt agglomeration. In 2012, four independent small agglomeration centers were located near the

southern old city railway station, including South Railway Station, Xinmin Road, Changjiang Road, and Xiaoximen subdistricts, while northern kernel density levels were low without obvious agglomeration areas. By 2018, Hetan Road, Beijing Road, and Altay Road formed a concentrated belt-shaped agglomeration area with a trend extending northward. No obvious agglomeration area formed in the north, but kernel density levels generally increased with expanded spatial coverage, indicating future agglomeration potential.

For three-star and four-star+ hotels, spatial agglomeration effects were less obvious than the former two types. Because higher-grade accommodation facilities have smaller quantities, location choices no longer tend toward agglomerated distribution due to market profitability and potential customer considerations, making agglomeration conditions increasingly strict and resulting in less obvious spatial agglomeration characteristics. Three-star agglomeration locations formed a relatively concentrated whole in Hetian Street, Xiaoximen, and Changjiang Road subdistricts, with new agglomeration centers in South Nanhu Road subdistrict. Four-star+ hotel spatial agglomeration characteristics showed minimal change.

2.4 Spatial Association Analysis Between Accommodation Facilities and Tourist Attractions

2.4.1 Fractal Structure Characteristics of Tourism Regional System

This study selects the Southern Airlines Pearl International Hotel and Urumqi International Grand Bazaar as the centers of tourism service facilities and tourist attractions, respectively. The Southern Airlines Pearl International Hotel is a five-star hotel with high specifications built early, while the International Grand Bazaar integrates culture, architecture, ethnic commerce, entertainment, and dining as Xinjiang' s tourism product collection and display center. Both are located in historically valley areas (now along Hetan Road), an early-developed region that remains the city' s development pole as an important commercial, cultural, and shopping center.

Calculations yield double logarithmic plots of Urumqi' s tourism and accommodation system aggregation dimensions (Figure 5 [Figure 5: see original paper]). The tourism system' s scale-free interval is relatively wide with an aggregation fractal dimension of 1.03 (<2) and R^2 of 0.993, showing good fitting results. This indicates that the International Grand Bazaar exerts certain attraction effects on other tourist attractions' spatial distribution. The system has evolved into a self-organizing fractal system with density decaying from the central tourist attraction to surrounding areas, forming a compact agglomeration pattern.

The accommodation facility system exhibits multifractal characteristics. The first scale-free interval corresponds to Rs range of 0-0.43 km with R^2 of 0.96 and aggregation dimension of 1.32 (<2), mainly comprising high-end hotels with small quantities and loose spatial structure. The central hotel' s control is limited. The second scale-free interval corresponds to Rs range of 0.43-3.38

km with R^2 of 0.94 and aggregation dimension of 2.23 (>2), indicating subsystems' spatial agglomeration significantly decreased and accommodation facilities within this radius shifted from agglomeration to dispersion. The third scale-free interval corresponds to Rs range of 3.38-8.16 km with R^2 of 0.92 and aggregation dimension of 1.85 (<2), returning to agglomeration state. However, the fractal dimension meaning differs: for the 0-0.43 km interval, limited land and high prices determine that accommodation facilities are mainly high-end or chain hotels; for the 3.38-8.16 km interval, accommodation facilities are mostly social hostels and guesthouses with small scales, low land costs, and natural self-organizing agglomerated distribution without artificial control, showing obvious "center-periphery" phenomena with high agglomeration around the system center.

To measure fractal coupling between the two subsystems, we first integrate the two scale-free intervals of accommodation facilities (D_1=1.36, D_2=1.85) and calculate the geometric mean with tourist attraction aggregation dimension D_3=1.03, yielding tourism regional system spatial fractal dimension Dd=1.18 (<2). This indicates strong spatial coupling between Urumqi' s main urban area tourist attractions and accommodation facilities, with obvious centrality and monocentric distribution. Both show density decay from center to periphery, indicating high spatial structure compactness. According to the tourism regional system evolution pattern "point development–agglomeration development–polycentric development–integrated development,"the system is currently in the primary stage of monocentric agglomeration development with relatively weak self-organizing optimization capacity. Based on development trends in peripheral Midong and high-speed rail districts, the system may evolve toward a polycentric model. However, the scale-free intervals do not obviously cover the entire area, and the system' s spatial absorption radius has not reached maximum. The final integrated state of tourism regional systems must present a single scale-free interval covering the entire area, indicating that although coupling coordination is good, distribution has not reached ideal optimal structure and fractal structure requires adjustment and optimization.

2.4.2 Empirical Analysis of Tourism Regional System Spatial Coupling Fractal aggregation dimension calculation assumes that tourism facilities and accommodation facilities possess fractal characteristics in space. This section explores their spatial association through empirical analysis. Using ArcGIS, we measure coupling from global and local distribution perspectives. Within the main urban area, we establish fishnet grids and calculate the quantity of both facility types in each grid. Pearson correlation analysis of their quantity matrices yields a correlation coefficient of 0.77 (p=0.01), indicating significant spatial synergy. This is because tourism development drives accommodation facility growth, while increased accommodation provides more choices for tourists, with both industries mutually promoting tourism regional system development.

From a local layout perspective, given that Altay Road, Beijing Road, and Hetan Expressway are main distribution areas, we establish road buffers with five levels (500 m, 1,000 m, 1,500 m, 2,000 m, 2,500 m). Tourist and accommodation facilities within buffers account for 92.6% of the total, well representing the study area' s tourism regional system. Statistical analysis of both facility types within each buffer level yields R^2 of 0.926 (Figure 6 [Figure 6: see original paper] and Figure 7 [Figure 7: see original paper]), demonstrating strong spatial correlation and synergy. The correlation of industrial functions determines their spatial proximity.

3. Conclusions

Based on measuring Urumqi's accommodation industry spatiotemporal patterns, this paper examines the spatial relationship between accommodation facilities and tourist attractions, reaching the following conclusions:

1) Between 2012 and 2018, all types of accommodation facilities in Urumqi' s main urban area increased significantly, generally distributed along major transportation routes such as Hetan Road and Altay Road. The convention center 商圈, high-speed rail station 商圈, and Midong New District show potential to become peripheral accommodation agglomeration centers.

2) The overall accommodation facility pattern shifted northeast, transitioning from axial agglomeration to discrete distribution. Different accommodation types show varying spatial agglomeration characteristics: ordinary type evolved from isolated cores to belt-shaped multi-core patterns with obvious central agglomeration-peripheral diffusion trends; budget hotels transformed from point agglomeration to belt agglomeration, forming concentrated contiguous distribution in urban areas; three-star and above hotels mainly formed agglomeration centers in the Xiaoximen area with minimal spatial agglomeration changes. We recommend increasing high-grade hotel numbers in the northern new district to meet urban northward expansion needs.

3) Accommodation facilities and tourist attractions show strong spatial coupling. The tourism regional system follows a monocentric development model with high spatial structure compactness but has not reached ideal optimal structure, requiring fractal structure adjustment and optimization. Both global grid matrix and local road buffer analyses show strong spatial correlation between the two facility types. Their industrial function correlation determines strong spatial association, though some areas show 不协调 situations. We recommend adding tourist attraction service facilities near new urban districts like Midong New District and high-speed rail station district to coordinate with accommodation facilities and meet tourist demands.

Due to limited data access, this paper only analyzes accommodation indus-

try evolution from 2012-2018 without considering tourism markets and other tourism nodes' impacts on the tourism regional system, which may result in incomplete analysis and insufficient mechanism explanation. Future research could explore accommodation spatiotemporal evolution over longer time scales or propose regulation and optimization methods for tourism regional systems.

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Note: Figure translations are in progress. See original paper for figures.