Spatio-temporal Differentiation and Identification of Active Zones of Urban Night-time Economy in Tianjin

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Abstract

The night-time economy serves as a pivotal engine driving consumption upgrading, and the identification of its spatio-temporal differentiation laws is of great significance for optimizing urban resource allocation. Taking the six central districts of Tianjin as the study area, this paper integrates social media data with the Spatial, Temporal, and Space-Time Scan Statistics Software (SaTScan) spatiotemporal scan statistics method to systematically reveal the spatio-temporal dynamic characteristics of night-time economic activities. The main conclusions are drawn as follows: (1) Night-time economic activities exhibit significant seasonal fluctuations, with the intra-day activity showing a single-peak distribution. (2) The spatial pattern of night-time economic activities presents a gradient characteristic of core-periphery, where Heping District and its surrounding streets have a high level of activity. (3) The cultural and tourism belt along the Haihe River and transportation hubs reflect the waterfront economy mode and transportation-oriented mode, respectively, and there are significant differences in the intensity and duration of night-time economic activities across different time periods and locations. This study can provide methodological and case support for research on urban night-time economic vitality.

Keywords

Urban night-time economy, Social media data, Spatio-temporal differentiation, Tianjin city

Introduction

In recent years, with the accelerated transformation of urban economic structures and the upgrading of consumption patterns, the night-time economy has emerged as a crucial engine for stimulating urban vitality and promoting consumption growth. The night-time economy refers to a collection of service-oriented economic activities occurring between 18:00 and 06:00 the next day, encompassing diverse business formats such as catering, shopping, and leisure and entertainment [1]. Early research on the night-time economy primarily focused on fields like public safety and sociology, with a particular emphasis on the correlation between the night-time economy and crime rates [2]. In recent years, scholarly explorations have shifted toward the spatial distribution and development measures of the night-time economy [3,4]. However, analyses of its spatiotemporal interaction characteristics remain relatively limited. The advancement of big data technology has driven innovations in research methodologies. Studies based on social media data have effectively overcome the limitations of traditional survey data, such as high costs and poor timeliness, providing a new pathway for micro-scale spatiotemporal analysis [5]. Meanwhile, the SaTScan spatiotemporal scan statistics method, which integrates spatial and temporal dimensions for joint analysis, has been applied in fields like urban vitality assessment, offering methodological support for identifying spatiotemporal active zones of the night-time economy in this study [6]. In summary, this study takes the six central districts of Tianjin as the research case. It integrates Weibo check-in data, the SaTScan spatiotemporal scan statistics method, time stratification, and spatial autocorrelation analysis to systematically reveal the spatiotemporal differentiation laws of night-time economic activities and identify key active zones. The research findings aim to provide a scientific basis for optimizing the spatial layout of the night-time economy and enhancing urban governance efficiency.

Data sources

Social media data were retrieved via the Location-Based Service (LBS) Application Programming Interface (API) of the Sina Weibo Open Platform using Python, with a total of 98,341 original records collected for the night-time window (18:00-06:00) from January to December 2024 in the six central districts of Tianjin. The dataset included attributes such as user ID, username, geographic location, location type, longitude, latitude, posting time, and post text. A rigorous data cleaning process was applied to the original social media data to ensure data quality, with the following steps implemented: (1) Abnormal user filtering: Users who posted 10 or more times per day were excluded to eliminate the interference of extreme posting behavior on the overall analysis. (2) High-frequency location deduplication: For the same user posting three or more times at the same location within one hour, only the first record was retained to avoid data redundancy caused by repeated check-ins. (3) Business format screening: Based on the location type information in the dataset, only check-in data related to the night-time economy were preserved. After the above cleaning procedures, a total of 65,486 valid records were obtained for subsequent analysis.

Research methods

(1) Time stratification method

Based on the time tags of social media data, a multi-scale time stratification framework was constructed to analyze the temporal dynamics of night-time economic activities from multiple dimensions, with the specific stratification design as follows: (1) Daily stratification: The study period was divided into weekdays (18:00-06:00 from Monday to Thursday) and rest days (18:00-06:00 from Friday to Sunday) to capture the differences in night-time economic activity patterns between work and leisure periods. (2) Hourly segmentation: The entire night-time window (18:00-06:00) was divided into 12 consecutive hourly time intervals to reflect the fine-grained temporal variation of night-time economic activities. (3) Monthly stratification: The annual data were partitioned by natural months to explore the seasonal and monthly fluctuation characteristics of night-time economic activities. The activity level of each time interval was measured by the check-in rate.

(2) Spatial autocorrelation analysis

Spatial autocorrelation analysis is an important method to detect the spatial dependence and heterogeneity of geographical elements. It reveals the characteristics of data distribution by quantifying the spatial association patterns of attribute values. Spatial autocorrelation analysis can be divided into global and local types, among which local spatial autocorrelation analysis can further identify the locations and spatial distribution characteristics of attribute agglomeration areas within a region [7]. This study aims to explore the spatial distribution characteristics of night-time economic activities in Tianjin by adopting global and local spatial autocorrelation analysis methods.

(3) SaTScan spatiotemporal scan statistics

SaTScan is an analytical tool based on spatiotemporal scan statistics, which detects abnormal clustering patterns in spatiotemporal data by constructing a dynamic scanning window. This study adopted its Space-Time Permutation Model to identify the spatiotemporal active areas of night-time economic activities in Tianjin. Originally, the core advantage of this model is that it does not require preset population risk distribution and can identify significant clusters only by virtue of the number of cases and spatiotemporal coordinates. This makes it suitable for scenarios lacking background benchmark data, such as the night-time economy. The basic principle of the model is to construct a dynamic scanning window, with the spatial dimension being circular or elliptical areas of different radii and the temporal dimension being continuous time periods of different lengths [8]. Within each scanning window, the Likelihood Ratio between the actual number of cases and the expected number of cases under the null hypothesis is calculated, and its statistical significance is tested via Monte Carlo simulation, thereby identifying high-density spatiotemporal agglomeration areas [9]. In this study, the number of cases refers to the number of social media posts. First, a sensitivity test of spatial resolution was conducted, and a 150m×150m grid was selected as the basic spatial unit. Each check-in post was matched to the corresponding grid unit according to its longitude and latitude coordinates. Then, in accordance with the definition of the night-time economy, the period from 18:00 to 06:00 was divided into 12-time intervals, thus constructing a case file containing the ID of each spatial unit, time interval and the number of cases. Calculations were performed using SaTScan, and the statistical significance of each scanning window was evaluated through Monte

Carlo Hypothesis Testing, so as to identify the significant agglomeration areas [10].

Research results

Temporal variation characteristics of night-time economic activities

Night-time economic activities in Tianjin exhibited significant seasonal differences. As shown in Table 1, the active peak period occurred from April to August, with the check-in volume accounting for 53.52% of the total; the monthly peak appeared in May, reaching 12.12%, while the winter months (December to February) only contributed 14.45%. Air temperature was significantly positively correlated with check-in density, indicating that climatic comfort is the primary driver of seasonal fluctuations in night-time economic activities. Further analysis revealed a notable difference in the vitality of night-time economic activities between weekdays and rest days. The average daily check-in volume on rest days was 2.27 higher than that on weekdays, which demonstrates that the increase in residents' disposable time significantly stimulates nighttime consumption.

Table 1. Monthly variation in night-time economic activity levels in Tianjin's six central districts.

Month	1	2	3	4	5	6
Number of check-ins	3,646	3,669	4,972	6,912	7,935	7,172
Weekday check-in rate (%)	0.06	0.07	0.06	0.11	0.13	0.09
Weekend check-in rate (%)	0.05	0.04	0.09	0.11	0.11	0.13
Month	7	8	9	10	11	12
Number of check-ins	6,313	6,716	6,076	6,247	3,681	2,147
Weekday check-in rate (%)	0.10	0.10	0.09	0.11	0.05	0.03
Weekend check-in rate (%)	0.09	0.10	0.09	0.08	0.06	0.04

In terms of intra-day distribution (Table 2), the night-time activity presented a single-peak structure. The golden hours (18:00-23:00) accounted for 82.93% of the total check-ins, with the peak occurring in the period of 22:00-23:00 (15.59%). Night-time activities were more concentrated on weekdays, with the proportion of check-ins during 18:00-23:00 reaching 71.68%, compared with 68.12% on rest days. However, the late-night activity level (23:00-02:00) on rest days was higher than that on weekdays (26.91% vs. 24.14%), which reflects the restrictive effect of social work and rest systems on the time periods of night-time economic activities. Sustained activity was still observed after 02:00 in the early morning, with a daily average of 4.62% of the total check-ins, which was mainly concentrated in 24-hour business formats such as bars, KTVs and convenience stores. This finding highlights the resilience of Tianjin's nightlife.

Table 2. Hourly distribution of night-time economic activity levels in Tianjin's six central districts.

Time period	18:00-18:59	19:00-19:59	20:00-20:59	21:00-21:59
Number of check-ins	7,674	8,756	9,149	9,846
Weekday check-in rate (%)	0.12	0.14	0.15	0.16
Weekend check-in rate (%)	0.12	0.13	0.13	0.14
Time Period	22:00-22:59	23:00-23:59	0:00-0:59	1:00-1:59
Number of check-ins	10,206	8,679	5,500	2,648
Weekday check-in rate (%)	0.16	0.13	0.08	0.04
Weekend check-in rate (%)	0.15	0.14	0.09	0.04
Time period	2:00-2:59	3:00-3:59	4:00-4:59	5:00-5:59
Number of check-ins	1,357	667	401	603
Weekday check-in rate (%)	0.02	0.01	0.01	0.01
Weekend check-in rate (%)	0.02	0.01	0.01	0.01

Spatial distribution characteristics of night-time economic activities

The night-time economic activities in the six central districts of Tianjin presented significant spatial differentiation characteristics as a whole. Global spatial autocorrelation analysis was conducted on each subdistrict, yielding a global Moran's I value of 0.248914, a Z statistic of 3.554603 and a P value of 0.000379. These results indicate that the night-time economic activities in the six central districts of Tianjin have a significant positive spatial autocorrelation overall, showing obvious agglomeration characteristics.

The local Moran's I index identified six high-high (H-H) agglomeration areas (Table 3), which are mainly concentrated in Xiaobailou Subdistrict, Quanyechang Subdistrict and other subdistricts. These areas share the common characteristics of profound commercial and historical heritage, improved supporting facilities, and a rich variety of culture-tourism integrated business formats, exerting a positive driving effect on the surrounding subdistricts. As the commercial core area of Tianjin (Golden Street and Binjiang Road Business District) and a cultural and tourism hub (Five Great Avenues and Porcelain House), Heping District has a significantly higher level of night-time economic vitality than other areas. Combined with its transportation convenience and business format diversity, it forms a strong attraction. Low-high (L-H) agglomeration areas are mostly found in subdistricts closely connected to the core area, such as Nanyingmen Subdistrict and Dayingmen Subdistrict. Despite their relatively weak own foundation, these subdistricts have shown a good performance in night-time economic vitality driven by the spillover effect of the adjacent prosperous business districts. Low-low (L-L) agglomeration areas are mainly located in the northeastern and western fringe zones of the urban area, where the commercial supporting facilities and transportation accessibility are significantly lagging behind.

In general, the night-time economy in the six central districts of Tianjin presents a significant core-periphery characteristic. The core business districts and their surrounding subdistricts form the main high-intensity consumption areas, while the vitality of the night-time economy gradually declines with the increase in distance from the city center.

Table 3. LISA cluster analysis of night-time economic activity levels in Tianjin's six central districts.

Agglomeration area	Subdistrict
High-high	Xiaobailou subdistrict, Quanyechang subdistrict, Nanshi subdistrict, Tiyuguan subdistrict, Guangfudao subdistrict, Dawangzhuang subdistrict
Low-high	Nanyingmen subdistrict, Dayingmen subdistrict
Low-low	Xiangyanglu subdistrict, Jianchangdao subdistrict, Yueyahe subdistrict, Jiangdulu subdistrict, Lushandao subdistrict, Changzhoudao subdistrict

Identification of spatiotemporal active zones of night-time economic activities

Based on the SaTScan Space-Time Permutation Model, 13 significant spatiotemporal clustering zones were identified and numbered in descending order of the number of check-in posts, meaning zones with smaller numbers have more active night-time economic activities. Their spatial distribution was then visualized via ArcGIS (Figure 1). It can be seen that the 13 spatiotemporal active zones are mainly distributed in the urban core commercial districts and tourist scenic spots, nine of which are adjacent to the Haihe River, confirming the agglomeration effect of the waterfront economic belt.

In general, the distribution of active zones is relatively concentrated with a compact spatial radiation range, indicating that the focus of night-time economic activities remains in traditional consumption agglomerations, while such activities are scarce in the urban periphery or residential areas with single functions. High-intensity active zones are concentrated in well-known leisure and entertainment areas such as Jinwan Plaza (ID1), Golden Street (ID2) and the Tianjin Eye (ID3), where the culture-tourism integrated business formats are highly consistent with Tianjin's brand strategy of Night Tour on the Haihe River. In addition, emerging hotspots, such as the area near the Olympic

Center (ID4), have witnessed a sharp surge in night-time check-ins during large-scale events (e.g., concerts and sports events), with the surrounding catering and accommodation formats contributing significantly to the activity level, which confirms the event-driven night-time economic model.
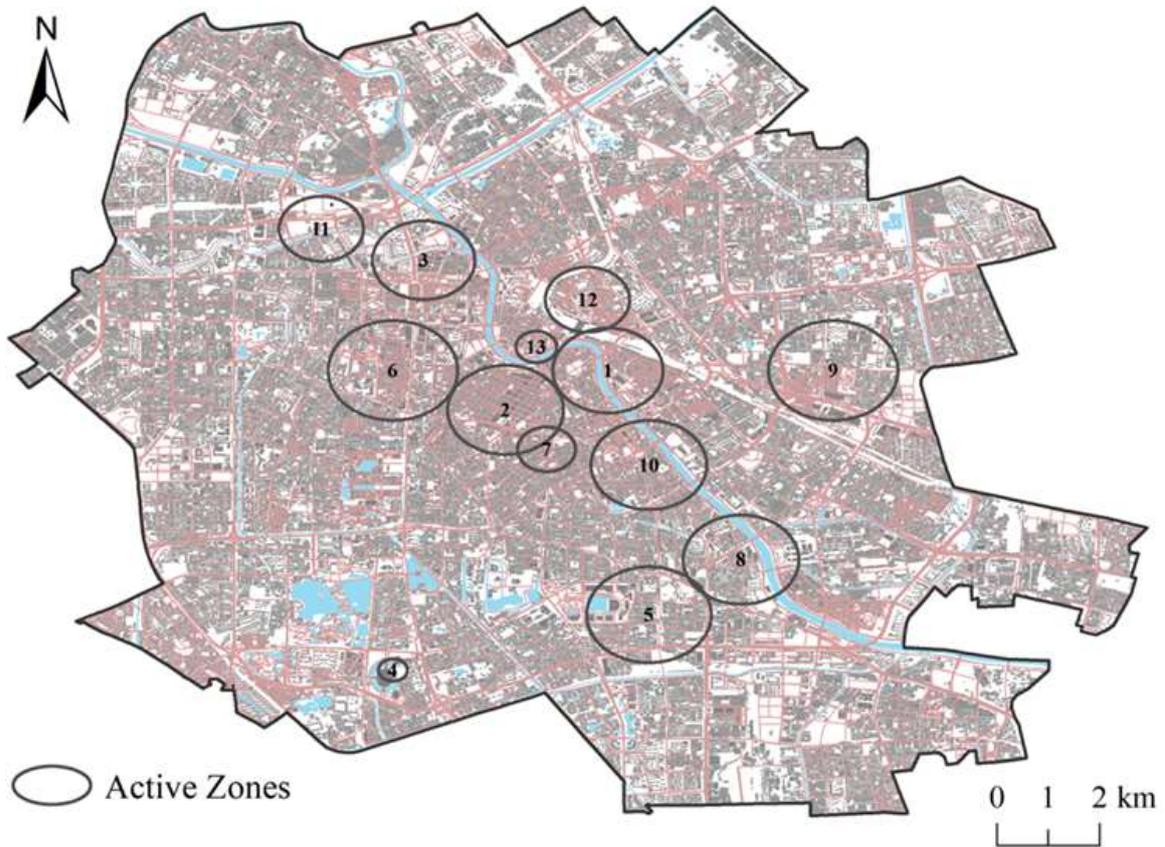

Figure 1. SaTScan-based spatiotemporal distribution of night-time economic active zones in the six central districts of Tianjin.

In the temporal dimension (Table 4), the active zones present a bimodal characteristic: the first peak occurs from 18:00 to 20:00, accounting for 25.09% of the total check-ins, and the second peak is from 23:00 to 01:00 (21.65%). The number of active check-ins in the Olympic Center area (ID4) exceeds 1,000 in the late night (00:00 to 04:00), reflecting the extension effect of cultural and sports events on night-time periods. Zones around transportation hubs (ID12, ID13) maintain a certain level of activity in the early morning (00:00 to 05:00) due to night train schedules, with convenience stores and fast-food restaurants as the main contributing formats, highlighting the characteristics of the transportation-oriented night-time economy.

Overall, night-time economic activities in the six central districts of Tianjin exhibit the spatial characteristics of core agglomeration and multi-point dispersion, as well as temporal differences of concentration and delay.

Table 4. Hourly activity patterns of night-time economic active zones in Tianjin's six central districts.

ID	Active time periods	ID	Active time periods	ID	Active time periods
1	21:00-0:00	6	18:00-20:00	11	18:00-19:00
2	18:00-20:00	7	22:00-0:00	12	2:00-5:00
3	21:00-0:00	8	0:00-4:00	13	0:00-4:00
4	0:00-4:00	9	18:00-20:00		
5	18:00-19:00	10	18:00-19:00		

Conclusion

Based on social media data, this paper explores the spatio-temporal differentiation characteristics of the night-time economy in the six central districts of Tianjin by using the time stratification method and spatial autocorrelation analysis and identified the significant active zones in combination with SaTScan. The research conclusions are as follows: (1) The activity intensity showed seasonal fluctuations, with high levels in spring and summer and a significant decline in winter; the intra-day activity presented a single-peak distribution, rising rapidly after 18:00 and peaking at 22:00-23:00. In addition, the late-night activity level (23:00-02:00) on rest days was significantly higher than that on weekdays, which reflects the comprehensive influence of seasonal climatic factors and residents' living habits on night-time economic behaviors. (2) The night-time economic activities presented a core-periphery gradient pattern. As the commercial core area, Heping District attracts a large number of citizens and tourists by virtue of its superior location and complete commercial functions, while the night-time economic vitality of subdistricts near the urban fringe was relatively low. Global and local spatial autocorrelation analysis confirm such spatial agglomeration characteristics: The high-high agglomeration areas are mainly distributed in the commercial and cultural blocks in the city center, and the low-low agglomeration areas are mostly located in the northeastern and western fringe zones of the city. (3) The spatiotemporal active zones of the night-time economy are identified via SaTScan, and it is found that the intensity and duration of night-time commercial and entertainment activities varied significantly across different time periods and locations. The major commercial blocks and scenic spots in the city center maintain significant activity during the golden hours at night. The culture-tourism integrated zones along the Haihe River and transportation hubs reflected the waterfront economy and transportation-oriented modes respectively, and the late-night activity level near sports venues was relatively high during large-scale events.

Recommendations

The development of Tianjin's urban night-time economy needs to balance core quality improvement and edge activation and promote the balanced vitality of the whole region through policy regulation. (1) Optimize the spatial layout of core leadership and multi-polar linkage. First, strengthen the radiation efficiency of the core area: take the existing high-density agglomeration areas such as Golden Street and Jinwan Plaza in Heping District as hubs, create the brand IP of Night Tour on the Haihe River through activity upgrading and business format integration, and enhance the added value of cultural and tourism consumption. Second, activating the vitality of edge nodes: in low-low agglomeration areas such as Xiangyang Road Subdistrict in Nankai District and Lushan Road Subdistrict in Hedong District, layout community-based night-time convenient service circles, add 24-hour convenience stores and self-service libraries, and configure special night bus lines to make up for the shortcomings of commercial supporting facilities and transportation. (2) Constructing a flexible temporal management system of all-time and seasonal differentiation. Extending services during peak periods: extending the operation time of some subway lines to 01:00 a.m. on weekends and holidays to ensure the convenience of night-time travel. Innovating business formats in winter: in response to the decline in winter activity caused by low temperatures, build immersive indoor consumption scenarios, construct a constant temperature corridor system in business districts such as Binjiang Road, and link merchants to launch seasonal business formats. (3) Deepening the dual-drive mode of events and transportation. Empower the event economy: establishing a linkage mechanism for large-scale events in areas such as the Olympic Center (ID4), coordinating the discount bundle marketing of concerts, sports events with surrounding catering and accommodation services, and amplify the traffic-to-consumption conversion rate. Carrying out night-time transformation of transportation hubs: adding late-night bus transfer points around Tianjin Station (ID12) and Tianjin West Station (ID11) and building an integrated station-city night-time service network.

Conflicts of Interest

The author declares no conflict of interest.

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