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Spatiotemporal Structure Features of Network Check-in Activities of Urban Residents and Their Impacting Factors: A Case Study in Six Urban Districts of Beijing

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Abstract

In this paper, six urban districts of Beijing were used in a case study in which the check-in data of Sina Micro-blog (Weibo), a micro-blogging website, from September 24 to October 7, 2014, were acquired, and the spatial and temporal distributions of the check-in activities of urban residents and their impacting factors were investigated through GIS kernel density analysis and SPSS correlation analysis. The results showed that in a continuous time period, the check-in activities assumed a wavy periodic motion with a cycle of 24 hours and also time differentiation characteristics. The spatial variations in the check-in activities in spatial agglomeration centers among the districts were somewhat large, with Chaoyang District being the most concentrated area among the spatial agglomeration centers. The distribution of the check-in activities exhibited significant features of rating-scale and core-periphery. The factors affecting the time distribution of the check-in activities mainly derived from the regularity of human activities, and the distance attenuation law and the urban services industry exerted important impacts on the spatial structure of check-in activities.

Keywords: big data; check-in activities; spatiotemporal structure; Beijing

1. Introduction

Against the backdrop of the rapid development of science and technology, communication technologies, and "big data", the application of social media network is changing people's daily life habits. The spatial activities of urban residents have gradually changed from the single space of home or office in the past to the multiple spaces of leisure and entertainment, outdoor recreation, and shopping centers (Cho *et al.*, 2013). The applications of online social media not only meet people's new daily needs but also change people's temporal behavior and activities (Gao *et al.*, 2014; Liang *et al.*, 2014). For example, online social media applications based on a location-based service (LBS) have guided check-in activities in particular locations during the process of business model development

(Kling and Pozdnoukhov, 2014), which have expanded the scope of geographic information recognition and activity spaces and are playing an increasingly important role in investigations on urban activity spaces (Rosler and Liebig, 2013).

Check-in activities can be monitored by using behavioral applications developed based on LBSs, in which people register their spatiotemporal behavior based on the specific purpose of their activities to record the real-time location, textual and image information, and activities within specific time and geographical ranges of locations with physical properties through mobile computing devices with the GPS function. As a unique geospatial and social networking behavior, it is also a novel human spatial behavior in the era of communication technology development and big data (Scellato *et al.*, 2011); the recording of large amounts of spatial traces obtained in network check-in activities makes it possible to investigate the spatiotemporal structure of urban activities by making use of the mobile traces in check-in activities (Ying *et al.*, 2012). On the one hand, residents' check-in activities occur in specific spatial locations, accompanying specific urban activities that also possess certain temporal characteristics (Zhan *et al.*, 2014). On the other hand, the rapid development of science and technology has prompted

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the greater visibility of "urban big data", and the effective utilization of these data in the investigation of urban spatial distribution characteristics has lent a new perspective to many urban issues (Malmiand and Daniel, 2013). However, the existing theoretical significance and research method concerning check-in activities remain at the exploratory stage, and a large number of case studies on spatial and temporal distribution check-in activities are required.

The dynamic nature of human activities determines the time series diversity of urban activity spaces (Taylor and Parks, 1975). Moreover, with the acceleration of urbanization and informatization, the network activities of Chinese urban residents become more frequent, and therefore, investigations on the change in residents' activities at the city scale, the spatiotemporal structure, and the activity monitoring on virtual network social activities in urban spaces have become issues facing many cities in China.

As the capital of the world's most populated nation, Beijing has an ever-increasing urban population. With the rapid increase in population, the chaotic sprawl of urban spaces in the pancake style has been prevalent over the years. As China's center of politics, culture, international exchanges, and scientific and technological innovations, Beijing has frequent information exchange with the rest of the country. It also leads the nation in terms of the utilization and penetration rates of the Internet. The frequent exchange of information and residents' everyday lives, with fast-paced spatiotemporal transformations, are also constantly changing the spatial form of the city.

The growths in population and land use have made Beijing a mega-city. Indeed, Beijing's urban population density is much lower than other global metropolitan areas. Nevertheless, it is faced with more severe urban diseases related to traffic and environment. The irrational layout of urban spaces is one of the main reasons for these problems. Therefore, in this study, Beijing was used as a case study, and the check-in data of a micro-blogging site were collected to investigate the spatiotemporal distribution of the network check-in activities of urban residents and its major affecting factors, which can improve our understanding of urban space structural features, shed new light on how to improve the efficiency of urban space use, and guide the sustainable development of Chinese cities. In particular, it contributes to the existing studies using check-in data in two aspects. Firstly, it carries out comprehensive analysis of the spatiotemporal structure of check-in activities. More importantly, it provides new insights into how the check-in activities are affected by traditional rhythms of urban activities and distribution of services.

2. Literature Review

The value of check-in data has been recognized in studies on human movement patterns (Zheng *et al.*,

2010; Bao *et al.*, 2012), urban agglomeration centers (Ferrari *et al.*, 2011), urban cyberspace systems (Long, 2014), and urban management (Wei *et al.*, 2012). The examination of the distribution of check-in activities in geographic spaces from a macro perspective to investigate their spatiotemporal distribution was once a hot topic in geographical studies (Bannur and Alonso, 2014). With the influence of post-modernism and the return of humanism, investigations on the trigger mechanism of human behaviors from the micro perspective in combination with sociology have been carried out by an increasing number of geographers and sociologists.

The spaces of check-in activities are important parts of urban activity spaces, which, as the unique perspective of urban studies, have received much attention from various disciplines such as geography and urban planning (Wu, 2001; Tang, 1997). The distribution, scale, and spatiotemporal characteristics of network check-in activities triggered by primary motivations such as being social, shopping, and playing games are becoming new topics in urban activity spaces (Feng *et al.*, 2013). On the one hand, as a new tool for people in a new era to become social and claim a social identity (Brown *et al.*, 2007; Iachello *et al.*, 2005), check-in activities are affecting the reconstruction of social networking space and are indispensable in understanding the rule of human behavior (Tang *et al.*, 2010). On the other hand, the distribution of people's check-in activities within the city can help city planners effectively understand the process of the agglomeration of urban activities and address the supply and demand balance in the space, thereby improving the efficiency of urban space utilization. Therefore, as the space created by check-in activities has becoming an important part of the space of urban activity, investigations on the structure of the new urban space using check-in data can provide insights into the formation of social space and the performance of urban space.

Studies on urban activity spaces have used both qualitative and quantitative methods. Qualitative studies require the researchers to collect and collate a large number of interviews through long-term and careful experiments and observations to obtain detailed first-hand data. Limited by factors such as the design of the questionnaires and the rules for the interviews, they tend to be limited by the smaller spatiotemporal scale of the sample distribution, which makes it difficult to represent the space of urban activity at the city scale. Quantitative studies mainly use traditional data such as the existing census and activity logs. However, traditional census data are relatively static and inelastic, and the activity log data are closely associated with subjective factors such as the memory, attitude and habits of the logger, largely reducing the accuracy of the data. In recent years, applications based on GPS mobile positioning technologies have

greatly enhanced the accuracy of the data, but the high cost in the data acquisition process has prohibited their wide application (Shen and Chai, 2013; Zhang and Chai, 2014). There is an urgent need for breakthroughs and innovations in the methods of data collection and analysis.

The development of information technology has made it possible to perform large-scale studies on activity spaces. As information and communication technologies (ICTs) rapidly develop, big data are impacting many aspects of urban planning and geography with new data generation methods such as full sample, mass data, and "4V" features. Big data applications based on mobile social networking and smartphone users in the field of urban and rural planning are becoming increasingly widespread. The occurrence of check-in behavior has attracted the attention of many scholars. In studies on data from social media networks, the check-in locations of network users are recognized mostly through the inherent function on the activity classification of the social media networking software, by which the daily human activities are correspondingly classified. Ying, Malmi, and other investigators have used the check-in data of Bright kite, GoWalla and Foursquare users, respectively, to establish the users' habits in different locations and predict the hot spots in the city (Ying *et al.*, 2012; Malmi and Dainiel, 2013). Zhang uses a state-of-the-art technique to analyze the check-in data of Twitter users to examine the land use types in New York City (Zhang *et al.*, 2014). Researchers are attempting to take advantage of this new aspect to broaden people's perspective on urban activity spaces, which are no longer confined within a certain type of activity space but instead are becoming more comprehensive and dialectical in terms of the understanding of the urban activity space.

3. Methodology

The scope of this study is the central regions of Beijing, i.e., Dongcheng, Xicheng, Haidian, Chaoyang, Shijingshan, and Fengtai Districts, hereafter referred to as the "six urban districts", in accordance with the districts of the administrative regionalization conducted in 2010. The population density of the central regions of Beijing is as high as 20,000 people / square kilometer, being the most concentrated urban area in terms of population, facilities, and transportation in the city.

The open source data of Sina Micro-blog, China's most visited social media micro-blogging website, were used to collect a total of 335,123 items of check-in data from the period from 00:00 September 24 to 24:00 October 7, 2014, of the six urban districts of Beijing. These data were integrated into the ArcGIS World Administrative Map based on the geographic information and latitude and longitude of the locations of the check-ins to convert them using the Data

Frame geographic reference system into data points. The points with erroneous geographic coordinate information and falsification or with overlapped check-ins and attributes were excluded or deleted. This leaves us with the final total of 215,185 effective check-in points, all of which were then reintegrated into the administrative map of the six urban districts.

The data has three basic attributes. 1) Temporal characteristics: previous studies have found that studying the check-in density of the activities using the minute as the time measuring unit did not completely reflect the characteristics of the dynamics and lost statistical significance. Therefore, the data collection cycle was set at 24 hours, in which the hour was used as the basic unit of time to acquire the check-in data at different time points. 2) Spatial characteristics: the check-in data were all labeled with the location point, e.g., the latitude and longitude, the name of the location, the administrative division, and other basic information. 3) Social characteristic: the Sina Micro-blog mainly focuses on broadcasting a newsletter edition blog. The micro-blogging content of the check-in data included MText showing that this type of check-in activity occurred at a specific place, which could be classified into a specific spatial classification system based on its social attribute.

This paper analyzes the data in two main aspects, i.e. the spatiotemporal structure of the check-in activity and the factors that determine or affect such spatiotemporal structure. More specifically, in terms of the temporal aspect, it looks at the temporal fluctuation of check-in activities on weekdays and on holidays, and the temporal affection by the rhythm of human activities. In terms of the spatial aspect, it analyzes the agglomeration, the core-periphery and the distance attenuation of such activities, and how they are affected by the distribution of services.

4. Temporal Structure Characteristics of Check-in Activities and their Influencing Factors

4.1 The Temporal Fluctuation

The change in the frequency of check-in activities per hour is analyzed to reveal the temporal fluctuation of check-in activities. The time period of September 24 to 30 was treated as workdays, whereas that of October 1 to 7 was treated as National Day holidays to compare the number of check-ins at each of the time points and the total check-ins per day. During the holiday period, the total check-ins in the six urban districts increased significantly compared with those of the workdays.

To more clearly analyze the pattern of changes in check-ins at each time point, the data were compared in percentage form. Figures 1 and 2 show that during the September 24-30 period, check-in activities plummeted starting in the early morning but increased at 6:00 and then plummeted again at 10:00, 13:00, 16:00, 19:00, and 22:00. The check-in activities on Friday proved to be a special case in which check-in activities increased

slowly from 5:00 to 12:00, increased explosively after 13:00, and continued to increase until 16:00, when they started to decrease. By comparing the check-in activities on other workdays, in a typical workday, the check-in activities decreased at 16:00, whereas on Friday, the check-in activities fluctuated drastically at 16:00 and had more significant increased at 20:00 and 23:00 than at the other time points. The dynamic patterns of the check-in activities on workdays and the holiday period were similar.

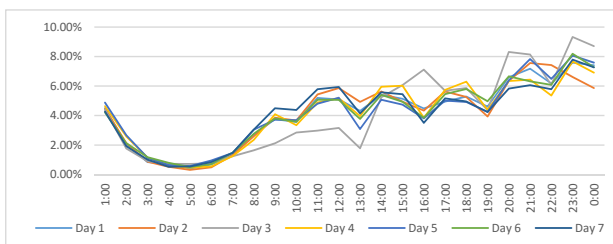


Fig.1. Check-ins in Percentage Form at Each Time Point on Workdays

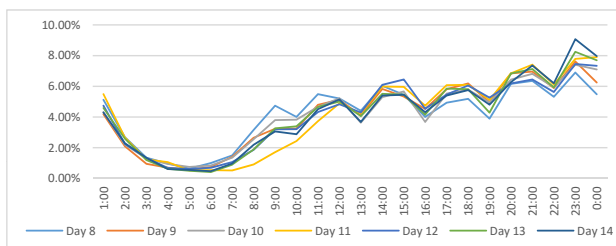


Fig.2. Check-ins in Percentage Form at Each Time Point on Holidays

4.2 Verification Analysis of the Rhythm

The percentage changes in check-ins per unit of time in 14 consecutive days show that the quantitative change in the check-in activities exhibited regular fluctuations to some extent. To verify the cycle length of the fluctuation, a Fourier analysis was conducted on the spectrum calculation to generate the frequency-spectral density chart for the 14 days. Spectrum analysis has been applied for two reasons: first, it has been used to detect the cycle or rhythm of change in a

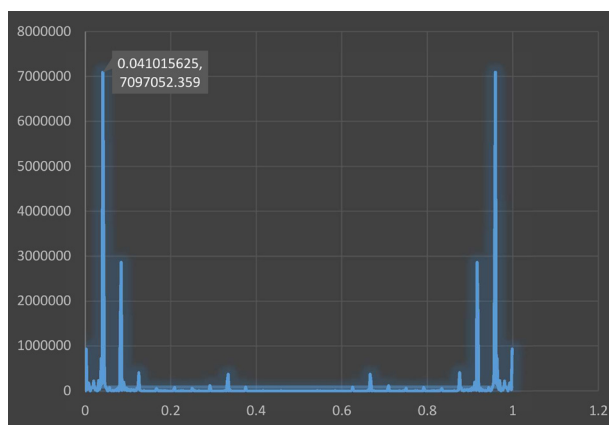


Fig.3. Fourier Analysis on Check-in Activities

system so that a causality relationship can be found and applied to predict a certain development; second, it has been used to find patterns in addition to the periodic cycle so that the spatial and temporal structures of the system can be explained.

Fig.3. shows that the frequency variation range in use was 0-1 and that the plotted spectrum was symmetrical. When $f = 0.5$ was set as the threshold, the peak value of the periodic point was $f = 0.041015625$, and the reciprocal of the time period was taken. The results show that the check-in activities exhibited a periodic 24 hour pattern, regardless of workdays or holidays. With the periodic change in time, the check-in activities also assumed a period of 24 hours, undergoing the wave-band style dynamics of "peak-trough-peak-trough".

4.3 Time Constraint of Human Activities

The rhythm of people's everyday lives has been an important factor affecting human behavior. Although the development of modern science and technology has enriched the network behavior and social life of urban residents, the traditional system of work and rest still dominates the daily activity pattern of urban dwellers.

The pace of life in Beijing, a first-tier city in China, is much faster than that in other second- and third-tier cities. Life in a typical workday shows regularity: rush hour is typically at approximately 7:00; during an average commute time of 40-60 minutes, people start to check in to the micro-blog and other websites on the way to work, leading to the fast increase in check-in activities. At approximately 9:00, check-in activities stabilize, and some employees have arrived at their workplace and habitually process social media network information. At approximately 10:00, people begin their formal work, leading to a sharp decline in check-in activities, whereas 11:00 is a turning point, when the work break and the approaching lunchtime cause a rapid growth in check-in activities. In the afternoon, a similar pattern repeats, and people engage in leisure and entertainment for one hour after work. In the evening, 20:00-23:00 mark nighttime events, fluctuating in activities. Starting at 23:00, network activities sharply decline, followed by a trough of low activity for four hours, indicating that the majority of the network population has retired. When placing the same pattern in the case of holidays, the pattern of residents' activities during holidays in Beijing is shown to be similar to that during workdays. For example, starting at 7:00, tourists, outing locals, and various entertainment activities also commence. Because of the time restriction on the schedules of tourist attraction sites and activities, the activities of visitors and residents are mostly arranged within an hour, after which they have more leisure time to surf the Internet on their mobile phones. Moreover, during holidays, residents are more inclined to take a full rest in the evening so that the tourist activities the next day can be undertaken.

5. Spatial Structure Characteristics of Check-in Activities and Influencing Factors

5.1 Spatial Differentiation of Agglomeration Centers

The kernel density analysis was carried out for the check-in data using GIS platform. The results show that there were spatial central nodes derived from the agglomeration of check-in activities in each of the districts (Figs.4. and 5.). Chaoyang District was the main area of the agglomeration center of check-in activities, accounting for 32.7% and 42.6% of the total on workdays and holidays, respectively. This indicates that as the main agglomeration area of check-in activities, Chaoyang District has various kinds of spaces to accommodate such check-in-related activities, e.g., office, catering, entertainment and leisure, etc.

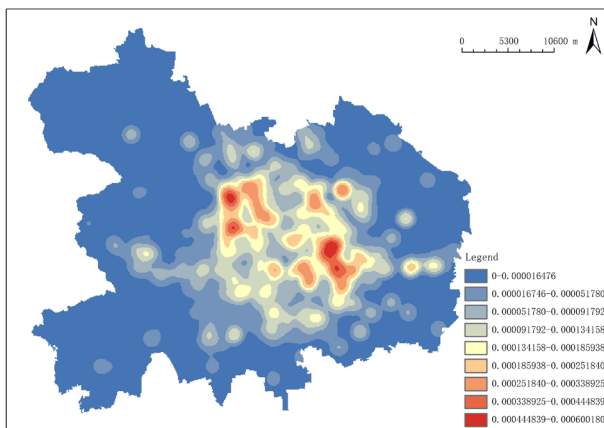


Fig.4. Kernel Density of Check-in Activities on Workdays

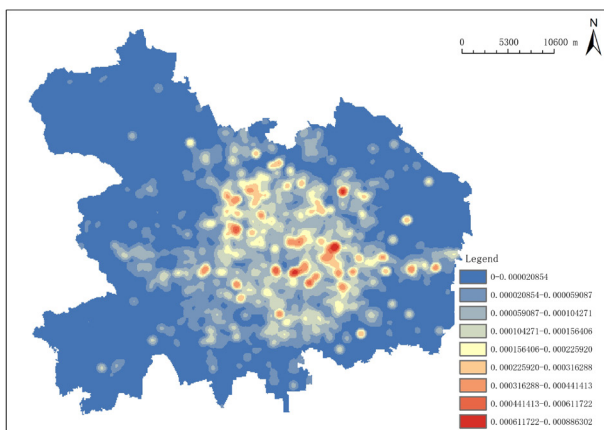


Fig.5. Kernel Density of Check-in Activities on Holidays

Dongcheng and Xicheng Districts came after Chaoyang as the second and the third in terms of the agglomeration of check-in activities. This is mainly because the two districts contain a large number of enterprises, governmental departments, and cultural attractions, which allow the residents working there to check-in at their workplaces, recreational facilities, and surrounding environment. Local residents and visitors can take advantage of wireless Internet devices at will to take pictures or engage in check-in activities while visiting tourist attractions.

Haidian District ranked fourth in terms of the agglomeration, indicating that during workdays and holidays, the activities of everyday life in the district are somewhat abundant, whereas those in Shijingshan District are somewhat scarce.

5.2 Rating-scale and Core-periphery Patterns

Thiessen polygons in the GIS system were created based on the selected major agglomeration centers of the activities. The results show that the check-in activities in the six urban districts exhibited the distinct distribution patterns of rating-scale and core-periphery, regardless of workdays or holidays (Figs.6. and 7.).

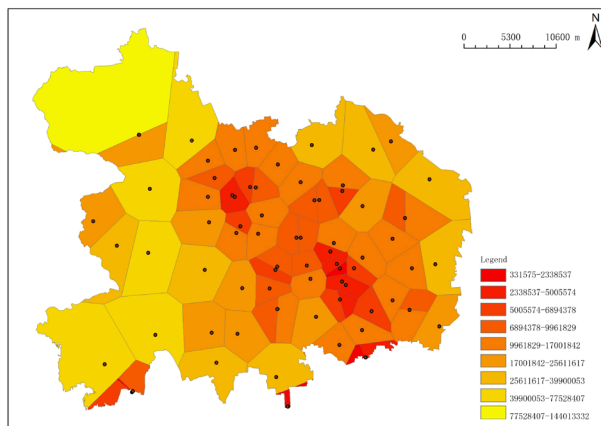


Fig.6. Check-in Activity Agglomeration Areas on Workdays

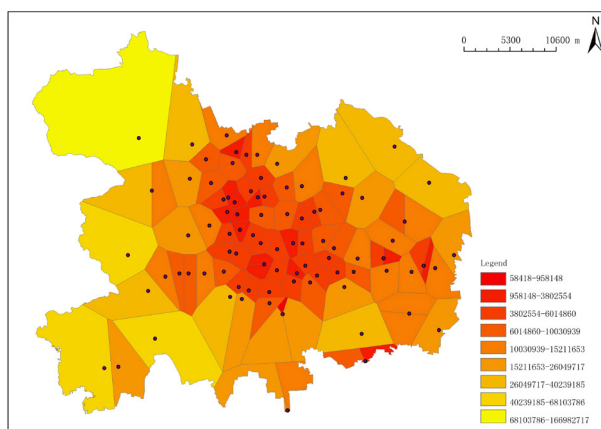


Fig.7. Check-in Activity Agglomeration Areas on Holidays

The main activity areas were divided into three levels, which are bordered by blue lines. The area with the deepest red is the Level I activity agglomeration area, and the Level II and Level III agglomeration areas of the check-in activities are similarly classified. In the case of workdays, there were 22 Level I activity agglomeration areas, accounting for 27% of the total, mainly in the vicinities of Zhongguancun and Wudaokou, the International Trade Building of Chaoyang District, and the areas surrounding Workers Stadium, in addition to the surrounding areas on the outskirts of the city. The Level II activity areas were widely distributed on the peripheries of the downtown area in a total of 45 areas, accounting for 44% of

the total; various stadiums, parks, universities, and shopping malls were the core areas of the check-in activities. The Level III activity areas had a total of 14 areas, accounting for 13% of the total, mainly in the peripheral areas of the downtown area, i.e., the border regions of Chaoyang, Haidian, Fengtai, and Shijingshan Districts.

When the agglomeration areas of the check-in activities were similarly divided in the case of holidays, similar structural characteristics of the significant core-periphery between the Level I and Level III activity areas were found, with a higher structured level than the activity area distribution of the check-in activities during workdays. Residents' Level I check-in activity areas were mainly distributed in the major colleges and universities in Haidian District, the commercial pedestrian streets and tourist attractions in Xicheng and Dongcheng Districts, and the outdoor recreational areas and various parks and stadiums in Chaoyang District. Residents' Level II check-in activity areas were mainly distributed in the major areas of Chaoyang, Fengtai and Haidian Districts, surrounding the peripheries of Dongcheng and Xicheng Districts. The Level III check-in activity agglomeration areas accounted for a small proportion of the total and were located on the outskirts, suburban areas, and places with a small stream of people.

5.3 The Effect of the Distance Attenuation Rule

Residents' network check-in activity is a type of urban activity that has developed based on network communication technologies. Whether check-in activity is restricted by distance remained unknown. Therefore, in this study, the agglomeration centers of activity spaces obtained from workdays and holidays were used to verify whether distance is a major limiting factor in the distribution of residents' network check-in activities.

First, the check-in data at different time periods were integrated into the GIS system, and buffer zones with a diameter of 200 m, 400 m, 600 m, 800 m, 1000 m, 1200 m, 1400 m and 1800 m, with the center of the circle at the agglomeration center, were generated. The distributions of the check-in points falling into each of the buffer zones at different distances were obtained by calculating the turning radius of the spatial nodes in the agglomeration centers and cutting the check-in points using the CLIP tool (Figs.8. and 9.).

To clearly observe the change in the number of check-ins with the distance to the agglomeration center, the data were imported into EXCEL, and turning radius analysis was performed. The results show that distance exerted an impact on the spatial distribution of network check-in activities, but at different time periods, its modes of action were different.

On workdays, residents' level of activity in the surrounding areas of the agglomeration center was high, exhibiting the characteristics of a wavy curve distribution. In places that were 400 m away from the

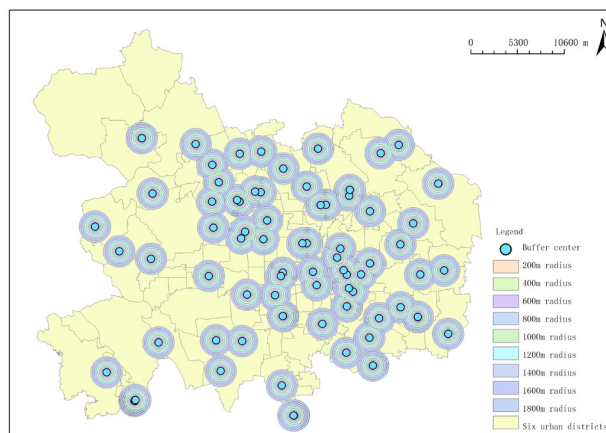


Fig.8. Buffer Zones Analysis on Check-in Activities on Workdays

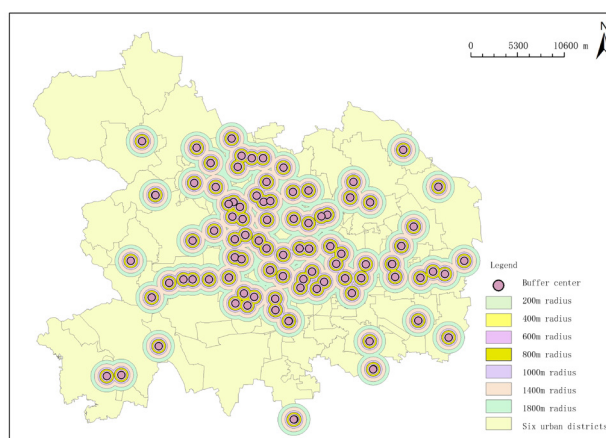


Fig.9. Buffer Zones Analysis on Check-in Activities on Holidays

agglomeration center, check-in activities were the most abundant and gradually decreased with distance, and the dynamics of the activities in places that were 100 m to 1800 m away from the agglomeration center showed a wavy curve distribution.

The check-in activities on holidays reflected the distance attenuation rule more accurately, showing a significant agglomeration distribution in the range of walking distances of 2-4 min; once beyond this range, check-in activities declined sharply.

5.4 Spatial Constraint of Human Activities

The spatial clustering of the services industry within the city is one of the major economic factors promoting the agglomeration of urban activities. As these activities are usually the ones that people check-in for, the spatial distribution of services are also a key factor affecting the spatial pattern of check-in activities. This is particularly the case in Beijing, which has been leading the nation in the development level of services, having established the new industrial structure dominated by the service economy as early as 2007.

Therefore, this study analyzes the correlation between the distribution of services and the spatial pattern of check-in activities using the POI (Point Of

Interesting) data of four categories of services in the six urban districts of Beijing in 2014 obtained using Baidu map. The POI data is chosen instead of other indicators such as floor area ratio, population density etc. for two reasons. Firstly, the services included in POI data are often the place for activities that can trigger check-in. The categorisation of services allows us to understand the purposes of check-in activities, which in turn reveals the pattern of residents' daily activities. Secondly, it has a higher geographical resolution and is more up-to-date. This allows for more precise analyzes at the point-to-point level.

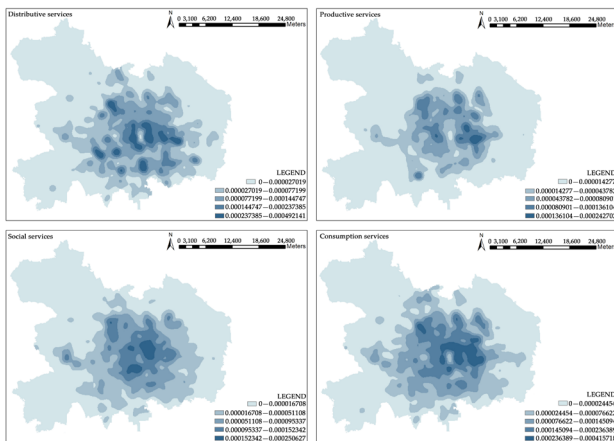


Fig.10. Kernel Density Analysis on Four Types of Services

The POI data were divided into productive services, consumptive services, distributive services, and social services according to the four categories in the services industry. The categorized service data points were then integrated into the GIS and analyzed using kernel density to reveal the spatial distribution pattern of each service category. These patterns were then analyzed with the Raster operation in the GIS together with the kernel density analysis chart (Fig.10.). Lastly, all of the data were exported, and analysis was conducted with the Pearson correlation test using the SPSS software package.

The results show that check-in activities and the distribution pattern of services were significantly correlated at the significance level of 0.01, indicating that check-in activities and the distribution of services had a correlation with a certainty of 99.99%. Different types of service industries had different levels of correlation with the distribution pattern of check-in activities at different time periods. For example, during workdays, productive services and consumptive services had higher correlations with the distribution of check-in activities, whereas during holidays, the correlations were lower.

Beijing has a large quantity of cultural and commercial service facilities, higher education clusters, sports facilities, shopping centers, and entertainment facilities, in addition to other social and consumption facilities. The spatial distributions of social and

consumption facilities, which have been acting as the major driving force of the aggregation of people, have a profound impact on the spatial pattern of the check-in locations of the social networking crowd. For example, there are a variety of social services organizations and facilities in multiple traditional alleyways (Hutong) in Dongcheng District and a number of universities and other social service facilities near Xueyuan Road, all of which have produced high-density check-in data in the above-mentioned areas. The distribution of consumption services was mainly to the west of and along the Central Road of the North Fourth Ring and along the Eastern Third Ring from Guomao to Sanyuanqiao Road; to some extent, this finding explains the formation of the high-density distribution pattern of activity spaces from Workers Stadium to the National Exhibition Centre. Distributive services had the lowest correlation with the distribution pattern of the activity spaces, indicating that the distribution of distributive services represented by transportation had a strong homogeneity, which enhanced spatial accessibility so that the activity spaces did not entirely depend on the agglomeration of transport infrastructure facilities despite being distributed along transport corridors.

6. Conclusion

Using the newly emerged check-in data, which provide much richer and more detailed temporal and spatial information than traditional data sources, this paper improves the understanding of the spatiotemporal structure of urban activities, through the new lenses of check-in activities. Firstly, it demonstrates that residents' check-in activities exhibited a periodic wavy fluctuation, in a 24-hour cycle, with volatile changes at multiple time points. Secondly, it shows that there is a spatial differentiation phenomenon between the check-in activity agglomeration centers of the six urban districts and distinctive structural features of "rating-scale" and "core-periphery". The check-in activity also follows the distance attenuation pattern observed in other urban activities.

Furthermore, by studying the affecting factors of the temporal and spatial pattern of urban activities, this paper provides new insights into the relation between urban activity and the rhythm of human activities and the spatial distribution of services. It reveals that as a behavior of recreation, leisure, and recording, the check-in activity of urban residents is affected by the rhythm of human activities. It also finds that the spatial distribution of services exerts an influence on the spatial distribution of the network check-in activities, and the impacts vary from industry to industry, as well as between working days and holidays.

In this way, this paper develops a method to continuously monitor the spatiotemporal pattern of urban activities, which can provide insight into how urban activities are changing with or without the

change of urban land use. After 30 years of rapid development since the reform and opening up, urban planning in China has transformed from "incremental planning" to "inventory planning". As urban construction activities have gradually been slowed down, how to arrange the spatial structure and urban activities system more effectively based on evaluations has become one of the most important tasks facing the urban planners. The method this paper develops therefore can be used for continuous evaluation and guidance for policies focusing on improving the quality of life in the social spaces of urban residents.

However, this paper still has a few limitations. Firstly, although the check-in data of Sina Microblog is much richer and more comprehensive than traditional data, it is still limited particularly in terms of its representativeness. Secondly, due to the word limit, this paper only investigates two of the most important factors affecting the spatiotemporal pattern of check-in activities. On this basis, in the future study, the authors will further examine the representativeness of the data and explore a way to extend it with other datasets. The authors will also explore more impacting factors affecting the spatiotemporal structure of the check-in activities. Moreover, they will investigate the definition of time in check-in activities in more depth, and analyze how the spatial pattern and the temporal pattern of check-in activities interact with each other.

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