

ANALYSIS OF URBAN SPACE VITALITY BASED ON WEIBO CHECK-IN DATA

A CASE STUDY OF SUZHOU

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1. Introduction

The city is a carrier of all kinds of residents' activities and the core of public activities [1]. With the rapid process of urbanization in China, the spatial structure of cities has been spreading, and in some cities, urban space has been redefined due to the construction of new districts and new cities, and the urban spatial structure has gradually evolved from a single center to a multicenter. In urban planning practice, multicentricity has become one of the common planning tools in major cities in recent years [2-4], and mega cities in China such as Beijing, Shanghai, Guangzhou, and Shenzhen all take multicentricity as the goal of urban development.

The research on urban spatial structure in China mainly involves: theoretical studies [5-6], studies on the characteristics of urban spatial structure patterns [7-9], studies on the relevance of urban structure to social problems [10-12], and the exploration of the relevance of urban structure to social economy [13-14]. The current stage of research mainly explores the spatial structure of cities by using planning and census data as the main data source and geospatial and morphological analysis as the method. However, these data have certain limitations, one of which is that the data accuracy is not sufficient to analyze the urban residents' aggregation within urban space at all scales, and the other is that the data are not real-time and cannot reflect the mobility characteristics of urban residents.

In recent years, with the development of information technology, big data has provided new data sources for urban spatial analysis. Among them, the more widely used are: social network pictures, night lighting data, shared bicycle travel data, heat map data, cell phone signaling data, and online taxi travel data, etc. Scholars such as Ying Long, Lu Yu, and Zhiying Li [15-18] have used these data to analyze urban space. However, these data have problems such as difficulty of access and few access channels for scholars. And the open-source Weibo check-in data provides a reliable alternative. Weibo check-in data records the check-in information of Sina Weibo users, which mainly includes information such as check-in time, check-in content, spatial location of check-in points, and the number of check-ins at check-in points [19]. The Weibo check-in data can be obtained through an API interface, which is easier to obtain compared with the other data which has mentioned before, and has been widely adopted in the current stage of urban spatial research. At present, domestic scholars mainly use Weibo check-in data as a measurement of foot traffic in various spaces and as a method to identify urban functional areas [20-21], but less research has been conducted on urban spatial vitality with this kind of big data.

At this stage, research on the spatial vitality structure of cities has mainly focused on megacities such as Beijing, Shanghai, and Shenzhen [22-24], with less attention paid to general prefecture-level cities. Suzhou, as an important part of the economically developed eastern provinces and cities in China, is one of the representative cities with the highest urbanization rate in China. At this stage, Suzhou has taken the lead in the country to enter the stage of re-urbanization,

and as one of the pilot cities for urban renewal announced by the Ministry of Housing and Construction in 2021, the focus of urban development has shifted from quantitative to qualitative models. The study based on the urban structure activation efforts of Suzhou has a good paradigm role for the rest of cities in China.

To this end, this study analyzes and investigates the spatial structure and spatial vitality of each area through Weibo check-in data, taking the scope of Suzhou city as an example. At this stage, the high-vitality areas of Suzhou are concentrated in the old city area, mainly the Pingjiang Road historical district, and the Jinji Lake area in the east of the Suzhou Industrial Park, with Suzhou Center and the Gate of the East as the core. This paper summarizes the spatial characteristics of Suzhou at the present stage of urban development through the study of Suzhou's urban vitality, and provides a reference for future urban development and spatial optimization.

2. Data and Methods

2.1 Data Source

Weibo check-in data was used in this study to measure users' geographic location and social activities. When users geo-tag posts using Weibo check-ins, their posts are tagged with highly accurate geolocation information. Using the API interface, the check-in information is captured and used as an indicator to measure the activity characteristics of the city's residents and, through time overlay, to capture the dynamic patterns of people's activity across the city. The data were collected over a one-week period (April 26, 2021 to May 2, 2021). The one-week data collection period provides a sufficient sample of data with cyclical characteristics. A total of 4,336 valid Weibo check-in data were collected during the time periods of 9:00-10:00, 12:00-13:00, 15:00-16:00, 18:00-19:00, and 21:00-22:00.

2.2 Research Methodology

2.2.1 Crowd Gathering Density Analysis Based on Weibo Check-in Data

In this study, the temporal and spatial dimensions were overlaid and analyzed in ArcGIS software based on microblog check-in data to reveal the characteristics of changes in the correlation between social activities and urban spatial environment of urban residents during a week's time. With reference to related scholars' studies, the relationship between the density of various types of social activities, the spatial duration cycle of urban activity and urban spatial structure at this scale was further explored using 1 km X 1 km as the unit of analysis [25]. Here, density is defined as the number of people visiting a unit area during a predetermined time period. Combined with previous studies [25], we introduce kernel density analysis as a tool to measure the density values within each unit area, which is calculated as shown below.

$$p_{ii} = \frac{1}{n\pi R^2} \times \sum_{j=1}^n \frac{k_j}{D_{ij}} \left(1 - \frac{D_{ij}^2}{R^2}\right)^2$$

Where: k_j is the weight of study object j ; i in D_{ij} is the distance between spatial point i and study object j ; R is the bandwidth of the selected study area.

2.2.2 Characterization of residents' activities in the context of multi-scale spatial environment

In addition, by selecting the two units with the highest spatial activity during the data acquisition period, we conducted a multi-temporal analysis to explore the relationship between urban spatial structure, residents' social activities and spatial activity.

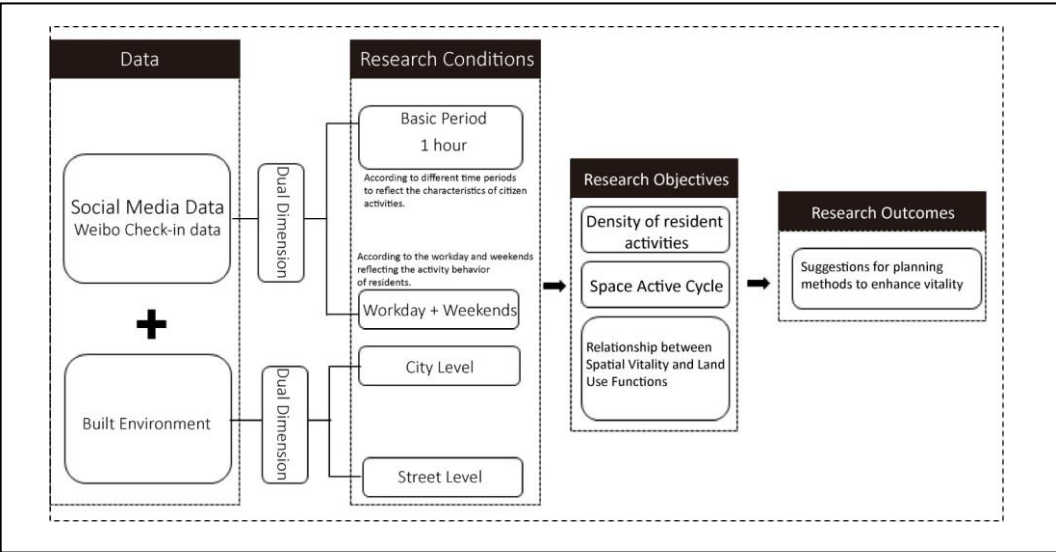


Fig.1 the Research Framework

This study uses the above three research methods as entry points to analyze the spatial dynamics in Suzhou at different scales, and the research framework is shown in Figure 1. The correlation between citizen activities and the surrounding built environment and land use mix was also analyzed by selecting the areas with high activity.

3. Exploration of Vital Space in Suzhou
3.1 Spatial Structure of Suzhou in Urban Scale

Figure 2 shows the physical geographic check-in locations where Weibo check-ins were performed during the study period. These spaces can be categorized into the following six main types: offices, restaurants, parks and tourist attractions, schools and research institutes, medical facilities, and entertainment venues. As can be seen from the figure, within the city of Suzhou, the majority of check-in destinations are still dominated by the old city, with the exception of educational and scientific research check-in locations. The spatial structure of the whole city is still based on the old city as the gathering area of people, and some peripheral areas only have the tendency to gather in the check-in locations in the office category. Recreational check-in locations represented by restaurants, parks and entertainment facilities are even more highly concentrated in the old city. This also reflects from the side that at this stage, in terms of urban spatial vitality, Suzhou is still centered on the old city, and other areas only begin to show a local gathering trend in office space, while other types of check-in locations still do not show an obvious gathering trend, and this phenomenon is most prominent in restaurants and parks and tourist attractions check-in locations.

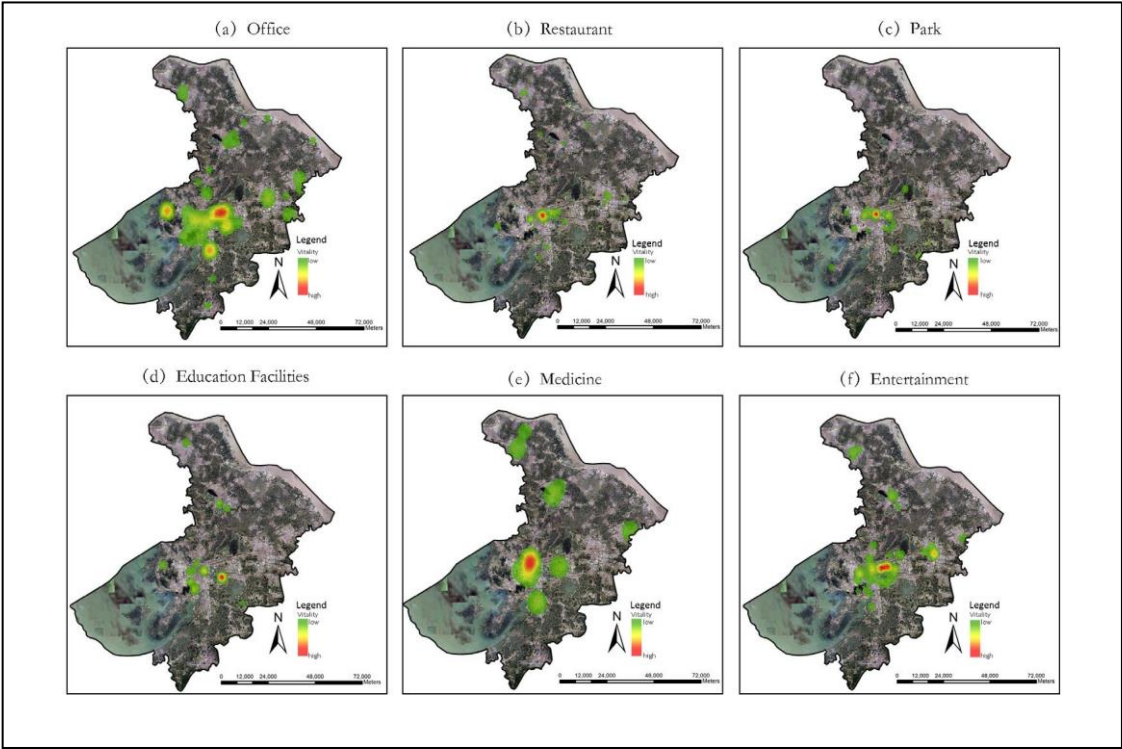


Fig.2 Weibo check-in geographic element classification

Figure 3 shows the spatial distribution of Weibo check-in users under the change of multiple time dimensions. In the figure, as the number of check-ins increases, the color of the display gradually deepens. From the figure, we can see that the areas east of the old city and west of the industrial park are more attractive to the crowd. On weekends, as people have more opportunities to travel and more time to travel, the crowd starts to spread to the surrounding areas of Suzhou, and although the high gathering degree of the old city has weakened, the old city is still one of the main destinations for people to visit. In addition to the old city, the area with obvious gathering effect is the area bordering the old city in the west of Suzhou Industrial Park. This area is located at the edge of Jinji Lake with good landscape resources and recreational facilities, and the surrounding land is rich in functions and has the property of high land compound utilization, which is a more ideal leisure place for the surrounding residents. From the figure, we can also see that, except for Taihu Lake in the west, the vitality of urban space in the north and east of Suzhou is not high, especially in Kunshan City and Taicang City in the east and northeast, which are located on the Suzhou-Shanghai development axis, but the spatial vitality is at a low level.

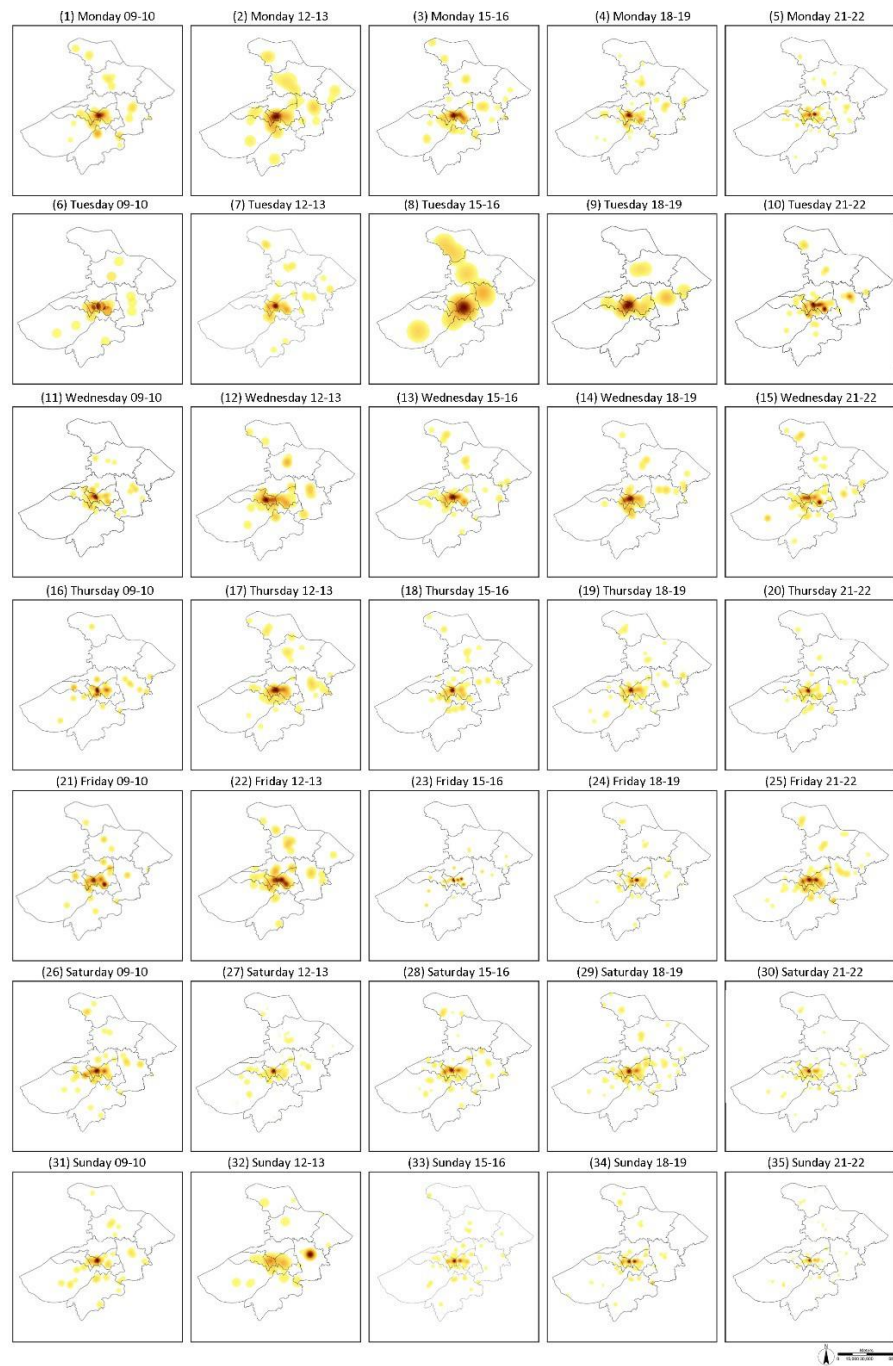


Fig. 3 Weibo Check-in one week density change

In order to further explore the relationship between urban space and regional liveliness with high precision. We use a 1km X 1km grid to calculate the vibrancy of Suzhou city as shown in Figure 4. The spatial vibrancy of Suzhou city with 1km X 1km as the basic unit in the time range of data collection is listed in the figure. According to the figure, two cells, Pingjiang Road Historic District and Suzhou Center, are the areas with the highest vibrancy. In addition to the central city, the areas with high urban vitality in Suzhou are located in the industrial park in the east, where in the western part of the park adjacent to the Jinji Lake area, which forms a high vitality horizontal axial direction with the old city, but the distance is short and the radiation range is limited.

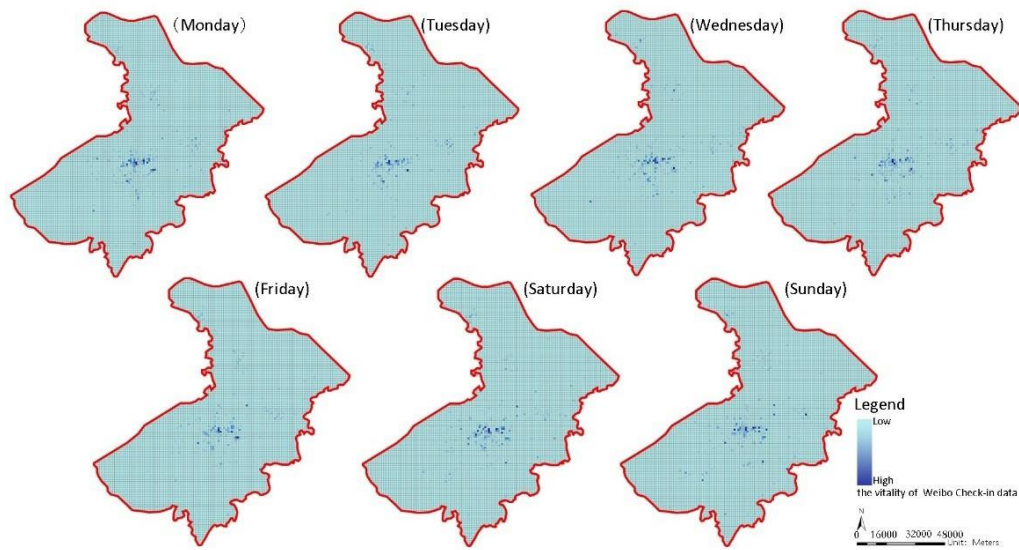


Fig.4 1km X 1km basic unit check-in activity

3.2 Street Scale Suzhou City Spatial Structure

Based on the above, the two basic units with the highest activity levels were selected in Figure 5 for the study related to street-level activity. The study period encompasses weekdays and weekends, with Mondays selected as representative of weekdays due to the regularity of weekday movement. The color of each building (street) in the figure from green to red represents the sign-in intensity of each cell.

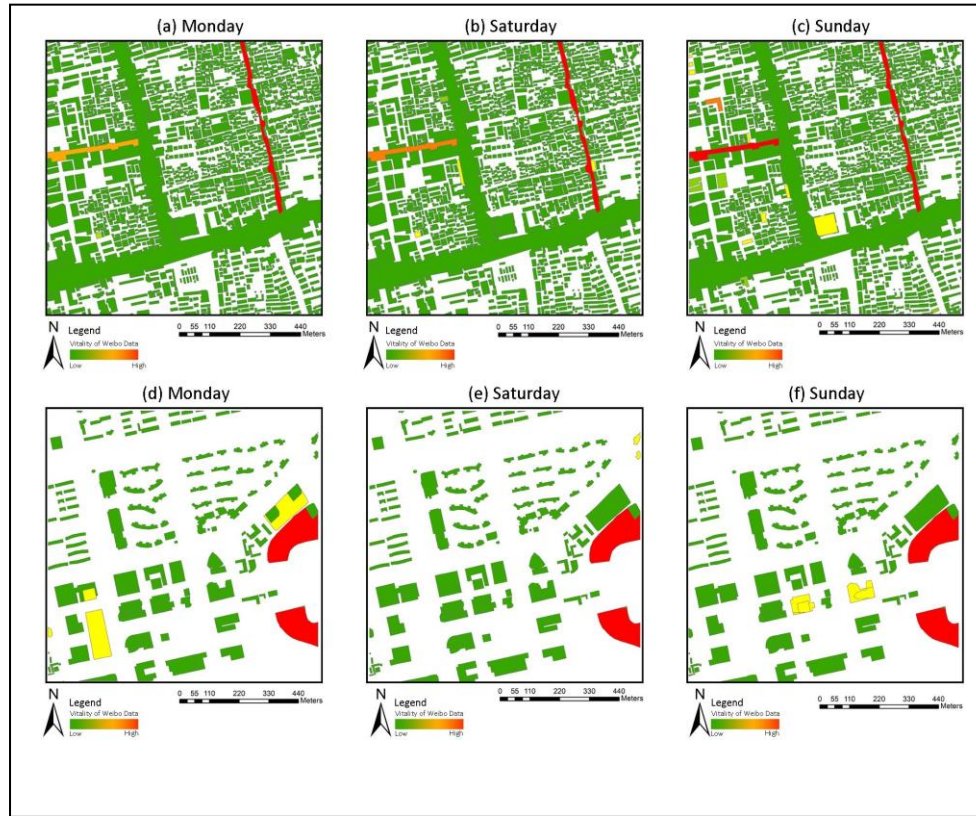


Fig.5 Street-level data of Weibo check-in on working days and rest days

As can be seen from the above figure, (a)-(c) show the old city section of Suzhou, and the areas with high personnel activity in this section are mainly concentrated in the Pingjiang Road Historical and Cultural District and Guanqian Commercial Street. Among them, Pingjiang Road Historical and Cultural District, as the city card of Suzhou, has high activity on both Mondays and weekends. The Guanqian Commercial Street, which is less than 500 meters away from it, is a little less active on weekdays. As a famous commercial complex in Suzhou, Suzhou Center is rich in internal functions and has rich external facilities, which can provide rich activities such as dining, shopping and entertainment for city residents. Therefore, Suzhou Center has a strong attraction to the public on both weekdays and weekends.

To further explore the spatial distribution of citizens under spatial and temporal changes, further analysis of crowd gathering at different time periods at street scale was carried out for these two segments (as in Figs. 6 and 7). The time periods used here are the same as above: 9:00-10:00, 12:00-13:00, 15:00-16:00, 18:00-19:00, and 21:00-22:00, including Mondays (weekdays), and Saturdays and Sundays (rest days).

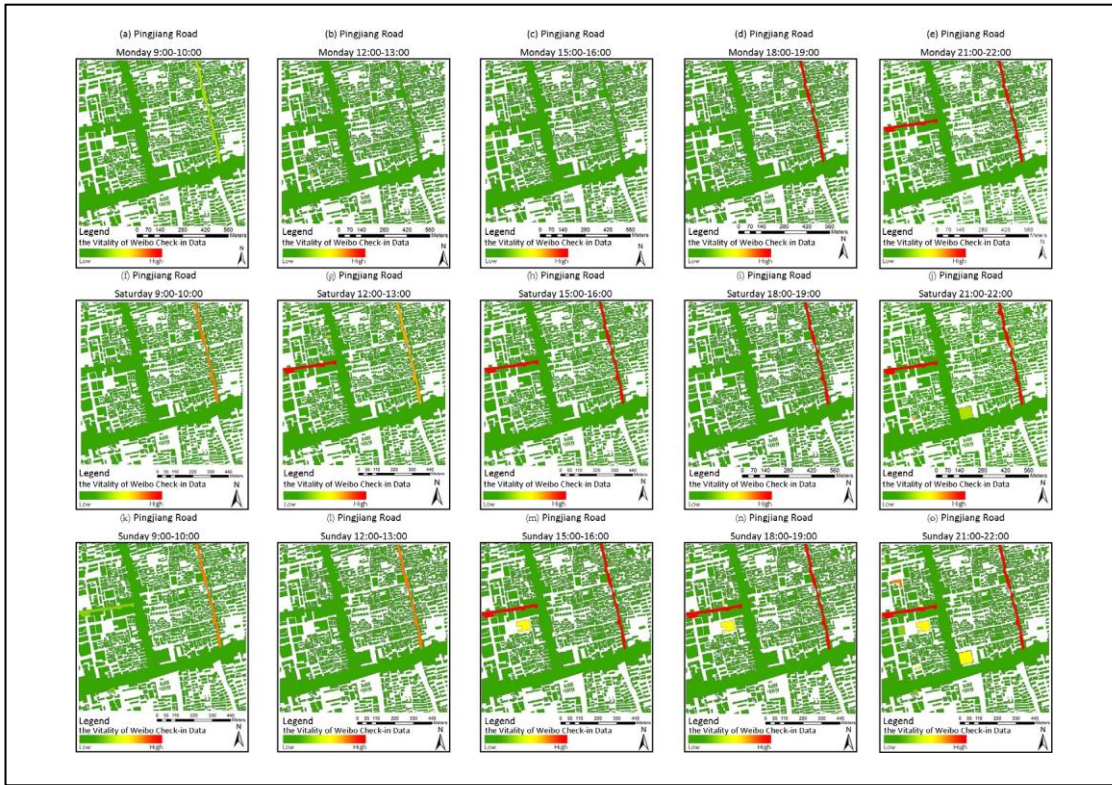


Fig.6_Weibo check-in data of old city by time

As can be seen in Figure 6, the time period in which Guanqian Street is more active during weekdays is after 21:00. The rest of the time, the gathering of people is low. The activity level of Pingjiang Road is similar to that of Guanqian Street on weekdays, except that the time period of high activity is slightly earlier, and there is already a high level of activity during the data collection time period of 18:00-19:00, which is in contrast to the surrounding areas of the board. And the two streets have a high activity level from late afternoon during the weekend. And the various commercial facilities around the two streets also show a certain degree of population gathering during the weekend.

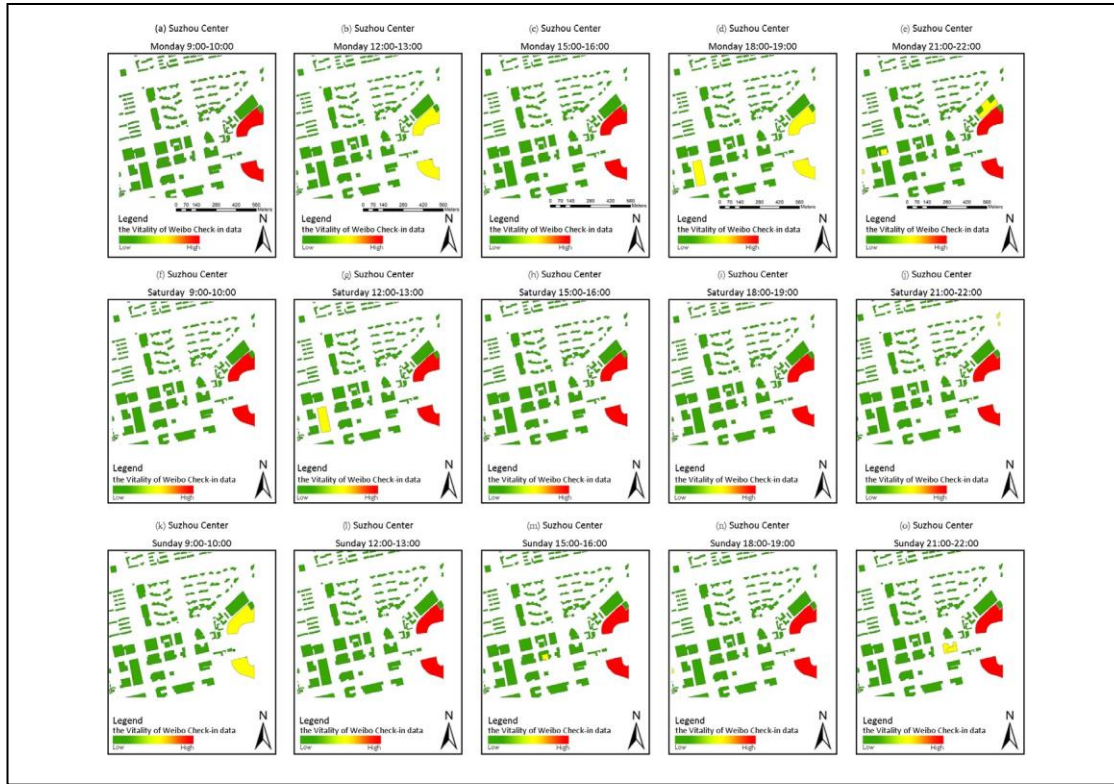


Fig. 7_Weibo check-in data of Industrial Park according to time zones

As shown in Figure 7, Suzhou Center, as the area with the highest activity in the industrial park, has a very high degree of gathering of people compared to the surrounding areas, and the gathering time lasts long. Almost on weekdays and weekends, Suzhou Center has a high degree of gathering. As mentioned above, the highly complex spatial types of Suzhou Center provide a wide range of choices for the public and can attract them continuously during weekdays and weekends.

As can be seen from Figures 6 and 7, as the two segments with the most obvious degree of people gathering in Suzhou, both of them have a large number of commercial and entertainment spaces as the spatial elements to attract people to come. However, a comparative observation shows that it is not guaranteed to provide a high-intensity attraction for places if the business function is single. Take the Pingjiang Road segment as an example, this segment in Pingjiang Road as well as Guanqian Street is to have commercial and residential facilities as the main business form. However, its activity level is not high during weekdays, and there are no more citizens gathering in this area, and only after 18:00 in the evening does the crowd gather at a high level. On the contrary, Suzhou Center is located in the industrial park area. Within 1km of Suzhou Center, there are not only a large number of commercial and entertainment facilities, but also office, residential and tourist attractions and other facilities. The injection of these facilities provides a guarantee that the area will continue to maintain a high level of activity.

4. Discussion

In this study, we used social media data to depict the spatial vitality structure of Suzhou city. From them, we also analyzed the high aggregation of crowds and urban spatial correlation at city level and street level, respectively. Using this feature of citizens' ability to share geo-tagged information on microblogs, social network activities were used to measure the built environment of the city and reflect the behavioral characteristics of citizens. The results of the study show that the check-in areas of check-in users are highly concentrated in Suzhou city, mainly in the west side of the old city and the east side of the industrial park, forming an east-west axial relationship of activity with a high level of dining, leisure and entertainment.

However, the comparison reveals that the duration of regional activity is also influenced by the degree of mixed use of surrounding land. For example, the high activity areas in the office and residential complex functional areas have a longer duration of vitality than the single-occupancy areas.

The methodology explored in this study can also be used as one of the methods to study the dynamic movement of people at the regional level. This study analyzes the dynamic movement of people at city and street scales and verifies the feasibility of this research method. In this way, it can be extended to analyze the dynamic movement of people at the regional level because the microblog check-in data has high-precision geographical coordinate information. In the past, the study of people's dynamic migration at the regional level often required a lot of human and material resources, so the areas where the study was conducted were limited. Now, with the help of microblog check-in data, we can understand the dynamic migration process of people in a larger scale area, and this method can support the analysis and research of urban spatial structure in the future.

5. Conclusion

With the rapid development of cities, both the morphology and spatial nature of cities are changing. As users of urban space, citizens' perception of urban spatial structure has a significant role in improving the efficiency and quality of urban space. However, there are few studies on urban space based on users' perceptions of the built environment and people's activities under dynamic conditions. This study examines the relationship between crowd activity intensity and urban spatial environment structure in the context of quantitative data analysis, using social network data as a carrier, using Suzhou as an example. By using one hour as the basic time unit, microblog check-in data were collected periodically over a week within the Suzhou city area. The study demonstrates how social network media data can be applied to characterize the degree of vitality of urban spatial structures at all levels. It is expected that this method will provide a reference and basis for researchers and designers to understand and perceive the city.

The main findings of this study: First, the spatial structure of Suzhou city is still centered on the old city, and with the development of SIP in recent years, a vibrant development axis with SIP to the west and the old city to the east has begun to emerge. However, the area radiated by the axis is limited, and the radiation is only confined to the old city and SIP. Apart from this area, the vitality of the surrounding areas is still at a low level. There is still a certain gap between this and the "multi-center, cluster, network" spatial layout proposed in the Suzhou Territorial Spatial Plan (2021-2035), especially in Kunshan and Taicang, which are located on the Suzhou-Shanghai development axis, where the liveliness is still at a low level. In terms of improving the liveliness of urban areas, these two areas should learn from the development model of Suzhou's existing high liveliness areas, and add various other facilities around the industrial parks to increase the mixed use of land against the background of many existing industrial parks. At the same time, attention should also be paid to the construction of various leisure and recreational facilities, so as to create a highly complex space with integrated functions for business and living.

Second, this study provides a method for applying social network data to the analysis of dynamic urban spatial liveliness. We show how to depict the urban spatial environment activity level through microblog check-ins, and carry out an analysis of the temporal and spatial correlation with the urban spatial environment in this regard.

This paper explores how to map urban residents' activities into the urban spatial structure. Through this method, big data can be used as one of the data sources to study the spatial structure and spatial characteristics of the city, and this method can better perceive the various scales of urban space from the perspective of space users. It is possible to investigate the relationship between urban residents and various types of urban built-up space environments from the user's perspective, and to provide a reference method for the improvement of spatial quality and the shaping of spatial vitality in urban planning in the future.

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