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Exploring the Relationship between Potential and Actual of Urban Waterfront Spaces in Wuhan Based on Social Networks

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Received: 7 May 2019; Accepted: 10 June 2019; Published: 14 June 2019

Abstract: The geographical location of residents and the distribution of points of interest (POI) are key factors affecting the spatial value of urban waterfronts. This study designed an association scheme based on tourists' geographical location information (obtained from social networks) and the distribution of facilities around lakes to evaluate the spatial value of urban waterfronts. Accordingly, it explored the causes of the current condition of the waterfronts. Using the distribution status of eight types of facilities, a multivariate regression model was established to predict the number of tourists that the lakes attract. Predicted results were compared with the actual condition. The clustering degree of various POI in the waterfronts was graded by using the kernel density estimation, and the difference between the predicted results and actual value was analyzed to reveal the current condition of the urban waterfronts and the reasons for their formation. On the basis of this survey, the situation of 21 major lakes within the third ring road in Wuhan, China was investigated. Results show that existing waterfronts in some areas have a considerable number of users, but the facilities fail to meet their needs. Thus, Wuhan city's waterfront space needs to be used more effectively. This study can help with making targeted recommendations with reference to future city waterfront planning.

Keywords: waterfronts; social networks; point of interest; multiple linear regression; kernel density estimation

1. Introduction

Water is the material element that connects all things in the world. The quality of and changes in regional water systems often reflect the development status of regional urban systems [1]. The most effective ecological paradigm of urban design examines the suitability of the development mode of the urban functional space based on the original water system or landform [1]. The focus of urban design work is people [2]. In the past few decades, most studies have focused on the impact of urban structures on population mobility [3–5]. However, little research has been conducted on the impacts of human activities on urban space in China and other developing countries, especially on waterfronts. Although cities in developed countries are basically stable in terms of structure and mobility, developing countries, such as China, are currently undergoing rapid urbanization and need to shape their spatial forms in accordance with the actual needs of their residents [6]. In the past 40 years, China has achieved rapid urbanization, with the urbanization rate rising from 17.9% in 1978 to 58.5% in 2017 [7]. China has gone through the urbanization process that developed countries have undertaken over the past century and made remarkable achievements. According to a general definition, an urbanization rate between 30% and 70% signifies rapid urbanization. China is still in the strategic opportunity period of rapid urbanization development. In such a high-speed process, we need urban space planning that is in line with residents' needs and expectations [8].

A waterfront is a specific spatial location in a city. It refers to lands or buildings adjacent to rivers, lakes, and oceans—that is, the part of the town adjacent to the water. Waterfront is defined as the interaction area between urban development and the needs of the city and its residents [9]. Waterfront is the most attractive waterscape for human habitation [10]. People prefer waterfront areas for carrying out festivals, religious activities, or leisure activities [11]. Nowadays, waterfront construction is a global trend, with thousands of projects built in big cities, medium-sized cities, and even small towns [12]. Recent international urban waterfront developments show that urban waterfronts can help restore or enhance the vitality of urban developments, improve local environments, seize development opportunities, and reshape regional characteristics and image. Unlike general urban areas, waterfronts have obvious advantages in terms of economic development, ecological environment, community life, function superposition, and regional sharing [13]. In the era of neoliberal urbanization, waterfronts have become the focus of planning interventions [14]. The construction and redevelopment of urban waterfronts are often accompanied by the functional transformation and improvement of the city. With increasingly fierce international competition, the revitalization of waterfronts is not only essential to urban development but also an important way for a city to improve its ability and compete globally [15]. Several waterfront plans have had worldwide impact [16]. In China, the development of urban waterfronts has become a hot topic [17]. The majority of major cities in China have important water bodies that are inseparable from urban growth and development. The revitalization of urban waterfronts has become a necessary catalyst for sustainable urban development [8]. In recent years, waterfronts in economically developed cities, such as Shanghai, Tianjin, and Dalian, have taken on a new look. Urban environmental protection and renovation have resulted in progress. However, despite well-designed waterfront spaces, the public utilization rate is still low, resulting in a lack of urban vitality [18]. The waterfront infrastructure is far from meeting the needs of residents, and their development faces significant challenges [19].

In early studies, the potential value of urban public spaces was mostly studied through empirical investigation [20] or accessibility analysis [21]. Many researchers have applied census and socioeconomic data to evaluate urban public spaces and social supply [22–27]. Most accessibility assessments are based on a simple buffer analysis of urban space or road network analysis, without considering the number of users, degree of spatial aggregation, and service capacity [28], which have limitations. The use of data mining to determine residents' points of interest (POI) can provide a scientific basis and reference for value assessment based on spatial location [29]. In recent years, the use of urban big data to analyze the spatial behavior of urban residents and the mechanism behind urban functions has become possible with the rapid development of information technology [30]. For example, with the development of embedded systems in smartphones, users' movements can be tracked [31]. The era of information explosion generated by digital technology and novel data sources has recorded almost all human activities [32]. Fixed and mobile sensor networks, such as smartphones, GPS, and credit cards, can monitor people's spatial behavior throughout the day [33]. Some researchers use check-in data from social media platforms to capture the activities of individuals in urban areas, such as the estimation of user location [34,35], location identification of family members [36], and the use of social media data to characterize activities in a place [37]. These new geolocation sources provide a wealth of opportunities to use location data to reflect visitors' preferences and expectations for waterfronts. The determination of waterfront spatial carrying potential is achieved by using open data source POI. POI data are smoother, more accurate, and easier to share than traditional geographic data [38]. Such data will not only reduce the cost of research but also provide more value for researchers; these values include the classification and decomposition of urban land use, the identification of the location of a geographical cluster in a plane panorama image, and the identification and characterization of parcels [39–41]. The relationship between space and surrounding factors is one of the most basic and decisive factors in urban design [42]. Some empirical studies have identified the spatial distribution of urban tourists by analyzing social media data [43,44]. However, few studies have attempted to combine it with urban spatial potential to study the relationship between waterfronts and human settlements.

This study aims to establish a model based on the distribution of POI of surrounding facilities in the urban waterfront, predicting the number of tourists to the waterfront, and defining this number as the potential value of attracting tourists to the lake. The geographical location data of social media platforms reflect the actual number of tourists attracted to the lake. In this study, the potential and actual values were compared, and the reasons for the differences were explored from the perspective of the distribution of various POI in each waterfront area to provide suggestions and references for planning waterfront areas in the future. To facilitate quantitative research, the ring-shaped area along the lakeshore of each lake is defined as the corresponding waterfront of the lake. After repeated tests using ArcGIS10.5, concentric rings extending 200, 400, and 600 m outward from the lake were determined as the three-level buffer zone according to the geographical scale of Wuhan and each lake. Considering the number and level of facilities and Sina Weibo users' check-in points, we chose the 600-m scale as the scope of the waterfront area covered in this study. The buffer zones referred to below are areas extending 600 m from the shore. In this study, the location information of tourists is obtained through social media platforms. The geographic location data of tourists are fitted by the distribution of eight types of POI, namely, entertainment, catering, transportation, public services, medical treatment, education, life services, and accommodation services. Multiple linear regression was used to establish the fitting model to explore the correlation between POI distribution and user distribution in the waterfront. On the basis of this spatial correlation, the POI aggregation degree of the waterfront was analyzed using the kernel density method. Accordingly, the reason for the differences between the actual value and potential value of the lake in attracting tourists was explored. Section 2 describes the basic social and natural background of the study area and data content used in this study. Section 3 presents the methods proposed, including building a model to calculate the tourist attraction potential of the lake based on the distribution of various POI, using multiple linear regression method, and analyzing the distribution of various POI through kernel density method. Sections 4–6 explain the results, discussion, and conclusions of the study.

2. Materials

2.1. Study Area

The study area is concentrated in Wuhan (113°41′–115°05′ E, 29°58′–22°31′ N), within three lake waterfronts (Figure 1). Wuhan is the capital of Central China's Hubei province. Located east of Jianghan Plain, Wuhan is the seventh-largest city in China, with a population of 6.6 million. Home to the world's third-longest river and with its largest tributary Han River traversing the center of the city, Wuhan has gained the aliases "river city" and "city of hundreds of lakes." It is rich in water resources, rivers, lakes, and unique harbors. The water in Wuhan covers a total area of 2217.6 square kilometers, which is more than a quarter of the city's entire area. The lake area is 803.17 square kilometers, and the water surface rate of the lake ranks first among all major cities in China [45]. A total of 166 lakes of various sizes can be found in Wuhan, 43 of which are located in the central city [46]. Among them, East Lake in Wuchang was once the largest city lake in China. With the continuous urban expansion in Wuhan, Tangxun Lake in the southern suburb of Wuchang has replaced East Lake as the largest city lake in China. According to research, the development and utilization degree of water resources in Wuhan is 48.09%, which is more than the internationally recognized ecological warning line of water resources development [47]. Although the water resources in Wuhan are abundant, the carrying capacity of the water environment is slightly overloaded, and major lakes and reservoirs cannot meet the requirements of functional zoning [47].

Wuhan has three ring roads. The first ring road is the core area of the city, also known as the inner ring road. The second ring road is the expressway around the central city, with a total length of 48 km. The third ring road is the boundary between the city and suburbs, which is surrounded by the

Wuhan Baishazhou Yangtze River Bridge and Tianxingzhou Yangtze River Bridge. Its total length is 91 km and it surrounds the entire central city [48]. The third ring road can be divided into three regions, namely Hankou, Hanyang, and Wuchang. Given that the city within the third ring road has mature development, the development of economy, culture, industry, and commerce in the area is relatively fast. Sina Weibo users and the POI data are also mainly distributed within the third ring road. Thus, this research is focused on the waterfront area within the third ring road (Figure 2).

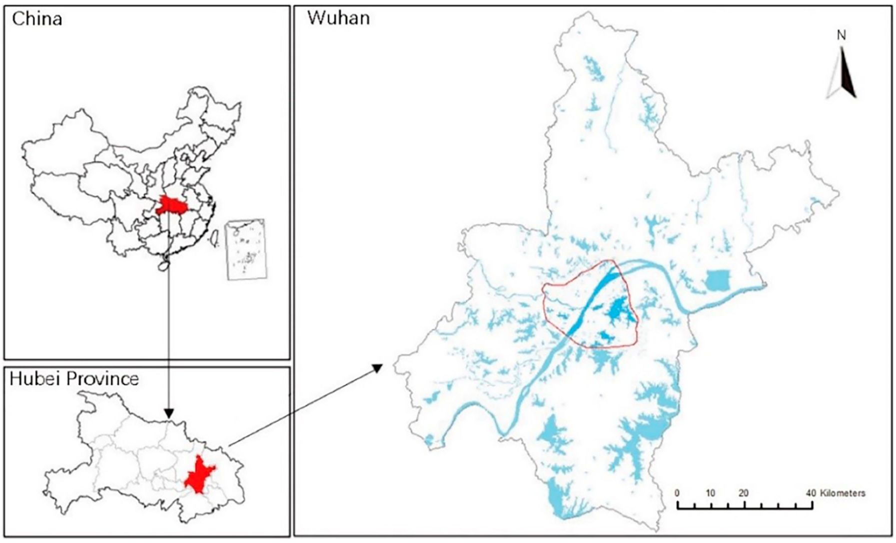

Figure 1. Location of the study area.

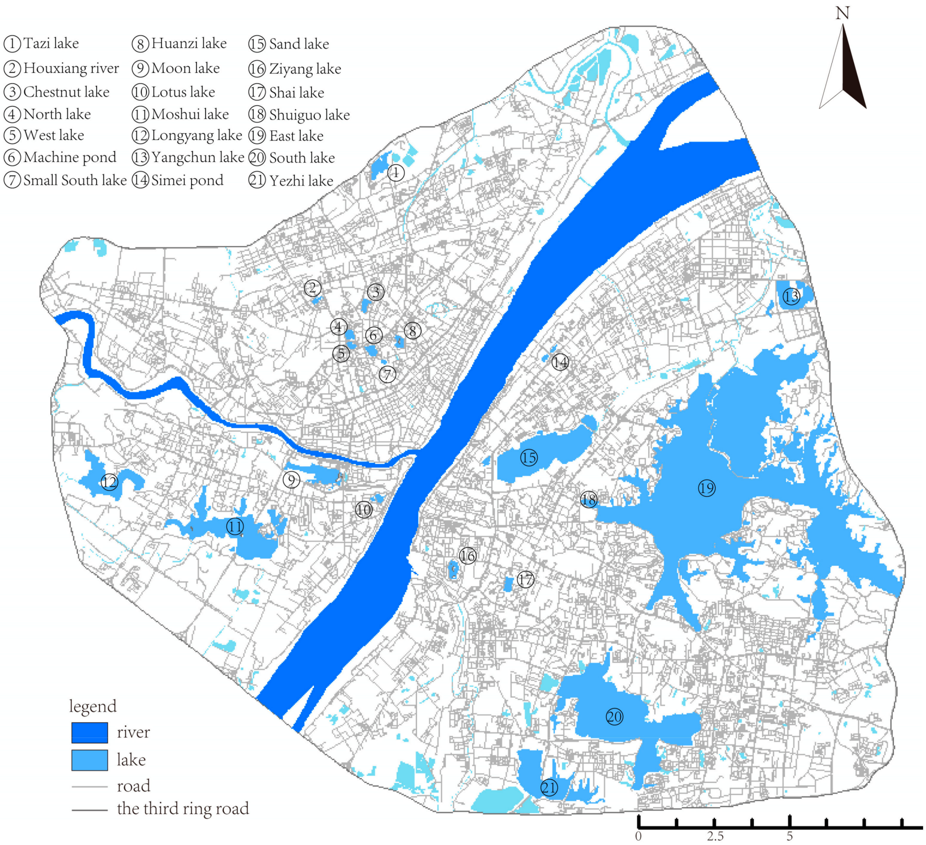

Figure 2. All lakes studied.

2.2. Data Sources and Pre-Processing

2.2.1. Data Sources

Sina Weibo (MicroBlog, Beijing, China) is a microblogging service operated by Sina Corp. Users can publish information through web pages, Wireless Application Protocol, external programs, and mobile phone SMS or MMS. Users can also upload pictures, link videos, and instantly share content. Sina Weibo is a platform for information sharing, dissemination, and access based on user relationships, which accounts for 57% of the total number of Sina Weibo users in China and 87% of the total number of Sina Weibo activities in China. Sina Weibo is one of the most visited websites in mainland China. Its users can share their current geographic location on the network platform. We obtained more than 88.83 million POI check-in data points through the official open API (Application Programming Interface, Wbm.SinaV2API) of Sina Weibo, with a total of 165.2 million check-in times. The acquired data include names, addresses, spatial coordinates, and other check-in information (acquisition date: 1 November 2014). POI data were acquired from China POI data network. After arranging the data by administrative region and time, we obtained the POI data of Wuhan in 2014.

2.2.2. Data Preprocessing

We used geographical coordinates to intercept the location data obtained from Sina Weibo into the third ring road of Wuhan with the remaining 120,000 pieces. These data were imported into ArcGis 10.5 (Environmental Systems Research Institute, Redlands, CA, USA), and after pre-processing such as coordinate correction, a distribution map of tourist check-in points in the study area was generated to reflect tourists' expectations for the waterfront (Figure 3a). POI within the third ring road were cleaned and sorted into eight categories, namely, entertainment, public services, catering, transportation, education, medical treatment, life services, and accommodation, and processed similarly (Figure 3b). Users' geographical location and POI distribution are most concentrated in Hankou, followed by Wuchang, whereas the aggregation degree is the lowest in Hanyang. The geographical location of users is basically consistent with the distribution of POI (Figure 3c).

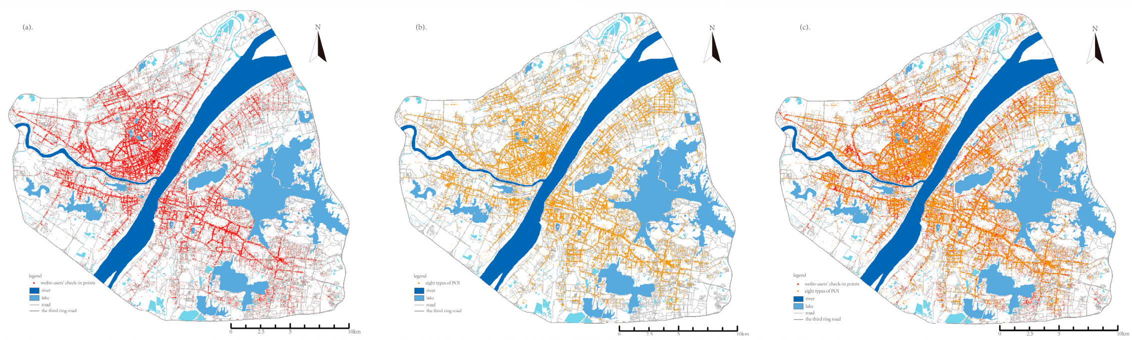

Figure 3. (**a**) Distribution of Sina Weibo users' check-in points within the third ring road; (**b**) distribution of eight types of POI within the third ring road; (**c**) coincidence of Sina Weibo users' check-in points and POI distribution points.

3. Methods

3.1. Multiple Linear Regression Analysis

In economic forecasting, when the predicted object is affected by multiple factors x_1, x_2, x_3, . . . , x_d, and if the relationship between each influencing factor x and y can be approximately expressed as linear at the same time, then a multiple linear regression model can be established. The least squares method can be used to conduct the best line fitting analysis and prediction for the known data. The general form of multiple linear regression model is

$$\overline{y} = w_1x_1 + w_2x_2 + \ldots + w_dx_d + b. \tag{1}$$

The vector form is

$$\overline{y} = w^Tx. \tag{2}$$

In Equation (1), x_i (i = 1, 2, . . . , d) is the dependent variable, that is, the number of various POI around a lake, and y is the predicted value, that is, the predicted number of tourists attracted to the lake according to the number of POI. w_i (i = 1, 2, . . . , k) is the partial regression coefficient, and b is the intercept.

In Equation (2), $w = (w_1, w_2, w_3 \ldots\ w_d; b)$ and $x = (x_1; x_2; x_3 \ldots\ x_d; 1)$.

The purpose of fitting this multiple linear regression model is to minimize the errors between the predicted y and the actual number of tourist check-in points around the lake. In statistics, minimizing the error sum of squares is usually attempted to estimate w, that is

$$w = \text{argmin}(y - X_w)^T(y - X_w).$$

Among them,

$$\begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1d} & 1 \\ x_{21} & x_{22} & \ldots & x_{2d} & 1 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ x_{m1} & x_{m2} & \ldots & x_{md} & 1 \end{bmatrix}$$

$$y = (y_1;\ y_2;\ y_3 \ldots y_m).$$

In machine learning, the cost function usually used is

$$E_w = \frac{1}{2}(y - X_w)^T(y - X_w).$$

Then, we take the derivative of w:

$$\frac{\partial E_w}{\partial w} = X^T(Xw - y) = 0.$$

When X^TX is a full-rank matrix or a positive definite matrix,

$$\hat{w} = \left(X^TX\right)^{-1}X^Ty.$$

Therefore, we can solve for w, and the multiple linear regression model can be determined.

3.2. Kernel Density Estimation

Kernel density estimation (KDE) is a statistical method for nonparametric density estimation [49]. This estimation is a generalization of Rosenblatt [50] and Parzen's [51] idea of histogram density estimation. It is a nonparametric statistical method for estimating unknown probability distributions [52]. When a histogram is used for density estimation, the histogram is always a discontinuous step function, even if random variables are continuous. KDE can solve this shortcoming, thereby obtaining a smooth estimation of density function. Its core is a smooth differentiable kernel function. KDE is a method commonly used in spatial econometrics to calculate the density of elements in surrounding areas. The calculation principle is to study the spatial distribution characteristics of points by analyzing the spatial variation of point density in the regular region. One of the most important parameters, step h, has a key impact on KDE. Although KDE has many different mathematical forms in practical applications, as long as parameter step h is determined, the influence of kernel functions in different mathematical forms on kernel density is small. In this study, the commonly used kernel functions of quartic polynomials were adopted [53]:

$$\hat{\lambda}_h(S) = \sum\nolimits_{i=1}^{n} \frac{3}{\pi h^2}\left[1 - \frac{[S-S_i]^2}{h^2}\right]^2,$$

where S is the location of the point to be estimated. It is the location of the ith facility POI or the check-in point of Sina Weibo users within the circular range with S as the center and h as the radius. $S - S_i$ is the distance from the check-in point Si of facility POI or Sina Weibo users to check-in point S, and h is the step length. In this study, ArcGIS 10.5 was used to conduct core density analysis and relevant mapping of POI of waterfront facilities and check-in points of Sina Weibo users within the third ring road of Wuhan.

4. Results

4.1. Distribution of POI and Visitor Check-In Points within the Buffer Zone

By filtering the data, eight types of POI and Sina Weibo users' check-in points in the 600 m buffer zone of 21 lakes was obtained (Tables 1 and 2). The distribution of these data points is visualized in Figure 4. The distribution of visitors positions and POI is highly similar. Based on the visualization results, Sina Weibo users' check-in points are densely distributed in several lake buffer zones with small water areas in Hankou. The distribution of sign-in points in Hanyang is the most sparse, with a few points concentrated north of Inks Lake and around Moon Lake. Points along the southern side of the Han River are slightly dense. In Wuchang, the points around Sand Lake, the southwestern area of East Lake, and the northern area of South Lake, Ziyang Lake, and Sun Lake are concentrated. The location of Wuhan Railway Station around Yangchun Lake and that of several universities on the eastern side of South Lake also exhibited clustering. The number of facilities near East Lake is the largest, which is directly related to its large area, long shoreline, and large buffer area. The number of facilities in the buffer zones of Huanzi Lake, Machine Pond, North Lake, Chestnut Lake, Sand Lake, and South Lake is also large, whereas that of Taizi Lake, Longyang Lake, and Yangchun Lake is small.

Table 1. POI count in the lake buffer zones.

Lake	**SiMei Pond**	**YeZhi Lake**	**HouXiang River**	**Lotus Lake**	**YangChun Lake**	**LongYang Lake**	**TaZi Lake**
POI	656	646	593	554	213	89	43
Lake	**Small South Lake**	**ZiYang Lake**	**MoShui Lake**	**West Lake**	**Moon Lake**	**Shai Lake**	**Shui Guo Lake**
POI	1427	1419	1404	1312	1133	1099	906
Lake	**East Lake**	**Machine Pond**	**Chestnut Lake**	**Sand Lake**	**HuanZi Lake**	**South Lake**	**North Lake**
POI	4215	2245	2118	1982	1891	1691	1664

Table 2. Number of tourist check-in points in the lake buffer zones.

Lake	**SiMei Pond**	**YeZhi Lake**	**HouXiang River**	**Lotus Lake**	**YangChun Lake**	**LongYang Lake**	**TaZi Lake**
The number of tourist check-in points	950	357	748	563	16	29	51
Lake	**Small South Lake**	**ZiYang Lake**	**MoShui Lake**	**West Lake**	**Moon Lake**	**Shai Lake**	**ShuiGuo Lake**
The number of tourist check-in points	1883	844	1671	2437	1418	789	739
Lake	**East Lake**	**Machine Pond**	**Chestnut Lake**	**Sand Lake**	**HuanZi Lake**	**South Lake**	**North Lake**
The number of tourist check-in points	2736	2940	2606	1398	2221	1500	2300

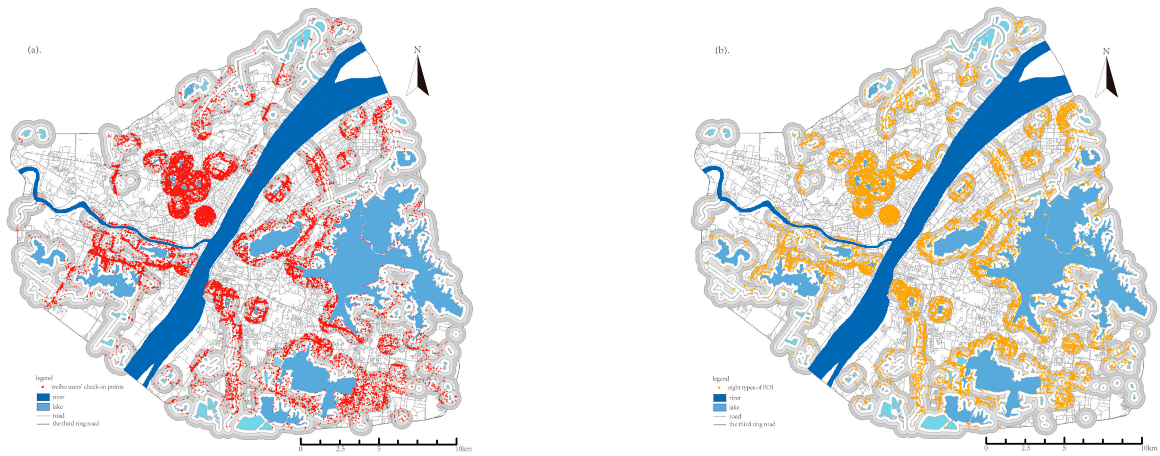

Figure 4. (**a**) Distribution of Sina Weibo users' check-in points in the lake buffer zone; (**b**) distribution of eight types of POI in the lake buffer zone.

4.2. Fitting the Location Check-In Point of Tourists and the POI Distribution Point of Facilities

4.2.1. Partial Regression Coefficients of Various POI

In establishing the multivariate linear regression model, the partial regression coefficients of the eight POI were obtained by minimizing the sum of squares of errors between the predicted values and actual values (Table 3). When the number of a certain POI is fixed, its coefficient directly determines the size of its influence on the predicted value of tourist attraction. Thus, this coefficient represents the ability of the corresponding type of facilities within the research scope to attract tourists. Based on the results, the partial regression coefficient of entertainment facilities is the largest. In other words, the capacity of entertainment facilities to attract tourists is the largest within the buffer zone of the main lake within the third ring road of Wuhan, followed by dining facilities and medical facilities. However, transportation, public service, educational, life service, and accommodation facilities in the waterfront are relatively weak in attracting tourists.

Table 3. Partial regression coefficients of POI.

POI	**Leisure Facilities**	**Catering Facilities**	**Transportation Facilities**	**Public Service Facilities**
Partial regression coefficient	4.182235	2.798696	−0.134538	−1.816302
POI	**Medical Facilities**	**Educational Facilities**	**Living Service Facilities**	**Accommodation Facilities**
Partial regression coefficient	1.148177	−2.551964	0.169248	0.212403

4.2.2. Potential Tourist Value and Actual Value Fitting of the Lakes

Based on the calculated partial regression coefficient, the potential value model that determines the number of tourists attracted to the lake is

$$Y = -11.763612 + 4.182235 \times A + 2.798696 \times B - 0.134538 \times C - 1.816302 \times D + 1.148177 \times E - 2.551964 \times F + 0.169248 \times G + 0.212403 \times H$$

where A–H represent the number of leisure, catering, transportation, public service, medical, educational, living service, and accommodation facilities, respectively. The potential value of each lake to attract tourists and the difference between the potential value and actual value are obtained through the model calculation (Table 4). The difference values were counted (Figure 5). In more than half of the major lakes within the third ring road of Wuhan, the actual number of tourists attracted to the lakes was greater than their potential value. Among them, the actual number of tourists attracted to the buffer zones of Moshui Lake, Moon Lake, Houxiang River, North Lake, Machine Pond, Simei Pond, Small South Lake, and West Lake is far greater than the potential value. This result indicates that the number of tourists in these waterfront areas exceeds the bearing capacity of the layout of its facilities. The actual number of tourists attracted to the buffer zones of Shuiguo Lake, South Lake, Tazi Lake, East Lake, Lotus Lake, Huanzi Lake, Longyang Lake, and Chestnut Lake is close to the potential value and reaches basic saturation. However, the actual number of tourists attracted to the buffer zones of Ziyang Lake, Sand Lake, Yezhi Lake, Shai Lake, and Yangchun Lake is far lower than its potential value. This result indicates that the number of facilities in these waterfront areas fails to meet the needs of tourists and the value of its waterfront space is yet to be developed. Moreover, the spatial utilization of the surrounding area of more than 60% of the lakes does not match tourists' expectations. The potential value of major waterfront areas in the third ring road of Wuhan has not been fully tapped yet. Therefore, further measures should be taken to plan the urban space in these locations.

Table 4. Differences between the actual value and potential value of lakes in attracting tourists.

Lake	MoShui Lake	Moon Lake	HouXiang River	North Lake	Machine Pond	SiMei Pond	Small South Lake
The actual value of tourist attraction	1671	1418	748	2300	2940	950	1883
Tourist attraction potential	1218.7852	1093.9848	443.05486	2051.8322	2723.131348	738.87456	1695.5058
The difference between actual and potential	452.21478	324.01519	304.94514	248.16776	216.8687	211.12544	187.49419
Lake	**West Lake**	**ShuiGuo Lake**	**South Lake**	**TaZi Lake**	**East Lake**	**Chestnut Lake**	**LongYang Lake**
The actual value of tourist attraction	2437	739	1500	51	2736	2606	29
Tourist attraction potential	2270.0128	684.1813	1480.092	32.09269	2726.412038	2607.7847	37.935987
The difference between actual and potential	166.98721	54.818696	19.908038	18.90731	9.587962	−1.784667	−8.935987
Lake	**HuanZi Lake**	**Lotus Lake**	**YangChun Lake**	**Shai Lake**	**YeZhi Lake**	**Sand Lake**	**ZiYang Lake**
The actual value of tourist attraction	2221	563	16	789	357	1398	844
Tourist attraction potential	2255.4239	612.30666	230.43231	1010.8976	642.22916	1892.5403	1748.4898
The difference between actual and potential	−34.4239	−49.30666	−214.4323	−221.8976	−285.22916	−494.5403	−904.4898

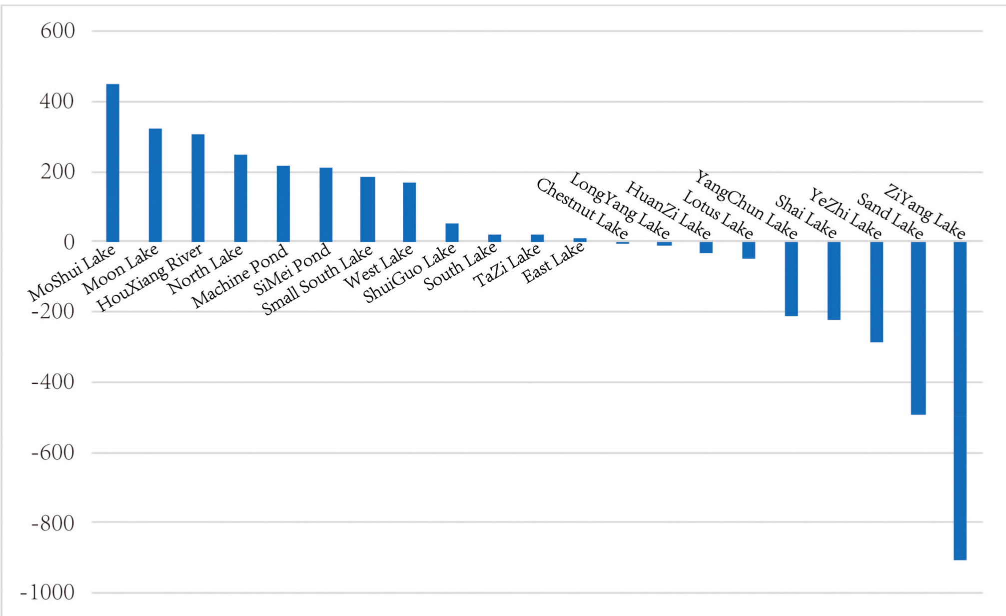

Figure 5. Differences between the actual value and potential value of lakes in attracting tourists.

4.2.3. Analysis of the Differences between Potential Values and Actual Values

To facilitate the analysis of the reasons for the difference between the potential value of each waterfront area for attracting tourists and the actual number of tourists, core density analysis was carried out on the eight POI within the 0–600 m buffer zone of the 21 lakes within the research range. The aggregation degree of points was divided from high to low into one to nine levels in terms of the unit area value (Figure 6). Based on the visualization results, all kinds of POI generally present a large number of low-level clusters. The higher the number of high-level clusters, the smaller the number of high-level clusters. Catering and life service facilities show the absence of medium- to high-level clusters. Moreover, the high-level cluster of facilities generally appears in the business center of Hankou, which indicates the lack of high-level clusters in various facilities in Hanyang and Wuchang.

Lakes with Higher Actual Values of Attracting Tourists Than Their Potential Values

According to the statistical results, the cluster levels of education, medical care, public services, and entertainment facilities in the buffer zone of Moshui Lake exhibit relatively high actual values of attracting tourists, which exceed their potential values. This result may be attributed to the large number of residential communities around Inks Lake and public places, such as Moshui Lake Park and Wuhan Zoo. Within the buffer zone of Moon Lake, public service and entertainment facilities are rated higher than other POI. This result is also attributed to the presence of cultural attractions, such as Zhangzhidong Museum and Qintai Theater around Moon Lake. Houxiang River Park, where Houxiang River is located, is near Hankou Railway Station, an important traffic hub in Wuhan found on the North of the city museum. Therefore, the aggregation degree of traffic and accommodation facilities in the buffer zone of Houxiang River is considerably higher than that of other POI. West Lake and North Lake, and nearby Machine Pond and Small South Lake are all located in the downtown area of Jianghan District. They are surrounded by many residential areas, adjacent to the Jianghan District government, Wan Song Yuan business circle, Zhongshan Park, Hankou, a cultural and sports center, and other large public places. Thus, all types of POI in the buffer zone of West Lake, North Lake, Machine Pond, and Small South Lake present a high aggregation degree. Simei Pond is surrounded by an industrial zone dominated by Wuhan Railway Station and heavy railway industries in China; hence, the distribution of POI is not dense. Wuhan Wuchang Hospital is not far from Simei Pond, so the level of medical and public service facilities in the buffer zone in the area is higher than that of other POI clusters.

Lakes with Almost Equal Actual and Potential Values of Attracting Tourists

In lakes with almost equal actual and potential values of attracting tourists, the POI concentrations of all types are at a medium level and relatively uniform in the buffer zone of Shuiguo Lake. Primary schools near Fruit Lake and the medical department of Wuhan University and other schools surround Shuiguo Lake. Therefore, the degree of POI concentrations in educational facilities is slightly higher than that of other POI concentrations. Longyang Lake and South Lake are urban lakes with relatively large water area. However, POI clusters around them are of low levels. Thus, their potential and actual values of attracting tourists are low. This finding may be attributed to the poor water quality in the two lakes. A large amount of domestic sewage and industrial wastewater is discharged into Longyang Lake, thereby causing water quality deterioration every year. With urban expansion and environmental destruction from human activities, the ecological environment of Longyang Lake is seriously threatened. South Lake is now moderately and severely eutrophic, with a trend of deterioration every year. Every late spring and early summer, a large number of dead fish appear in South Lake and some of its tributaries. The improvement of the water quality of South Lake is also the focus of the provincial and municipal congresses and the CPPCC. Tazi Lake is close to the boundary of the third ring road, and many villages in the city around it wait to be transformed. Therefore, the distribution of POI in the buffer zone is sparse, and the potential and actual values of attracting tourists are relatively low. East

Lake is the largest urban lake in Wuhan, and the POI clusters around it are generally at a medium level. However, the distribution of educational facilities is highly concentrated. This case is similar to the situation of Wuhan University, Huazhong University of Science and Technology, China University of Geosciences, Wuhan Institute of Physical Education, and many other universities located around East Lake. Chestnut Lake and Huanzi Lake are located in the central urban area of Hankou. POI clusters around them are at a medium to high level and attract a considerable number of tourists. The water quality in Chestnut Lake and Huanzi Lake is also seriously deteriorated. Given that Chestnut Lake is not connected to the Yangtze River, Han River, and other water bodies, the incoming water from the lake is supplemented by rainwater, surrounding lakes, and other water systems. The ecological environment of Huanzi Lake has been degraded due to water pollution caused by fish breeding, the excessive destruction of lakeside ecology, and the pollution of lake bottom mud, among others. This situation is not optimistic. Later, after the government heavily invested in long-term reconstruction, Grass Carp Lake was developed into Treasure Island Park and became a leisure attraction for citizens. Longyang Lake, South Lake, and other lakes that encounter water quality problems can be referred to the governance cases of Chestnut Lake and Huanzi Lake to some extent. Lotus Lake is located in Hanyang district, surrounded by residential areas, and has sufficient supporting facilities. Therefore, POI of all types are at a moderate level and relatively balanced.

Lakes with Lower Actual Values of Attracting Tourists Than Their Potential Values

The actual value of the five lakes in the study area was much lower than their potential value. Yangchun Lake is located in the sub-center of Hongshan District; thus, the level of traffic facility cluster in the buffer zone is higher than that in other POI. However, the overall level is relatively low, and the actual value of attracting tourists is even lower. This may be because Yangchun Lake has been affected by surrounding construction projects and silt for many years, causing its water area to considerably shrink and its water function to deteriorate. According to the general plan of the deputy urban center of Yangchun Lake of Wuhan (2006–2020), Yangchun Lake and its surrounding areas will be built into a transportation hub and city comprehensive service center, relying on Wuhan Railway Station of the Beijing–Guangzhou dedicated passenger line. This move could improve the water quality of Yangchun Lake and bring unprecedented vitality to the waterfront. A high agglomeration of medical facilities is present around Shai Lake, and the lower actual value of its tourist attraction than the potential value may be attributed to the lack of entertainment and catering facilities around it. Although most residential areas are located around the lake, the distribution of life services, education, and public service facilities in the buffer zone is relatively sparse, causing the actual value of the lake to be lower than the potential value. The water area of Sand Lake is large, and the distribution of traffic facilities in the buffer zone is also considerable. The results show that the relative absence of accommodation services, education, entertainment, and catering facilities may have caused the actual value of Sand Lake to be lower than its potential value. In all lakes, Ziyang Lake's tourist attraction value is lower than the potential value of most lakes. Although it is surrounded by all types of high-level POI, the water quality of Ziyang Lake deteriorated from 2000 to 2017 because of sewage problems. This issue led to a reduced ability to attract tourists. Data from 2014 reflect this situation. Ecological environment has a great impact on the vitality of the lake. After treatment, Ziyang Lake is now in a healthy state with clear water and green grass.

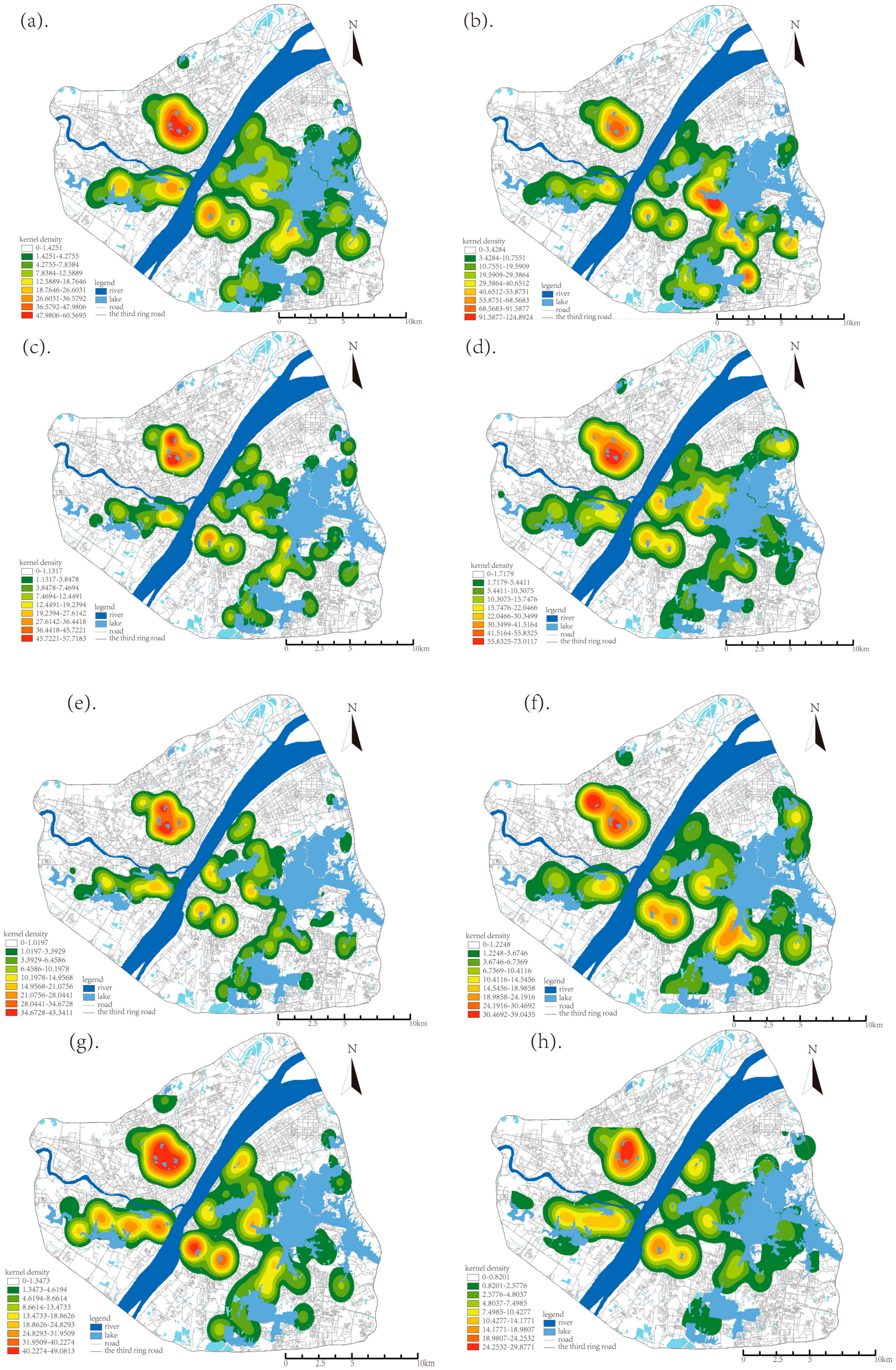

Figure 6. Kernel density of various POI in the lake buffer zone: (**a**) leisure, (**b**) education, (**c**) catering, (**d**) transportation, (**e**) living service, (**f**) accommodation, (**g**) medical, (**h**) public service.

5. Discussion

Urban societies have long been given priority in terms of constructing structures near rivers. Historically, water has been the cultural and economic center of most cities and an indispensable living element in the urban landscape [54–57]. The development of urban waterfronts and making full use of them are important parts of urban planning. Urban waterways have become an important policy goal of every city. With substantial public investment and support, many urban waterfront areas have been redeveloped from abandoned, underused, or former industrial areas into new spaces supporting commercial, recreational, and cultural uses [58]. Waterfront space is one of the areas that have a great impact on urban ecology. The space has many public activities, complex functions, and rich historical and cultural factors. The waterfront space has many spatial characteristics, such as natural, open, and directional. It promotes active civic life and helps improve citizens' quality of urban life [59]. In recent years, the potential of urban waterfronts began to be valued again. The improvement of civic awareness, implementation of sewage treatment technologies, and recognition of the role played by these natural systems have led to a large number of river regulation and improvement projects that aim to promote the public use of waterfront spaces [60–62]. To improve the ecological quality of cities, urban landscape should be protected and meet the needs of leisure tourism and urban ecological conditions. In the first decades of the 21st century, the focus of river management in China was the improvement of water quality [63], which answers the question of what the construction of waterfront space should focus on in the future. In this context, the research framework proposed in this study provides a new perspective for displaying tourists' preference for urban waterfronts and exploring the utilization mode of urban waterfronts.

The analysis of the difference between the actual value and potential value of attracting tourists shows that each lake has its own characteristics and faces its own problems. The distribution of POI can be used as a means to reflect the status quo of lakes and the reasons for such conditions. The above analysis also reveals that lakes that attract tourists with actual value higher than potential value may face a problem: the number and distribution of existing facilities might not meet the needs of a large number of tourists. The service quality and efficiency of various facilities also need to be improved. At the same time, improving the ability of other lakes to attract tourists, entertain them, and avoid the development imbalance caused by excessive concentration is highly important. Lakes whose actual value is lower than the potential value can be explored from the perspective of POI distribution proposed in this study, targeted governance and rectification, further construction and improvement of weak POI types in waterfront areas, and improvement of lake vitality.

Based on the analysis results in this study and the comparison of relevant planning, problems have been noted in the facilities POI and tourist gathering points of waterfront areas within the third ring road of Wuhan. Facility cluster with a high degree of aggregation is excessively concentrated in Hankou area, and a high-level cluster of various facilities is lacking in Wuchang and Hanyang. The high concentration of tourists' points in Hankou may also be due to the fact that this area is the commercial center of Wuhan and the economy is relatively developed. However, the focus of this study is the facilities around the waterfront. Therefore, in future urban waterfront plans, strengthening the efforts to continue to promote the outward dredging of various facilities in Hankou waterfront is necessary. Check-in points of Sina Weibo users are also concentrated in Hankou. Comparing the actual and potential values of lake buffer zones attracting tourists, we see that the actual and potential values of most waterfront attracting tourists do not match, and these areas have an insufficient carrying capacity for tourists. Under the guidance of the overall urban planning, Hanyang area uses the south bank of the Han River as the entry point, makes full use of superior natural resources and profound historical deposits of Hanyang area, and continues to build characteristic projects represented by the Moon Lake cultural and art district. Wuchang proposes continuing the urban design project of "sub-center of South Lake City" and establish country parks represented by East Lake to form an organic entity with the urban green space system and extend outward relying on the landscape. More emphasis should be placed on the cultural and artistic positioning of East Lake area, for example, hosting more sports events and literary and artistic activities to attract more tourists and improve the public's concern for the waterfront. For lakes like Moshui Lake and North Lake, where the actual tourist attraction value is much higher than the potential value, the government should strengthen the construction of related facilities to meet the needs of tourists to improve the tourist carrying capacity of the waterfront and build a harmonious urban ecological pattern. For lakes, such as Tazi Lake and Longyang Lake, which are extremely short of various facilities, the government should focus on lake protection and ecological environment restoration. The government should build a greenway around the lake and comprehensively carry out the four major water environment improvement projects, focus on developing sports leisure, health services, and cultural innovation.

Some measures and strategies have been taken to enhance the value of the waterfront space. Dredging works in Longyang Lake have started. "Hanyang Longyang Lake sewage and dredging project implementation plan" has also passed the review. According to the arrangement of the "Hanyang six lakes connection project," the water from Han River will enter Longyang lake, flow through other lakes in Hanyang, and finally exit the Yangtze River from the east wind sluice of south Taizi Lake. This plan can transform Hanyang into an ecologically sustainable and livable area for business exhibitions. With the development of the city, enterprises, institutions, and residents have built a large number of buildings along the lake, which basically cut off the natural inflow of water from the lake. As a result, the lake lost its self-purification ability and the water quality deteriorated every year. However, in 2008, the municipal government proposed the "One Lake One Scene" project, in which Chestnut Lake was included in the scope of regulation. Today, the management of the lake is effective, and the ecological park and business district surrounding Wanda Plaza have been built around the lake. This arrangement has greatly changed the living conditions of residents around the lake and also brought vitality to the area.

6. Conclusions

The data samples in this study were acquired from Sina Weibo. The use of a large amount of network data to a certain extent reduces the impact of some false information on the overall sample, which can roughly reflect the distribution of people and various facilities within the third ring road of Wuhan. With the advent of big data, many network platforms provide a large amount of data with a wide range and easy access. To illustrate the value of massive Internet data in urban research and planning practice, the method proposed in this study can also be applied to other types of urban space and urban problems.

This study has limitations. For example, most Sina Weibo users are young people, and the trajectory characteristics of this group may be different from those of the middle-aged and elderly groups. This difference limits the scope of the sample. Second, some registered Sina Weibo users may be residents who live in the lake buffer zone, which affects the statistical accuracy of the number of tourists in the waterfront. The above problems need to be further considered in future studies.

This study uses social media data and the spatial distribution of the eight types of POI to demonstrate the value of the main lake waterfront in the third ring road of Wuhan. It also explores the relationship between the spatial value of urban waterfronts and the degree of tourists' attraction toward waterfronts. Spatial and temporal characteristics of social media data can be used to explore the latest urban activity space pattern [64] and verify the effectiveness of POI attraction [29]. As the main crowdsourced data source, social media data can be linked and aggregated into multiple map layers and GIS datasets with multiple uses [65]. The research shows that the spatial correlation between the trajectory of human settlement behavior and various POI layouts can determine the value of the existing lake waterfront and find areas where the spatial value of the waterfront has not been fully utilized yet. The results of our study are of great value to people involved in urban planning and design. These results can likely assist them with identifying priority areas and designing measures to tap spatial potential to ensure full utilization of urban waterfront spaces. The findings can also provide useful information for the improvement of urban waterfront space planning. Moreover, balancing and improving the spatial value of Wuhan waterfront are highly achievable given that the urban environment has high plasticity. We hope that our new method can be applied to other types of future urban developments, such as urban green space service capacity estimation, urban park site selection, commercial space potential analysis, and so on.

Author Contributions: Conceptualization, J.W.; methodology, J.W. and J.L.; software, J.L.; validation, J.W., J.L. and Y.M.; formal analysis, Y.M.; investigation, J.L.; resources, Y.M.; data curation, J.L.; writing—original draft preparation, Y.M.; writing—review and editing, J.W. and J.L.; visualization, J.L.; supervision, J.W.; project administration, J.W.; funding acquisition, J.W.

Funding: This research was funded by the National Natural Science Foundation of China (NSFC) Youth Program, grant number 51808409, and the Fundamental Research Funds for the Central Universities (Interdisciplinary Project), grant number 2042019kf0211.

Conflicts of Interest: The authors declare no conflict of interest.

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