An Evaluation of Spatial Distribution of Public Parking Facilities in Huizhou Downtown

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Abstract. The survey and evaluation of existing public parking facilities were carried out, which had important practical significance to resolve conflicts over demand and supply of parking facilities. Taking Huizhou downtown as a study area, we surveyed parking facilities mainly by daily observing and recording. Parking facilities supply, characteristics, and demand were analysed by calculating parking utilization and turnover rate. Based on GIS, the distance-based and time-based accessibility of parking facilities were analysed to evaluate spatial distribution. The results indicated that a large spatial difference in supply and characteristics of parking was shown in public parking facilities of Huizhou downtown and that the parking demand was large. Furthermore, there existed imbalance in spatial distribution of parking facilities in Huizhou downtown area. Our study suggested that it was imbalanced and irrational between parking facilities supply and parking demand, that the planning of parking facilities was inadequate and that management system was incomplete.

1. Introduction
The spatial distribution of parking facilities, as a part of traffic problems in urban areas, has been extensively studied in recent years. Since the implementation of China’s reform and opening-up policy in 1980s, China has witnessed enormous social changes. Not only has the economy boomed, but also the quality of people’s life has improved sharply. At the same time, urbanization process has been accelerating. With the increasing number of private cars, it is more convenient and efficient for people to travel. However, the parking problem has becoming one of the most outstanding problems in many cities, especially big cities. A series of contradictions were produced between demand and supply of parking facilities, which has had a deep impact on traffic operation and hindered the sustainable development of the city.

Researchers have discussed the parking demand, parking behaviors, spatial distribution, parking facilities planning and evaluation. These have been studied by researchers abroad since 1940s. The prediction model of parking demand was built by large-scale surveys to revise indicators of parking facilities in the USA [1]. Location models of parking facilities have been set up by many researchers based on various indexes about their distribution. For example, a location model of minimum walking distance to parking facilities was proposed in Japan, under the circumstance that the demand and the supply of parking facilities were constant [2]. The related studies were launched late in China, which just focused on parking facilities surveys at the beginning, and the parking location planning was studied in 1990s [3]. What’s more, the Maximum Entropy (Max Ent) model for the distribution of parking facilities was established so as to coordinate the parking location with road networks [4]. The evaluation
index and decision for parking planning were discussed and the index system was set up to evaluate the planning as well as socioeconomic benefits, by studying the decision making system of parking planning in the urban business district. Additionally, some researchers designed another system of evaluating planning of parking facilities [5-7]. Although a number of studies have been carried out to analyze the demand of parking and to evaluate distribution of parking facilities in the big cities, especially in downtown area, less attention has been paid to the medium and small cities. However, in the future, most of them are likely to become big cities, so it is also uneatable and urgent to focus on the public parking problem in big or small cities and solve it.

Our study was designed to evaluate the spatial distribution of parking facilities by taking downtown of Huizhou as a study area. The parking facilities were surveyed mainly by daily observing and recording. Parking facilities supply, demand, and characteristics were analyzed by calculating parking utilization and turnover rate. Based on GIS, the distance-based and time-based accessibility of parking facilities were analyzed to evaluate spatial distribution.

2. Dataset and Method
Huizhou is located in the northeast of the Pearl River Delta, the southern coast of Guangdong province, China. Taken into account the typicality of the spatial distribution of public parking facilities, Huizhou downtown, with a large population and a high level of economy, ranging from the 3rd Ring Road South to the East River, was divided into 3 regions including He Nan’an, Qiaoxi and Qiaodong as shown in Figure 1. To achieve the purpose of the paper, the data of public parking facilities in Huizhou downtown, including location, types and parking spaces etc., were collected by parking survey from July to August in 2015. They were combined with Huizhou City Planning and Construction Bureau statistics and other network search results like Baidu Map etc. The basic road network and other data were obtained by registration and vectorization based on the map of the related area.

For the purpose of collecting the data to analyse the parking characteristics and calculating parking utilization rate and turnover rate in different time, the method of field survey was used by means of daily observing and recording on weekdays (from Monday to Friday) and weekends (from Saturday to Sunday) in each divided region of the study area. Based on the data above, the evaluation indicator system of parking facilities was established as shown in Figure 2.

2.1. The indicators of parking supply and demand
The parking supply refers to the ability to meet the demand of the parking facilities [8]. Generally, parking space is the most important and direct indicator to reflect the parking supply, which is the sum of actual parking spaces. Meanwhile, there are two major types of parking spaces including Off-street Parking and On-street Parking.

The parking characteristics refer to the use of parking facilities. In our study, two representative indicators including Parking utilization rate and Parking turnover rate were selected to analyse the parking characteristics of Huizhou downtown [9-10]. Parking utilization rate is the foundation of assessing the utilization with many factors, such as the location of parking lots, the development of surrounding economy and population status, etc. [11]. Parking turnover rate refers to the average frequency of parking in a unit parking space in a certain period of time, reflecting the parking capacity. The higher the turnover rate is, the stronger the ability of parking service is with more vehicles accommodated [12].

2.2. The indicators of spatial distribution analysis
Accessibility refers to the traffic condition from one place to others or from other places to one. It is also an important factor in the evaluation of spatial distribution. There are a variety of evaluation methods of accessibility. The common model were used to evaluate the accessibility based on the minimal traffic impedance in the ArcGIS when multiple choices of parking, the distance to destination and the time spent in walking were taken into account. The two models, including distance-based accessibility model concerning shortest distance and time-based accessibility model that focuses on time
spent, were selected for the analysis of the minimum impedance. Network Analyst Extension in the ArcGIS was used to set up the traffic network, analyse and obtain the results.

Figure 1. Geographical location of the study area

Figure 2. the evaluation indicator system of parking facilities

3. Results and analysis

3.1. Public parking situation analysis
3.1.1. Supply situation analysis

According to the methods above, the situation of parking spaces for the supply of parking facilities in Huizhou downtown is shown in Table 1.

**Table 1.** The current supply of public parking area of Huizhou city downtown

| Region   | Off-street Parking | On-street Parking | Total | Off-street Parking | On-street Parking | Total |
|----------|--------------------|-------------------|-------|--------------------|-------------------|-------|
| He Nan’an| 25                 | 6                 | 31    | 3358               | 336               | 3694  |
| Qiaoxi   | 16                 | 4                 | 20    | 1930               | 850               | 2780  |
| Qiaodong | 9                  | 13                | 22    | 790                | 1065              | 1855  |
| Total    | 50                 | 23                | 73    | 6078               | 2251              | 8331  |

As can be seen from Table 1, there are altogether 73 parking facilities in the study area, including 50 off-street parking lots and 23 on-street parking lots, which provide 8789 standard parking spaces, including 6078 off-street parking spaces and 2251 on-street parking spaces, accounting for 25% of the total.

3.1.2. Parking characteristics analysis

According to the collected data of the three regions, the parking utilization rates in each interval on weekdays and weekends are shown in Figure 3. It indicates that the utilization rates of parking facilities in Huizhou downtown are generally higher than 80%. And on weekends, they are almost over 100 %, which means that the supply of parking spaces may fall short of the demand.

Parking turnover rates are shown in figure 4. It shows that the rates of weekends are less than the weekdays between 8:00 and 15:00. After 15:00, the turnover rates of weekends are higher than weekdays. But trends of parking turnover rates are substantially the same at all times, and it reaches maximum between 17:00 and 18:00. It also can be seen from the figure 4 that parking turnover rates have two peaks between 9:00 and 11:00 and between 17:00 and 18:00, when residents travel frequently.

**Figure 3.** Parking utilization rate of parking facilities in Huizhou downtown.

**Figure 4.** Parking turnover rate of public parking facilities in Huizhou downtown.

3.1.3. Demand situation analysis

As mentioned above, the results reveal that the utilization rate of parking facilities in Huizhou downtown is generally high. In the morning, when residents rush to work between 8:00 and 9:00, most of vehicles are mobile, so the parking utilization rate is below 50%; Between 9:00 and 18:00, the parking utilization rates exceed 80%, and the turnover rates wavyly rise, which suggests that parking demand and fluidity of parking spaces increase; Many activities like shopping, dining, etc., mainly distribute in public service facilities after 17:00 on weekends, which leads to the fact that the parking utilization rates are over 100% and the demand is greater than the supply.

3.2. Spatial distribution analysis of public parking facilities based on GIS

3.2.1. Spatial distribution situation analysis
Based on the location of public parking facilities, the map of spatial distribution was obtained in ArcGIS. In Figure 5, it is obvious that public parking facilities mainly distribute in the northwest of He Nan’an district, southeastern of Qiaoxi district and south-central of Qiaodong district on both sides of the main roads, and the quantities of facilities in the east of He Nan’an district, the east of Qiaoxi district and the west of Qiaodong district turn out to be less, where the old town used to be located.

3.2.2. Service level analysis
The service area ratio is one of the indicators to measure differences in public services and facilities, which equals to the ratio of the services and facilities area to the total area. The ratio of He Nan’an district, Qiaoxi district and Qiaodong district were calculated as shown in Table 2, from which we can know that the ratio of service area in Qiaodong district is highest and Qiaoxi district is the lowest.

**Table 2. Statistics of rate of service area of parking facilities in Huizhou city downtown.**

| Region     | Number of facilities | Service area | Service area ratio |
|------------|----------------------|--------------|--------------------|
| Henanan    | 31                   | 2.218        | 39.33%             |
| Qiaoxi     | 20                   | 1.397        | 22.60%             |
| Qiaodong   | 22                   | 1.598        | 46.45%             |

Figure 5. Spatial distribution of parking facilities in Huizhou downtown.

3.2.3. Public parking accessibility assessment
It is shown in Figure 6 that the accessibility of Maidi block in He Nan' an district, Dongping block in Qiaodong district are less than 50 or range from 50 to 100; The accessibility of the West Lake in Qiaoxi district, the old town in Qiaodong district, and both sides of Maidi Road and so on range from 100 to 200 and even exceeds 200. Similarly, as shown in Figure 7, the district with small traffic impedance and great accessibility has a better time-based accessibility, and vice versa.

Figure 6. Distance-based accessibility of public parking in Huizhou downtown.
4. Conclusion
From the analysis above, we can conclude that the quantities of parking spaces and public parking facilities in Huizhou downtown are apparently inadequate. As far as the supply of public parking facilities is concerned, the gap between new urban areas and the old areas is wide, so it is with the core areas and the edge areas. Thus, there exists an imbalance and irrational structure between the supply of parking facilities and the demand of parking in Huizhou downtown, the planning of parking facilities and the management system are incomplete.

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