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A Method for Public Parking Facilities Operation Condition Evaluation and Supply Scale Forecasting

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Abstract

Based on the traditional trip attraction model, a new method of operation condition evaluation and supply scale forecasting for public parking facilities is proposed. It begins with the operation condition investigation of existing parking facilities, and then analyzes qualitatively the existing parking facilities supply scale by four indexes. Finally, it can calculate the supply scale in predict year. Combined with concrete work of urban parking facilities planning in china, the evaluation index and prediction model were applied, and the parking facilities operation condition, demand, supply scale and internal structure are analyzed deeply. The method proposed in the paper can provide the theory basis for the public parking facilities planning in other cities.

Keywords*: public parking facilities, operation condition evaluation, supply scale forecasting, trip attraction model*

1. Introduction

Parking has been studied many years and has a great development in developed countries, while there is still backward in this field in China. Compared with other countries, because of the different social situation, the research achievements about parking planning from developed countries are not suitable for China. Chinese parking problems have been extensively studied in 1990s, a brief summary of the past research is presented below. Yan Kefei presented static occurrence rate model based on land use, Li Feng presented traffic impact analysis model, China Academy of Urban Panning And Design presented trip attraction model, etc.

Previous research has shown that the traditional prediction model for parking demand has its deep base of practice in China [1-3]. Based on the experiences of the previous researchers, this paper endeavored to present a method of operation condition evaluation and supply scale forecasting for public parking facilities based on trip attraction model. By means of improving traditional trip attraction model, a prediction model for public parking facilities is established as a core of the new method [4-7]. A case study is also performed to show the application of the method.

2. Methodological Approach

2.1. Work Flow

Parking facilities planning is intended to provide better urban traffic service level. It should be solved the problems about service and management of existing parking facilities. Therefore, it begins with the operation condition investigation of existing parking facilities, and then analyzes qualitatively the existing parking facilities supply scale by the detailed data, finally, it can calculate the supply scale in predict year.

There are three kinds of parking demand forecasting model, prediction model based on land use; on trip; and on the characteristics of social economic activities. As a part of urban comprehensive transportation planning, parking facilities planning is considered as the following items [8-10]. Generally, a complete OD data is obtained before the parking facilities planning.

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Therefore, the prediction model for trip attraction is more convenient.

Take the trip attraction model as the core, the working process operation condition evaluation and supply scale forecasting for public parking facilities can be depicted as Figure 1.

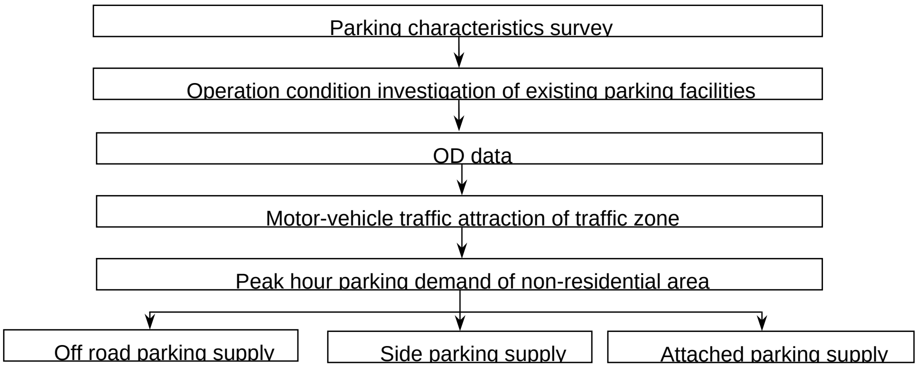

Figure 1. Process of Public Parking Facilities Scale Forecasting

2.2. Operation Condition Evaluation Indexes

The operation condition of existing parking facilities can be evaluated by following indexes.

(1) Berth turnround rate λ, the index to measure the usage times of parking berths during the investigation. λ indicates the average usage times of every parking berths. λ also reveal the activity of parking demand, that is, larger λ, the more vehicles access to parking facilities. It is not only related with parking demand, but also related with parking supply. The equation is given by:

$$\lambda=S/C \tag{1}$$

where S is the parking numbers during the investigation, C is the parking capacity.

(2) Berth turnround rate in peak hour α, indicates the degree of crowding in peak hour and is an important index of parking supply. If α is high, the existing parking facilities capacity is low. If α is low, the existing parking facilities capacity is high and the utilization is low. α can be depicted as follow:

$$\alpha=N_j/C \tag{2}$$

where N_j is parking numbers in rush hours.

(3) Average parking time $\overline{t}$, the index to measure the traffic loading and turnround rate of parking lot. $\overline{t}$ is longer, the better used for parking facilities in time domain. It can be depicted as follows:

$$\overline{t}=\frac{\sum t_i}{S} \tag{3}$$

where t_i is the parking time of the car i.

(4) Berth utilization η. It reveals the utilization strength of parking lot. It depends on parking lot location, capacity, and parking management and so on. Too high or low are not well, if η is low, a large proportion of parking facilities will be a waste, and if the utilization is high, it will make the parking crowded.

$$\eta=\frac{\sum\left(t_i\cdot P_i\right)}{T\cdot C}\cdot 100\% \tag{4}$$

where P_i is the numbers of cars in parking time t_i, T is the survey time, C is parking capacity.

2.3. Prediction Model

The generation of public parking demand is related to social economical intension, and social economical intension depends on the traffic attraction of traffic zone. Parking demand can be obtained according to the relationship between public parking demand at peak hour and motor-vehicle attraction in traffic zone. Based on the supply rate and supply structure, different types of parking facilities supply in predict year can be acquired. Considering the impacts of parking management on the parking demands, the improved model based on the traditional model can be defined as follows.

$$P_{\mathrm{D}} = A \cdot \beta \cdot \gamma / (\alpha \cdot \mu) \tag{5}$$

$$P_{\mathrm{S}}^{i} = P_{\mathrm{D}} \cdot \omega \cdot \theta_i \tag{6}$$

where, P_{D} is the peak hour public parking demand of traffic zone in predict year, A is non-residential motor-vehicle traffic attraction of traffic zone in predict year, β is the parking generation of motor-vehicles, γ is the influence coefficient of parking management, μ is the parking correction coefficient at peak hour, P_{S}^{i} is the parking facilities supply of type i, ω is the parking supply rate of traffic zone, θ_i is the parking facilities supply proportion of type i.

The model above is the improved prediction model, its parameters calibration should follow parking characteristics in predict year. The successful experience of other parking facilities planning in similar cities can also be taken as reference to calibrate parameters. However, the experience has no guidance because of difference of traffic in different cities.

3. Application Analyses

3.1. Basic Situation of Public Parking Facilities in S City

The traffic zone division of S city is shown in Figure 2. According to the difference of parking characteristics in different traffic zones, the traffic zones can be divided into two categories, one for core area (No.1 and No.2), one for non-core area (others). The existing public parking facilities are mainly attached parking lot and side parking lot. At present, there are 450 parking lots for motorcars and 31,720 parking berths in urban. Among of these, there are 10,676 berths are charging, and 38,334 berths are free. Generally, parking lots is comparatively centralized in core area. Moreover, the core area also has the most prominent problem between parking supply and demand. The distribution density of parking berths in core area is shown in Figure 3.

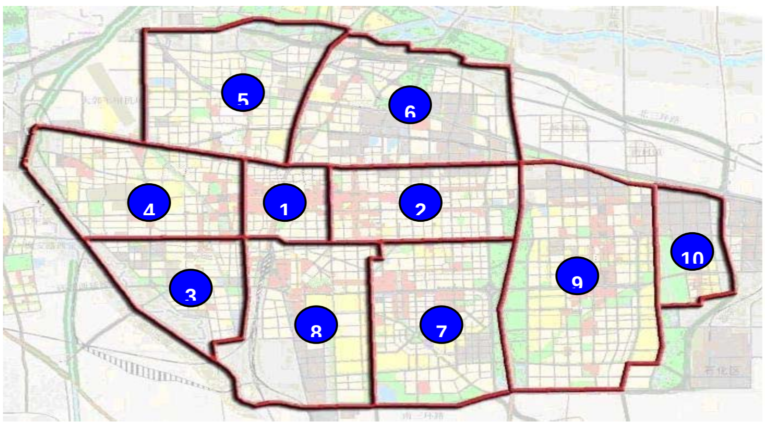

Figure 2. The Traffic Zone Division

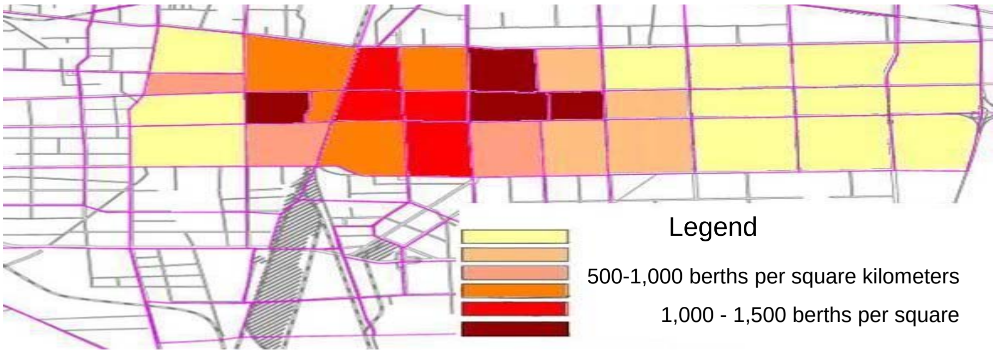

Figure 3. The Distribution Density of Parking Berths in Core Area

Since the proportion of motorcars and parking berths in core area is 15, and it is far from the international standard, so the gap of public parking berths is also large. The contradiction of parking supply and demand in traffic area1 is the most serious. The number of side parking berths in existing public parking facilities is large, and the driving is disturbed greatly by it. In the peak hour, the average parking of traffic is about 40 vehicles per kilometer. It may directly lead to the traffic in the chaos, and it will also reduce the traffic capacity of relevant road. Attached parking lots include parking lots for various types of architectures. As the common phenomenon of attached parking lots are occupied, there are less parking berths than actual berths, and the result leads to the increase of public parking facilities demand.

3.2. Operation Condition Evaluation of Public Parking Facilities

For the operation condition evaluation of S city's public parking facilities, 18 typical public park lots in core area were selected to survey, the basic information of survey samples is shown Table 1. The pre-investigation indicates the parking demand on holidays is much higher than parking demand on workdays, so the survey time is determined at 7:00~19:00 on Sunday. The indexes which are shown in Table 2. can be calculated after data processing.

Table 1. The Basic Information of Survey Samples

Location	Number		
	Side Parking Lot	Off Road Parking Lot	Attached Parking Lot
Around Market	2	2	2
Around Restaurant	2	2	2
Around Hotel	2	2	2

Table 2. Operation Condition Evaluation Indexes of Public Parking Facilities in S City

Parking Facilities Type	λ	α	η/(%)	$\bar{t}$ (min)
Side Parking Lot	5.6	3.1	56	66
Off Road Parking Lot	4.7	3.0	50	86
Attached Parking Lot	4.8	2.8	49	78

According to Table 2, the operation condition features of public parking facilities can be obtained as follows:

(1) λ and α is relatively high. According to the survey data in developed countries, α of side parking lot is usually about 3.8, and α of off road parking lot or attached parking lot is usually at the range of 1.0~2.3. λ and α shows that the parking facilities utilization is high, but it is essential for increase the parking supply.

(2) Side parking lot have the shortest $\bar{t}$. It is because that the side parking lot is most near the working location, and people usually choose the nearest place to park. People who have enough time may choose off road parking lot or attached parking lot.

(3) η of side parking lot is higher than others. According to the investigation, it can be found that the side parking lot has obvious peak-hour and the shortest $\bar{t}$, so there will be

differences on η. According to the features of side parking lot, low η is better for reducing the influence to dynamic traffic.

3.3. Trip Attraction

The total volume of the urban resident travels is 9.675 million person-time per day in predict year. The structure of resident trip purpose is shown in Table 3. The structure of resident trip mode in different trip purpose is shown in Table 4. A can be got by comprehensively considered resident trip purpose and resident trip mode.

Table 3. The Structure of Resident Trip Purpose (%)

Go to Work	Go to School	Business	Go Home	Shopping	Entertainment	Visiting	Others	Total
25.4	9.0	1.8	47.7	6.8	3.0	1.4	4.9	100.0

Table 4. The Structure of Resident Trip Mode in Different Trip Purpose (%)

Ways	Go to Work	Go to School	Business	Go Home	Shopping	Entertainment	Visiting	Others
Walk	16.3	31.3	6.2	26.9	45.8	69.1	11.0	30.8
Bicycle	53.6	53.6	26.8	47.8	36.7	20.7	42.1	36.8
Electric Bicycle	16.2	2.2	9.0	10.2	3.6	2.1	5.9	7.8
Bus	4.9	9.0	6.8	7.0	9.5	4.0	29.1	7.7
Private Car	4.6	0.9	25.1	3.5	1.5	1.2	4.6	5.3
Taxi	0.4	0.1	5.8	0.7	0.6	1.1	4.6	1.9
Official Car	2.2	0.1	18.4	1.2	0.1	0.2	0.4	0.9
Motorcycle	1.5	0.3	1.3	1.2	0.5	0.6	1.2	2.1
Others	0.5	2.5	0.6	1.5	1.6	1.1	1.1	6.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 5. θ_i in Different Traffic Zones (%)

Traffic zone	Type	θ_i		
		Side Parking Lot	Off Road Parking Lot	Attached Parking Lot
1, 2	Core Area	8	14	78
3, 4, 5, 6, 7, 8, 9, 10	Non-Core Area	5	10	85

3.4. Parameter Calibration

The parameters of different kind of traffic zones are calibrated as follows:

(1) Parking generation of motor-vehicles β. The parking time which less three minutes is mainly the temporary parking that the passengers get on or off the vehicles, in this case, it produces no parking demand. According to the actual condition, the percentage for temporary parking of core area and non-core area are 15% and 12% respectively, so the generations of motor-vehicles are 85% in core area, 88% in non-core area.

(2) Influence coefficient of parking management γ. According to the differences in the conflict between parking supply and demand, differrent traffic management strategy can be considered, it is 0.9 in core area and 1.0 in non-core area.

(3) Berth turnround rate in peak hour α. Based on the parking sample survey, the average turnround rate of various parking facilities are usually range from 1.0 to 5.0. In China the rate are range from 1.5 to 4.0. typesis 5.0 in core area, and 4.0 in non-core area. Due to the reinforcement of parking management and the implemenatation of parking charging, the rate will be improved greatly. α will be 5.0 and 4.0 respectively in core area and non-core area.

(4) Parking correction coefficient at peak hour μ. Based on actual condition of planning area and experience of other cities, μ is 1.2 in this paper.

(5) Berth supply rate ω. Generally, the value of ω is range from 1.10 to 1.30. Considering the scarcity of land resources and irrationality of traffic trip mode, the ω of core area and non-core area are 0.95 and 1.15 respectively.

(6) Parking facilities supply proportion θ_i. Due to the rebuild difficulties in core area, the proportion of attached parking berth cannot be enhanced greatly, so the parking problem can be solved mainly by off road parking facilities. However, in the non-core area, the problem was solved mainly by attached parking berth. For the public parking facilities, the proportion of side parking to off road parking in S city is about 1.00. But in China, the value is about 0.25. So the

proportion of side parking should be reduced properly, the selected result of θ_i is shown Table 5.

3.5. Forecasting Results

According to the above analysis, the public parking demand and parking supply are shown in Table 6.

Table 6. Forecasting Results of Parking Demand and Parking Supply (10^4 berth)

Traffic Zone	P_D	P_i			
		Side Parking Lot	Off Road Parking Lot	Attached Parking Lot	Total Supply
1	2.92	0.23	0.39	2.16	2.77
2	4.73	0.36	0.63	3.50	4.49
3	2.58	0.15	0.3	2.52	2.97
4	5.03	0.29	0.58	4.92	5.78
5	4.65	0.27	0.53	4.55	5.35
6	3.46	0.2	0.4	3.38	3.98
7	6.24	0.36	0.72	6.1	7.18
8	4.12	0.24	0.47	4.03	4.74
9	6.28	0.36	0.72	6.14	7.22
10	0.15	0.01	0.02	0.15	0.17
Total	40.20	37.50	4.80	2.50	44.70

4. Conclusion

On the basis of absorbing and learning from previous research, this paper presents the method of operation condition evaluation and supply scale forecasting for public parking facilities based on trip attraction model, with the static traffic management influence coefficient, the traditional attraction model is improved. Finally, a case study was also performed to show the application of the method. The model and its parameter calibration principles which is proposed in the paper could provide the theoretical basis for the public parking facilities planning in other cities.

Further research needs to be conducted to deal with more problems in the model, and to seek out other possible parameters. The available model remains relatively limitations, and so improvements in this area are also welcomed.

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