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The Model of Parking Demand Forecast for the Urban CCD*

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Abstract

With the increase of the number of automobiles, the city parking demand occurred a rapid growth, and the city automobile parking had become a very serious traffic problem for Central Commercial District in cities. The parking demand forecast is the key of public parking planning and provides the basic data for the size of the parking lot. On the basis of the Parking Generation Rate Model, the improved model was set up, considering more factors, such as the average turnover rate, parking place occupancy, service level, parking fees and growth rate of automobiles. Meanwhile, the capacity of road network is applied to rectify the short-term parking demand forecast. Finally, the model was applied to Binjiang Road CCD, Tianjin, China.

Keywords : Central Commercial District(CCD); Parking Lot; Parking Demand Forecast; Capacity of Road Network

1.Introduction

The urban Central Commercial District is a citywide and regional conmmercial area, where automobiles and pedestrians are concentrated, especially heavy shopping and sightseeing vehicle flow as well as stream of people; therefore, CCD faces the prominent regional traffic problems. Parking demand forecast and analysis in CCD have been a hot reseach topic for the experts. In 1988, U.S. Federal Transit Administration funded a joint research project called "The Policy of Car Owners Turnning to Public Transportation". Conducting research on 20 metropolitans, investigaters showed that[1]: parking fee is much more effective to decline in SOV (special orientation visit) commute and to increase public transportation utilization than to improve the availability and attandence of public transportation. Daniel

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Bzldwin Hess (2001)[2] made a forecast for traffic modes to Porland CBD (Central Business District): when parking fee is free, 62% of commuters will choose travel by car; 10% will choose to ride togerther; 22% will choose public transportation. When parking fee is up to 6 dollars, 46% of commuters will travel by car; 4% will choose to ride together; 55% will choose public transportation. Based on the investigation of aperiodically travel from Sydney to CBD, it has been showed by David A, Hensher, and Jenny King (2001) that[3]: if parking fee rate in each hour at central district increase 1%, the person to park in this district will decline 2.04%. Other scholars, such as Bianco, M.J (2000)[4],Richard Voith (1998)[5], Richard Arnott, John Rowse (2009)[6] also conducting research on this issue, have revealed similar conclusion.

About the method of parking demand forecast, Professor Yan Kefei (1994)[7] established Static Parking Generation Rate Model based on land use and Linear Correlation Model based on vehicle travel; Professor Chen Jun(1999)[8] established Static Parking Generation Rate Model and gave searching algorithm from analysis on the factors of urban parking lot demand; Guan Hongzhi(2006)[9] established Parking Supply-Demand Forecast Model. According to construction indices from the planned land in all traffic areas, Zhang Jin(2003)[10] set up improved Parking Generation Rate Model to calculate parking demand. Bai Yu, Xue Kun, and Yang Xiaoguang(2004)[11], under the limitation of network capacity and network service level, have modified the OD forecast method and set up a new method of parking demand forecast based on the capacity of network. However, this model cannot be widely applied to practice because of the difficulty in obtaining OD data in CCD.

The models, mentioned in this paper, were applied widely to practice, include Parking Generation Rate Model, Travel Attraction Traffic Model, Regression Analysis Model, etc. On the basis of Parking Generation Rate Model, the improved model was set up and the illustrative case was given in this paper.

2.The Establishment of Parking Demand Forecast Model in Urban CCD

2.1.Parking generation rate model

Parking Generation Rates are parking demand quantities generated from land use in per unit area, on the basis of land use types, which are applied to study parking demand in the certain area. The parking demand in certain CCD is equal to the total parking quantities generated by these individual areas[12]. The fomula is,

$$y = \sum_{i=1}^{n} a_i \times R_i (i = 1, 2, \cdots, n) \tag{1}$$

Where:

y refers to parking demand in certain CCD in rush hour; unit is lot;

a_i refers to parking generation rates, which are the quantities of parking demand in per unit area;

R_i refers to the individual area m^2 .

2.2.Improved Parking Demand Forecast Model

Considering several factors, Parking Generation Rate Model was improved in this paper. The improved model is,

$$y = (\sum_{i=1}^{n} \frac{a_i \times R_i}{\mu_i \times \gamma_i}) \times \delta \times L \times \beta (i = 1, 2, \cdots, n) \tag{2}$$

Where:

y, R_i is the same as above; According to building classification in domestic and foreign cities and present situation in study cities and areas, land use types have been determined, including residential block, shopping centres, office buildings, culture and entertainment dining, schools, hospitals, factories and railway stations[9]. In researching on specific areas, the proper one can be chosen to analysis present situation.

a_i is the same as above. Parking generation rates from each type of land use can be obtained from the research on parking characteristic in this parking lot, by means of recording the number and time of in-out cars. Regular pattern, the number of cars increasing and decreasing with the variation of time, can be obtained according to the measured data. Then the largest number of vehicles in one day will be calculated, calculating peak parking attraction out of these, dividing building's floor area. Peak parking generation rates will be gotten [13].

μ_i refers to average turnover rates, which are defined as average times of parking in each turnover lot in certain hour. The expression is based on the ratio of cumulative number of parking vehicles and parking infrastructure capacity in a certain period of time. The equation is,

$$\mu_i = \frac{A_i}{D_i} \tag{3}$$

Among them, μ_i is parking turnover rates; A_i is total amount of parking; D_i is total number of lots. When μ_i is larger than 1, supply is less than demand. When μ_i is less than 1, supply is larger than demand..

γ_i refers to lot occupancy, which is parking time of each lot divided by the total time in a certain period of time. The fomula is,

$$\gamma_i = \frac{\sum t_{ij}}{D_i T} \ (j = 1, 2, \cdots D) \tag{4}$$

Where: γ_i refers to utilization rate of parking; t_{ij} refers to parking time in each lot; D_i refers to total number of parking lots; *T* refers to working time of parking lot.

L refers to parking price impact coefficients. With the increasing of parking price rates, the proportion of car travel will reduce, but the proportion of buses and taxies will increase [14], resulting from the variation of travel modes. The scale of L is relevant to flexibility of parking demand in study area. For the area with weak flexibility of parking demand, the flexibility of parking demand is inversely proportional to the scale of L.

δ refers to parking service level, which has a positive impact on parking demand. Cars will be attracted with increasing at the level of proposed parking service; δ is larger than 1.While the service level is poor, δ is less than 1. Parking service should follow urban transport planning. While starting long-term forecast, good service level has better been chosen[15].

β refers to growth coefficients of motor vehicles, which have a positive effect on parking demand. Parking lot will be needed more with increasing in motor vehicles. The growth coefficients of motor vehicles have been determined by following expression,

$$\beta = \frac{Z_1}{Z_2} \tag{5}$$

Among them, β refers to vehicle growth coefficients; Z_1 refers to the number of motor vehicles in the future year; Z_2 refers to the number of motor vehicles in base year. When forecast year is base year, β is equal to 1. The number of motor vehicles of forecast year can be calculated according to historical data, by mean of flexibility coefficient method[16].

2.3.Parking demand under road network capacity limitation

In urban CCD during rush hours, road network is often saturated and supersaturated. At this period, parking demand in this area has been influenced by the capacity of network, comprehensive reduction coefficients, and the ratio of parking behavior. Considering these three factors, Parking Demand Model has been rectified under road network capacity limitation. The specific model is as follows,

$$P = C_r \times S \times \rho \tag{6}$$

Where:

P refers to parking demand under road network capacity limitation;

C_r refers to road network capacity in this area, which can be calculated by consumption space-time method or import and export capacity method[17];

S refers to expected network service coefficients, which are comprehensive reduction coefficients used in commercial road network. The scale of S should follow urban transport planning. Considering unpredictability of transportation demand, good service level is encouraged to be chosen in making long-term forecast [18];

ρ refers to the ratio of parking, which is the ratio of the number of vehicles parking in certain area to the total number of vehicles travel in this area.

2.4.Modification of parking demand under road network capacity limitation

In this paper, parking demand calculated by road network capacity should be the maximum number of parking infrastructure provided in CCD. If parking facility supplements are more sufficient than parking demand under road network limitation, the more cars will be attracted to this area, causing seriously traffic congestion with increasing of cars into this area. Hence, in researching on the amount of parking demand, the values of parking demand forecast should be less than the amount of parking demand under road network capacity limitation. Give an assumption, P_1 refers to parking demand calculated by improved Parking Demand Rate Model; P_2 refers to parking demand under road network capacity limitation. In researching on present parking demand forecast, two conditions were considered:

- $P_1 < P_2$

On this condition, P_1 should be taken as forecast amount of present parking demand, which should be taken as reference values to analysis the amount of parking infrastructure. This method would both meet parking demand and not exceed road network capacity limitation.

- $P_1 > P_2$

On this condition, under the limitation of road network capacity, the values of P_2 should be larger than cars travelling to CCD. But it is difficult to increase road network capacity in short-term; therefore, P_2 is taken as the forecast values of parking demand in short-term.

3.Case Study

In this paper, taken as a research case, the Tianjin Binjiang Road CCD is the largest leisure commercial centre in Tianjin, China, Where entertainment, Dining, shopping, leisure are held for the integration of multiple consumption functions.

3.1.The scope of the Binjiang Road CCD

The district of Binjiang Road consists of Hami Road, Xingan Road, Dagu Road, Yingkou Road, Nanjing Road, which includes five pedestrian shopping streets, as shown in Figure1.

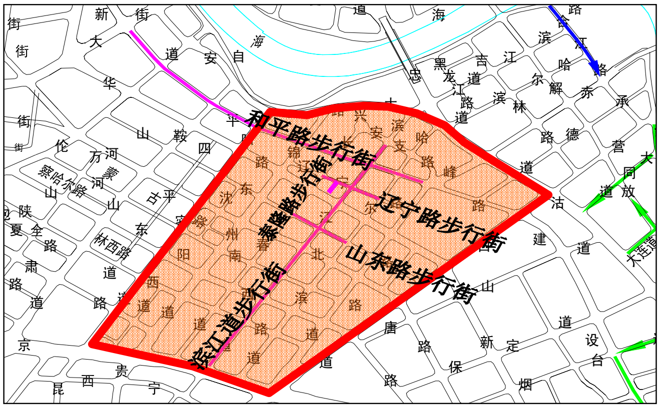

Fig1 The Regional Scope of Tianjin Binjiang Road CCD

3.2.The collecting and processing of data on that CCD

Through the site survey, the data of various types of land in the working days and the non-working days were obtained, including the parking generation rate a_i, average lot turnover rate μ_i, and average lot utilization rate γ_i, which were shown in TABLE I and Ⅱ:

TABLE I THE AVAILABLE DATA OF VARIOUS TYPES OF LAND IN THE WORKING DAYS

Land types	Parking generation rate	Average lots turnover rate	Average lots utilization rate
Commercial areas	1.22 lots /100 m^2	1.81	0.88
Residential areas	0.38 lots /100 m^2	1.26	0.60
Office areas	0.69 lots /100 m^2	1.42	0.78
Cultural entertainment and Dining	0.76 lots /100 m^2	1.26	0.62
The school areas	0.12 lots /100 m^2	1.00	0.56

TABLE Ⅱ THE AVAILABLE DATA OF VARIOUS TYPES OF LAND IN THE NON-WORKING DAYS

Land types	Parking generation rate	Average lot turnover rate	Average lot utilization rate
Commercial areas	2.26 lots /100 m^2	2.05	0.93
Residential areas	0.40 lots /100 m^2	1.12	0.56
Cultural entertainment and Dining	1.63 lots /100 m^2	1.80	0.73

The floor area and average plot ratio of various types of land can be obtained from the departments of planning, as shown in TABLE Ⅲ:

TABLE Ⅲ THE PERCENTAGE AND CORRESPONDING AREA OF VARIOUS TYPES OF LAND

Land types	Percentage	Floor area	Average plot ratio	Building area (R_i)
Commercial areas	85.00%	134756.18 m^2		552500.34 m^2
Residential areas	5.50%	8719.86 m^2		35751.43 m^2
Office areas	4.30%	6818.01 m^2		27953.84 m^2
Cultural entertainment and Dining	2.30%	3647.12 m^2	4.1	14953.19 m^2
The school areas	1.80%	2853.66 m^2		11700.01 m^2
Other	1.10%	1743.90 m^2		7150.00 m^2
Total	100.00%	158536.58 m^2		650008.81 m^2

Because the current existing parking demand of Tianjin is more than parking facilities supply, and the guidance and management system of parking is imperfect, which cause the queuing phenomenon of car parking in peak hours, the whole service level of parking is not high, and we let $\delta = 85\%$.

The surveyed CCD is located in the heart of the city center region, parking facilities are in short supply, hence, the department of traffic management takes the measures to decrease parking demand by a higher parking price to alleviate regional parking and traffic pressure. Although parking restrictions are carried, the current charging system is incomplete and the parking demand elasticity changes little with the price, therefore, the price impact coefficient $L = 90\%$. According to the amount of motor vehicles of the calendar year, we can figure out the motor vehicle growth factor β. The growth factor in motor vehicles was forecast and shown in TABLE Ⅳ through calculation.

TABLE Ⅳ THE FORECASTING OF GROWTH FACTOR IN MOTOR VEHICLES

Years	2009	2010	2011	2012	2013
The amount of motor vehicles	1.00	1.06	1.12	1.18	1.25

3.3.Parking Demand Forecast Based on the Model

The amount of parking demand forecast begins with 2009 years. The initial short-term parking demand of Binjiang Road CCD in the working and non-working days can be calculated through formula (2), as shown in TABLE Ⅴ.

TABLE Ⅴ THE INITIAL SHORT-TERM PARKING DEMAND OF BINJIANG ROAD CCD

Years	2009	2010	2011	2012	2013
Parking demand of working days(Num)	3639	3857	4076	4294	4549
Parking demand of non-working days(Num)	5327	5647	5966	6286	6659

3.4.Parking Demand under the Road Network Capacity limitation

The road network capacity (C_r) of Binjiang Road CCD is 5251 vehicles through the statistical data. As the whole service level of the traffic network is low, the selecting network service level $S = 0.95$. Considering the Binjiang Road is one of the most prosperous CCD in Tianjin, we select the proportion of parking behaviour $\rho = 0.95$

According to the formula (6), the lots of parking demand under road network capacity limitation is 4490.

3.5.The rectification of Parking Demand Forecast

According to the above calculation, the parking demand of working days and non-working days can be forecasted by the model mentioned above. The lots of parking demand under the road network capacity limitation is $P_2 = 4490$. The forecast results of the short-term parking demand of the Binjiang Road CCD are shown in TABLE Ⅵ and Ⅶ

TABLE Ⅵ THE MODIFICATION OF SHORT-TERM PARKING DEMAND FORECAST

Years	2009	2010	2011	2012	2013
Parking demand of working days(Num)	3639	3857	4076	4294	4490
Parking demand of non-working days(Num)	4490	4490	4490	4490	4490

Currently, the actual number of parking spaces is 1395 in the Tianjin Binjiang Road CCD, including attached parking lots, public parking lots, special-purpose parking lots and so on. As a result, the lack number of parking spaces can be calculated according to data of the table so that the number of public parking spaces can be calculated.

TABLE Ⅶ THE LACK NUMBER OF CURRENT PUBLIC PARKING SPACES

Time	working days	non-working days
Lack-of-Parking lots	2244	3095

According to TABLE Ⅶ, in 2009, the parking demand of non-working days is the road network capacity limitation because the result obtained from the model is more than it, however, the parking demand of working days is the less than he road network capacity limitation, hence the results from the model are taken as the parking demand of non-working days. Obviously, the parking demands of the working days and non-working days are on the rapid rise in the next years.

4.Conclusion

In this paper, with the consideration of the average turnover rate of parking spaces, the utilization of the lot, the service level of parking, parking fees and automobile growth rate, the improved model was set up on the basis of the parking generation rate model. Meanwhile, the amount of parking demand should be in a rational quantity range under the road network capacity limitation to avoid the amount of parking demand forecast exceed the actual road network capacity. By the case study, the improved model was applied to the Tianjin Binjiang Road CCD, which illustrated it was applicable and practicable.

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