TSINGHUA SCIENCE AND TECHNOLOGY
ISSN 1007-0214 10/25 pp632-635
Volume 13, Number 5, October 2008

Trip Generation Model Based on Destination Attractiveness*

YAO Liya (姚丽亚), GUAN Hongzhi (关宏志)**, YAN Hai (严 海)

Key Laboratory of Traffic Engineering, Beijing University of Technology, Beijing 100022, China

Abstract: Traditional trip generation forecasting methods use unified average trip generation rates to determine trip generation volumes in various traffic zones without considering the individual characteristics of each traffic zone. Therefore, the results can have significant errors. To reduce the forecasting error produced by uniform trip generation rates for different traffic zones, the behavior of each traveler was studied instead of the characteristics of the traffic zone. This paper gives a method for calculating the trip efficiency and the effect of traffic zones combined with a destination selection model based on disaggregate theory for trip generation. Beijing data is used with the trip generation method to predict trip volumes. The results show that the disaggregate model in this paper is more accurate than the traditional method. An analysis of the factors influencing traveler behavior and destination selection shows that the attractiveness of the traffic zone strongly affects the trip generation volume.

Key words: traffic demand forecasting; trip generation; attractiveness; disaggregate model

Introduction

Trip generation predictions are the first step of the traffic demand prediction process in the traditional four-step prediction method. The reliability of forecasting results influences the following steps such as trip distribution, mode split, and traffic assignment. Therefore, improved trip generation models are needed to improve forecasting precision[1].

Many have made studies of trip generation forecasting[2,3]. Traditional methods forecast the trip generation volume according to the trip rate based on family type or land use[4]. In the forecasting method based on family type, families were classified by the three characteristics of population, income, and number of cars. The number of trips in a zone per unit time and the trip rate for the family are determined by sampling, with the trip generation volume calculated from the trip rate and the number of families in the future. In the land use-based method, the average trip rate per unit land area at present is determined by spot checks with the trip generation based on the species and the future land development plans.

Traditional forecasting methods have several problems. For example, trip rates for the same families or land use types in different zones are not the same because of the different economic levels and land use. The forecasting errors produced by different trip rates are then due to the attractiveness of the different traffic zones. The attractiveness of various traffic zones is based on the different utility values of the alternative of the travelers. The unit rate of trip generation is then different for different distributions of the zone center of gravities.

Traditional forecasting methods do not consider the travel behavior, so the attractiveness of various traffic zones cannot be determined from behavior analysis. In this paper, the traffic zone attractiveness is calculated using a disaggregate model[5,6] that considers all the

Received: 2006-10-23; revised: 2007-11-26

* Supported by the National Natural Science Foundation of China (No. 50478041) and the Natural Science Foundation of Beijing (No. 8053019)

** To whom correspondence should be addressed.
E-mail: hguan@bjut.edu.cn; Tel: 86-10-13701142716

factors influencing traveler behavior such as the traveler characteristics, the trip characteristics, and the traffic service level in a modified trip generation model[7].

1 Basic Method

The trip rates in different traffic zones differ because the attractiveness of each traffic zone differs. The attractiveness is reflected by the utility of the destination selection. Therefore, the attractiveness is influenced by the traveler characteristics (such as sex, age, occupation, and income), the trip characteristics (such as the trip objective, the distance, and the cost), and the traffic service level (such as trip cost and time).

The influence of these various factors on the trip generation can be reflected by adding a traveler utility dispersion into the trip generation forecasting model.

In this paper, the area for the trip generation forecast is divided into several zones. The destination selection data was collected by investigations of the areas. Utility theory[8] is used to develop a destination selection model with the traffic zone attractiveness and then to modify the traditional trip generation model.

2 Trip Generation Model

2.1 Calculation of traffic zone attractiveness

For traffic demand forecasting, the areas for the traffic volume forecasts are divided into several zones. The traffic zones attractiveness differs in each zone because of different zone characteristics and traffic patterns. The trip rate for unit land area is high when the zone attractiveness is high. Assume that the zone attractiveness can be denoted by

$$\Lambda_i = f(S_{0i}, R_i, A_i) \tag{1}$$

where Λ_i is the attractiveness of traffic zone i, S_{0i} is the distance from zone i to the center of the city, R_i is the traffic advantage index, and A_i is the acreage of each land use type.

In practice, S_{0i} is determined by the travel distance and R_i is determined from expert opinions. There are then errors produced by different public traffic modes and the subjective bias of the experts. Therefore, accurate values of Λ_i cannot be easily determined from Eq. (1).

Some studies have tried to calculate traffic zone attractiveness using an aggregate model. The traffic zone attractiveness can be calculated by regression analysis of the relationship between the forecasting error and the zone attractiveness. The trip generation model can then be modified, but the relationship between the attractiveness and the trip generation rate needs extensive historical data for the regression analysis and the zone advantage index needs to be estimated by experts, so the analysis is quite complex.

This paper develops a method based on the disaggregate model to calculate the zone attractiveness. The relationships between the destination selection and the traveler characteristics, the trip characteristics and the traffic service level are found through investigations. The factors influencing the destination selection are arranged in a utility matrix, with the zone attractiveness then calculated from

$$\Lambda_i = \ln \sum_{j=1}^{M} \exp\left[\frac{1}{N}\sum_{n=1}^{N}(V_{jn} - V_{in})\right] \tag{2}$$

where M is the number of possible destinations, N is the number of swatches, and V_{jn} is the fixed utility for individual n to select destination j, and V_{in} is the fixed utility for individual n to select destination i. V_{jn} and V_{in} are obtained from the destination selection model as

$$V_{jn} = \sum_{k=1}^{K} \theta_k X_{jnk} \tag{3}$$

where K is the number of variables, X_{jnk} is the value of variable k that influences whether individual n selects destination j, and θ_k are the coefficients that correspond to variable k.

2.2 Trip generation calculation

The trip generation for land use attribute k in zone i is

$$G_i^k = \lambda_i \Lambda_i^{\gamma} + \delta^k N_i^k + C \tag{4}$$

where δ^k is the trip rate for land use attribute k in zone i, N_i^k is the acreage of land use for attribute k in zone i, λ_i is a modulus of zone i which has the dimensions of traffic volume divided by the traffic zone attractiveness, C and γ are coefficients to be determined.

The total trip generation for zone i can then be calculated as

$$G_i = \sum_{k=1}^{n} G_i^k \tag{5}$$

where n is the number of different land use attributes in zone i. Λ_i can be calculated from Eqs. (2) and (3).

3 Data and Results

In practice, the investigated area is often divided into several traffic zones. In this study, the travel behavior was investigated for traffic in Beijing where the traffic can be divided based on the ring roads. Zone 1 was selected as the area inside the second ring road, zone 2 was the area between the second and fourth ring roads, and zone 3 was the area outside the fourth ring road.

Based on relativity analysis of the variables and the results, a conclusion can be drawn that variables that influence the destination selection are age, income, objective, having a car or not, payment mode, time, and cost as listed in Table 1.

Investigation data was used to establish a disaggregate model with the destination selection model calibration results in Table 2.

Table 1 Destination selection model variables

Utility	Fixed parameters		Traveler characteristics			Trip characteristics		Public variables	
			Age	Car	Income	Objects	Payment mode	Time	Cost
	X_{in1}	X_{in2}	X_{in3}	X_{in4}	X_{in5}	X_{in6}	X_{in7}	X_{in8}	X_{in9}
Zone 1	0	0	X_{1n3}	0	0	0	0	X_{1n8}	X_{1n9}
Zone 2	1	0	0	0	X_{2n5}	0	X_{2n7}	X_{2n8}	X_{2n9}
Zone 3	0	1	0	X_{3n4}	0	X_{3n6}	0	X_{3n8}	X_{3n9}
Parameter	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	θ_8	θ_9

Table 2 Destination selection multinomial logit model calibration results

Parameters		Zone 1		Zone 2		Zone 3	
		Parameter value	*t*-test value	Parameter value	*t*-test value	Parameter value	*t*-test value
	Fixed parameter 1	0.3915	0.8237	−1.1059	−1.3535	−3.1634	−0.2596
	Fixed parameter 2	−0.7894	−2.3381	−0.4183	−1.2818	−0.2563	−0.8738
Discrete variables	Less than 40 years	0.2546	0.8357	0.5349	1.7493	0.0316	0.1074
	Have a car	0.9506	2.5992	0.1916	0.3889	−0.1551	−0.5291
	Income less than 30 000 RMB per year	−0.1549	−0.5365	0.0990	0.2190	−0.5318	−1.5169
	Going to work, study, business	0.0903	0.2734	−0.1790	−0.5033	0.1250	0.4763
	Paying by himself	−0.0759	−0.1695	1.2047	1.8427	9.1036	0.2579
Continuous variables	Time	0.0285	2.2939	0.0077	1.2484	0.0247	2.2372
	Cost	−0.0408	−1.9902	−0.0153	−0.6501	0.0143	0.8223

The precision test of the model is in Table 3. In Table 3, $L(0)$ is the value of the likelihood function when all the estimated parameters equal zero. $L(\hat{\theta})$ is the value of the likelihood function when the final estimated values of the parameters are used in the function. $-2(L(0)-L(\hat{\theta}))$ is a statistical value to test whether all the parameters equal zero. ρ^2 is the fit ratio. $\bar{\rho}^2$ is the fit ratio after regulation of the degrees of freedom. In practice, the model precision is acceptable when ρ^2 and $\bar{\rho}^2$ are between 0.2 and 0.4. In Table 3, ρ^2 and $\bar{\rho}^2$ are between 0.1851 and 0.2085, so the model is acceptable.

Table 3 Destination selection model precision tests

Parameters	Zone 1	Zone 2	Zone 3
$L(0)$	−254.8645	−235.6784	−285.8477
$L(\hat{\theta})$	−239.9465	−220.3979	−272.0013
$-2(L(0)-L(\hat{\theta}))$	29.8360	30.5610	27.6927
ρ^2	0.2085	0.1948	0.2084
$\bar{\rho}^2$	0.2013	0.1851	0.2040

The model can be used to predict the travel utility of all travelers among the three zones and the attractiveness of each zone. The results can then be used in Eqs. (4) and (5) to calculate the trip generation volume in all traffic zones based on the forecasted land use acreage and trip generation rate. The results are compared with traditional results in Table 4.

Table 4 Trip generation forecasting results

Zone	Λ_i	Actual value of G_i	Traditional method		Disaggregate method	
			G_i	Forecasting error (%)	G_i	Forecasting error (%)
1	3.5064	526	467	11.2	506	3.8
2	1.0876	775	720	7.1	752	2.9
3	4.4521	854	761	10.9	807	5.5

The results in Table 4 show that the forecasting error of the disaggregate model is much less than that of the traditional method and that the zone attractiveness is positively related to the forecasting error. That is, as the traffic zone attractiveness increases, the disaggregate model gives a better result than the traditional method.

4 Conclusions

A destination selection model that considers the traffic zone attractiveness was developed using utility theory based on the disaggregate model.

(1) The traffic zone attractiveness evidently influences the trip generation volume. Factors that affect the traffic zone attractiveness are age, income, objective, having a car or not, payment mode, time and cost.

(2) The traffic zone attractiveness can be calculated for each zone with the final forecasting result showing that the accuracy of the disaggregate trip generation model is greatly improved considering the destination attractiveness.

(3) The factors that influence the traffic zone attractiveness should be studied further to improve the model precision.

(4) The Beijing road system was divided into three traffic zones since insufficient traffic data was available to further divide the area. Future studies should include more traffic data with smaller traffic zones to improve the accuracy of the trip generation model.

References

[1] Golob F T. A simultaneous model of household activity participation and trip chain generation. In: Transportation Research Record, Journal of the Transportation Research Board, No. 34, TRB. Washington, USA, 2000: 355-376.

[2] Kanafani A. Transportation demand analysis. New York, USA, 2001.

[3] Smiller J, Hoel L A. Assessing the utility of private information in transportation planning studies: A case study of trip generation analysis. *Journal of Socio-Economic Planning Sciences*, 2006, **40**(3): 94-118.

[4] Liu Canqi. Advanced Traffic Planning. Beijing: People’s Traffic Publishing Company, 2001. (in Chinese)

[5] Ben-Akiva M E, Lerman S R. Discrete Choice Analysis: Theory and Application to Travel Demand. Cambridge, Mass, USA: MIT Press, 1985.

[6] Guan Hongzhi. Disaggregate Model-a Tool of Traffic Behavior Analysis. Beijing: People’s Traffic Publishing Company, 2004. (in Chinese)

[7] Fujii S, Garling T. Application of attitude theory for improved predictive accuracy of stated preference methods in travel demand analysis. *Transportation Research Part A*, 2005, **37**(4): 389-402.

[8] Morikawa T. Correcting state dependence and serial correlation in RP/SP combined estimated method. *Transportation Research Part B*, 1994, **21**(2): 153-166.