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A Traffic Mode Choice Model for the Bus User Groups Based on SP and RP Data

Zhihu Zhang[a,*], Hongzhi Guan[a], Huanmei Qin[a], and Yunqiang Xue[b]

[a] Beijing Key Lab of Traffic Engineering, Beijing University of Technology, Beijing, 100124, China
[b] Jinan Urban Transport Research Center, Jinan, 250031, China

Abstract

Enhancing the bus share rate is a major measure to relieve the traffic congestion. To analyze the effect of public transit policy, this paper establishes MNL models based on both SP data and combining SP and RP data, which was collected in Jinan city. Then the paper analyzes how the influencing factors affect the choice proportion of bus travel mode for the bus user groups. In the end, the paper obtains some significant conclusions and proposes measures which would enhance the bus attraction.

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Keywords:SP and RP Survey; MNL model; Combining data; Sensitivity analysis;

1.Introduction

With the rapid development of economy, the total number of motor vehicles ownership in large and medium-sized cities in China grows rapidly. Traffic demand grows continuously, while the supply of urban land resources strains increasingly. The contradiction between traffic supply and demand is obvious. It is unable to meet the growing travel demand by relying solely on expanding and increasing the road construction. Bus priority policy can improve the utilization rate of road resources, which is the effective way of solving road congestion problems in city. It is the focus of study for many scholars to increase the public transit share rate.

Several studies have been conducted to increase the public transit share rate. Li studied the bus priority policy affected the development of urban traffic. Wang studied the method of making the subway ticket price. Litman studied how to predict the travel impacts of specific price reforms and management strategies. Paulley et al

* Corresponding author. Tel.:+86-10-67391870
E-mail address: q322101@126.com

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studied bus travel demand was affected by the fare, service level, individual income and the number of car ownership.

It is essential to discuss the bus travel demand under different service level and technology before studying the bus share rate. RP data(revealed preference data, RP data for short) can't describe the nonexistent traffic mode, on the contrary, SP data(stated preference data, SP data for short) can design future traffic scene and analysis the traffic demand under different conditions. However, revealed preference choice may be in contradiction with stated preference choice, in others ways, the SP data has the biases. Many scholars made studies to solve problem of SP data biases. Guan et al established the combining model by combining the traffic experiment data and SP data and solved the SP data deviation. Ben.A et al combining RP data and SP data which is revised by RP data established model to solve the SP data biases.

This paper uses above method and establishes MNL models using the SP and RP data of the bus user groups in Jinan city. Then the paper makes the sensitivity analysis of some main factors in order to analyze their effects on enhancing the bus attraction. In the end, some significant recommendations are concluded.

2. Travel Behavior Survey of the Bus User Groups

The method of Revealed Preference (RP) survey and Stated Preference (SP) survey was used to analyze the user behavior in this paper. The survey items include three parts.

- Personal information including gender, age, occupation, car purchase plan, and monthly household income
- Bus travel behavior including weekly trip times of used traffic mode, payment mode, bus travel time and bus satisfaction degree
- Stated Preference survey

Bus ticket price, bus travel time, parking fee and fuel cost are four important influencing factors and used to design the questionnaire survey.

Air-conditioned bus and non air-conditioned bus price are set three levels. Bus travel time is set two levels. Parking fee and fuel cost are set two levels. Orthogonal design method is used to obtain the most suitable factor combination as shown in table 1.

Table 1. Factors Combination of SP

Air-conditioned and non air-conditioned bus ticket price	Travel time	Parking fee and fuel cost unchanged	Parking fee and fuel cost increased	
1yuan /0.5yuan	unchanged	–	–	Available traffic modes including Car, bus, motorcycle, bike, walking others
1yuan /0.5yuan	decreased by *20* %	–	–	
1.5yuan /0.8yuan	unchanged	–	–	
5yuan/0.8yuan	decreased by *20* %	–	–	
3yuan /2yuan	unchanged	–	–	
3yuan /2yuan	decreased by *20* %	–	–	

Household survey method was used in this paper. The interviewees of the bus user groups choose one travel mode under different travel conditions. The survey was conducted from June 16 to June 24 in 2012. 1359 questionnaires are retrieved and the effective sample is 1223.

3. Model and Combining SP Data and RP Data

3.1.MNL Model

MNL(Multinominal Logit)Model is the basic type of logit models. The random utility ε_{in} is mutually independent and obeys the same Gumble extreme value distribution. Based on probability theory, MNL model with J options can be expressed in the following formula.

$$p_{in} = \frac{\exp(\theta V_{in})}{\sum_{j=1}^{J} \exp(\theta V_{jn})} \qquad i = 1, 2, \ldots\ldots, J \tag{1}$$

Where, p_{in} is probability of any alternative i being selected by person n from choice set J, θ is unknown coefficient and V_{in} is called the systematic components of the utility of alternative i.

3.2.Combining SP data and RP data

SP data and RP data can't be combined simply because their random parts are different. Therefore, the balance coefficient μ is introduced to estimate the parameters of random parts. The equation is shown below.

$$Var(\varepsilon^{\mathrm{RP}}) = \mu^2 Var(\varepsilon^{\mathrm{SP}}) \tag{2}$$

Where, $\varepsilon^{\mathrm{RP}}$ and $\varepsilon^{\mathrm{SP}}$ are respectively the random parts of RP data utility function and SP data utility function.

It can establish the disaggregate model with combining the SP data which is revised by balance coefficient and RP data. Simultaneous estimation method and phase estimation method are two ways to estimate parameters. This paper uses phase estimation method.

The following equations are respectively utility function of SP data model and RP data model.

$$\mathrm{u}_{\mathrm{in}}^{\mathrm{RP}} = \beta' \chi_{\mathrm{in}}^{\mathrm{RP}} + \alpha' \mathrm{w}_{\mathrm{in}}^{\mathrm{RP}} + \varepsilon_{\mathrm{in}}^{\mathrm{RP}} \tag{3}$$

$$\mathrm{u}_{\mathrm{in}}^{\mathrm{SP}} = \beta' \chi_{\mathrm{in}}^{\mathrm{SP}} + \gamma' \mathrm{z}_{\mathrm{in}}^{\mathrm{SP}} + \varepsilon_{\mathrm{in}}^{\mathrm{SP}} \tag{4}$$

Where, u_{in} is the utility function of alternative i being selected by person n, χ_{in} is the common variable of RP data utility function and SP data utility function, w_{in} and z_{in} are respectively variables of RP data utility function and SP data utility function, α', β', γ' are the unknown parameters.

The specific steps of parameters estimation are shown below.

The first step is to obtain the value of parameter $\hat{\mu}\beta'$ and parameter $\hat{\mu}\gamma'$ by model with SP data and replace V^{RP} with $\mu\beta' X^{RP}$.

The second step is to suppose the utility function of RP data model is $\mathrm{u}_{\mathrm{in}}^{\mathrm{RP}} = \lambda \mathrm{V}_{\mathrm{in}}^{\mathrm{RP}} + \alpha' \mathrm{w}_{\mathrm{in}}^{\mathrm{RP}} + \varepsilon_{\mathrm{in}}^{\mathrm{RP}}$ and obtain the value of parameter $\hat{\lambda}$, parameter $\hat{\alpha}'$ and parameter μ which is equal to $1/\hat{\lambda}$.

The third step is to obtain the revised SP data using χ^{SP} and z^{SP} multiplying by μ. Then combining revised SP data and RP data establish model and regain the value of parameter α', parameter β' and parameter γ'.

4.MNL Model Estimation and Analysis

In order to avoid model misconvergence and estimated errors caused by the empty cells, the monthly income, occupation, factors affecting travel and car purchase plan are reclassified and combined based on correlation analysis. Table 2 shows the classification setting of these factors.

Bicycle travel mode and walking travel mode are merged into other travel modes because the total choice proportion of bicycle travel mode, walking travel mode and other travel modes are less than 4%. Different traffic modes utility functions include different variables of affecting factors. Parking fee, fuel cost, weekly trip times, the number of car ownership, car purchase plan, driving experience and driver's license constitute the systematic components of the utilities for car travel mode. Bus ticket price, travel time, monthly income, occupation, age, gender, payment mode, factors affecting travel and bus satisfaction degree constitute the systematic components of the utilities for bus travel mode. Weekly trip times and the number of motorcycle ownership constitute the systematic components of the utilities for motorcycle travel mode. Weekly trip times and the number of other vehicles ownership constitute the systematic components of the utilities for other traffic travel modes.

Table 2. The Classification Setting

Variable		Classification	Dummy variable		
Monthly income	Monthly income 1	Not more than 999 yuan;	1	0	0
	Monthly income 2	Between 1000 yuan and 3999 yuan;	0	1	0
	Monthly income 3	Between 4000 yuan and 7999 yuan;	0	0	1
	Monthly income 4（reference type）	Not less than 8000yuan;	0	0	0
Occupation	Occupation 1	Public utilities, non-public utilities ,education ,health protection ,scientific research, individual household and freelancer;	1	0	0
	Occupation 2	Primary school, middle school or college student;	0	1	0
	Occupation 3	Organization unit, non- organization unit, agriculture, forestry, animal husbandry, jobless or retirees;	0	0	1
	Occupation 4（reference type）	Soldier and others;	0	0	0
Factors affecting travel	Factors affecting travel 1	Ticket price;	1	0	0
	Factors affecting travel 2（reference type）	Travel time, travel comfort ,safety or convenience;	0	0	0
Car purchase plan	car purchase plan 1	Having car, one year or two year;	1	0	0
	car purchase plan 2	Three year;	0	1	0
	car purchase plan 3（reference type）	Not less than four year or No consideration	0	0	0

The result of model calibration is shown in table 3.Asymptotic rho squared ρ^2 and adjusted rho squared $\bar{\rho}^2$ are two important indexes of the model evaluation. Generally, the model precision is high when ρ^2 and $\bar{\rho}^2$ are both between 0.2 and 0.4.

The coefficient of parking fee and fuel cost is -0.866, which indicates the choice proportion of car travel mode for the bus user groups will decrease when the parking fee and fuel cost is increasing. The coefficient of bus travel time is 0.004 and is not practical, which may derive from the irrationality of bus user groups. The coefficient of bus ticket price is -0.46, which indicates the choice proportion of bus travel mode for the bus user groups will decrease when the bus ticket price is increasing. The coefficient of bus satisfaction degree is 0.466, which indicates the choice proportion of bus travel mode will increase when the bus service level is improved.

For SP and RP model, ρ^2 is 0.654 and $\bar{\rho}^2$ is 0.653. This indicates the precision of SP and RP model is better than that of SP model. The balance coefficient is 0.135 and the t test is 20.45, which indicates the establishment of SP and SP model is significant. The balance coefficient is less than 1, which indicates the random noise

interference of SP data is higher than that of RP data. The variable coefficient signs of SP and RP model are coincident with the fact. The coefficient of travel time is -0.019 and the coefficient of bus ticket price is -3.401,which indicates the choice proportion of bus travel mode for the bus user groups will decrease when the bus travel time and bus ticket price are increasing. The coefficient of weekly trip times is 0.003, which indicates the choice proportion of car travel mode for the bus user groups will increase when the weekly trip times of car increase. The coefficient of payment mode is 0.225, which indicates the choice proportion of bus travel mode for the bus user groups will increase when the reimbursement of bus travel fare is increasing. The coefficient of driver's license is -0.703, which indicates that the choice proportion of car travel mode for the bus user groups will increase if the bus user has had the driver's license.

Table 3. The Result of Model Calibration

	SP model		SP and RP model	
Variable name	Parameter value	t test	Parameter value	t test
Constant dummy 1	3.189	17.332	1.916	20.128
Constant dummy 2	2.501	11.384	3.12	49.879
Constant dummy 3	0.654	13.741	0.365	8.729
Parking fee and fuel cost	-0.866	-15.294	-6.005	-14.977
Weekly trip times	0.03	10.909	0.003	0.405
The number of vehicles ownership	0.172	8.733	0.297	7.908
Car purchase plan 1	0.159	2.657	0.417	3.153
Car purchase plan 2	0.477	4.353	-0.512	-1.364
Driving experience	-0.031	-1.563	-0.028	-0.915
Driver's license	-0.645	-8.489	-0.703	-8.498
Bus travel time	0.004	6.061	-0.019	-17.648
Bus ticket price	-0.46	-20.86	-3.401	-21.29
Bus satisfaction degree	0.446	12.744	0.6	9.619
Factors affecting travel 1	-0.154	-2.797	-0.157	-1.247
Monthly income 1	-0.16	-1.174	-0.856	-3.079
Monthly income 2	-0.41	-4.746	-0.927	-5.071
Monthly income 3	-0.525	-6.206	-0.425	-2.326
Occupation 1	0.371	5.647	0.148	1.074
Occupation 2	0.839	7.785	0.539	2.51
Occupation 3	0.287	3.711	0.049	0.271
Age	0.02	1.303	0.321	8.833
Gender	-0.027	-0.689	-0.012	-0.136
Payment mode	–	–	0.225	3.424
Balance Coefficient	–	–	0.135	-20.45
L(0)	-21443.201		-42886.402	
L(θ)	-12051.573		-14847.901	
$-2(L(0)-L(\hat{\theta}))$	18783.256		56077.002	
ρ^2	0.438		0.654	
$\overline{\rho}^2$	0.437		0.653	

5. Model Sensibility Analysis

Parking fee, fuel cost, bus ticket price and bus travel time are four important influencing factors which are choosen to make sensibility analysis. The paper respectively discusses the sensibility analysis when the parking fee and fuel cost are unchanged or increased.

5.1.Parking fee and fuel cost unchanged

The choice proportion of bus travel mode for the bus users groups is shown in figure 1[a] when the parking fee and fuel cost are unchanged. The bus travel time varies between 0 minutes and 100 minutes and the bus ticket price varies between 0 yuan and 5 yuan.

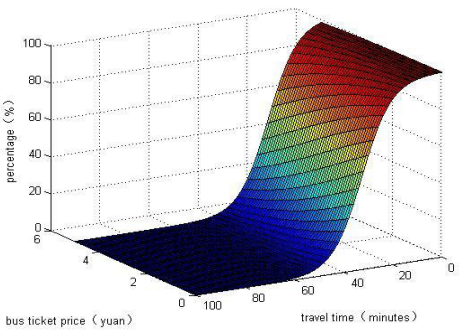

Figure 1[a] The choice proportion of bus travel mode

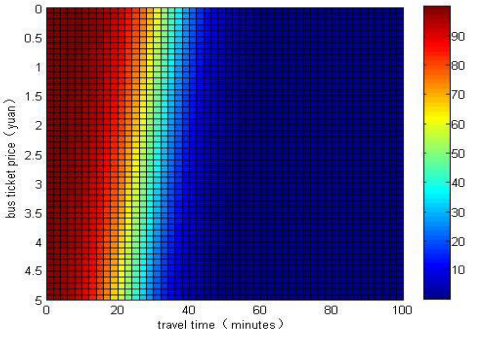

Figure 1[b] the shadow of figure 1[a]

It can draw some conclusions from the above figure 1[a]. When the parking fee and fuel cost are unchanged, the choice proportion for the bus user groups who continue choosing bus travel mode gradually decreases with the increasing bus travel time and ticket price. The choice proportion for the bus user groups who continue choosing bus travel mode varies little when the bus travel time ranges between 60 minutes and 100 minutes or between 0 minutes and 20 minutes. When the bus travel time ranges between 20 minutes and 60 minutes, the choice proportion who continue choosing bus travel mode exhibits considerable variation.

Figure 1[b] shows the choice proportion for the bus groups who continue choosing bus travel mode on two-dimensional plane of figure 1[a] under different bus ticket price and bus travel time.

Figure 1[b] indicates that the bus user groups are more sensitive to the change of bus travel time than that of bus ticket price. When the air-conditioned bus ticket price varies between 0yuan and 5yuan and bus travel time varies between 0 minutes and 20 minutes or between 40 minutes and 100 minutes, the choice proportion for the bus groups who continue choosing bus travel mode varies little. When the air-conditioned bus ticket price varies between 0 yuan and 5 yuan and bus travel time varies between 20 minutes and 40 minutes or between 40 minutes and 100 minutes，the choice proportion for the bus groups who continue choosing bus travel mode exhibits considerable variation, which is regarded as the sensitive area.

5.2.Parking fee and fuel cost increased

The choice proportion of bus travel mode for the bus users groups is shown in figure 2[a] when the parking fee and fuel cost are increased. The bus travel time varies between 0 minutes and 100 minutes and the air conditioned bus ticket price varies between 0 yuan and 5 yuan. The figure 2[b] is the shadow of figure 2[a].

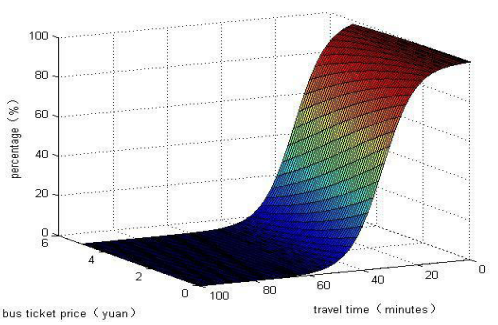

Figure 2[a] The choice proportion of bus travel mode

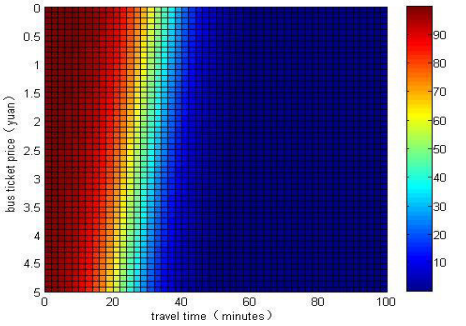

Figure 2[b] The shadow of figure 2[a]

The changing trend of choice proportion of bus travel mode for the bus user groups with bus travel time and bus ticket price changing is similar to that in figures 1[a] and 1[b] when the parking fee and fuel cost are unchanged.

Therefore, the parking fee and fuel cost has little effect on the choice of bus travel mode for the bus user groups.

6.Conclusions

At first, the paper makes a survey of the bus user groups in Jinan city and establishes the MNL model as well as SP and RP model. Next, the paper made model sensibility analysis and evaluation. In the end, it discusses the relationship between the choice proportions for the bus user groups who continue choosing bus travel mode and parking fee, fuel cost, bus ticket price and bus travel time.

The conclusions are as follows.

- The higher the public transit groups are satisfied with bus service, the easier the users choose the bus mode as the traffic mode.
- The choice proportion of the bus user groups who continue to choose bus mode will decrease when the bus travel time and bus ticket price are increasing.
- The bus user groups are more sensitive to the change of bus travel time than that of bus ticket price.
- The parking fee and fuel cost has little effect on the choice proportion of bus travel mode for the bus user groups.
- The choice proportion of the bus user groups who continue choosing bus travel mode exhibits considerable variation when the air-conditioned bus ticket price varies between 0 yuan and 5 yuan and the bus travel time varies between 20 minutes and 40 minutes.

Therefore, there are two aspects to enhance the bus attraction and increase the choice proportion of the bus user groups who continue to choose bus travel mode. One is offering higher bus service level and the other is decreasing the bus travel time by designing the bus lane, bus signal and bus entrance lane, and so on.

This paper merely analyzes the travel mode choice for the bus user groups. However, the car user groups, motorcycle user groups, bicycle user groups and other user groups also may choose bus travel mode as the traffic mode. Some of them were the potential bus user and not included in this paper. It deserves analyzing for further research.

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