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Procedia - Social and Behavioral Sciences 96 (2013) 2373 – 2382
Procedia
Social and Behavioral Sciences

13th COTA International Conference of Transportation Professionals (CICTP 2013)

Analysis on Bus Choice Behavior of Car Owners based on Intent —— Ji'nan as an example

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Abstract

This paper establishes MNL and joint SP-RP MNL models to analyze the bus choice behavior of car owners based on disaggregate utility theory in middle-sized cities of China. The preference survey of travel behavior for car traveler groups is conducted in Ji'nan city. Travel time, bus comfort, parking fee and fuel cost are chosen as four important factors to analyze the behavior intent of car traveler groups who will switch to public transit. The research finds that car traveler groups are more sensitive to the change of parking fee and fuel cost and not sensitive to the change of bus comfort. The sensitivity to the bus travel time for the car traveler groups decreases as the bus travel time increases. The research conclusions will provide the base of decision – making for transportation policy and enhancing the bus share ratio.

Keywords: car traveler groups; bus choice behavior; MNL model; sensitivity analysis

1. Introduction

With the pace of urbanization accelerated, the urban traffic jam spread from big cities to middle and small sized cities in China. The urban traffic jam has decreased city's attraction, integrated competition ability and efficiency. For example, the number of motor vehicles has reached 139.58 millions in which the number of private cars is 91 millions in Ji'nan city. The average growth rate of private cars reached 20.11% in nearly three

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doi:10.1016/j.sbspro.2013.08.266

years. The problems of traffic congestion become more and more prominent. The increased trips by private cars would need lots of road resources and produce serious air pollution, while the bus travel has the advantage of intensive, effectiveness, energy-conservation and environment-protection. Therefore, bus priority is an effective mean for alleviating traffic jams. It would be meaningful to increase bus's competition ability and attract more car travelers to switch to public transport.

2. Literature review

Scholars and abroad have done much research on car travel behavior and bus switching behavior.

Zuo et al (2011) have explored the differences between travel speed of buses and cars and modal shift relationship. The result shows that in accordance with distinct passenger trip volumes and modal parameter values, there is an appropriate range of bus. Within this range, car travelers are willing to shift to buses and road traffic system can be optimized as well.

Liu et al (2009) have developed the discrete choice model of factors influencing car usage and calibrate the parameters with 2005 Beijing Household Travel Survey data. The estimation results and elasticity effects indicate that such factors as number of household bikes, working or not, monthly ticket, trip purpose, parking fee and trip time have negative effects on private car usage, while number of household cars, child, driving license, main user or not, company and trip distance make positive effects.

Yang et al (2011) have established a model of departure time choice of private car by using the MNL model and inducted departure time influencing factors such as characteristics of personal, family, social as well as economic, and the attribute of travel. It focuses on exploring the key factors influencing the departure time choice of private cars to provide theoretical basis and data support for drawing up effective managing measures.

Zhou (2012) has studied university students' commute and housing behaviors using samples from Los Angeles, a place notorious for car dependence and dominance. It finds that being embedded in this place does not make university students drive alone more than their peers in other places. Being multimodal and having a discounted transit pass increase the odds of alternative modes while holding a parking permit reduces the odds of these modes.

O'Fallon et al (2004) conducted a stated preference experiment in the three largest New Zealand urban areas. It not only quantifies the likely impact of a wide range of policy tools (both 'sticks' discouraging car use, and 'carrots' encouraging alternative modes) for each area, but also identifies many significant constraints.

Gärling et al (2000) investigated what car-use reduction measures are perceived by households to be feasible if their goal is to reduce car driving. The study suggested that switching to public transport was the most likely choice for work trips. Women were more likely than men to choose public transport and trip chaining, whereas men were more likely than women to choose motorbike/moped.

The above researches mainly focus on car travel behavior. This paper will establish MNL model and mixed RP and SP model to analyze the bus choice behavior of car owners based on disaggregate utility theory in middle sized city. The preference survey of travel behavior for car traveler groups is conducted in Ji'nan city. Travel time, bus comfort, parking fee and fuel cost are chosen as three important factors to analyze the behavior intent of car traveler groups who will switch to public transit. The research conclusions will provide the basis of decision – making for traffic policy and enhancing the bus share ratio.

3. SP and RP survey

The method of SP (Stated preference) and RP (Revealed preference) is used to collect the travel choice behavior data for car traveler groups. The survey contents mainly include three parts.

(1) Personal information includes sex, age, occupation, monthly household income, household population, car purchase plan, driving years, the number of different means of transportation and so on.

(2) Revealed behavior survey includes weekly trip times of used travel mode, familiarity degree with road conditions, traffic jam degree in morning and evening peak hours, travel time and distance, the condition of parking spaces supply and parking fee in workplace and settlements, and the payment mode for fuel cost.

(3) Stated Preference survey

Travel time, bus comfort, parking fee and fuel cost are three important influencing factors for analyzing the bus switching behavior of car traveler groups. Travel time is set three levels: decreased by 20%, unchanged, increase by 20%. Bus comfort is set two levels: unchanged and increased. Parking fee and fuel cost is set two levels: unchanged and increased. Orthogonal designing method is used to obtain the most suitable factor combination of SP questionnaire as shown in Table 1.

Table 1. Factor combination of SP

Bus travel time compared to that by car	Bus comfort	Parking fee and fuel cost		Available travel modes：
		unchanged	increased	
decreased by 20 %	unchanged			①car ②bus ③motorcycle ④others
same	increased			
increased by 20 %	increased			
decreased by 20 %	increased			

Household survey method was used in this paper. The interviewees of the car traveler groups were required to choose one travel mode under different travel conditions. The survey was conducted from June 16 to June 24 in 2012. 1079 questionnaires were retrieved and the effective sample is 1001.

4. MNL model and mixed SP and RP model

4.1MNL model

According to the Random Utility Theory (Hensher & Button, 2000), the utility U_{in} when individual n select option i can be expressed as formula (1).

$$U_{in} = V_{in} + \varepsilon_{in} \tag{1}$$

Where, V_{in} is the deterministic component of utility for option i by individual n; ε_{in} is the random component of utility for option i by individual n. i is the available options of car, bus, motorcycle and others.

The deterministic component of the utility can be expressed as a linear function of different influencing factors.

$$V_{in} = \sum_{k=1}^{K} \theta_k X_{ink} \tag{2}$$

Where, k is the number of variables; θ_k is corresponding coefficient to be estimated; and X_{ink} is the variable k when individual n chooses option i.

MNL (Multinominal Logit) Model, one of the common disaggregate models has been widely used in the travel behavior analysis field. By assuming that the random component ε_{in} in formula (1) follows Gumbel distribution, independently and identically across options, the probability P_{in} for travel mode i by individual n can expressed in formula (3).

$$P_{in} = \frac{\exp(V_{in})}{\sum_{j \in J} \exp(V_{jn})} \tag{3}$$

Where, J is the set of available travel modes.

The parameters θ_k in formula (2) can be estimated by using the Maximum Likelihood and Newton-Raphson method.

4.2Mixed approach with SP and RP data

Some researchers have compared and analyzed RP and SP approaches to determine the validity of SP methods (Cummings et al., 1986). It is found that the strengths of the RP approaches are the weaknesses of the SP approaches. So a new mixed approach combined and jointly estimated with RP and SP data emerged in the marketing and transportation literatures (Ben-Akiva & Morikawa, 1990; Morikawa et al., 1991; Hensher & Bradley, 1993).

MNL model estimated with SP data can be combined with RP data. The choice probability p_{Rij} for option j with RP data is expressed in formula (4).

$$p_{Rij} = \frac{\exp(\mu_R \beta_R^{'} X_{ij})}{\sum_{j=1}^{J} \exp(\mu_R \beta_R^{'} X_{ij})} \tag{4}$$

Where, β_R is the vector of RP parameters and μ_R is the RP scale parameter which is inversely related to the variance of the error term (Swait & Louiviere, 1993). With identical elements in the X_{ij} vector, a similar model results can be obtained when MNL model is used to estimate choice probabilities with SP data in formula (5):

$$p_{Sij} = \frac{\exp(\mu_S \beta_S^{'} X_{ij})}{\sum_{j=1}^{J} \exp(\mu_S \beta_S^{'} X_{ij})} \tag{5}$$

When RP or SP data are estimated separately, the scale parameter is arbitrarily set equal to one, as in all discrete choice modeling (Maddala, 1983). When RP and SP data are stacked and estimated jointly, it is common for the error terms that result from the different data to have unequal variance leading to unequal scale parameters.

5. Model estimation and analysis

5.1 Selection and setting for influencing factors

Travel time, bus comfort, parking fee and fuel cost, monthly income, car purchase plan, driving years, occupation, age, sex, the number of vehicles ownership, weekly trip times of used travel mode, familiarity degree with road conditions, traffic jam degree in morning and evening peak hours, the condition of parking spaces supply in workplace and settlements are chosen as the main influencing factors by correlation analysis.

In order to avoid model misconvergence and errors caused by the empty cells, the discrete variables of monthly income, occupation and age are reclassified and combined. The classification setting of these factors is shown in Table 2.

Table 2. Classification setting of discrete variables

Variable		Classification	Dummy variable	
Monthly income	Monthly income1	≤2999yuan	1	0
	Monthly income2	3000~11999yuan	0	1
	Monthly income3	≥12000yuan	0	0
Occupation	Occupation1	Government and non government service staffs, self-employed staffs, freelancers, unemployed and retired persons	1	0
	Occupation2	Employees in educational institution, health agencies and institutes of scientific research, students in colleges and universities and others	0	1
	Occupation3	Soldiers	0	0
Age	Age1	6~12years old	1	0
	Age2	≥13years old	0	0

Different influencing factors are included in different deterministic component of utilities for car, bus, motorcycle and others. Travel time by car, parking fee and fuel cost, driving years, car purchase plan, the number of car ownership, weekly trip times by car, familiarity degree with road conditions, traffic jam degree in morning and evening peak hours, the condition of parking spaces supply in workplace and settlements are included in the deterministic component of utility for car. Travel time by bus, bus comfort, monthly income, occupation, age, sex are included in the deterministic component of utility for bus. The number of motorcycle ownership and weekly trip times by motorcycle are included in the deterministic component of utility for motorcycle. The number of other means of transportation and weekly trip times by other travel modes are included in the deterministic component of utility for others.

5.2 Model estimation and analysis

The MNL model and mixed SP and RP model regarding travel mode choice and bus switching for car traveler groups are estimated based the survey data collected in Section 3 and the results are shown in Table 3.

Table 3. Estimation results of models

Variable name	SP model		Mixed SP&RP model	
	coefficient	t test	coefficient	t test
Constant dummy for car	4.865	25.849	5.484	31.937
Constant dummy for bus	2.695	10.738	2.197	9.208
Constant dummy for motorcycle	0.456	4.846	0.561	6.013
Travel time	-0.006	-2.329	-0.010	-5.417
Weekly trip times	0.025	5.382	0.026	7.483

The number of vehicles ownership	0.239	7.953	0.177	7.649
Car purchase plan	0.014	1.425	0.010	1.308
Driving years	0.044	3.176	0.030	2.794
Parking fee and fuel cost	-1.194	-25.054	-1.006	-29.641
Traffic jam degree	0.103	3.270	0.066	2.725
Familiarity degree with road conditions	0.016	0.386	-0.013	-0.400
Parking spaces supply in settlements	-0.145	-3.969	-0.122	-4.332
Parking spaces supply in workplace	-0.034	-0.921	-0.038	-1.322
Bus comfort	0.019	0.338	0.178	4.647
Sex	0.069	1.371	0.075	1.949
Age 1	-1.788	-2.897	-1.390	-2.932
Occupation 1	-0.083	-0.473	0.128	0.956
Occupation 2	0.256	1.497	0.375	2.865
Monthly income 1	0.635	5.606	0.515	5.854
Monthly income 2	0.205	2.159	0.208	2.817
Scale parameter μ			1.296	0.48
L(0)	-15365.687		-16747.822	
L(θ)	-10353.028		-11154.116	
$-2(L(0)) - L(\hat{\theta})$	10025.316		11187.413	
ρ^2	0.326		0.334	
$\bar{\rho}^2$	0.325		0.333	

Asymptotic rho squared ρ^2 and adjusted rho squared $\bar{\rho}^2$ are two important indexes of model evaluation. Generally, the model precision is high when ρ^2 and $\bar{\rho}^2$ are both between 0.2 and 0.4. Table 3 shows that ρ^2 and $\bar{\rho}^2$ are 0.326 and 0.325 respectively for SP model. ρ^2 and $\bar{\rho}^2$ are 0.334 and 0.333 respectively for mixed SP and RP model. By t test, car purchase plan, familiarity degree with road conditions, the condition of parking spaces supply in workplace, occupation1, sex have small effect on the choice behavior of car traveler groups.

For SP model, the analyses for main influencing factors are as follows.

The coefficient of parking fee and fuel cost is -1.194, which indicates that the choice proportion of car travel mode for car traveler groups will decrease as the parking fee and fuel cost is increasing.

The coefficient of travel time is -0.006, which indicates that the proportion of chosen travel mode for car traveler groups will decrease when the travel time by the chosen travel mode is increasing.

The coefficient of bus comfort is 0.019 and the value of t test is less than 1.96, which indicates that bus comfort has small effect on the choice behavior of car traveler groups.

The coefficient of weekly trip times is 0.025, which indicates that the proportion of chosen travel mode for car traveler groups will increase when the weekly trip times by the chosen travel mode is increasing.

The coefficient of the number of vehicles ownership is 0.239, which indicates that the proportion of chosen travel mode for car traveler groups will increase when the number of vehicles ownership by the chosen travel mode is increasing.

The coefficient of the number of vehicles ownership is 0.239, which indicates that the proportion of chosen travel mode for car traveler groups will increase when the number of vehicles ownership by the chosen travel mode is increasing.

The coefficient of traffic jam degree is 0.103, which indicates that the choice proportion of car travel mode for car traveler groups will increase when the traffic condition is smooth.

The coefficient of parking spaces supply in settlements is -0.145, which indicates that the choice proportion of car travel mode for car traveler groups will decrease when the parking supply in settlements is scarce.

The coefficient of monthly income 1 and 2 is positive, which indicate the low-income car traveler groups will be more inclined to switch to public transit than high-income car traveler groups.

For SP and RP model, the scale parameter is 1.296 and the value of t test is 0.48, which indicates the establishment of mixed SP and SP model is not significant. So the analysis is mainly focus on the SP model.

5.3 Model sensibility analysis

In order to analyze the affecting degree of main factors on travel modes choice for car traveler groups who are likely to switch to public transport, travel time, parking fee and fuel cost and bus comfort are chosen as three important influencing factors to make sensibility analysis.

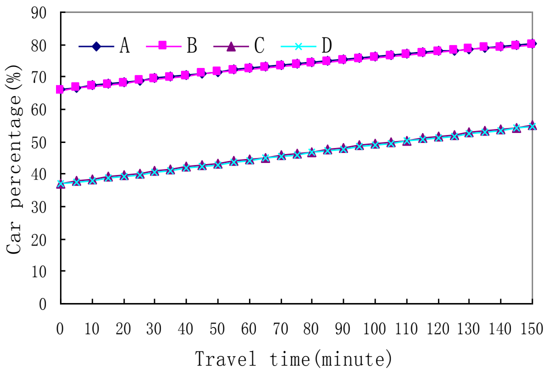

Fig. 1. Choice proportion of car under different bus travel times

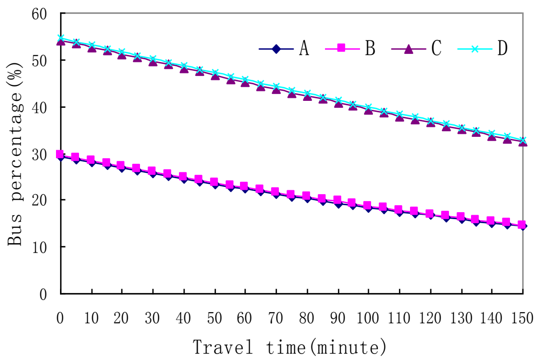

Fig. 2. Choice proportion of bus under different bus travel times

In Figures 1, 2, 3 and 4, A indicates unchanged parking fee and fuel cost and bus comfort, B indicates unchanged parking fee and fuel cost and increased bus comfort, C indicates increased parking fee and fuel cost and unchanged bus comfort and D indicates increased parking fee and fuel cost and bus comfort.

The choice proportions of car for car traveler groups gradually increase with the increasing bus travel time as shown in Figure 1. The choice proportions of bus for car traveler groups gradually decrease with the increasing bus travel time as shown in Figure 2. The choice proportions of car dropped about 20~30 percent under increased parking fee and fuel cost compared with unchanged parking fee and fuel cost when the bus travel time is basically the same. This indicates that the car traveler groups are more sensitive to the changes of parking fee and fuel cost. The choice proportions of bus and car are nearly equal under unchanged and increased bus comfort. This indicates that the car traveler groups are not sensitive to the changes of bus comfort.

The bus travel time is divided into 30 equal intervals and 5 minute is one time interval as shown in Table 4. The mode choice proportions trends for the car traveler groups under different travel time intervals will be analyzed.

Table 4. Intervals setting of bus travel time（minute）

Number	Interval	Number	Interval	Number	Interval
1	0-5	11	50-55	21	125-130
2	5-10	12	55-60	22	130-135
3	10-15	13	60-65	23	135-140
4	15-20	14	65-70	24	140-145
5	20-25	15	75-80	25	145-150
6	25-30	16	80-85	26	150-155
7	30-35	17	85-90	27	155-160
8	35-40	18	90-105	28	160-165
9	40-45	19	105-120	29	165-170
10	45-50	20	120-125	30	175-180

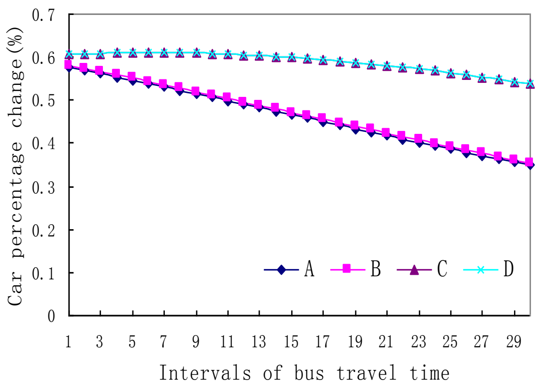

Fig. 3. Choice proportion change of car under different bus travel time intervals

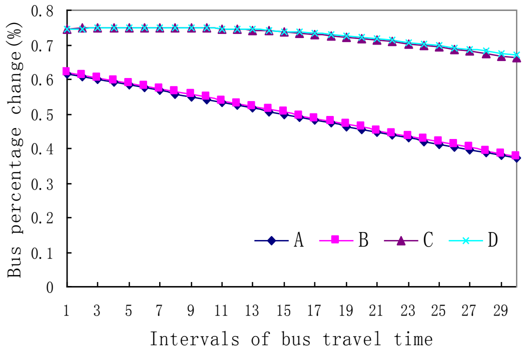

Fig. 4. Choice proportion change of bus under different bus travel time intervals

As shown in Figures 3 and 4, the choice proportions changes for car and bus gradually decrease with the increase of bus travel time interval. That is to say, the sensitivity to the bus travel time for the car traveler groups decreases when the bus travel time increases.

6. Conclusions

This paper has established the MNL model and mixed RP and SP model to analyze the bus choice behavior of car owners based on disaggregate utility theory in Ji'nan of China. Travel time, bus comfort, parking fee and fuel cost were chosen as three important factors to analyze the behavior intent and sensitivity of car traveler groups who are likely to switch to use public transit. The conclusions are as follows:

Travel time, bus comfort, parking fee and fuel cost, weekly trip times, the number of vehicles ownership, parking spaces supply in settlements have important effects on the travel mode choice and bus switching of the car traveler groups.

The car traveler groups are more sensitive to the changes of parking fee and fuel cost and not sensitive to the changes of bus comfort.

The sensitivity to the bus travel time for the car traveler group decreases when the bus travel time increases.

The research conclusions will provide the basis of decision – making for traffic policy and enhancing the bus share ratio.

Acknowledgements

This research was supported by National Basic Research Program of China (No. 2012CB725403). We are very grateful for the comments from the anonymous reviewers.

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