International Journal of Transportation
Vol.3, No.2 (2015), pp.73-80
http://dx.doi.org/10.14257/ijt.2015.3.2.07

Stated Diversion of Car Commuters to Public Transit: A Case Study in Jinan

Zhihu Zhang[a], Hongzhi Guan[b1], Huanmei Qin[c] and Yunqiang Xue[d]

The College of Architecture and Civil Engineering, Beijing University of Technology, Beijing, 100124, China;
[a]q322101@126.com, [b]hguan@bjut.edu.cn, [c]hmqin@bjut.edu.cn
[d]xueyun12345678@163.com

Abstract

Comparing to trips by bus, a person's trip by car generally needs more road resources for the same distance. If some of car owners give up car use and choose buses to complete their trips, traffic jams may be alleviated largely. When those factors affecting trip generation are changed, car owners may change their choice of cars and public transit. The purpose of this paper is to identify those traffic conditions that may make car owners change their trip modes, from cars to public transit. For this, we designed a questionnaire by orthogonal table design and collected 1079 filled forms. Based on the valid forms we established a MNL model. The resulting model, consistent with the surveyed data or common sense, shows that the improvement in bus service and the increase in parking fee and fuel cost may force car owners to turn from car use to bus ride. This model may be used for other purposes.

Keywords: *SP and RP survey; MNL model; Sensitivity analysis; Measures*

1. Introduction

In the past decade, car ownership has been growing sharply with the development of economy, which takes up a large number of road resources and results in traffic congestion. The high proportion of private car commuters in congested road traffic reduces the efficiency of road utilization. Previous studies mainly focused on car traveler behavior. Wang (2012) established a discrete choice model about car travelers' behavior at weekends using the random utility theory and showed that the weather, road congestion degree and parking situation had a great role in car travelers' behavior. Li and Peng (2009) investigated the car travelers' characteristics in the city of Kunmin and analyzed available methods for travel behavior modeling. Zhang (2007) took the social marginal cost as the benchmark and explored the impact of internalization of external costs on transport behaviors by using the car-based travel demand function, average travel cost and social marginal function. 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 (including 'sticks' discouraging car use, and 'carrots' encouraging alternative modes) for each area, but also identifies many significant constraints. Gärling et al (2000) investigated the feasibility and effectiveness of various car-use reduction measures and suggested that switching to public transport be the most likely choice for work trips as the level of public transit service improves. Their investigation also shows that women are more likely than men to choose public transport and complete a series of daily activities along a trip chain, whereas men were more likely than women to choose motorbikes/mopeds.

[1] Correspondence author

ISSN: 2287-7940 IJT

To carry out this research, the city of Jinan --- capital of the Shandong province --- has been chosen to carry out a case study. This city is famous for its natural foundation across the downtown, which deters the local government to plan and construct an underground transportation system for traffic congestion mitigation. A few years ago the city received a large amount of loans from the World of Bank to restructure its public transit system by introducing a BRT network, which has been a very successful project so far.

This paper conducted stated preference (SP) plus revealed preference (RP) surveys on bus choice behavior for car travelers, based on which a multinomial logit (MNL) model was established and the relationship between bus choice behavior and influencing factors for car travelers was investigated. Based on this established model, the paper proposed certain measures that may make car users move to public transit services.

2. Car Traveler Behavior Survey

RP and SP data were collected to analyze car users' choice behavior in this paper. The questionnaire for the survey was composed of three parts. The first part was to collect personal information, including gender, age, occupation, car purchase plan, and family monthly income. The second part was about car traveler behavior information: weekly trip times of each used mode, parking lots in place of work and parking lots in place of residence. The third part was designed by orthogonal table for SP data. The orthogonal table was consisted of three important influencing factors: bus service level, parking fee and fuel cost. Bus services were set at two levels while both parking fees and fuel costs were set at three levels.

The specific design was presented in Table 1, in which it can be seen that there are 10 kinds of traffic scenes. Respondents can choose one of traffic modes in different scenes.

Table 1. Factor Combination of SP Survey

Parking fee	Fuel cost	Bus service level unchanged	Bus service level improved	Available traffic modes
unchanged	10yuan per liter			Car, bus, motorcycle, bike, walking and others
5yuanper hour	unchanged			
5yuanper hour	12yuan per liter			
10yuan per hour	10yuan per liter			
10yuanper hour	12yuan per liter			

The survey began on the seventeenth of June 2012 and ended on the twenty-sixth of June 2012. The size of the available survey sample is 1079.

3. MNL Model

According to the Random Utility Theory (Hensher and Button, 2000), the utility U_{in} when individual n selects option i can be written as.

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

where V_{in} and ε_{in} are respectively the deterministic and random components of the utility for option i chosen by individual n, and i represents an available option of trip modes (*e.g.*, 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. The parameters θ_k in Eq. (2) can be estimated by using the Maximum Likelihood and Newton-Raphson methods.

MNL model models have been widely used in travel behavior analysis. By assuming that the random component ε_{in} in Eq. (1) follows the Gumbel distribution, independently and identically across options, the probability Pin for individual n choosing mode i can written as follows:

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

where J is the set of available trip modes.

4. MNL Model Estimation and Analysis

In order to avoid premature convergence and estimated errors caused by empty cells, the monthly income, occupation, factors affecting travel and car purchase behavior are reclassified and combined based on correlation analysis. Table2 shows a classification of these factors. The dummy variables takes two values: 0 and 1. When the categorical variables were divided into *n* kinds of classes, it can be represented by (*n*−1) dummy variables. For example, monthly income was divided into 4 categories, so we can use 3 dummy variables to represent them; at each observation, only one of the three takes the value of 1.

Table 2. Classification

Variable		Classification	Dummy variable		
Monthly income	Monthly income 1	Not more than 999yuan;	1	0	0
	Monthly income 2	Between 1000 yuan and 1999yuan;	0	1	0
	Monthly income 3	Between 2000 yuan and 11999yuan;	0	0	1
	Monthly income 4（reference type）	Not less than 12000yuan;	0	0	0
Occupation	Occupation 1	Public utilities, non-public utilities, individual household and freelancer, college student, Organization unit, non- organization unit, unemployed, retirees;	1	0	0
	Occupation 2	education , health protection, scientific research, Primary school, middle school; agriculture, forestry,	0	1	0

		animal husbandry, others;			
	Occupation 3（ reference type）	Soldier;	0	0	0
Factors affecting travel	Factors affecting travel 1	Travel time, Ticket price;	1	0	0
	Factors affecting travel 2	travel comfort;	0	1	0
	Factors affecting travel 3（reference type）	Safety, convenience;	0	0	0
Car purchase plan	car purchase plan 1	Having car, one year, two years, three years, four years;	1	0	0
	car purchase plan 2	Not less than five years;	0	1	0
	car purchase plan 3（ reference type）	No consideration;	0	0	0
Age	Age 1	From 6 years old to 12 years old;	1	0	0
	Age 2(reference type)	Not less than 13 years old	0	0	0

Based on the data collected in the city of Jinan, the result of model calibration is shown in Table 3. Goodness of fit ρ^2 and adjusted goodness of fit $\overline{\rho^2}$ are two important indexes for us to evaluate the fit model. Generally, the model precision is acceptable when ρ^2 and $\overline{\rho^2}$ are both between 0.2 and 0.4.

Table 3. The Result of Model Calibration

SP model		
Variable name	Parameter value	t test
Constant dummy 1	5.435	27.354
Constant dummy 2	2.185	4.323
Constant dummy 3	0.551	7.409
Parking fee	-0.134	-18.660
Weekly trip times	0.023	5.814
The number of vehicles ownership	0.238	9.525
Car purchase plan 1	-0.124	-2.186
Car purchase plan 2	0.200	1.858
Driving experience	0.030	2.436
Parking numbers in place of work	-0.186	-5.537
Parking numbers in place of residence	-0.117	-3.540
Factors affecting travel 1	-0.166	-3.668
Factors affecting travel 2	-0.309	-4.166

Monthly income 1	0.564	3.367
Monthly income 2	0.933	5.973
Monthly income 3	0.525	6.213
Occupation 1	-1.072	-2.182
Occupation 2	-0.801	-1.625
Age1	-1.079	-2.760
Bus service level	0.761	17.973
Fuel cost	-0.147	-9.063
Sex	0.089	2.010
L(0)	-13821.355	
L(θ)	-9400.452	
$-2(L(0)-L(\hat{\theta}))$	8841.806	
ρ^2	0.320	
$\bar{\rho}^2$	0.318	

5. Model Sensibility Analysis

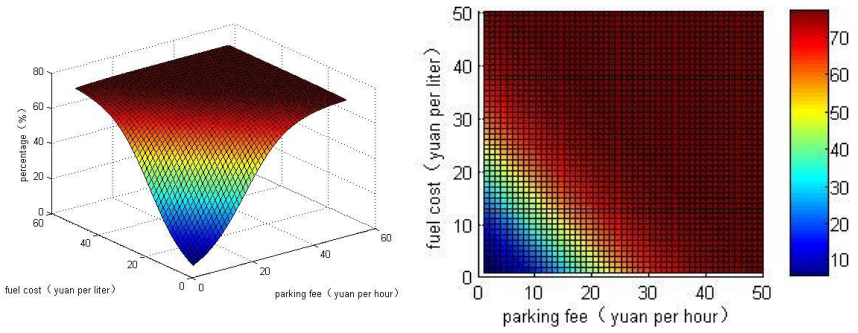
Parking fee, fuel cost and service level are three important influencing factors and accordingly have been chosen for sensibility analysis. We carry out this analysis based on whether the level of bus service remains unchanged or improved.

5.1. Bus Service Level Unchanged

Car travelers' choice proportion of bus travel modes is shown in Figure 1when the bus service level is assumed to stay unchanged while the parking fee varies between 0 yuan per hour and 50 yuan per hour and the fuel cost varies in [0, 50] yuan per liter. This figure shows that, when the bus service level is unchanged, the proportion of travelers choosing cars increases as the fuel cost and/or parking fee fall.

The coefficients of parking fee and fuel cost are respectively -0.134 and -0.147, as shown in Table 3. So, in this survey, the car users are sensible to the fuel cost and the parking fee to almost the same level. Figure 1 shows that parking fee and fuel cost give exactly symmetric output in the fit model; it is noteworthy stating that this similarity may not be due to the same scale but their similar coefficient. Parts (a) and (b) of Figure 1 show the variation trend of proportion of choosing bus travel for the car travelers, which is composed of five parts. Figure 1(a) includes a blue triangular area which consists of parking fee from 0 yuan per hour to 15 yuan per hour and fuel cost from 0 yuan per liter to15 yuan per liter. The proportion of travelers choosing bus travel is about 15% in this area. Figure 1(b) contains a green trapezoidal area which consists of parking fee from 15 yuan per hour to 20 yuan per hour and fuel cost from 15 yuan per liter to 20 yuan per liter. The proportion of travelers choosing bus travel is about 30% in this area. The third part is the yellow trapezoidal area which consists of parking fee from 20 yuan per hour to 25 yuan per hour and fuel cost from 20 yuan per liter to25 yuan per liter. The proportion of car commuters turning to public transit service is about 50% in this area. The fourth part is the light red trapezoidal area which consists of parking fee within the interval of [25, 35] yuan per hour and fuel cost within [25, 35] yuan per liter. The proportion of

car commuters turning to public transit service is about 60% in this area. The fifth part is the red polygonal area which is associated with parking fee from 35 yuan per hour to 50 yuan per hour and fuel cost from 35 yuan per liter to50 yuan per liter. The proportion of car commuters turning to public transit service is about 70% in this area.



(a) (b)

Figure 1. Profiles of Proportions of Car Commuters Turning to Public Transit Service when the Bus Service Level Remains Unchanged [Part (b) is the Projection of the Graph In Part (a) on to the (Parking Fee, Fuel Cost) Plane]

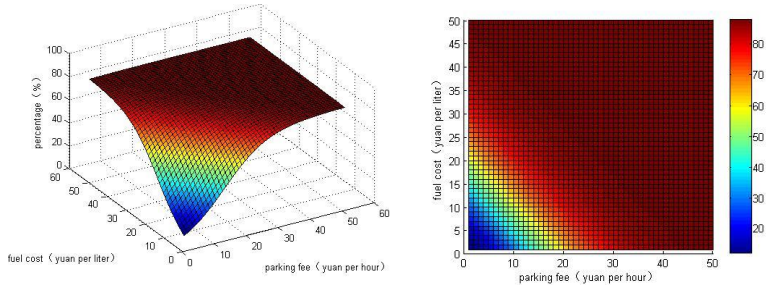
In the neighborhood of each of four points corresponding to the parking fee and fuel cost respectively equal to (15yuan per hour, 15yuan per liter), (20yuan per hour, 20yuan per liter), (25yuan per hour, 25yuan per liter) and (35 yuan per hour, 35 yuan per liter), the proportion of car commuters turning to public transit service changes greatly.

5.2. Bus Service Level Improved

Figure 2 shows the profiles of proportions of car commuters turning to public transit service when the bus service level improves. The parking fee varies between 0 yuan per hour and 50 yuan per hour and the fuel cost varies between 0 yuan per liter and 50 yuan per liter. This figure shows that, when the bus service level is unchanged, the proportion of travelers choosing cars increases as the bus service level improves.

As shown in Figure 2, the profiles of proportions of car commuters turning to public transit service can be divided into five parts. One is the blue triangular area, which consists of parking fee from 0 yuan per hour to 10 yuan per hour and fuel cost from 0 yuan per liter to10 yuan per liter. The proportion in this area is about 20%. Part 2 is the green trapezoidal area, which consists of parking fee from 10 yuan per hour to 15 yuan per hour and fuel cost from 10 yuan per liter to15 yuan per liter. The proportion of car commuters turning to public transit service is about 40% in this area. The third part is the yellow trapezoidal area which consists of parking fee from 15 yuan per hour to 20 yuan per hour and fuel cost from 15 yuan per liter to20 yuan per liter. The proportion of car commuters turning to public transit service is around 60% in this area. The fourth part is the light red trapezoidal area which consists of parking fee from 20 yuan per hour to 30 yuan per hour and fuel cost from 20 yuan per liter to30 yuan per liter. The proportion of car commuters turning to public transit service is 70% or so in this area. The fifth part is the red polygonal area which consists of parking fee from 30 yuan per hour to 50 yuan per hour and fuel cost from 30 yuan per liter to50 yuan per liter. The proportion of car commuters turning to public transit service is about 80% in this area.

In this circumstance, such four points in the plane of parking fee and fuel cost as (10yuan per hour, 10yuan per liter), (15yuan per hour, 15yuan per liter), (20yuan per hour, 20yuan per liter) and (30 yuan per hour, 30 yuan per liter) have been identified, in each of whose neighborhoods the proportion of car commuters turning to public transit service changes greatly.



(a) (b)

Figure 2. Profiles of Proportions of Car Commuters Turning to Public Transit Service when the Bus Service Level Improves [Part (b) is the Projection of the Graph in Part (a) on to the (Parking Fee, Fuel Cost) Plane]

It can be drawn from the previous analysis that the level of bus service has an important effect on the proportion of car commuters turning to public transit service and that the improvement in the bus service level can increase the proportion.

6. Conclusions

Based on the SP and RP surveys, an MNL model has been established to analyze the effects of potential factors that may move car commuters to public transit. An emphasis has been given to analysis of how the parking fee, fuel cost and bus service level affected the proportion of car commuters turning to public transit service. New findings include:

- The proportion of car commuters turning to public transit service will increase with the increase in parking fee and fuel cost.
- The improved level of public transit service can also increase this proportion.
- Either the bus service level remains unchanged or improved, certain points in the plane of parking fee and fuel cost can been identified, in whose neighborhood the proportion of car commuters turning to public transit service changes greatly.

Therefore, we may increase attraction of public transit to car commuters, at least by offering higher service level or increasing parking fee and fuel cost.

This paper merely analyzes car commuters' choice of travel modes. However, bus travelers, motorcycle travelers, bicycle travelers and travelers by other modes may also turn to other alternative modes. It may be worth further investigation on this matter in a number of cities and identify certain factors that can be used for turning travelers to low-carbon trip modes.

Acknowledgements

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

References

[1] K. Wang, "Analysis and model of the car travel behavior on weekend", Highways and Automotive applications, vol. 5, **(2012)**, pp. 54-55.
[2] Z. Li and K. Peng, "Study on Survey and Analysis of the Travel Characteristic of Private Cars in Kunming", Technology and Economy in Areas of Communications, vol. 5, **(2009)**, pp. 43-46.
[3] X. Zhang, "Analysis impact of car use external cost of the internalization", China soft science, vol. 8, **(2007)**, pp. 156-160.
[4] Z. Feng, J. Liu and Y. Li, "Selected model and sensitivity analysis of aggressive driving behavior", China jour of Highway and Transport, vol. 25, no. 2, **(2012)**.
[5] M. Liu, J. Guo and L. Gao, "Analysis and modeling of private car usage through travel behavior", Journal of Jilin university, **(2009)**.
[6] M. M. Hamed and H. H. Olaywah, "Travel-related decisions by bus, services taxi, and private car commuters in the city of Amman, Jordan", Cities, vol. 17, no. 1, **(2000)**, pp. 63-71.
[7] C. O'Fallon, C. Sullivan and D. A. Hensher, "Constraints affecting mode choices by morning car commuters", Transport Policy, vol. 11, **(2004)**, pp. 17-29.
[8] T. Gärling, A. Gärling and A. Johansson, "Household choices of car-use reduction measures", Transportation Research Part A, vol. 34, **(2000)**, pp. 309-320.
[9] H. Guan, "Disaggregate model: A tool of traffic behavior analysis", China communication press, **(2004)**.
[10] D. Hensher and K. Button, "Handbook of Transport Modelling", Elsevier Science Ltd., Amsterdam, **(2000)**.
[11] J. Li, "Analysis of Holiday Travel Behavior Characteristic", Beijing jiaotong University, **(2007)**.
[12] F. Gao, "A study of method on private car travel attribute", Beijing jiaotong university, **(2007)**.
[13] F. Yao, "The development and study of the private cars", Southeast university, **(2003)**.

