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STUDY ON INFLUENCING FACTORS OF RESIDENTS TRAVEL MODE CHOICE FOR HO CHI MINH CITY

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ABSTRACT

Considering the travel character of travelers, attribute of travelers and the original attribute of transportation modes, and searching the travel cost and travel time of private cars and public buses, this paper sets up a logistic model to investigate the travelers' behavior in Ho Chi Minh city. Specifically, the significance level used in this model is 0.05. Through this model, it shows that the major factors affecting the behavior of traveler are travel distance, the difference of travel cost between cars and buses, the cost of congestion, the parking fee of cars, the difference of time between cars and buses, and the time for travelers to reach the bus stops on foot. Furthermore, this model indicates that by increasing the fuel fee, parking fee and congestion fee, less travelers would choose cars as their travel tool.

Keywords: traffic travel, travel mode choice, travel cost, Ho Chi Minh city.

1. INTRODUCTION

Analyzing and valuating the traffic flow is a kind of approach for evaluating, distributing, and balancing private traffic flow and public traffic flow. Under the precondition of satisfying travelers' demand for traffic system, the implementation of traffic charge is a commonly used measure for traffic management and traffic jam control. In order to valuate the traffic charge plan's effectiveness, a common way is to establish traffic system model. However, one of the most diffcult problems of the traditional public traffic system model is that it is hard to describe how the travelers choose traffic route and service. Murthy and Ashtakala [1] think that the Logit model is featured in clear physical meaning and is easy for calculation, so that it is the most widely applied disaggregate model [2]. According to this model, Wu et al. [3] propose a model for settling the traffic jam. This requires the public traffic system to be expanded as a multi-model transport system, and meanwhile, the vehicle parking, driving, and price systems [4] shall be viewed and analyzed in overall aspects [5]. The purpose of adopting multi-model transport system is to optimize public traffic service capacity. Vedagiri and Arasan [6] study the balance of private and public vehicles on a road transport system. Gito et al. [7] apply select probability model for travel mode to conduct estimation on travel modes sharing rate. In order to study the traffic and transport plan in an overall manner, the travel status of all vehicles shall be

considered. However, the variation of travel vehicle demand and the interactive effect of private cars and public vehicles on the road make this problem very difficult to be settled [8].

According to the travel data of Ho Chi Minh City in Octomber of 2013, this paper studies the affecting factors in travel mode selecting. Specifically, we use the data to capture the value of the travel fee and time of private cars and public vehicles, on which we build the Logit regression model. In this procedure, the selection of the characteristic variables is the key point [9]. Based on the Logit regression model, the utility difference of travel modes is calculated and used for describing the utility derived from the traveler's selection change in travel mode.

2. THE THEORY OF LOGIT MODEL

In order to simulate the travel behavior of travelers, a utility value can be determined for each type of travel mode, which would reflect the utility that the traveler obtains by selecting the specific travel mode. All the travelers always hope to select a travel mode with the largest utility. Factors that affect the utility value of travel mode are numerous and complicated, and are also random to some extent. Therefore, the utility value is a random variable and is usually called the random utility.

Assume that there are m travelers in the actually observed traffic system, the utility of the travel mode selected by traveler can be expressed by the following formula:

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

in the formula, U_{in} represents the random utility value of No.i travel mode to traveler-n; V_{in} represents the utility value that can be determined or observed; ε_{in} is the random error term; the utility value V_{in} that can be observed could be expressed by the following formula:

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

in the formula, X_{ink} represents No.k eigen value of No.i travel mode selected by traveler-n, such as travel fee, travel time, and comfortable feeling; θ_k is specific parameter, which can be estimated by statistical inference method from the observed data. Since the utility value of a specific type of travel mode is a random variable, the travel mode selection of travel is actually concerned to probability, namely how much probability that the travel could select a certain type of travel mode. However, such selection probability depends on the eigen value of utility function and distribution of random error terms. It could be obtained that the probability of selecting No.i travel mode by traveler-n is as follow:

$$Pr_{in} = \frac{\exp(V_{in})}{\sum_{i=1}^{N} \exp(V_{in})} \tag{3}$$

in the formula, N represents the total number of travel modes available.

3. ANALYSIS ON FACTORS AFFECTING THE RESIDENTS' SELECTION OF TRAVEL MODES

Travel mode selection of is a key point of travel behavior study. It points out how travelers select travel vehicles under the affect of various factors [10]. These factors mainly include the travel characteristics, traveler attribute, and the build-in attribute of travel mode.

Travel characteristics include travel purpose, travel distance, and trave frequency, etc. The

travel mode selection of travelers is mostly affected by travel distance and frequency. The travel distance directly affect the travel fee, and the increase of travel fee could directly affect sharing rate of private cars and public vehicles.

Traveler attribute include the individual attribute and family attribute. Among them, gender, age, payment mode, and the number of family members are the key variables of travel mode selection.

As for the build-in attribute of travel mode, Hino and Sato [11] think that the two travel modes of private car and public vehicle contain five build-in attributes: travel cost, congestion fee, private car parking fee, travel time, and public vehicle waiting time. Among the above, if the traveler selects private car, the specific build-in attributes that can affect its decision would be travel time, travel cost, congestion fee, and parking fee; and if the traveler selects public vehicle, the specific build-in attributes that can affect its decision would be travel time, public vehicle waiting time and travel cost.

The travel time of private car is defined as the the ratio of travel distance and vechile's average travel speed. According to the Ho Chi Minh City traffic report issued by Tien-Phong Company [12], the average travel speed of private car during rush hours is 16.7km/h. And the travel distance would be acquired by investigating the actual travel behavior of traveler.

The travel cost of private car is composed of two parts: vechile operating cost (VOC, here in this paper, the private car fuel fee is the only item that is counted) and travel time cost [13]. Among the above, the private car fuel fee equals the number that the travel distance multiply private car unit distance fuel consumption and multiply fuel price; and the private car travel time cost equals to the number that the travel time of the private car multiply traveler's unit time value (also called the value of time, VOT). Here in this paper, the following method is adopted to calculate the unit travel time value, we assume that the month average income for the citizens in Ho Chi Minh City is 350 dollars ($), working time is 40 hours per week, and for each month, there's $\frac{52}{12} = 4.33$ weeks, namely, the working time each month is $4.33x40 = 173.2$ hours. Therefore, the VOT is $VOT = \frac{350}{173.2} = 2.02$ $/h. In this paper, the #95 gasoline price of October in 2013, which was 1.158 $/L, is taken as the gasoline price. Moreover, the unit distance fuel consumption volumen, which is determined by investigating the traveler's travel behavior, is 9.5 L/100 km.

Travel cost of public vehicle also contains two parts: ticket price and time cost during travel; the travel time of public vehicle consists of the time on the vehicle and the waiting-for-vehicle time.

The existing literatures usually only consider the congestion fee or parking fee, and mainly use the ratio of congestion fee and total travel cost, or the ratio of parking fee and total travel cost as the main attribute, which, however, lacks of overall and specific consideration. In order to visually show the process of travel mode selection, in this paper, the congestion fee and parking fee are both considered. And the travel time difference of private car and public vehicle, and travel cost difference of private car and public vehicle are also treated as the characteristic variables. Traveler's travel mode selection model is applicable for complicated actual travel mode selection problem, especially in the downtown area with congestion.

The above are the main factors considered in this paper that can affect the travel mode selection. Certainly, factors that can affect the travel selection are far more than these, such as the travel time period and travel start and end points in the travel characteristics; profession,

living habit, and drive license in the traveler characteristics, as well as family structure, family income, ownership and (or) use right status of individual vehicles (car, motorcycle, bicycle, etc.). However, since the factors that may affect the travel mode selection are numerous, it is impossible to record all variables in the investigation. That's why we always select those factors having major effect according to the consciousness when designing the questionnaire. For example, Xu et al. [14] only select factors of month income, gender, age, driving years, education background, car purchase fee, payment mode, travel purpose, travel time ratio and trave cost ratio when studying how the travel cost affects Beijing residents' selection of travel mode; Han et al. [15] focus on gender, age, income, bus IC card, family members, (have or have no) children under 6 years old, car amount, travel distance, travel frequency, and car travel time, public vehicle travel time, car travel fee, public vehicle travel fee, and congestion fee ratio when studying how the congestion fee affects residents' selection of travel mode; Tushara et al. [16] only investigate traveler's gender, age, profession, and income when studying Calicut (where the travel distance is fixed) staff (namely part of the travelers' characteristics are fixed) travel mode selection; Zhou et al. [17] only focus on travel vehicle price, on-time performance, comfort performance, travel time, and safety when studying travel mode selection of travelers in metropolitan cities; Zhu et al. [9] only considers travel time and travel fee when establishing travel mode predictive Logit model with fuzzy variables. In this paper, according to the actual condition of Ho Chi Minh City, we preliminary select some factors and make some transformation of the factors. For example, since this paper only study the selection behavior of travelers between private car and public vehicle, the travel cost and travel time of private car and public vehicle are not separately studied in this paper. Instead, we focus on the travel time difference and travel cost difference. Such kind of transformation reduces the scale of data record, and makes the data collection and analysis easier and more convenient.

Definitions of characteristic variables of travel mode selection are as shown in Table 1. Let X_{ink} be the factor affecting the travel mode, among which, i=1,2 respectively represents that traveler n selects private car and public vehicle for his/her travel, k=1, 2,..., 12 respectively represents No.k kind of factor affecting the travel mode selection.

Table 1. The definition of special variable of travel modes.

Affecting factor	Variable value	Symbol
Gender	Male shall be 0; Female shall be 1	X_{in1}
Age	Under 20 years old, 20-30 years old, 31-40 years old, 41-50 years old, over 51 years old, shall be respective valued as 1-5	X_{in2}
Purpose of Travel	Flexible travel (leisure and shopping) shall be 1; rigid demand travel (go for business, go to school, go to work)	X_{in3}
Payment Mode	Pay by traveler itself; pay by the unit	X_{in4}
Family Members	1 person: 1; 2 persons: 2; 3 persons: 3; 4 persons and over: 4	X_{in5}
Travel Frequency	1 time: 1; 2 times: 2; 3 times: 3; 4 times and over: 4	X_{in6}

Travel Distance	<5 km:1, 5～10 km: 2, <10～15 km: 3, >15 km: 4	X_{in7}
Travel Cost Difference of Private Car and Public Vehicle	Actual values of investigation	X_{in8}
Congestion Fee	X_{1n9}: actual value of investigation data, $X_{2n9} = 0$)	X_{in9}
Private Car Parking Fee	X_{1n10}: actual value of investigation data, $X_{2n10} = 0$	X_{in10}
Time Difference of Private Car and Public Vehicle	Actual values of investigation	X_{in11}
Waiting Time of Public Vehicles	$X_{1n12} = 0$, X_{2n12}: actual value of investigation data	X_{in12}

4. FACTORS AFFECTING THE SELECTION OF TRAVELER'S TRAVEL MODE

After sufficiently introducing the travel behavior and analyzing the characteristics of factors affecting the behavior of travel, this section will establish a Logistic regression model to unveil the objective and subjective factors affecting the travel behavior and how these factors work on the traveler's travel decision.

4.1. Logistic regression model

In this paper, the statistics and analysis software SPSS is adopted for performing logistic regression analysis. We define the public vehicle travel mode as "0", and define the private car travel mode as "1". And, the probability selecting private car for travel and the probability of selecting public vehicle for travel would respectively be:

$$Pr_{1n} = \frac{1}{1+\exp(-y)} \tag{4}$$

$$Pr_{2n} = 1 - Pr_{1n} = \frac{\exp(-y)}{1+\exp(-y)} \tag{5}$$

where,

$$y = V_{1n} - V_{2n} = B + \theta_1 X_{in1} + \theta_2 X_{in2} + \cdots + \theta_{12} X_{in12} \tag{6}$$

in the formula, V_{1n} is the utility obtained by selecting private car for travel; V_{2n} is the utility obtained by selecting public vehicle for travel; B is a constant; $\theta_1 \sim \theta_{12}$ is respectively the coefficient for each affecting factor; and $X_{in1} \sim X_{in12}$ is the variable shown in Table 1.

In order to determine proper travel mode selection for Ho Chi Minh City, the investigation questionnaire is designed by combining with the affecting factors in Table 1. We conducted the investigation with the travelers taking private car and public vehicle for travel on the main road and downtown area (road section length in the restricted region of downtown area is about 4.8 km) of Ho Chi Minh City in October 2013. We totally obtained 250 effective answered questionnaires in the end. The questionnaire information includes: private car traveler individual information, travel mode selection information (travel distance, travel frequency, private car and public vehicle travel time, and travel cost, etc.) and relative preferential data on travel mode

selection in face of different congestion fees (for each time of entering downtown area: $0.5, $1, $1.5, and $2) and different parking fees (for each day: $1.5, $1.85, and $2).

4.2. Selection of regression variables

Chi-square test (also called the Pearson Chi-square Test) is adopted for examining the independence among variables. The contingency table analysis method and the Chi-square Test method are adopted in this paper to check the relation between independent variable and dependent variable. Various affecting variables can be further divided into lots of types. Some of the types can be directly checked by Chi-square Test, some of the types need to be determined by the purposes, and some of types cannot adopt the Chi-square Test. Therefore, not every type of variables can adopt the Chi-square Test. The statistic used for the Chi-square Test is

$$\chi^2 = \sum \frac{(h-\hat{h})^2}{\hat{h}} \tag{7}$$

where h is the actually viewed frequency, while $\hat{h}$ is the anticipated frequency.

The results of Pearson Chi-square Test are given in Table 2. Setting significance probability level as 0.05, and eliminating the affecting factors having over 0.05 significance probability, the affecting factors of the probability model are travel distance, travel cost difference between private car and public vehicle, congestion fee, private car parking fee, travel time difference between private car and public vehicle, and waiting time for public vehicle.

Table 2. Pearson chi square value.

Utility function (y) / Affecting factor ($X_{in1} \sim X_{in12}$)		Sig.	Pearson Chi-square value
Gender	X_{in1}	0.106	2.606
Age	X_{in2}	0.579	2.877
Purpose of Travel	X_{in3}	0.229	1.447
Payment Mode	X_{in4}	0.550	3.686
Family Members	X_{in5}	0.515	5.224
Travel Frequency	X_{in6}	0.563	2.044
Travel Distance	X_{in7}	0.000	40.531
Travel Cost Difference of Private Car and Public Vehicle	X_{in8}	0.000	1.619E2
Congestion Fee	X_{in9}	0.000	55.029
Private Car Parking Fee	X_{in10}	0.000	32.341
Time Difference of Private Car and Public Vehicle	X_{in11}	0.001	68.386
Waiting Time of Public Vehicles	X_{in12}	0.000	1.109E2

According to the investigation data, the traveler's probability of travel mode has been made of statistics. And the affecting factors of traveler's selection of travel mode are known. Then, the

values of coefficients corresponding to all affecting factors $\theta_7 \sim \theta_{12}$ can be obtained by adopting regression analysis on Formula (6). Since the data of the corresponding variables $X_{in7} \sim X_{in12}$ that are adopted for regression analysis are not original data, but the data calculated by original data, values $\theta_7 \sim \theta_{12}$ obtained from regression would have certain difference. But it can be seen from the deduction process that, the values $X_{in7} \sim X_{in12}$ obtained from the regression analysis $\theta_7 \sim \theta_{12}$ values can be deemed as affecting degree of the affecting factor on the selection of travel mode by the traveler.

4.3. Model constants and coefficients estimation

With the 250 collected investigation data, we use SPSS to conduct a binomial Logistic regression at significance level 0.05. While conducting the binomial Logistic regression, for the sake of accuracy, we shall conduct it forward stepwise. Score test is an initial test, which determines the close relations between independent variable and dependent variable at the beginning of the modeling. However, for the convenience of understanding, it is necessary to examine the relationship between Cox-Snell goodness-of-fit as well as Nagelkerke goodness-of-fit value and maximum likelihood square logarithm value.

Table 3 gives the value of the maximum likelihood square logarithm, Cox-Snell goodness-of-fit and Nagelkerke goodness-of-fit. The value of the maximum likelihood square logarithm, -2loglikelihood, is 45.397, while the value of the Cox-Snell goodness-of-fit is 0.489. The value of the Nagelkerke goodness-of-fit is equal to that in Cox-Snell goodness-of-fit after correction, the value of the goodness-of-fit after correction can be deemed as 0.852.

Table 3. Estimation Results of Model Summary.

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	45.397	0.489	0.852

In general, the maximum likelihood estimation method is used for the regression of the model utility function of probability of travel mode selection. Through the regression analysis of the above data, the final results are got as shown in Table 4.

Table 4. Estimation Results of Model Parameters.

Affecting factor	Constants and coefficients B, $\theta_7 \sim \theta_{12}$	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B)	
							Lower	Upper
X_{in7}	10.118	4.051	6.238	1	0.013	2.478E4	8.828	6.956E7
X_{in8}	-39.840	12.142	10.767	1	0.001	0.000	0.000	0.000
X_{in9}	-2.605	1.231	4.473	1	0.034	0.074	0.007	0.826
X_{in10}	-6.029	1.956	9.499	1	0.002	0.002	0.000	0.111

X_{in11}	60.599	20.819	8.472	1	0.004	2.078E26	3.947E8	1.094E44
X_{in12}	-173.493	47.329	13.437	1	0.000	0.000	0.000	0.000
Constant	0.884	6.743	0.017	1	0.896	2.421		

Table 4 shows that the factors, such as gender, age, travel purpose, payment method, family members, and travel frequency are eliminated because their significance level is not sufficient. Therefore, the factors which influence the travel mode selection for the residents in Ho Chi Minh City are mainly travel distance, difference of travel cost between private car and public vehicle, congestion fee, parking fee, difference of travel time between private car and public vehicle, and the waiting time of public vehicle. There are both similarities and differences between our findings and that in existing studies of Zhou et al. [17], Xu et al. [14], Han et al. [15], Zhu et al. [9], and Tushara et al. [16]. In what follows, we would explain these results one by one with the circumstance of Ho Chi Minh City.

Travel distance: this factor is also significant in the study of Han et al. [15], but not significant in other studies. This difference is mainly because the focuses of the studies are not the same. For example, the research issue of Han et al. [15] and this paper are both the affecting factors of travel decision-making for the travelers in the downtown, while Tushara et al. [16] focus on the travel selection for the workers in certain areas. Obviously, for the workers, because the travel distance (distance between home and working place) has been fixed, the travel distance is not the factor considered by the workers while making travel selection.

Difference of travel cost between private car and public vehicle: in most of the comparative studies, the travel cost is the only factor that is investigated, and this factor is significant in these studies. However, Tushara et al. [16] gives a different result. The reason for this phenomenon is possibly that the staff's travel expenses are paid by their company. Thus, the travel cost is obviously not the significant factor of travel mode selection for these staff.

Congestion fee: among the mentioned study, only the study of Han et al. [15] and this paper take the congestion fee as the candidate factor, so only in that study, congestion fee is also significant. However, it shall be pointed out that the congestion fee will actually induce the change of the travel cost. So it can be foreseen that if all the mentioned studies take congestion fee as the candidate factor, the congestion fee would be significant.

Parking fee of private cars: in all of the comparative studies, this factor is not the candidate factor. However, in this paper, it shall be considered due to the local conditions of Ho Chi Minh City-the parking fee is very flexible. In addition, like the congestion fee, the parking fee will affect the travel costs. Therefore, it can be predicted that if it were the candidate factor in the mentioned studies, it will be significant.

Difference of travel time between private cars and public vehicle: except the study of Tushara et al. [16], this factor is significant in all the results of the above studies. It can be easily seen that the travel time would significantly influence the traveler's decision of travel mode selection. However, in the research of Tushara et al. [16], when the travel distance is small, the difference of travel time of all kinds of travel modes is small, and so the travel time will not significantly affect traveler's decision.

The waiting time of public vehicle: in all of the comparative studies, some do not consider this factor, while it is not significant in the studies that consider it. However, in Ho Chi Minh City, it occurs often that the buses are not punctual, so the traveler always takes the delay of

public vehicle into account while making decisions. On the other hand, since the center of Ho Chi Minh City is a business developed area, the travelers in this area will pay much attention to the punctuality of public transport. That is to say, the waiting time of public vehicle will greatly affect the choice of travelers.

These results also indicate that it is feasible and effective for the Ho Chi Minh City to take economic measures (such as increasing parking fee of private car, collecting congestion fee, and so on) to guide travelers' travel mode choice. In addition, differed form the results of studies of Xu et al. [14], the results of this paper do not include the factor of "payment mode" (whether pay by themselves). This is because the travelers are mainly paying at their own expense in Ho Chi Minh City. And differed from the study result of Tushara et al. [16], the results of this paper do not include the "gender" and "age". This is because the travelers in the downtown of Ho Chi Minh City are mostly middle-aged and male.

The utility function of travel mode selection can be established as follows:

$$U = V_{1n} - V_{2n} = 0.884 + 10.118X_{in7} - 39.840X_{in8} - 2.605X_{in9} - 6.029X_{in10} + 60.599X_{in11} - 173.493X_{in12} \quad (8)$$

Substitute formula (8) into (4) and (5), then we can respectively get the selection probabilities model of private cars and public vehicles:

$$Pr_{1n} = \frac{1}{1 + \exp(-(0.884 + 10.118X_{in7} - 39.840X_{in8} - 2.605X_{in9} - 6.029X_{in10} + 60.599X_{in11} - 173.493X_{in12}))}$$

$$Pr_{2n} = \frac{\exp(-(0.884 + 10.118X_{in7} - 39.840X_{in8} - 2.605X_{in9} - 6.029X_{in10} + 60.599X_{in11} - 173.493X_{in12}))}{1 + \exp(-(0.884 + 10.118X_{in7} - 39.840X_{in8} - 2.605X_{in9} - 6.029X_{in10} + 60.599X_{in11} - 173.493X_{in12}))}$$

In the following, we translate the findings in the selection probabilities models of private cars and public vehicles.

(1) Travel distance: the regression coefficient of this factor is 10.118, which is greater than 0. This suggests that when the travel distance increases, travelers are more likely to choose private cars. This is consistent with the results of Han et al. [15].

(2) Difference of travel cost between private cars and public vehicle: the regression coefficient of this factor is -39.84, which is lower than 0. This suggests that when the cost of private cars is more expensive, travelers are less likely to choose private cars. This is the same as the results of the comparative study.

(3) Congestion fee: the regression coefficient of this factor is -2.605, which is lower than 0. This suggests that the more the congestion fee imposed on private cars, the less probability that travelers choose private cars.

(4) Parking fee of private cars: the regression coefficient of this factor is -6.029, which is lower than 0. This suggests that the more the parking fee imposed on private cars, the less probability that travelers choose private cars.

(5) Difference of travel time between private cars and public vehicle: the regression coefficient of this factor is 60.599, which is greater than 0. This shows that as the travel time of private car decreases or the one of public transportation increases, the travelers are more likely to choose private cars. That is the same as the results of the above comparative studies, such as Zhou et al. [17], Xu et al. [14], Han et al. [15], and Zhu et al. [9].

(6) The waiting time of public vehicle: the regression coefficient of this factor is -173.493,

which is lower than 0. This shows that the increase of waiting time of public transportation actually decreases the probability that the traveler choose private cars. This result seems to be contrary to the reality, so we would perform further research on it.

The results give some method to induce travelers' travel mode choice. For example, when the government wants more people to choose the public transportation as their travel mode, the government shall shorten the travel distance, shorten (increase) the travel time of public vehicle (private cars), decrease (increase) the travel cost of public vehicle (private cars), and increase the parking fee and congestion fee of private cars. However, some of them are difficult to put in practice, such as the travel distance. Therefore, the decision makers can achieve this abduction only through reducing the public traffic cost, shortening the travel time of public vehicles, and increasing the congestion fee and parking fee of private cars. Furthermore, according to the coefficient of each variable, when the travel cost of private cars (public vehicles) increases (decreases) $1, its contribution to y is 39.84, which is equivalent to the amount when congestion fee increases by $15.29, or when parking fee per day increases by $6.61, or when travel time of private cars (public vehicles) increases (decreases) 0.68 hours.These figures indicate that the increase of parking fee of private cars is more effective to encourage more travelers to choose public vehicles than the increase of congestion fee does if increasing amount is the same. However, this conclusion is directly obtained according to the formula (8), so the relations among variables are ignored. For example, when the congestion fee for private cars increases, part of the travelers will no longer use private cars and choose the public vehicles. The traffic flow on the road at this time will decrease, and the road will become smoother, thereby reducing the travel time of public vehicles. Therefore, when the congestion fee is increased by $1, its contribution to the y will be greater than 2.605. The reason for this result is that the data collected by questionnaire are stationary, i.e. it only tells how a single variable affects the traveler's choice given that the other variables are fixed, and fails to induce the respondent such change in this variable will also affect the other variables so that the impact of this variable on the choice is more than the change of itself. Therefore, the major contribution of formula (8) is to reveal which factors play important roles on the travel choice, and stationarily point out how they work.

5. SENSITIVITY ANALYSIS

In order to obtain the influence of each factor on the choice of travel mode, sensitivity estimation of variables is conducted in this paper. Through the analysis of flexibility, we can get the influence of each variable on travelers' choice [18].

According to the theory of Logit model, when the k-th factor changes, the formula of the changing rate of traveler i's choice is:

$$E_{X_{ik}}^{Pr_{in}} = \lim_{\Delta X_{ik} \to 0} \frac{\Delta Pr_{1n}/Pr_{1n}}{\Delta X_{ik}/X_{ik}} = \frac{\partial Pr_{1n}}{\partial X_{ik}} \times \frac{X_{ik}}{Pr_{in}}$$

$E_{X_{ik}}^{Pr_{1n}} = \theta_k X_{ik} (1 - Pr_{1n})$ is the direct elastic value. $0 < \left|E_{X_{ik}}^{Pr_{1n}}\right| < 1$ indicates that flexibility is insufficient, i.e., Pr_{1n} is not sensitive to the change of factor X_{ik}. $\left|E_{X_{ik}}^{Pr_{1n}}\right| = 1$ indicates the unit flexibility, i.e., Pr_{1n} has the equal changing rate of absolute value with the change of X_{ik}. $\left|E_{X_{ik}}^{Pr_{1n}}\right| > 1$ indicates that the flexibility is sufficient, i.e., Pr_{1n} is obviously sensitive to the change of the change of factor X_{ik}.

We studied the travel mode selection of a portion of citizens in Ho Chi Minh City in 2013. This studied was conducted in parking lots, public transportation stations and the surrounding residential areas in the center of the city. In order to better reflect the travelers' behavior in Ho Chi Minh City, we only collected the data between 7:00 - 21:00 of the working days (from Monday to Friday). And, the investigation mode of face-to-face talking was used in this study.

6. THE PROBABILITY OF THE CHOICE OF TRAVEL MODE FOR THE RESIDENTS

According to the formula of the changing rate, under different congestion fees, the value of flexibility of each factor is different. In this paper, we let the average congestion fee vary from \$1.5 to \$2, and the parking fees respectively take the value of \$1.5, \$1.85, \$2 per day. Subsequently, we calculate the value of flexibility of congestion fees and parking fees. These results are presented in table 5, table 6 and table 7 together with the value of flexibility of affecting factors and the probability of the choice of travel mode.

6.1. Travel mode selection analysis under different congestion fee levels when the parking fee is \$1.5.

When the parking fee is \$1.5, the travel mode selection analysis under different congestion fee level is as shown in Table 5. When the average congestion fee is \$2, the direct value of flexibility of congestion fee on private car travel mode is -0.523, and the direct value of flexibility of parking fee is -0.909, namely the travelers choosing private car for travel have insufficient sensitivity on the change of average congestion fee. When the parking fee is \$1.5, the result of probability that the travelers continue to choose the travel mode of private cars can be seen in Figure 1.

Table 5. Direct elastic value and travel contribution rate of different average congestion fee and parking fee is \$1.5.

Average congestion fee (\$)	Average parking fee (\$)	Elastic value (Factors affecting X_{in9}~X_{in12})						Car sharing rate	Bus steering rate
		X_{in7}	X_{in8}	X_{in9}	X_{in10}	X_{in11}	X_{in12}		
1.5	1.5	1.438	0.330	-0.278*	-0.643*	-1.899	1.487	92.89%	7.11 %
1.6		1.531	0.351	-0.315*	-0.684*	-2.022	1.584	92.43%	7.57 %
1.7		1.636	0.374	-0.358*	-0.731*	-2.160	1.692	91.91%	8.09 %
1.8		1.753	0.408	-0.406*	-0.783*	-2.315	1.813	91.33%	8.67 %
1.9		1.885	0.440	-0.461*	-0.843*	-2.490	1.950	90.68%	9.32 %
2		2.033	0.471	-0.523*	-0.909*	-2.685	2.103	89.95%	10.05 %

Note: "*" represents that the value of flexibility only affects the travelers choosing the private cars travel mode.

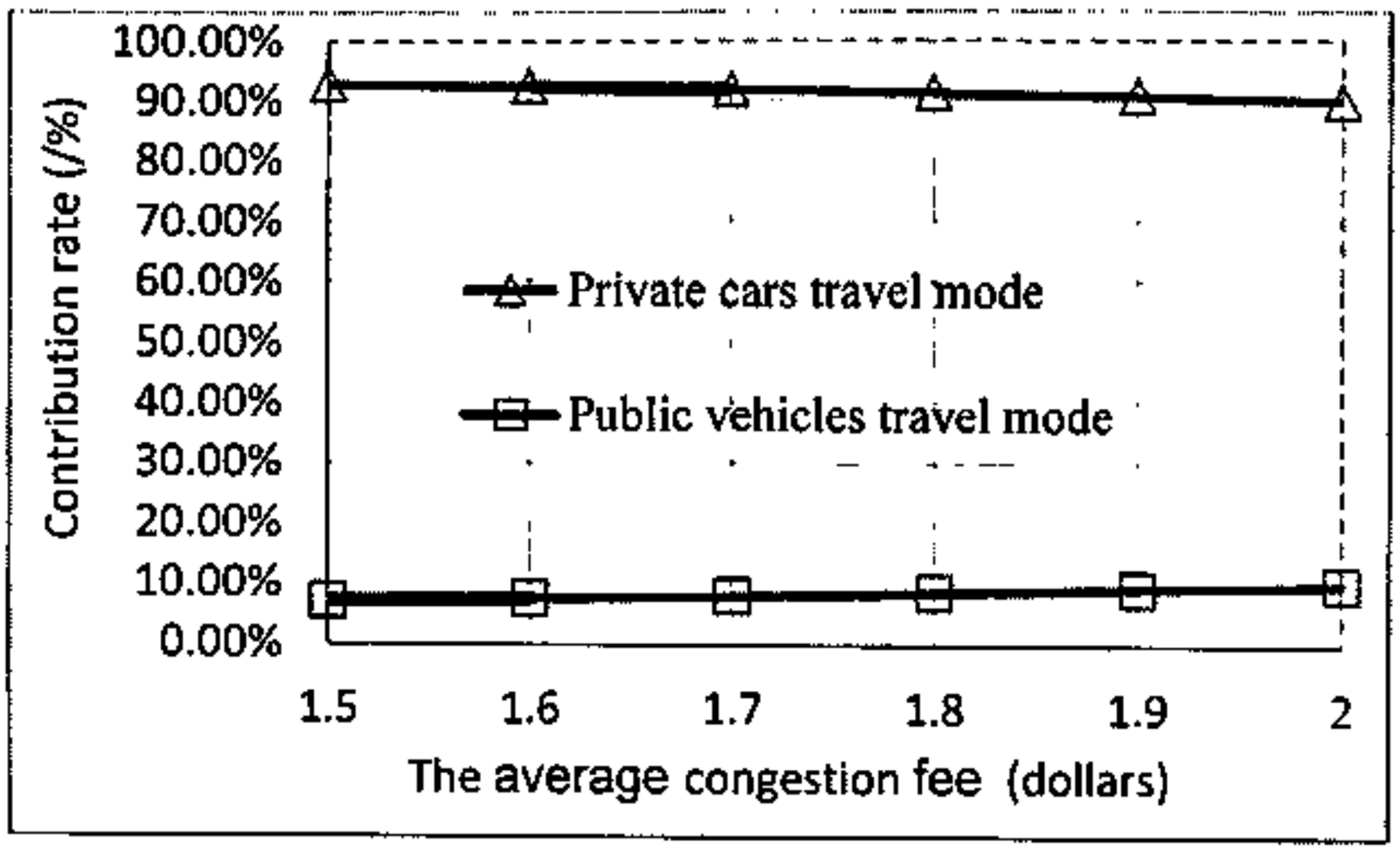

Figure 1. Mode of travel choice probability calculation results in the parking fee is $1.5.

As shown in figure 1, when the parking fee is $1.5 with an average congestion fee of $2, 89.95 % of travelers continue to go traveling by private cars, while 10.05% of them turn to choose public vehicles.

6.2. Travel mode selection analysis under different congestion fee levels when the parking fee is $1.85

Table 6 shows that when the average congestion fee is $2 and the parking fee is $1.85, the value of flexibility of congestion fee is -0.984, namely it is nearly sufficient flexibility. And the value of flexibility of parking fee is -2.109, namely it is sufficient flexibility. When the parking fee is $1.85, it can make some travelers prefer to choose the travel mode from private cars to public vehicles by adjusting the average congestion fee. The calculation of the probability for each travel mode is shown in Figure 2.

Table 6. Direct elastic value and travel contribution rate of different average congestion fee and parking fee is $1.85.

average congestion fee ($)	average parking fee ($)	elastic value (Factors Affecting X_{in9}~X_{in12})						Car sharing rate	Bus steering rate
		X_{in7}	X_{in8}	X_{in9}	X_{in10}	X_{in11}	X_{in12}		
1.5	1.85	2.596	0.596	-0.501*	-1.433*	-3.429	2.685	87.17 %	12.83 %
1.6		2.811	0.645	-0.579*	-1.552*	-3.712	2.907	86.11 %	13.89 %
1.7		3.041	0.695	-0.665*	-1.679*	-4.016	3.145	84.97 %	15.03 %
1.8		3.286	0.765	-0.761*	-1.814*	-4.340	3.399	83.76 %	16.24 %
1.9		3.546	0.827	-0.867*	-1.957*	-4.683	3.667	82.48 %	17.52 %
2		3.820	0.886	-0.984*	-2.109*	-5.045	3.951	81.12 %	18.88 %

Note: "*" represents that the value of flexibility only affects the travelers choosing the private cars travel mode.

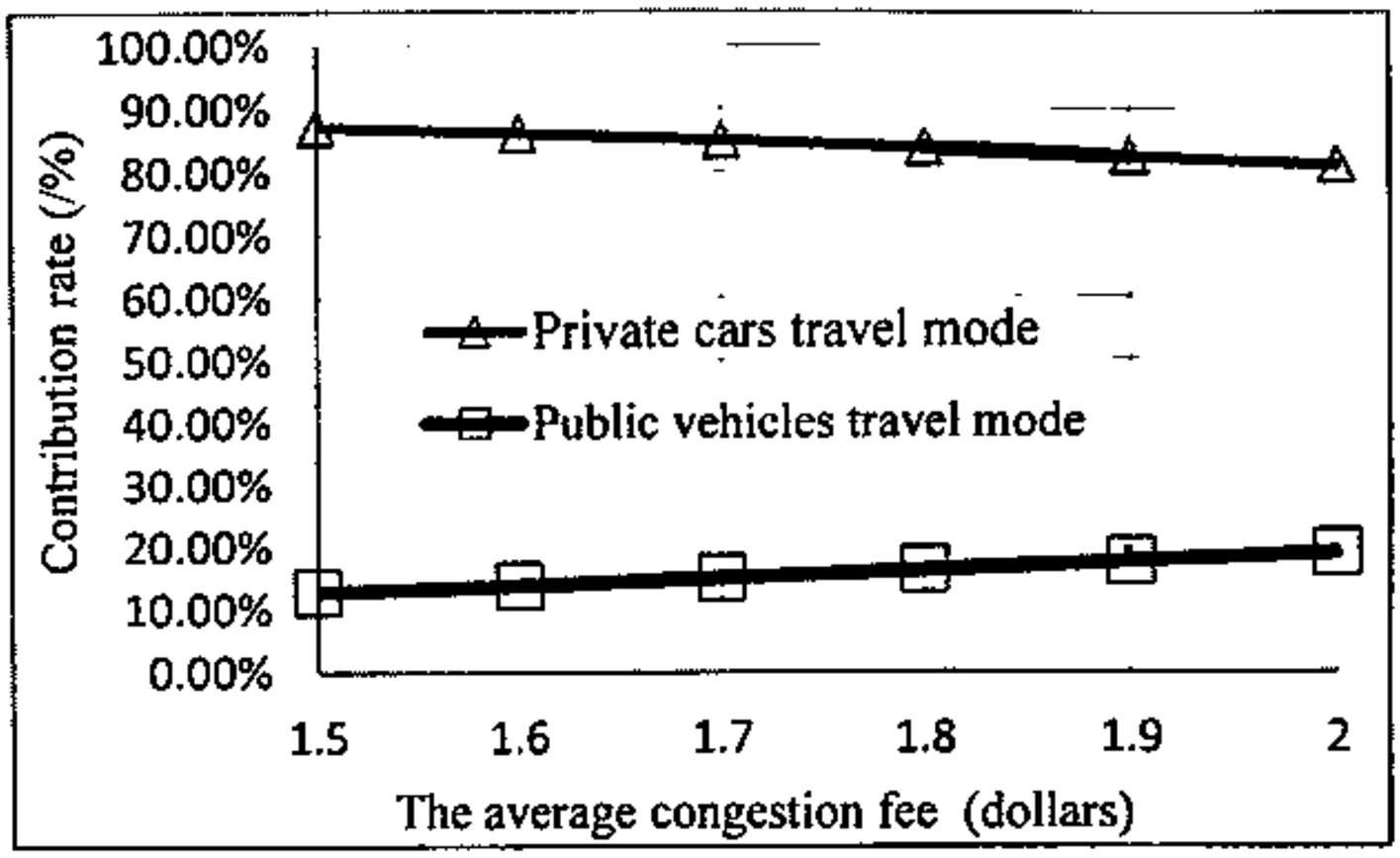

Figure 2. Mode of travel choice probability calculation results in the parking fee is $1.85.

Given that the parking fee is $1.85, when the congestion fee varies from $1.5 to $2, the sharing ratio of public vehicles travel mode changes from 12.83 % to 18.88 %, while the sharing ratio of private cars travel mode changes from 87.17 % to 81.12 %.

6.3. Travel mode selection analysis under different congestion fee level when the parking fee is $2

Table 7 shows that when the average congestion fee is $1.8 and the parking fee is $2, the value of flexibility of congestion fee is -0.985, namely it is nearly sufficient flexibility. And the value of flexibility of parking fee is -2.532, namely it is sufficient flexibility. When the parking fee is $2, the probability of travel mode selection for each mode is shown in figure 3.

Table 7. Direct elastic value and travel contribution rate of different average congestion fee and parking fee is $2.

Average congestion fee ($)	Average parking fee ($)	Elastic value (Factors affecting X_{in9}~X_{in12})						Car sharing rate	Bus steering rate
		X_{in7}	X_{in8}	X_{in9}	X_{in10}	X_{in11}	X_{in12}		
1.5	2	3.407	0.782	-0.658*	-2.030*	-4.499	3.523	83.17 %	16.83 %
1.6		3.673	0.843	-0.757*	-2.189*	-4.852	3.799	81.85 %	18.15 %
1.7		3.954	0.904	-0.865*	-2.356*	-5.223	4.090	80.46 %	19.54 %
1.8		4.250	0.989	-0.985*	-2.532*	-5.613	4.396	79.00 %	21.00 %
1.9		4.559	1.063	-1.115*	-2.717*	-6.022	4.716	77.47 %	22.53 %
2		4.882	1.132	-1.257*	-2.909*	-6.448	5.049	75.88 %	24.12 %

Note: "*" represents that the value of flexibility only affects the travelers choosing the private cars travel mode.

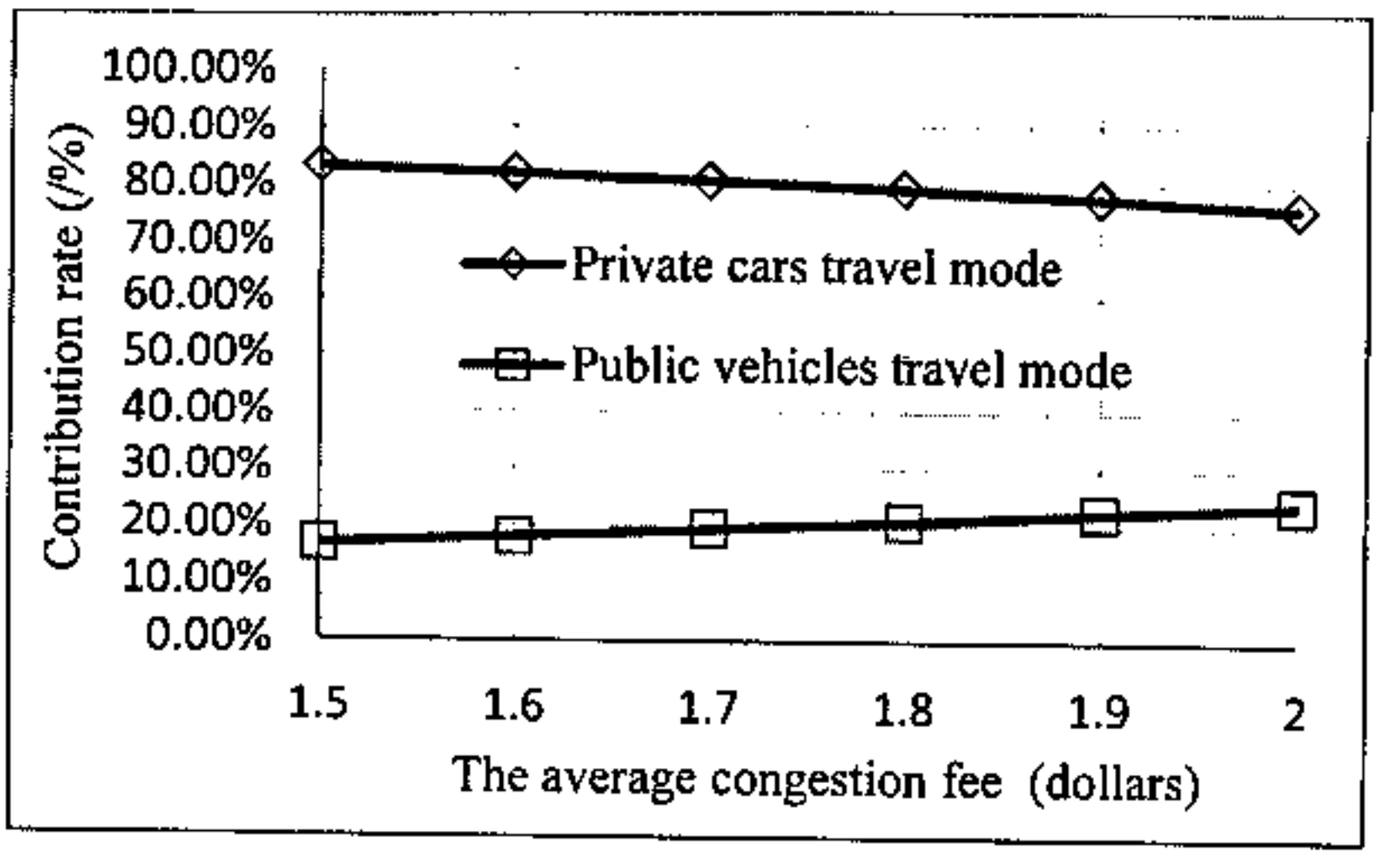

Figure 3. Mode of travel choice probability calculation results in the parking fee is $2.

6.4. Analysis

With the increase of congestion fee, the value of flexibility for private cars is increasing, which means that the travelers choosing private cars travel mode become more sensitive to the congestion fee and parking fee. In other words, the travelers choosing public vehicles travel mode become less sensitive.

The higher congestion fee is, the larger change of sharing rate will be. This indicates that with the increase of congestion fee and parking fee, travelers choosing private cars as travel mode have higher sensitivity on the congestion fee and parking fee, which is consistent with the results of flexibility analysis.

As for the traffic control in Ho Chi Minh City, the decision maker can induce more travelers to use the public vehicles via increasing the congestion fees and parking fees. For example, when the parking fee is $1.5, if the congestion fee increases from $1.5 to $2, then the sharing rate of public vehicles increases from 7.11 % to 7.11 %. When the congestion fee is $1.5, if the parking fee increases from $1.5 to $2, then the sharing rate of public vehicles increases from 7.11 % to 16.83 %.

From the perspective of traffic congestion fee and parking fee, we study the sharing rate of travel mode between private cars and public vehicles via on-the-spot investigation and the probability selection model. According to the investigation data of Ho Chi Minh City in 2013, when there was no congestion fee, the sharing rate of private cars on travel mode was 92.8 %, while that of public vehicle travel was 7.2 %. In the Logistic regression model, if the congestion fee is $2 and the parking fee is $1.5, the private cars travel model gets a sharing rate at 89.95 %, while public vehicles gets 10.05 %, and the travelers are sensitive to the changeof congestion fee or parking fee when making their decision on travel mode.

7. CONCLUSIONS

Based on the investigation on travel data of private cars and public vehicles in Ho Chi Minh City, we find out the affecting factors for travelers' choice on travel mode, model the utility difference of choosing private cars and public vehicles for travel, and establish the model to capture how travelers choose their travel mode. The existing literatures generally only consider the congestion fee or the parking fee, which is lack of comprehension. In order to solve

this problem, this paper considers the congestion fee and parking fee at the same time. Moreover, for the sake of convenience, we takes the difference of travel time and the difference of travel cost between private cars and publicvehicles as the condidate variables. Our model shows that when the difference of travel costs of private cars and public vehicles, congestion fee, and parking fee of private cars increased, the traveler will tend to choose public vehicles, which is consistent with the actual situation. Hence, our model not only characterizes the utility of travelers for each travel mode, but also can be used to improve the traffic management of the city.

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TÓM TẮT

NGHIÊN CỨU CÁC YẾU TỐ ẢNH HƯỞNG LỰA CHỌN PHƯƠNG THỨC LƯU THÔNG CỦA NGƯỜI DÂN TẠI THÀNH PHỐ HỒ CHÍ MINH

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Đối tượng nghiên cứu là xem xét đặc điểm di chuyển của người tham gia giao thông, thuộc tính của người tham gia giao thông và thuộc tính cơ bản của phương thức giao thông, thông qua khảo sát xác định chi phí lưu thông và thời gian lưu thông của phương tiện giao thông cá nhân và xe buýt công cộng, báo cáo này đã vận dụng phân tích hồi quy Logistic để điều tra hành vi lưu thông của người tham gia giao thông tại thành phố Hồ Chí Minh. Đặc biệt, kiểm tra mức độ ý nghĩa được sử dụng trong mô hình là 0,05. Thông qua mô hình này cho thấy rằng các yếu tố chính ảnh hưởng đến hành vi người tham gia giao thông là khoảng cách đi lại, sự khác biệt chi phí lưu thông giữa xe ô tô và xe buýt công cộng, chi phí ùn tắc giao thông, chi phí bãi đậu cho xe ô tô, sự khác biệt về thời gian lưu thông giữa xe ô tô và xe buýt công cộng và thời gian cho người tham gia giao thông đi bộ đến trạm dừng xe buýt. Hơn nữa, mô hình cho thấy rằng bằng cách tăng phí nhiên liệu, tăng phí đỗ xe và phí ùn tắc, làm giảm khả năng người tham gia giao thông lựa chọn xe ô tô lưu thông.

Từ khóa: lưu thông giao thông, lựa chọn phương thức lưu thông, chi phí lưu thông, Thành phố Hồ Chí Minh.