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Choice Behavior of Residents' Travel mode based on Mixed Logit Model: A Case Study of Riverside Garden Community

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Abstract

Effective low-carbon transportation policy making first needs to determine what factors affect residents' pattern choice behavior and how it can be intervened. In this study, based on mixed logit model, we analyzed the influence factors of residents' mode choice in Riverside garden community, which located in Suzhou of Jiangsu province. The results shows that age, income, number of families, travel time, travel purpose, travel expenses have a significant effect on the choice of residents' travel behavior. It helps decision-makers develop more effective mitigation strategies.

Keywords

Mixed-Logit model; Residents' travel mode; Low carbon transport.

1. INTRODUCTION

According to the International Energy Agency [1], the transport sector represent around nearly a quarter of global energy-related greenhouse gas emissions. What's more, vehicle ownership and travel demands grew rapidly, which is in turn accelerates transport carbon emissions. Facing the big challenge, most big cities, such as Beijing, have taken a series of measures to develop public transport and encourage residents to use lower carbon transport modes [2]. Travel mode choice is closely related to energy consumption, the modal shifts (MS) from car to foot/bicycle/subway able to play a significant positive influence on achievement of low carbon traffic [3].

More specifically, to formulate an effective low-carbon transport policy, it is first necessary to determine what are the main factors affecting residents' travel choice [4]. In conventional travel behavior theory, travel time is considered to be an important factor affecting the way of tourism, the private car often superior than public transport. The cost of time is the opposite of the cost of environmental pollution, the faster the mode of transportation, the greater the carbon emission, particularly on longer trips [5]. Residents' daily mobility is typically studied with travel surveys and travel diaries, and respondents are required to report their travel activities in a shorter time frame [6].

This study uses a mixed-Logit model to analyze the factors influencing of residents' travel mode choice of Suzhou residents by taking the Binhe Garden Community as an example. A questionnaire survey was conducted on March 15, 2018 to collect the latest data about residents' daily travel habits. The influencing factors on residents' travel choice from nine aspects (e.g. purpose of travel, travel expenses) had been considered, could provide references for public policy making.

The remainder of this paper is organized as follows: Section 2 describes the study area, Section 3 describes data collection and the methodology to find the factors influencing residents'

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mode choice. Section 4 presents the estimation results and discussion, and Section 5 concludes the research and discusses the solution.

2. STUDY AREA

We will focus on daily mobility originating from Binhe Garden Community, which was completed in 1999 and has three phases with 1,168 housing units. The community was located in the CBD core area of Shishan Road, Suzhou New District, and was adjacent to many commercial leisure facilities, including Dengwei Road Commercial Street, Darunfa, Shishan Yi Life Square, Shishan Road Commercial Circle, Longhu Times Tianjie, Golden Eagle Plaza, Suzhou Paradise, and Su Da Fu Second Hospital etc. In addition, Binhe Garden Community has access to the traffic environment, 500 meters near the tower park road station, riverside road station, a total of 26 bus lines and 5 public bike points. All manuscripts must be in English, also the table and figure texts, otherwise we cannot publish your paper. Please keep a second copy of your manuscript in your office.

3. METHODOLOGY AND DATA

3.1. Discrete Choice Model

In this study, we analyze the choice Behavior of Residents' Travel mode based on a mixed-Logit model, which has been widely used for choice-analysis including potential preference of Korean consumers for power generation resources [7], the choice of camping luxury [8] and fuel choices for cooking in China [9]. Utility theory is the basis for decision makers to choose behavior, which specifies the utility of choosing alternative as follows:

$$U_i = V_i + \varepsilon_i \tag{1}$$

Where εi is an extreme value of independently and identically distribution; Vi is observed part of utility, which is determined by variables Xk (k = 1,..., K).

$$V_i = \beta_{0i} + \beta_{1i} X_{1i} + \beta_{2i} X_{2i} + \cdots + \beta_{Ki} X_{Ki} \tag{2}$$

Different specifications of εi may result in different discrete selection models, in this study, because we chose a mixed logit, the formula is expressed in Eq. (3) and (4), as follows [4].

$$\varepsilon_i = \mu_i(\theta, \boldsymbol{Z}) + \omega_i \tag{3}$$

$$\mu_i(\theta, \boldsymbol{Z}) = \theta_{0i} + \theta_{1i} Z_{1i} + \theta_{2i} Z_{2i} + \cdots + \theta_{Mi} Z_{Mi} \tag{4}$$

Where M is the number of variables; ωi is the extreme value of identically distribution, θ = (θ1i, θ1i,..., θMi) is M random variables with a normal distribution of zero Z = (Z1i, Z2i,..., ZMi) M variables influencing εi. According to Byun and Lee (2017)[7], the mixed logit model is defined as:

$$P_i = \int \frac{e^{V_i + u_i}}{\sum_{j=1}^{J} e^{V_j + u_i}} \varphi(\theta) d\theta \tag{5}$$

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3.2. Data

3.2.1. Questionnaire survey design

Following existing studies, we used a questionnaire survey for data collection, including the basic personal attributes of the residents gender, age, monthly income, occupation, whether they own a private car, family structure, etc., travel information such as this trip destination, travel time, travel nature. Here, I chose 90 % confidence and 10% sampling error to determine the total sample size. First, families in Binhe Garden Community were also randomly chosen. Secondly, visit these families and ask family representatives (select only one family representative) to fill out the questionnaire to collect information about their last trip. Finally, 452 valid questionnaire samples were received, and the investigation time is from March 8, 2018 to March 15, 2018. Using symmetric coding, the attribute level and coding settings are shown in Table 1.

Table 1. Attribute level and coding

Attribute	code
Gender X_1	male: 1, female: -1
Age X_2	Under 20: -3, 20~35: -1, 35~45: 0, 45~60: 1, above 60: 3
Income X_3	under 3000: -3, 3001~6000: -1, 6001~10000: 0, 10001~30000: 1, above 30000: 3
Number of families X_4	1: -5, 2: -3, 3: -1, 4: 1, 5: 3, above 5: 5
Career X_5	retiree: -5, staff: -3, individual merchant: -1, student: 1 freelance: 3, other: 5
Whether own a private car X_6	no: -1, yes: 1
Commute time X_7	under 15mins: -3, 15~30: -1, 30~60: 1, above 1 hour: 3
Travel purpose X_8	entertainment: -3, work: -1, attend school: 0, life: 1, other: 3
Travel expenses X_9	free: -3 low level: -1, medium level:1, high level: 3

3.2.1 Sample description

Residents' travel options include bus, work, private car, subway, bicycle, and electromobile. The investigation was conducted in the Binhe Garden Community from March 7 to March 15, 2018, and 452 valid questionnaires were finally obtained, which meet the requirement of the total random sampling. Here, the basic personal attributes and travel behavior of the sample can be shown in Table 2.

4. RESUALTS

Based on valid samples, the statistical of residents' travel behavior characteristics, the results are shown in Figure 1. Obviously, the results show that the travel mode of private car from the most recent day dominated the total travel choice (around 31%), followed by subway, walk, electromobile, bus, and bicycle, which indicated a relatively green travel structure. A possible interpretation of the results is that the Binhe Garden Community belongs to the school district, is adjacent to the Shishan Central Business District (with many enterprises and administrative units) and .several schools. What's more, Binhe Garden has unique transportation conditions, located at the subway line of Line 2, and there are many bus lines passing by. More specifically, the purpose of using private cars is mainly to meet the needs of work (around a half), and part of it is for life trivia and entertainment.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202001_6(1).0018

Table 2. Sample data

Attribut	Option	Quantit	proportio	Attribute	Option	Quantit	proportio
Gender	male	224	49.60%	Career	retiree	57	12.60%
	female	228	50.40%		staff	181	40.00%
Age	Under 20	79	17.50%		individual	59	13.10%
	20~35	93	20.60%		student	62	13.70%
	35~45	144	31.90%		freelance	46	10.20%
	45~60	79	17.50%		other	47	10.40%
	above 60	57	12.60%	Time	under 15mins	104	23.00%
Income	under 3000	66	14.60%		15~30	100	22.10%
	3001~6000	101	22.30%		30~60	212	46.90%
	6001~10000	132	29.20%		above 1 hour	36	8.00%
	10001~3000	110	24.30%	Purpose	entertainmen	68	15.00%
	above 30000	43	9.50%		work	182	40.30%
Number	1	27	6.00%		attend school	57	12.60%
	2	22	4.90%		life	92	20.40%
	3	226	50.00%		other	53	11.70%
	4	100	22.10%	Expense s	free	148	32.70%
	5	77	17.00%		low level	41	9.10%
	above 5	0	0.0%		medium level	124	27.40%
Private owner	-1	230	50.90%		high level	139	30.80%
	1	222	49.10%				

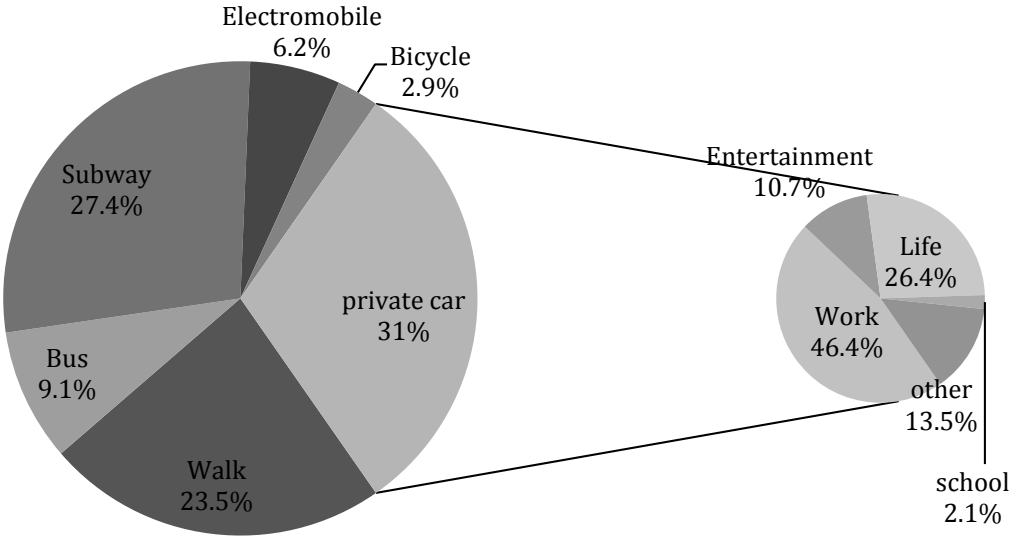

Figure 1. Proportion of different residents' travel modes and the travel purpose based private car

4.1. Parameter Estimation

Table 3 shows the parameter estimation taking electromobile as example. All statistical analysis was done by using SPSS software based on a mixed logit model. The results shows that men were 3.93 times more likely than women to choose electromobile in same situation, in addition, company staff and self-employed people tend to use battery cars more than other jobs, as well as work and entertainment for travel compared with other travel.

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202001_6(1).0018

Table 3. Parameter estimation: taking electromobile as an example

	B	Standard error	df	p	EX(B)
intercept	-100.524	1456.419	1	0.945	
gender = -1	1.369	1.401	1	0.328	3.933
gender = 1	0	.	0	.	.
age = -3	58.875	557.687	1	0.916	3.71E+25
age = -1	64.42	557.688	1	0.908	9.49E+27
age = 0	21.776	508.175	1	0.966	2.86E+09
age = 1	4.406	508.493	1	0.993	81.979
age = 3	0	.	0	.	.
Income = -3	12.584	670.682	1	0.985	291949.4
Income = -1	14.267	670.678	1	0.983	1571433
Income = 0	37.799	680.546	1	0.956	2.6E+16
Income =1	55.578	701.072	1	0.937	1.37E+24
Income =3	0	.	0	.	.
Number of families = -5	-21.731	115.534	1	0.851	3.65E-10
Number of families = -3	37.793	195.642	1	0.847	2.59E+16
Number of families = -1	-2.699	1.337	1	0.044	0.067
Number of families =1	-25.11	115.532	1	0.828	1.24E-11
Number of families =3	0	.	0	.	.
Career =-5	55.571	557.699	1	0.921	1.36E+24
Career = -3	-8.7	3.222	1	0.007	0
Career = -1	3.474	55.078	1	0.95	32.274
Career = 1	-4.206	3.504	1	0.23	0.015
Career = 3	-8.751	3.985	1	0.028	0
Career= 5	0	.	0	.	.
Whether own a private car = -1	-0.258	1.04	1	0.804	0.773
Whether own a private car = 1	0	.	0	.	.
Travel time =-3	32.459	1447.87	1	0.982	1.25E+14
Travel time = -1	28.997	1447.871	1	0.984	3.92E+12
Travel time = 1	29.767	1447.872	1	0.984	8.46E+12
Travel time =3	0	.	0	.	.
Travel purpose = -3	-4.63	2.425	1	0.056	0.01
Travel purpose = -1	-7.513	2.677	1	0.005	0.001
Travel purpose = 0	-3.129	2.915	1	0.283	0.044
Travel purpose =1	-8.353	2.69	1	0.002	0
Travel purpose = 3	0	.	0	.	.
Travel expenses = -3	5.297	955.796	1	0.996	199.829
Travel expenses = -1	-1.963	17554.99	1	1	0.14
Travel expenses =1	5.095	1649.967	1	0.998	163.16
Travel expenses = 3	0	.	0	.	.

4.2. Check Model

4.2.1. Model fitting information

Table 4 shows the model fitting information, it indicates that between chosen explanatory variable (e.g. residents gender, age, monthly income, occupation, whether they own a private car, family structure, etc.) and the behavior choice of residents' travel mode exist significant linear relationship, because of p = 0.00 (< 0.05).

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Table 4. Model fitting information

Model	Model fitting condition	Likelihood ratio test		
	-2 log likelihood	χ^2	df	p
Intercept only	1394.114			
ultimate	72.973	1321.141	145	0.000

4.2.2 Goodness of fit indicator

R-squared is been used to verify the effect of model simulation, the value generally range between 1 and -1. When the value is 1, it means that the model has a superior simulation effect, conversely, the model cannot be adopted reasonable (Yin et al., 2018). Table 5 shows the goodness of fit indicator. As expected, the value of R-square is very close to 1, it indicates that the model is suitable to find the residents' travel behavior characteristics.

Table 5. The value of R-squared

Model	*R*-square
Cox and Snell	0.946
Nagelkerke	0.991
McFadden	0.943

4.2.3 Likelihood ratio test

Table 6 shows the likelihood ratio test changes after the model introduces explanatory variables. As shown in the Table, age, income, number of families, travel time, travel purpose, travel expenses passed the significance test, which indicates the significant effect on the choice of residents' travel behavior. In order to achieve a greener travel structure and reduce energy consumption and carbon emissions pollution, we should further improve the advantages of public transportation and increase the share of public transportation, and achieve sustainable development.

Table 6. The results of likelihood ratio test changes

effect	**Model fitting condition**	**Likelihood ratio test**		
	-2log likelihood	χ^2	df	p
Intercept	72.973	0	0	.
Gender	74.712	1.739	5	0.884
Age	115.818	42.846	20	0.002
Income	112.445	39.472	20	0.006
Number of families	115.481	42.508	20	0.002
Career	100.419	27.446	25	0.334
Whether own a private car	76.389	3.416	5	0.636
Travel time	102.901	29.928	15	0.012
Travel purpose	116.709	43.736	20	0.002
Travel expenses	601.203	528.23	15	0.000

5. CONCLUSION

First, we found the travel structure of the residents of Binhe Garden Community is relatively healthy, with 31.0% private car trip. What's more, the green travel modes such as rail transit,

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electric vehicles and bicycles have been fully utilized. I think this can be attributed to the implementation of Suzhou green transportation policy. Of course, it is inseparable from the excellent location of the Riverfront Garden.

Besides, we analyzed the main influence factors of residents' travel behavior based on a mixed logit model. The results shows that age, income, number of families, travel time, travel purpose, and travel expenses had a significant effect on residents' travel behavior. Travelers with higher incomes and senior ages who have higher requirements for travel time often choose to travel by private car. For this group of people, the economic advantage of public transportation is no longer effective, it is necessary to improve the efficiency and comfort of public travel. At the same time, it will increase the publicity of low carbon transport transportation concepts and enable more people to join the ranks of green travel.

Green transportation is the trend of future traffic development. Last but not least, we proposed some method to promote the implementation of low carbon transportation. For example, (1) improve the transportation efficiency of all modes of transportation: we should strengthen road traffic management, standardize the driver's driving behavior to ensure the standard of traffic order, improve the urban road travel environment, thereby saving travel costs. (2) Improve public transport advantages: set up bus line on major roads to improve the speed of buses, and government departments should increase subsidies for public transport.

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