

Residents' Choice of Transportation Mode Based on Multiple Logit Model

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Abstract. In recent years, with the promotion of urbanization, China's urban structure has become larger and larger, and most cities have only one urban center. Commercial and residential areas are mainly concentrated in the city center, with high population density, which leads to great traffic pressure. Therefore, the factors affecting the residents' travel mode can be analyzed. The multiple logit model based on the random utility theory is used to analyze the travel mode of residents, and then the suggestions to improve the urban transportation facilities and land use mode are put forward, which is helpful to solve some urban congestion problems and reduce the urban traffic pressure. This paper takes Hangzhou, which is located in Zhejiang Province in East part of China as an example to analyze the travel mode of residents. Based on the investigation of local residents' choice of travel mode, three general travel modes, namely private cars, public transportation and non-motor vehicles, were selected as logarithmic model parameters for coefficient calibration, and the influence of gender, age, travel purpose, income and other factors on the choice of travel mode were analyzed. The study found that men are more likely to use private cars. The higher the monthly income, the higher the probability of private car travel. If the public transportation is more convenient in the place of departure and destination, the probability of choosing public transportation is also higher.

Keywords: Multiple logit model, Transportation, Travel mode choice, Land use.

1. Introduction

1.1. Research background

Nowadays in China, the urban scale is too large and the center of the city is too concentrated [1], which could result an unbalanced development of the city center and the suburbs. The population density in city center is too high and the traffic pressure is too large, so traffic jams often occur. As for the remote areas, although with low population density, the infrastructure and public transport are poor. This unreasonable intensity of urban land use leads to the imbalanced of urban development and many vehicles and public transport are concentrated in a certain area or road.

In this paper, Hangzhou is taken as an example to analyze the factors that affect residents' choice of travel mode. Hangzhou is an eastern city of China located in Zhejiang province and is one of China's new first-tier cities. According to the Hangzhou Comprehensive Transportation Special Plan (2021-2035), the goal of passenger transport is to form a "national 123 travel traffic circle" as shown in fig. 1. It means commute within the urban area of Hangzhou in 1 hour, connect Hangzhou to the major cities nearby in 2 hours and connect to major cities in China in 3 hours. By 2035, public transport will account for more than 35% of urban travel, green transport will account for more than 85% of urban travel, and car travel will be kept within 15% [2].

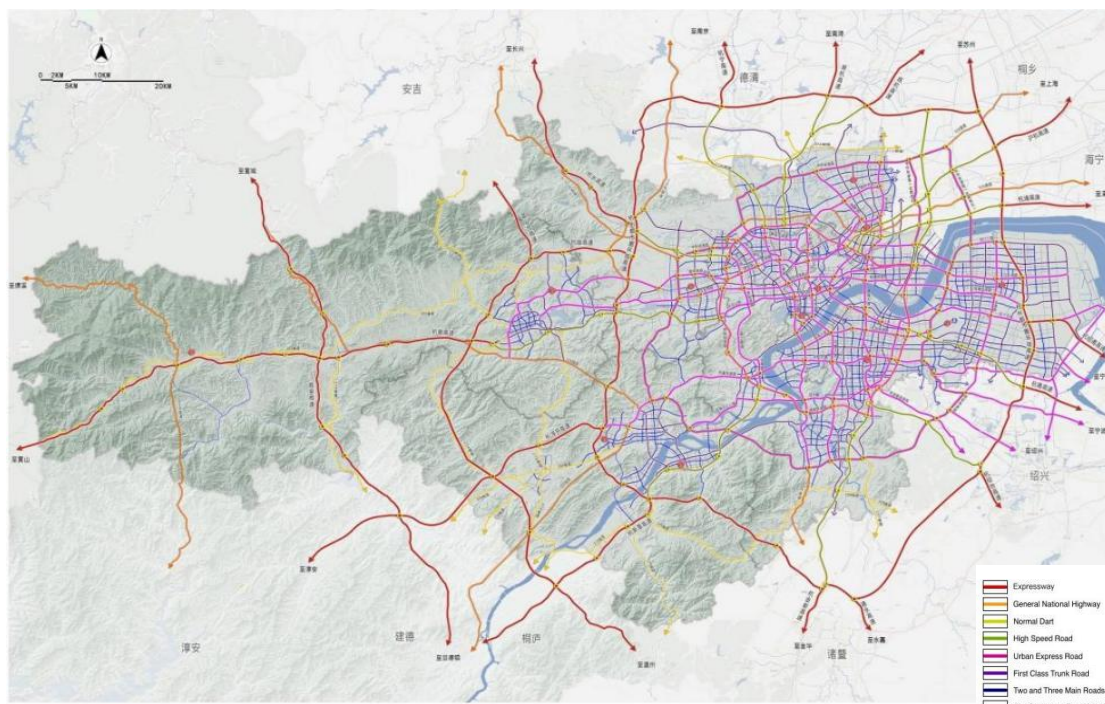


Figure 1. The traffic plan of Hangzhou City [3]

According to the long-term residents in the past population census, the population of Hangzhou was 8.7 million in the sixth census of 2010, and 11.93 million in the seventh census of 2020. Among them, the urban population was 7.53 million in 2010, and 10.71 million in 2020. The change of urban population is shown in the Fig. 2.

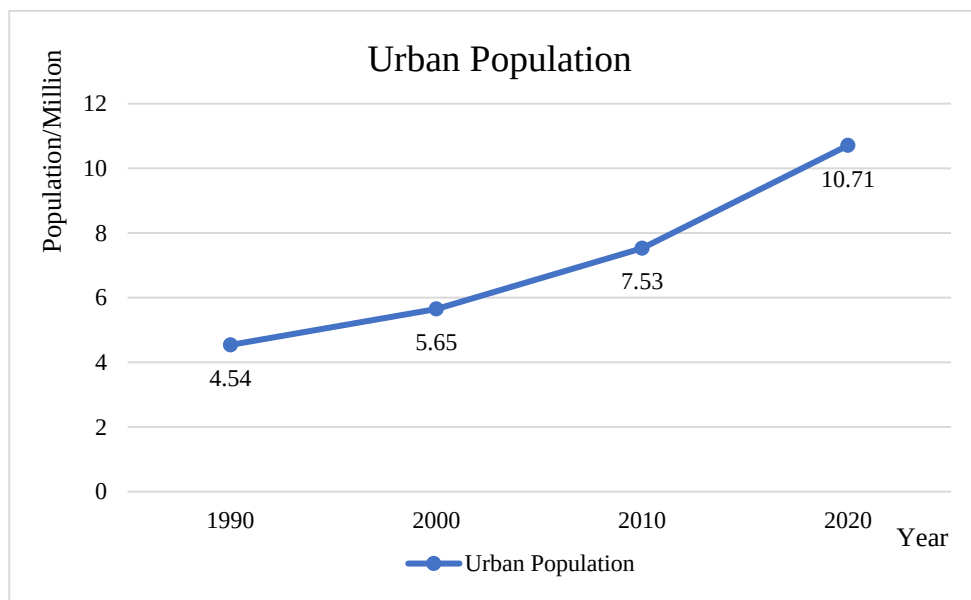


Figure 2. Urban Population (2021 Hangzhou Statistical Yearbook) [4]

As for the private car, with the development of cities, residents' requirements for quality of life are also increasing, which can be reflected in the increasing number of private cars. According to the 2021 Hangzhou Statistical Yearbook, the rate of family private car ownership among urban residents increased from 34.3% in 2012 to 65.3% in 2020. The growing population and the increasing number of private cars have put great pressure on urban traffic, especially during the rush hours, traffic jams often occur. The change in the number of private cars is shown in Fig. 3.

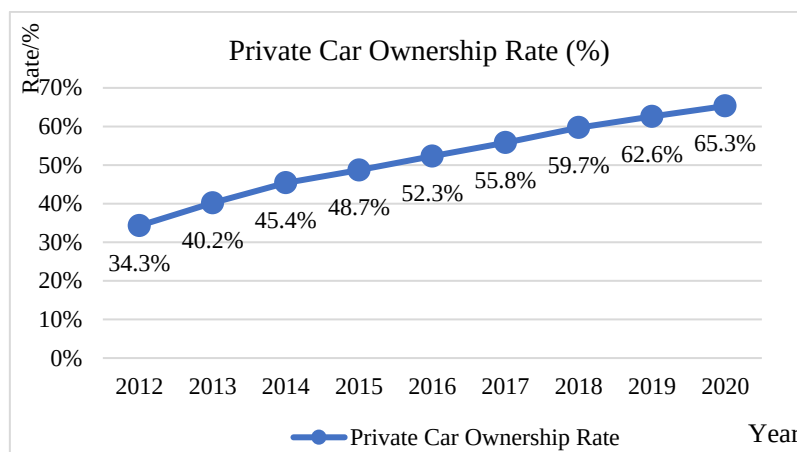


Figure 3. Private Car Ownership Rate (2021 Hangzhou Statistical Yearbook) [4]

1.2. Research motivation

Recent years, the process of China's urbanization and urban transportation have developed rapidly. But most urban structures in China adopt the single central structure, which is only one city center and generally located in the central area of city areas. This kind of distribution usually causes the unreasonable urban land use, makes the city center too centralized and the traffic pressure is greater. Especially now, the population is gradually moving from the countryside to the city, and the population density in the city center is getting higher and higher, which can result in the traffic congestion, environmental damage or other problems. Therefore, the cities of our country have gradually become "decentralized", and the central development areas of large cities have been undergoing corresponding transformation. Many traditional industries have been transferred to suburbs [5].

In view of the current situation, we can analyze the factors that affect residents' choice of travel mode and combine with land use policies to put forward methods to optimize the layout of land use and transportation, as well as suggestions to improve urban public transport facilities. All these are beneficial to the development of the city and traffic. Because they can ease the urban congestion caused by the rush hour and may reduce the use of private cars to improve the ecological environment.

1.3. Research objective

According to statistics, from 2000 to 2004, the number of public transport lines in operation in Hangzhou increased by 110%, and the length of operation increased by 125%. But the passenger volume only increased by 15% [6]. Although the government vigorously develops public transport facilities, the proportion of residents choosing public transport is still not high. From the perspective of travelers, this paper will conduct a sample survey of Hangzhou residents' recent travel information. The correlation and influence between independent variable and dependent variable were obtained by statistical analysis of the data and combining with multiple logit models. Then the correlation between the variables considered in this paper is verified by the parameter evaluation model. Finally, the paper analyzes the key factors that influence Hangzhou residents' choice of travel mode, and puts forward ways to improve traffic planning.

2. Methods

2.1. Multiple Logit Model

To analyzing the choices that affect residents' travel modes, Multinomial Logit Model (MNL) can be used [7]. This model is used to explain the travel decision-making behavior of travelers. The basic assumption of this model is that each individual is the basic unit to make the travel decision, which is free from the interference of external factors and every individual adheres to the principle of utility

maximization when making behavior choices. The application scope of MNL is that the dependent variable is a disordered variable, so three travel modes are selected as dependent variables in this research is conform to the modeling requirements of MNL.

The utility when the n th individual unit chooses to select branch i can be expressed as:

$$U_{in} = V_{in} + \varepsilon_{in} \quad (1)$$

In the formula, V_{in} is the utility fixed term of the observable element vector when the n th individual selection selects branch i . ε_{in} is the utility random term of the unobservable element vector when the n th individual selection selects branch i . In this research, alternative travel modes were selected, namely 1 (non-motor vehicle), 2 (public transport), and 3 (private car). Individual n is the total number of participants in the questionnaire survey.

When there is a linear relationship with explanatory variables included therein, then the equation is:

$$V_{in} = \sum_{k=1}^K \theta_k x_{ink} \quad (2)$$

In this research, i is 1 (non-motor vehicle) and 2 (public transport). K is the number of explanatory variables. θ is the parameter matrix. θ_k is the parameter corresponding to the k th variable. x_{ink} selects the k th characteristic variable of the i th activity mode for individual n .

Assuming that the random term of the utility function follows the double exponential distribution, the probability of the n th individual choosing i is:

$$P_{in} = \frac{e^{V_{in}}}{\sum_{j \in A_n} e^{V_{jn}}} = \frac{\exp(\sum_{k=1}^K \theta_k x_{ink})}{\sum_{j \in A_n} \exp(\sum_{k=1}^K \theta_k x_{jnk})} \quad (3)$$

The investigation case M = private car in Hangzhou is set as the reference class, which is as follows:

$$\eta_m = \log[P_r(m)/P_r(M)] \quad (4)$$

In the formula, P_r is the probability of the selection method, η_m is the logarithmic probability occurrence ratio of multiple logit model entering a class m (non-motor vehicle or public transport) relative to the entry class M (private car).

2.2. Data collection

In order to collect the data needed for this research, it is necessary to make a questionnaire about personal travel information for Hangzhou citizens. The questionnaire collected the travel information of Hangzhou residents by individual unit, including gender, age, mode of travel (i.e. private car, public transport and non-motor vehicle), purpose of travel (i.e. work, school, entertainment activities, etc.), monthly income, whether they own a private car, the distance from place of residence to destination, etc. The specific contents of the questionnaire are shown in Table 1.

Table 1. The questionnaire about travel information of Hangzhou citizens

No.	Question	Options			
1	Gender	☐ Man ☐ Woman			
2	Age	☐ 18~25	☐ 25~35	☐ 35~45	☐ ≥45
3	Monthly income	☐ <5000	☐ 5000~8000	☐ 8000~12000	
			☐ 12000~15000	☐ ≥15000	
4	Daily travel purpose	☐ Work	☐ School	☐ Entertainment activities	☐ Other
5	Whether have a private car	☐ Yes ☐ No			
6	Distance from place of residence to destination	☐ <5km	☐ 5km~10km	☐ 10km~15km	☐ ≥15km
7	Daily travel mode	☐ Private car ☐ Public transport ☐ Non-motor vehicle (Public transport include: bus, subway, etc.)			

2.3. Data processing

The analysis samples in this study were composed of residents over the age of 18, and were divided into five parts according to the monthly income of participants: less than 5000, 5000-8000, 8000-12000, 1000-15000 and more than 15000. According to the purpose of daily travel, it can be divided into work, study, recreational activities and other purposes. Since the multiple logit model is required to follow the principle that there is no correlation or minimal correlation between the variables, the influence of travel distance on travelers' choice of travel mode is ignored in this study. According to the 95 questionnaires collected, the statistics of sample variables are shown in the Table 2.

Table 2. Descriptive statistics of sample variables

Variable	Group	Symbol	Frequency	Proportion/%
Gender	0 (Woman)	WOMAN	48	50.5
	1 (Man)	MAN	47	49.4
Age	0 (18~25)	AGE	20	21.0
	1 (25~35)	AGEY	46	48.4
	2 (35~45)	AGEM	22	23.1
	3 (≥ 45)	AGEO	7	7.3
Monthly income	0 (<5000)	INCOME	13	13.6
	1 (5000~8000)	INCOMEUM	22	23.1
	2 (8000~12000)	INCOMEM	48	50.5
	3 (12000~15000)	INCOMELM	10	10.5
	4 (≥ 15000)	INCOMEL	2	2.1
Daily travel purpose	1 (Work)	WORK	76	80.0
	2 (School)	SCHOOL	13	13.6
	3 (Entertainment activities)	ENTERT	5	5.2
	4 (Other)	OTHER	1	1.0
Daily travel mode	1 (Private car)		57	60.0
	2 (non-motor vehicle)		10	10.5
	3 (Public transport)		28	29.4
Whether have a private car	0 (No)	NCAR	22	23.1
	1 (Yes)	CAR	73	76.8

SPSS software was used to take travel mode as the dependent variable in the analysis model and other survey factors as independent variables [8]. Then, multiple logit models are calibrated. In this analysis, private cars are taken as the reference category, the utility parameters of non-motor vehicles and buses are calibrated, and each factor is compared to analyze the behavioral tendency of travelers. The evaluation indexes of multiple logit model using SPSS software are shown in Table 3.

Table 3. Likelihood ratio test

	-2 times logarithmic likelihood	Chi-square	df	p
Intercept	171.674			
Gender	171.524	0.150	2	0.928
Age	149.184	22.490	2	0.000
Monthly income	116.916	54.757	2	0.000
Daily travel purpose	157.288	14.386	2	0.001
Whether have a private car	119.740	51.933	2	0.000

The p value is analyzed. If the value is less than 0.05, it indicates that the model is effective. Otherwise, it indicates that the model is invalid. It can be seen from Table 3 that all models except gender are valid models. This indicates that gender is a meaningless independent variable in this analysis. The likelihood ratio test values of the whole data are shown in Table 4.

Table 4. Total likelihood ratio test

	-2 times logarithmic likelihood	Chi-square	df	p
Intercept	171.674			
Final model	93.564	78.109	10	0.000

As can be seen from Table 4, this analysis model is an effective model. Therefore, the parameter calibration results are shown in Table 5.

Table 5. SPSS parameter calibration results

	Non-motor vehicle			Public transport		
	regression coefficient	Wald	p	regression coefficient	Wald	p
Gender	-0.035	0.003	0.959	-0.178	0.149	0.700
Age	-1.000	3.937	0.047	-1.579	14.888	0.000
Monthly income	-2.682	17.413	0.000	-2.695	24.206	0.000
Daily travel purpose	0.560	0.541	0.462	1.554	10.158	0.001
Whether have a private car	-25.555	0.000	0.999	-24.851	0.000	0.999

3. Results

According to multiple logit model analysis, when the significant level p is less than 0.05, it indicates that the independent variable is significantly correlated with the dependent variable. When the significant level p is slightly greater than 0.05, it indicates that the independent variable is slightly correlated with the dependent variable. When the significant level p is significantly greater than 0.05, it indicates that there is no correlation between the independent variable and the dependent variable. Taking private cars as the reference class, it can be seen from Table 5 that gender and owning private cars are basically irrelevant to the choice of travel mode. The three dependent variables, age, monthly income and travel purpose, have obvious influence on the independent variables.

From the perspective of gender classification, men are more inclined to choose private cars than women. According to the seventh national census, the male to female ratio in Hangzhou is 52.08% to 47.92%, with slightly more males than females. Moreover, according to the Ministry of Public Security, PRC, the ratio of male to female drivers is 1.97 to 1 [9]. As a result, men are slightly less likely than women to choose public transport or non-motor vehicles. As for age, the survey samples were all adults over 18 years old. The results show that the proportion of people aged 18-25 choosing to use private cars is lower than that aged 25-35. Residents aged 18-25 are more likely to choose public transport or non-motorized travel. In terms of monthly income, the nodes with an income of about 5,000 yuan are divided into different travel behavior tendencies. The higher the monthly income, the higher the proportion of people with private cars, and therefore more likely to choose to use private cars to travel. Those with a monthly income of less than 5,000 are more likely to use public transportation to travel. In the purpose of travel, the residents whose purpose is to work are more inclined to use private cars to travel. Public transport and non-motorized travel are more common among residents for school and entertainment activities purposes.

4. Discussion

In terms of transportation, we should strengthen the construction of public transport facilities in the suburbs and promote the coordinated development of rail transit, buses and walking roads. Strengthen the infrastructure construction around the track station, such as the development of commercial and residential areas. Or set up track stations and bus stops around the established commercial and residential areas with high population density, so that residents can choose to use public transportation. In addition, it is also necessary to establish a perfect transfer system, to realize

the interconnection between the stations, so that residents travel more convenient. For scenic spots, commercial areas and other areas with large traffic, a perfect public transport network should be established. Bus stops or shared bikes can be set up between areas that are close to each other. Control the flow of private cars in urban centers, and set up pedestrian walkways, underpasses and other facilities in areas with heavy traffic to reduce the direct contact between pedestrians and vehicles.

As for land use, we should strengthen the scale and efficiency of urban land agglomeration, strive to build a regional network land use pattern with central city land as the focus, suburban land as the support, central town land as the foundation, and high-grade highway land as the axis, so as to promote urban and rural integrated development and regional coordinated development [10]. In addition, parks, gardens and other scenic landscapes can be built in the central area of the city to make people more willing to choose walking or non-motor vehicle travel and improve the living environment of residents. The government can move some office space outside the central area to promote the development of the surrounding area and reduce the traffic and population pressure in the city center. For the villages and towns around the city, the new construction land should first choose to occupy the inferior land, no or less occupied farmland. Improve the infrastructure of villages and towns, make residents living in villages and towns more comfortably, reduce population migration, and relieve the population pressure inside the city.

5. Conclusion

Through the analysis, the main factors influencing Hangzhou residents' choice of travel mode are gender, age, monthly income and travel purpose. Most residents prefer to use private cars to travel, while those with lower monthly income or younger age will choose public transportation. A high proportion of people choose private cars to travel for work, which will cause great traffic pressure during commuting hours. Hangzhou should enhance the convenience of public transportation such as subway and bus to make it more convenient for residents to travel and use, so as to effectively relieve the traffic pressure of the city. Subway and bus stops could be placed around the residential, commercial and school areas. Through the analysis of the living range of residents who use the private car to travel, strengthen the construction of public transport facilities in these areas. Optimize the rules of vehicle use in urban centers, appropriately limit the traffic flow in areas with serious traffic congestion and optimize the setting of road facilities. In addition, more publicity is needed to encourage residents to choose green ways to travel and ease traffic pressure. The government also should improve the environment of the city center and set up some facilities such as footpaths and street gardens. In this way, residents are more willing to walk or use non-motor vehicles to travel in the small area. Due to the limited number of questionnaires, the data have certain particularity and the independent variables selected during the analysis have limitations. At the same time, the prediction accuracy of MNL (Multiple Logit Model) is limited, and it is easy to be affected by the unobserved deviation, resulting in the error of analysis results. Subsequently, ANN (Artificial Neural Networks) and PNN (Probabilistic Neural Networks) can be selected for more accurate predictive analysis.

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