Research Article **AJTL 2018,1:6**

American Journal of Transportation and Logistics
(DOI:10.28933/AJTL)

Factors Affecting E-bike Mode Choice in a Medium-sized Chinese City

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ABSTRACT

Chinese medium-sized cities have different travel characteristics compared to big cities. And as the rapid development of e-bike in China, some problems such as transportation safety has been discussed by scholars. This paper examines the factors affecting residents' travel mode choice in medium-sized city using travel survey data collected from residents in Zhongshan city. An estimated nested logit model of travel mode choice reveals that: (1) Older people prefer to travel by e-bikes than younger people. (2) Residents who own e-bikes tend to choose e-bikes, while not other vehicles. And the profession of people who prefer to travel by electric bicycle the white collar and blue collar. (3) About the attitude of Zhongshan residents to choose the way of transportation, the e-bike is considered the least safe, and electric bicycle users are concerned about the improvement of bicycle lanes. (4) The influence of built environment in the place of origin and the place of destination on the choice of e-bikes is different. (5) There is a substitution effect between e-bikes and traditional bicycles. The results strongly suggest that e-bike is a kind of important transportation in Chinese medium-sized city, and it is likely to regulate e-bike by transportation policies.

Keywords: E-bike, Travel behavior, Medium-sized Chinese cities, Zhongshan

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How to cite this article:
Dong Meixuan. Factors Affecting E-bike Mode Choice in a Chinese Medium-sized City. American Journal of Transportation and Logistics, 2018,1:6.

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1. Introduction

People in developed countries think that the electric bicycle is a kind of green, healthy and efficient way to travel, while the developing countries regard e-bikes as a backward, cheap and unsafe travel tool. In China, the rapid development of the electric bicycle market has brought security risks to urban traffic, and the e-bikes whose highest speed over 25km/h are not allowed to travel on the road. Since 1999, Zhongshan began to restrict the new boarding of motorcycles in the city, and the total amount of control was about 350 thousand. On March 1, 2000, the motorcycles in the city were prohibited from running in the municipal districts. Limiting the use of motorcycles has created opportunities for the rapid growth of e-bikes. The number of e-bikes in Zhongshan has increased rapidly since Zhongshan announced that e-bikes were allowed to travel on the road ion January 5, 2005. In August 2009, the number of e-bikes in the city reached 150 thousand. In 2012, compared with 2009, the share of e-bikes in Zhongshan increased significantly from 7.7% to 15.0%.

This paper presents an empirical study of the travel behavior of medium-sized city in China, based on data for Zhongshan. The research aims to answer two questions. First, what are the travel characteristics of e-bike riders living in the medium-sized city? Second, what factors are associated with residents' e-bike mode choice?

2. Literature review

Several bodies of literature are highly relevant to this research, and selected publications in each are reviewed here. One body of literature is on travel behavior in Chinese midium-sized cities. Another, drawn primarily from contributions by American and European researchers, presents characteristics of e-bike travelling. A third strand of literature examines factors influencing peoples' travel mode choice.

2.1 Travel behavior in Chinese medium-sized cities

Compared with big cities, small and medium-sized cities have their own characteristics in transportation planning and transportation. There are few studies on the characteristics of traffic travel in small and medium-sized cities. Most of the existing studies are based on the survey data of some small and medium-sized cities, including the number of trips, travel mode, travel purpose, travel time, peak and distance. Zhang Tao (2005) analyses the survey results of Foshan and Lanxi residents and found that four kinds of traffic modes, walking, bicycle, motorcycle, and bus, accounted for about 90% of the trip, and the proportion of bus travel was very low. The highest proportion of trips is travel to home, followed by work, school, and shopping. Due to the small scale of these cities, residents spend most of their trip time between 10-20 minutes. And travel time has 4 peaks, morning peak, evening peak and noon peak (11-12 points and 13-14 points). According to the analysis of the travel characteristics of the residents in Xinyi city of Jiangsu, Li yajun (2010) draws a conclusion similar to that of the former, and concludes that the distance of the residents in Xinyi is mostly within the range of 3km-5km, which is the range of the competition between the electric bicycle and the public transport, the traditional bicycle and the motorbike. In addition, the travel of small and medium-sized cities showed relatively concentrated and relatively short travel peak, which is also related to the size of cities in small and medium-sized cities. Shen Junjiang et al (2011) analyzed the survey data of the residents' trip in Anning City in 2009 and compared with the characteristics of the travel characteristics of the residents in some big cities. It is concluded that the travel distance of the small and medium-sized cities is much shorter and the main travel purpose is the commute.

The above research is aimed at the analysis of the travel survey data of the residents in a certain city, while some scholars have compared the travel characteristics in several small and medium-sized cities, and summed up the general travel characteristics in small and medium-sized cities. For example, Liu Lanhui (2004) compared the traffic characteristics of Xiaolan town, Yueqing city, and Hangzhou city, and concluded that the travel times per capita of small and medium-sized cities are higher than those in big cities, and the proportion of bus travel is lower than that of large cities. Taking into account the advantages of e-bikes travel distance is greater than traditional bicycles, it is proposed to encourage the development of e-bikes in medium-sized cities. Liu Hong et al (2015) investigated the characteristics of the residents travel in different small and medium-sized cities, and found that the larger the population size of the city, the smaller the average travel times of the residents. The main purpose of the small and medium-sized city residents is to go home, school and work. The main travel mode is walking and bike and most of the travel time is below 30 minutes.

2.2 Travel characteristics of the e-bike

E-bike riders are generally older. A study in Austria shows that e-bike users are generally older and many are retirees (Wolf A et al., 2014). In addition, electric bicycle users are generally higher in income and education. A qualitative study in Sacramento found that electric bicycle users are older, more educated and relatively higher than ordinary people in California, and 94% of the respondents have used traditional bikes before (Popovich N, et al., 2014). An Australian study includes 529 electric bicycle users, with more than half of those over 40 years old, 47% of those who have a higher income than average, 94% with cars and 70% with a college degree (Johnson M et al., 2013). The study of Chinese traditional bicycles and electric bicycle users also shows that, although the e-bikes users belong to low and middle-income groups (An K et al., 2013), compared with traditional bicycles, the income and education of e-bike users are higher (Cherry C et al., 2007). In addition, some scholars have studied the use of e-bikes in young people in Holland and found that students have a positive attitude to the use of e-bikes, showing the potential of the use of e-bikes in young people (Plazier P A et al., 2017).

People are affected by many factors when choosing whether to use e-bikes, including travel demand, characteristics of e-bikes, and so on. Compared with traditional bicycles, the demand for manpower for e-bikes is lower (Plazier P A et al., 2017). Therefore, for those who can not make bicycle trips because of physical limitations, e-bike will be a good choice. Jennifer Dill (2012) has interviewed 28 electric bicycle owners in Portland, USA, and found that the majority of people using e-bikes were women, elderly and physically disabled, and the most important reason for their choice to use e-bikes was to travel far with relatively less manpower. But in terms of physical exercise, walking and traditional bicycles, were more effective than e-bikes (Kenworthy et al., 1996).

In addition, providing a convenient way of travel for people with limited physical strength, electric bicycle travel solves the problems of people who are reluctant to ride traditional bicycles and provide some advantages such as length of travel, flexibility, speed and so on (Fyhri A et al., 2015). There are many studies on the travel range and speed of e-bikes, such as Cherry C et al. (2009) research on the use of e-bikes in

Kunming and Shanghai, China. It is found that the travel distance of e-bike is longer than that of traditional bikes. In addition, the speed of e-bikes is 10%-15% higher than that of traditional bicycles. Therefore, the average travel time of e-bikes is very small. A study in Portland shows that e-bikes can achieve long distance trips that people cannot achieve by traditional bicycles (Dill et al., 2012). Popovich N et al. (2014) interviewed 27 electric vehicle users in the great kamento area and found that e-bikes have the advantages of speed and riding range compared to traditional bikes so that people with limited physical strength can use it. John MacArthur et al. (2014) analyzed similar issues through a network survey of 553 electric bicycle users and found that e-bikes can travel longer distances and carry more goods, which will also increase the frequency of bicycle travel.

As for travel purpose, many commuters used to ride by e-bikes. Mao Lin et al. (2006) analyzed characteristics of e-bikes in Beijing, Tianjin, Handan, Changchun, Ji'nan, and Hohhot, and found that the main purpose of the electric bicycle users is to go to work and school. The study of Paola Astegiano et al. (2015) also proves this. By analyzing the age and income of electric bicycle users, whether they have e-bikes, as well as analysis of their travel habits, they found that e-bikes riders have a high proportion of commuters, and they prefer car trips in occasional trips.

The substitution effect of e-bikes for traditional bicycles and motorcycles is obvious. E-bikes can replace traditional bicycles to travel far away (Paul A. Plazier et al., 2017). The first electric bicycle sharing project in the United States found that 11% of the electric bicycle travel replaced cycling, 58% replaced walking, and 11% did not replace (Langford, B. et al., 2013). In the medium-sized city, the e-bike is a major way of the short trip for residents. In addition, some scholars have discussed the substitution effect of e-bikes on public transport and cars, for example, Liu Xianteng (2011) analyzed the competition between different modes of traffic, and believed that the development of electric bicycle technology will lead to the advantages of public transport was replaced. Longyu Wei et al. (2013) specialized in the survey of the travel characteristics of China's non-standard e-bikes. The conclusion shows that the non -standard e-bikes are very competitive for public transportation and bicycles, and the users are more inclined to travel longer distances. Once an electric bicycle is not available, the user will turn to motor vehicle traffic. It is considered that the electric bicycle is a transit from a bicycle to a bus, a transit from a bus to a car, which can replace the travel of buses, cars, and traditional bikes (Cherry C R et al., 2016). However, it is also suggested that e-bikes have a strong substitution effect on traditional bicycles, while the substitution effect for cars and public transport is limited (Kroesen M, etc., 2017).

2.3 Factors influencing travel mode choice

There have been a large number of articles on the choice of travel mode, mainly analyzing the impact of the built environment on the choice of travel mode. The built environment usually includes land use, urban design, and traffic system (Crane R, 2000). The land use factor is of great significance to the choice of travel mode. Robert Cervero (1999) used the binomial model to analyze the choice of traffic model and added land use variables on the base model. It is found that the land use factor has a significant influence on the travel mode selection of Montgomery County in 1994. On this basis, Narisia Limtanakool et al. (2013) added travel time factors to the model analysis. Using the 1998 Holland national trip survey, two models were established. One was the basic model that only included the socioeconomic characteristics of the individual travelers and the land use variables at the origin of the trip. The other was joined into the time factor and the fitting degree of the model is greatly improved by the variable. It is found that the spatial allocation of land use and traffic facilities have a significant influence on the choice of medium and long-distance traffic patterns by analyzing social and economic factors, land use and travel time. In addition, urban design or urban form is also a factor affecting the choice of residents' travel mode. Tracy E. McMillan (2006) used binomial logit regression model to analyze children's choice of walking or bicycle to school, including neighborhood safety, traffic safety, public transport selection, social, cultural, attitude and so on. With the addition of urban morphology variables, the goodness of fit of the model is significantly improved and indicated that the urban morphological variables are the important factors influencing children's choice of school trip mode.

In addition, travel habits as an important factor have been discussed by many scholars. For example, Christian A. Klockner et al. (2002) used binary logistic regressions to investigate the data of 160 participants' travel modes in German Bochum, and test the importance of individual, social variables and habits on the choice of travel mode, and also found that the influence of social variables and habitus on travel choice was not significant. Bert van Wee et al. (2003) use the multivariate model, taking the travel behavior as a dependent variable, personal, family and land use variables as independent variables, preference as an additional independent variable analysis, and found that it will overestimate the importance of other variables without this variable. Some scholars also discuss habits as a medium variable, for example, Benjemin Gardner (2008) proposed that only regard the correlation coefficient significance as the main standard of model reliability will be misleading, because the purpose behavior correlation coefficient is hidden with the habit effect, and the habit will reduce the relationship between purpose and behavior.

It is also an important research topic to distinguish the influence of built environment and the residents' self-selection on the travel choice and to determine the relative importance between them (Krizek et al., 2003). Self-selection refers to the tendency of people to choose their place of residence based on their travel ability, demand, and preferences (Litman et al. 2005). Patricia L. Mokhtarian et al. (2008) summarized the methodology of self-selection research and thinks that the existing research methods can be roughly divided into seven categories: direct question, statistical control, tool variable model, sample selection model, joint discrete selection model, structural equation model and longitudinal design. Chandra R. Bhat et al. (2014) analyzed resident travel behavior by using multidimensional selection model, and proposed that because of the significant existence of self-selection effect, modeling of multiple selection processes in an independent model series is difficult to reflect the true relationship between selections. Kamruzzaman M et al. (2015) selected factors by factor analysis to control the self-selection before regression. Dick Ettema et al. (2017) found out travel attitude and travel as a location choice would affect the choice of travel mode, indicating that the attitude of travel is not sufficient to reflect the process of self-selection. In addition, John Humphreys et al. (2014) analyzed the travel choice of Greater Dublin

Area residents, it is found that self-selection is less important than land use, but it is also suggested that the choice of residents and the characteristics of residence should be taken into consideration when making land use and transportation policy.

3. Research design

3.1 Study areas and data

To examine the effects of the medium-sized city on e-bike choice, we decided to undertake an empirical study of Zhongshan, a China's medium-sized city. According to the most recent census, Zhongshan's population was 3.23 million in 2016 (China Bureau of Statistics, 2017). This paper adopts the data of residents' trip sampling survey in Zhongshan in 2012. The data included 31897 households, 104848 residents, and 282721 trips. The number of residents surveyed accounted for 3.32% of the resident population in Zhongshan in 2012, and the data recorded all the trips of residents from 4 a.m. to 12 p. m.

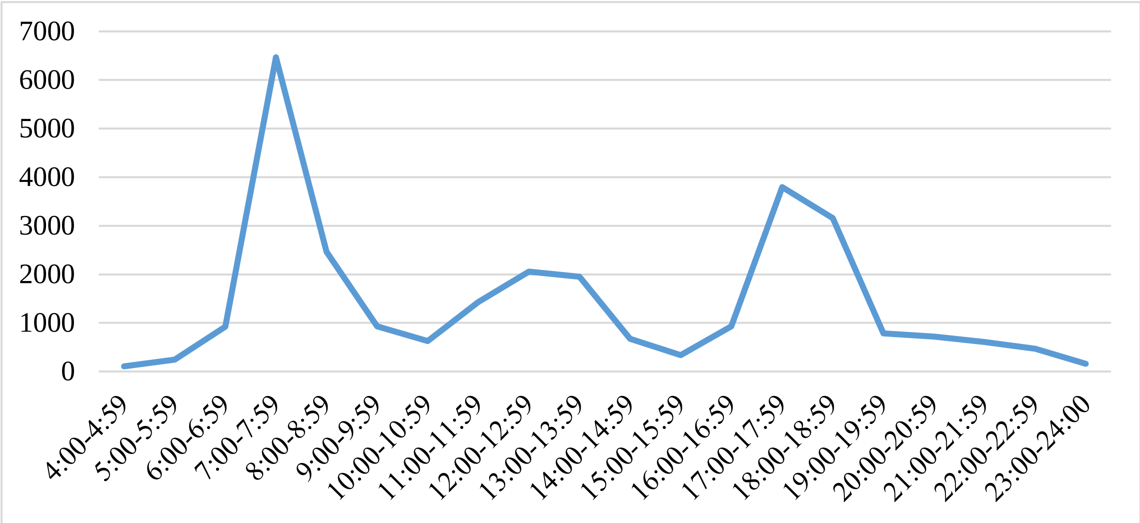
From Zhongshan residents' travel structure in 2012, as shown in Table 1, the highest proportion of travel mode in Zhongshan is the motorcycle, 30.89%. Bicycles (13.46%) and e-bikes (14.05%) also have a high proportion, more than cars (8.02%) and bus (4.38%). Two-wheeled traffic (bicycles, e-bikes, and motorcycles) account for a large proportion in Zhongshan, accounting for 61.4% of all travel. The proportion of motor traffic is 57.43%, and the proportion of motorcycles is much higher than that of cars. It can be seen that motorized traffic in Zhongshan is still dominated by motorcycles in 2012.

Table 1 Zhongshan residents' travel structure in 2012

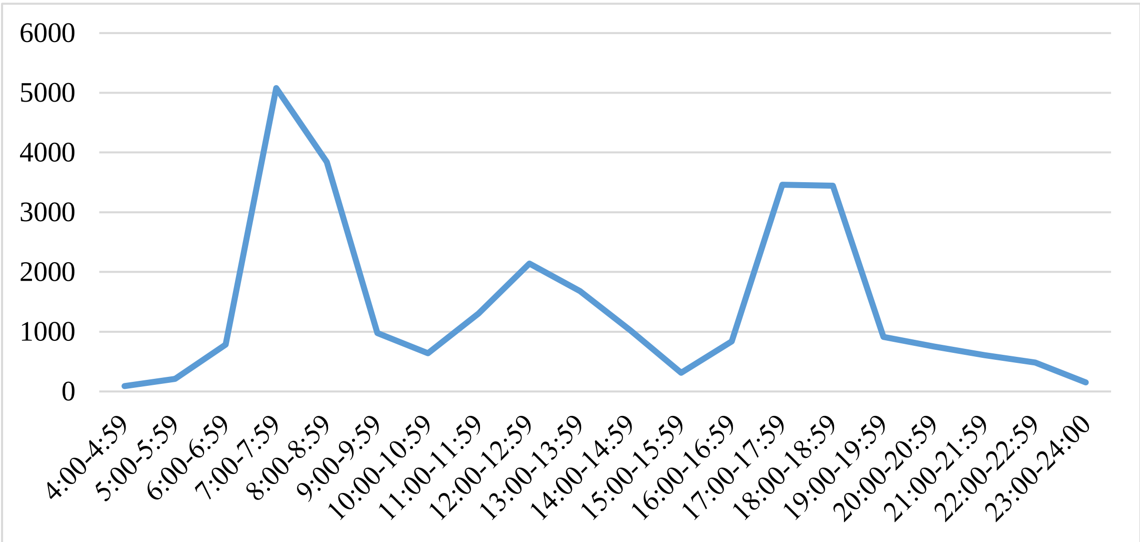
motorcycle	walk	bicycle	e-bike	car	bus	other	rail
30.89%	24.83%	16.46%	14.05%	8.02%	4.38%	1.27%	0.09%

The proportion of men and women in e-bikes is respective 50%. The age distribution of people using e-bikes was the largest among 21-30 years old, accounting for 31.45%, followed by 31-40 years old, which occupied 31.07%. It can be seen that the proportion of people using e-bikes under the age of 20 is very small, which is contrasted to bicycles, walking and bus trips. Compared with other modes of transportation, the proportion of e-bike riders who have Zhongshan's household registration is the smallest, only 30.55%. The proportion of blue collar in e-bike riders is higher than the blue-collar proportion in people choosing walking, bicycle, and motorcycles, while the proportion of white-collar and business owners is significantly lower than that of motorcycles and cars. Compared with motorcycles and cars, e-bike users may have a lower income, and e-bike users may have a higher income than walking, bicycles, and buses. The annual income distribution of e-bike users and motorcycles users is similar. The proportion of 2-2.9 million yuan is the largest, followed by 1-1.9 million yuan and 3-3.9 million yuan.

The main purpose of e-bike riders is to go home, followed by work and shopping. Compared with e-bike riders, the proportions of traveling to school in walking, cycling, bus, and rail are significantly higher. One possible explanation is that students who go to school rarely travel by themselves on e-bikes, and more likely parents ride e-bikes to pick up students. The starting time and arrival time of the electric bicycle in Zhongshan show a similar feature, that is, there are three obvious peak periods in one day - the morning peak, the evening peak, and the midday peak. The peak time is 7:00-8:00 in the morning, 17:00-19:00 in the evening, and 12:00-13:00 in the noon. Among them, the morning peak travel is more concentrated, while the late peak duration is longer.



(a) Travel time of e-bikes in origin



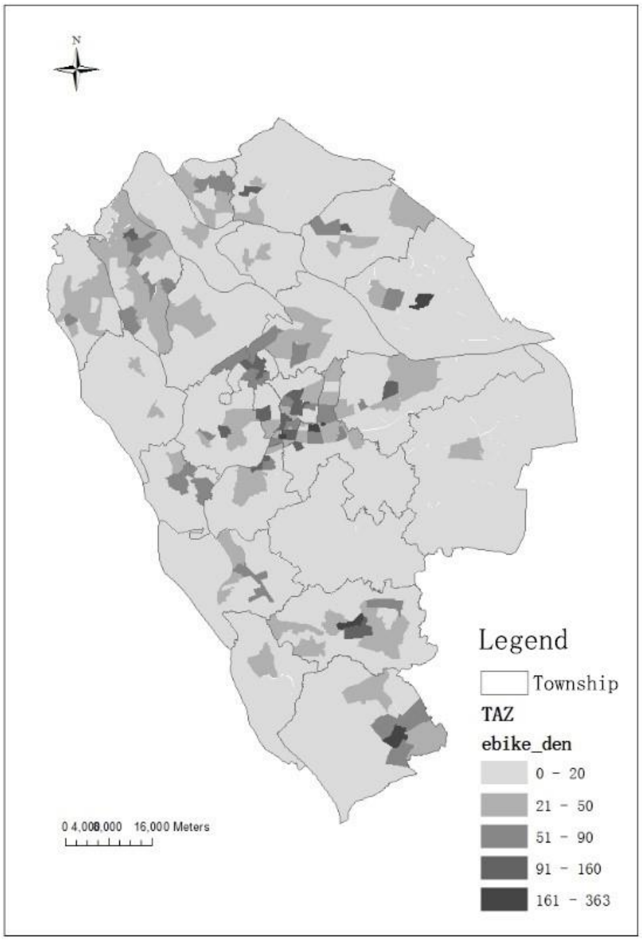
(b) Travel time of e-bikes in destination

Fig. 1 Travel time of e-bikes

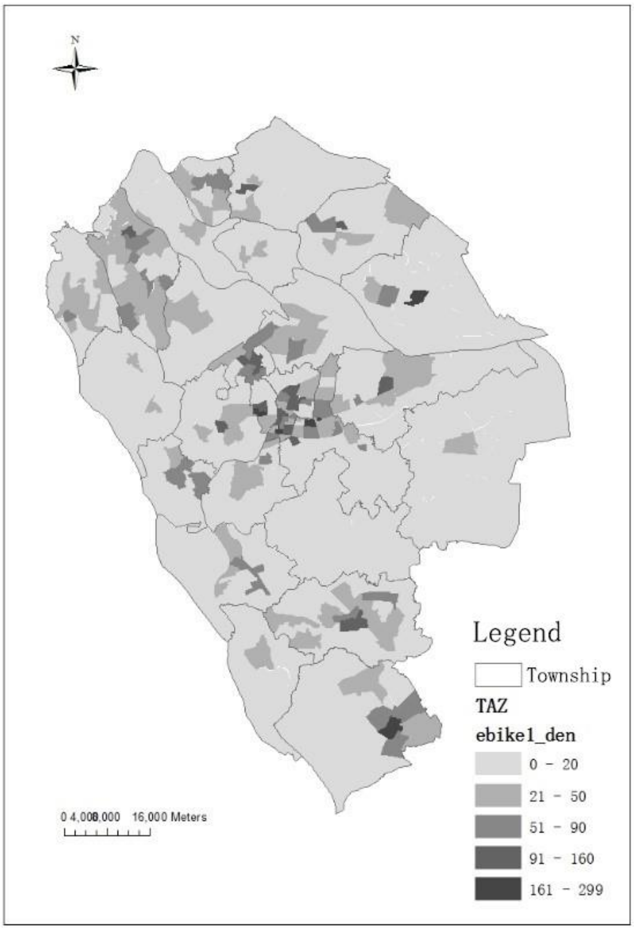
In the statistical analysis of travel time consumption, the maximum value of travel time is removed according to the mean plus three times the standard deviation, and the outliers are deleted. Assuming that the distribution of travel time consumption obeys normal distribution, this processing can remove about 1% of the abnormal data. From the average travel time consumption of all kinds of travel modes, the average travel time consumption of walk is the shortest, the average travel time of bikes, e-bikes and motorcycles are similar. As far as the towns in Zhongshan are concerned, the travel density of the e-bikes in the main urban areas is obviously higher, but there is also a high density of e-bike travel in the center of each district, as shown in Fig. 2.

Table 2 Average travel time consumption

walk	bike	e-bike	motorcycle	car	bus
13.37	15.33	15.32	15.55	19.59	28.37



(a) Travel density in the origin



(b) Travel density in the destination

Fig. 2 Travel density of e-bikes

Built environment was measured using GIS land use and road network data. Land use variables were quantified for each transportation area zone. These variables include the proportion of residential land, industrial land, commercial land and land use mixture in both origin and destination. And road network data include density of arterial road, sub-arterial road, branch road and expressway in both origin and destination.

The resulting dataset consists of 42 variables. Table 3 displays these variables, which are grouped into five categories, as well as their definitions. Research on the mode choice generally examined the built environment in the origin area of trips, while this paper focuses on comparing the difference between the influence of built environment in origin and destination area on mode choice, as we can predict that there will be significant impact of built environment on mode choice according to literate review.

Table 3 Variables and definitions

	Variables	Definitions
Dependent variables	Travel mode	Six primary modes were coded: walk, bike, e-bike, motorcycle, car, and bus; 1 for selected mode, 0 otherwise
Socio-economic factors	Gender	1 for male, and 0 for female
	Age	Age for respondent, in years
	Huji	1 for residents with Zhongshan huji, 0 otherwise
	Income	Annual income of respondent, in 10^4 ¥
	Car ownership	1 for households with a car, 0 otherwise
	Bike ownership	1 for households with a bike, 0 otherwise
	Motorcycle ownership	1 for households with a motorcycle, 0 otherwise
	E-bike ownership	1 for households with an e-bike, 0 otherwise
	White collar	1 for true, and 0 for false
	Blue collar	1 for true, and 0 for false
	Business owner	1 for true, and 0 for false
	Student	1 for true, and 0 for false
Travel	Peak	1 for true, and 0 for false
	Commute	1 for true, and 0 for false
	Distance	Length of the shortest path from origin to destination, in m
Attitude	Comfort	1 for selecting a mode because it is comfortable, 0 otherwise
	Convenience	1 for selecting a mode because it is convenient, 0 otherwise
	Safety	1 for selecting a mode because it is safe 0 otherwise
	Money	1 for selecting a mode because it is cheap, 0 otherwise
	Improve rail	1 for thinking rail should be improved, 0 otherwise
	Improve road	1 for thinking road should be improved, 0 otherwise
	Improve bus	1 for thinking bus should be improved, 0 otherwise
	Improve walk	1 for thinking walk environment should be improved, 0 otherwise
	Improve bike lane	1 for thinking bike lane should be improved, 0 otherwise
	Improve parking	1 for thinking parking should be improved, 0 otherwise
Built environment features	Origin residential land	Proportion of residential land in the origin
	Origin industrial land	Proportion of industrial land in the origin
	Origin commercial land	Proportion of commercial land in the origin
	Origin mixed land	Land use mixture in the origin
	Destination residential land	Proportion of residential land in the destination
	Destination industrial land	Proportion of industrial land in the destination
	Destination commercial land	Proportion of commercial land in the destination
	Destination mixed land	Land use mixture in the destination
	Origin arterial road	Density of arterial road in the origin, in km per km^2
	Origin subarterial road	Density of subarterial road in the origin, in km per km^2
	Origin branch road	Density of branch road in the origin, in km per km^2
	Origin expressway	Density of expressway road in the origin, in km per km^2
	Destination arterial road	Density of arterial road in the destination, in km per km^2
	Destination subarterial road	Density of subarterial road in the destination, in km per km^2
	Destination branch road	Density of branch road in the destination, in km per km^2
	Destination expressway	Density of expressway road in the destination, in km per km^2

3.2 Model specification

To address the second research questions, regression models are estimated to explain e-bike mode choice. Mode choice is modeled by applying the discrete choice framework. Six primary transportation modes are identified for this research: walk, bike, e-bike, motorcycle, car, and bus. Given these modes, the "independence of irrelevant alternatives"(ⅡA) property of the multinomial logit model may not hold because several modes are substitutes to some extent. Specifically, bike and e-bike are not independent choice alternatives. Therefore, the multinomial logit model may not be appropriate. Instead, we employ a nested logit model, which specifies a hierarchical structure of the choice alternatives such that ⅡA holds within each nest of alternatives but not across branched (Train, 2003). In this case, "bike and e-bike" is treated as a nest of alternatives, whereas "walk", "motorcycle", "car" and "bus" are independent alternatives. Thus, the resulting hierarchical structure has five branches of alternatives, as shown in Fig. 3.

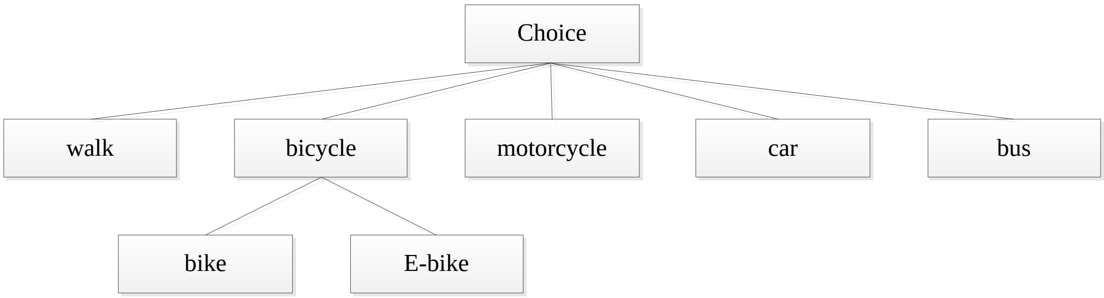


Fig. 3 Structure of the nested logit model

The choice probability for alternative i for person n, is shown in Eq. (1) (Train, 2003)

$$P_{ni} = \frac{e^{V_{ni}/\lambda_k}(\sum_{j \in B_k} e^{V_{nj}/\lambda_k})^{\lambda_{k-1}}}{\sum_{l=1}^{K}(\sum_{j \in B_l} e^{V_{nj}/\lambda_l})^{\lambda_l}} \quad (1)$$

Where V_{ni} is the observed utility that person n obtains from alternative i in nest B_k; similarly, V_{nj} is the observed utility that person n obtains from alternative j in nest B_l; λ_l is a measure of the degree of independence in unobserved utility among the alternatives in nest l. Each observed utility is a function of a vector of independent variables, which again include socio-economic, attitudinal and built environment measures but quantified for the individual traveler.

And the nested logit model is estimated using the R software.

4. Results

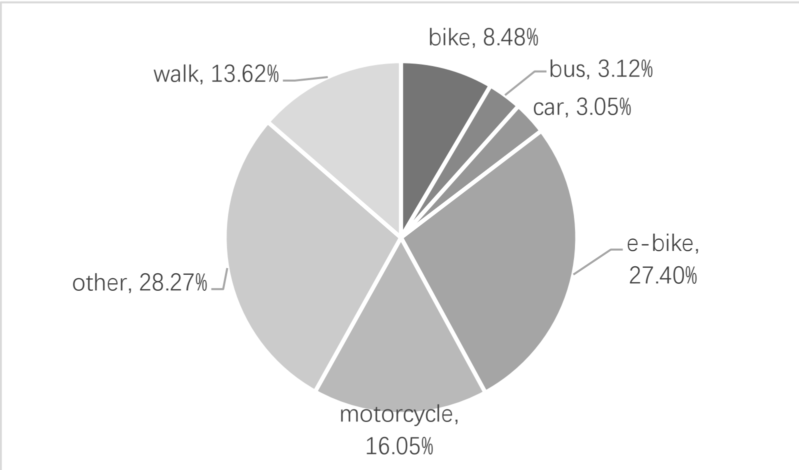
4.1 E-bike ownership and mode choice characteristics

Descriptive statistics for the independent variables to be included in the nested logit model are shown in Table 4. Impressively, there are 35% of respondents in Zhongshan city own e-bike, which is less than the proportion of owning bike and motorcycle but higher than that of owning car. The survey data indicated that there might be a significant relationship between e-bike ownership and travel mode choice. As shown in Fig.4, for households who own e-bikes, the proportion of e-bike mode choice is 27.40%, which is much higher than the proportion of e-bike mode choice for households who do not own e-bikes. Also, the results of nested logit model show that residents with e-bikes tend to choose e-bikes. Similarly, residents with cars, bicycles, and motorcycles tend to choose cars, bicycles and motorcycles respectively. It is worth noting that residents with bicycles are the least inclined to choose e-bikes as their travel mode.

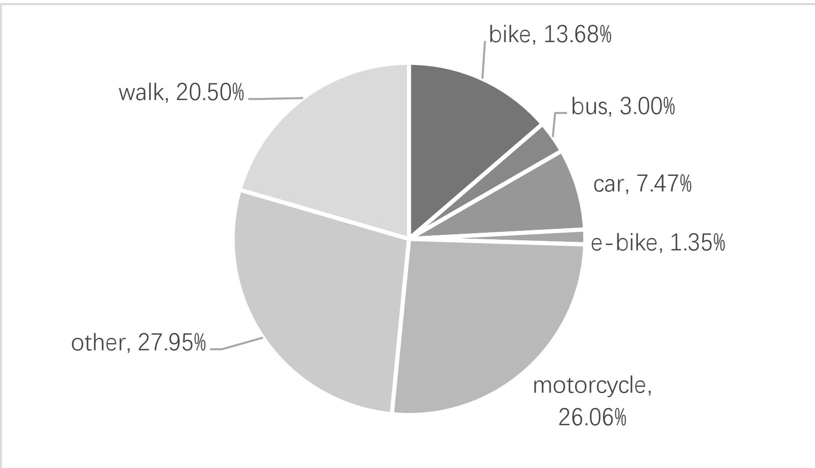
Table 4 Descriptive statistics of independent variables

		Mean	Sd	Min	Max
Socio-economic factors	Gender	0.53	0.50	0.00	1.00
	Age	35.28	13.86	0.00	101.00
	Huji	0.45	0.50	0.00	1.00
	Car ownership	0.20	0.40	0.00	1.00
	Bike ownership	0.52	0.50	0.00	1.00
	Motorcycle ownership	0.60	0.49	0.00	1.00
	E-bike ownership	0.35	0.48	0.00	1.00
	White collar	0.22	0.42	0.00	1.00
	Blue collar	0.40	0.49	0.00	1.00
	Business owner	0.10	0.30	0.00	1.00
	Student	0.08	0.28	0.00	1.00
	Income	2.53	1.89	0.00	12.00
Travel	Peak	0.47	0.50	0.00	1.00
	Commute	0.84	0.37	0.00	1.00
	Distance	2714.81	2998.22	223.35	51382.09
	Comfort	0.11	0.31	0.00	1.00
	Convenience	0.58	0.49	0.00	1.00
	Safety	0.07	0.26	0.00	1.00
	Money	0.15	0.36	0.00	1.00
	Improve rail	0.16	0.37	0.00	1.00
	Improve road	0.50	0.50	0.00	1.00
	Improve bus	0.78	0.41	0.00	1.00
	Improve walk	0.32	0.46	0.00	1.00
	Improve bike lane	0.14	0.35	0.00	1.00
	Improve parking	0.14	0.35	0.00	1.00
Built environment features	Origin residential land	0.34	0.19	0.00	0.74
	Origin industrial land	0.09	0.12	0.00	0.63
	Origin commercial land	0.06	0.07	0.00	0.54

Origin mixed land	0.44	0.15	0.00	0.81
Destination residential land	0.34	0.19	0.00	0.74
Destination industrial land	0.09	0.12	0.00	0.63
Destination commercial land	0.06	0.07	0.00	0.54
Destination mixed land	0.40	0.13	0.00	0.81
Origin arterial road	1.12	0.73	0.00	12.79
Origin subarterial road	1.48	0.98	0.00	6.12
Origin branch road	1.22	1.45	0.00	8.33
Origin expressway	0.30	0.52	0.00	3.24
Destination arterial road	1.12	0.73	0.00	12.79
Destination subarterial road	1.48	0.98	0.00	6.12
Destination branch road	1.22	1.45	0.00	8.33
Destination expressway	0.30	0.52	0.00	3.24



(a) Travel mode of households without e-bikes



(b) Travel mode of households owning e-bikes

Fig. 4 Residents' travel mode shares

4.2 Factors explaining e-bike mode choice

The results of nested logit model have been shown in Table 5, the social and economic variables, travel variables, attitude variables and built environment variables have the significant influence on Zhongshan residents' choice of travel mode. The reference of this model is e-bike so that we can compare the difference between the e-bike and other transportation modes.

The regression outcomes are reported in Table 5. The result indicate that: (1) Older people tend to choose e-bikes. Age is positive related to walk, while tis negative to bicycle, motorcycle, car and bus. E-bikes have electric power, and they are more labor-saving than bike. Besides, e-bikes are more portable and easy to operate than motorcycles and cars, which is suitable for older residents. (2) Those who prefer to choose e-bikes are white collar and blue collar. White collar workers consider whether to choose e-bikes only next to motorcycles and cars, and the blue-collar consider whether to choose e-bikes only next to bicycles and motorcycles. In addition, for students, e-bikes and motorcycles are the least likely way to travel. (3) All travel features are significantly related to transportation mode choice. (4) E-bikes are considered to be the least safe modes of transportation. There is significant positive correlations between safe and motorcycle, car, bus and walk which means residents think e-bikes are less safe than other kinds of transportation except for bike. Besides, e-bike is considered the most uncomfortable way of transportation except bicycle and bus. In terms of convenience, Zhongshan residents believe that e-bikes are easier to travel than bikes and less convenient to motorcycles. In addition, E-bike has no obvious advantage in terms of cost. Taking the cost of travel into account, Zhongshan residents prefer walking, bicycling and bus. (5) E-bike users are concerned about the improvement of bicycle lanes. The residents who think the bicycle lane needs to be improved are more inclined to choose bikes and e-bikes, indicating that the residents who use bikes and e-bikes are very concerned about the condition of the bicycle lane. In contrast, e-bike users do not care about whether the walking environment , road traffic, bus and parking environments need to be improved. (6) The influence of the built environment variables on the choice of e-bikes is different. The higher the mixture land use in origin area, residents are more inclined to choose bike, but not e-bike. As for the mixture land use in destination, this variable has a significant impact on each transportation mode, and the higher the mixture land use, the residents are more inclined to choose e-bike.

The regression outcomes strongly suggest that travel features influence their transportation mode choice. Most directly related to the purpose of this study is the highly significant is travel distance. The longer is the travel distance, the residents of Zhongshan are more inclined to choose motorcycles, cars, and buses than to choose e-bikes. Although there might be substitution effect between e-bikes and motorcycles, cars or buses according to the literature review, e-bikes are still difficult to meet residents' demand for long-distance travel. But Zhongshan is a medium-sized city in China, residents' trips might be shorter than those in big cities, which also shown in descriptive statistics that the average distance of respondents' trips is 2714.8 meters. Considering that there is not a huge demand for long distance trip, and the advantages of the e-bike, such as environmentally friendly, cheap, fast and less manpower, traveling by e-bike should be encouraged.

The regression results also indicate that the attitudinal variables are significant predictors of travel mode choice. And those results can provide suggestions for government to improve the whole transportation system. For example, concern for the improvement of the bike lane is negative related to other transportation modes other than the bike, which means bike and e-bike riders are concerned about if there are bike lanes to travel. Mixed traffic make some vulnerable transportation such as bike, e-bike, and motorcycle unsafe. To improve the safety of e-bike riders, separate e-bike traffic with motorized traffic is important. Besides, as the highest speed of e-bike being improved, it is worthy of consideration to separate the traffic of the bike and e-bike. In China, there have been several cities try to separate e-bike and other transportation by setting e-bike lanes.

In addition, the inclusive utility modeled is highly significant, indicating that the specified nested structure is appropriate to address the ⅡA issue.

The McFadden R^2 is 0.36576, which shows that the model performs very well in explain individuals' travel mode choice.

5. Conclusions

E-bikes in developed countries are regarded as a kind of environmentally friendly, healthy and efficient way to travel, while those in developing countries are considered as a kind of travel mode which is backward, cheap and unsafe. In China, the rapid development of electric bicycle market has brought security risks to urban traffic, so different urban governments have taken different measures to improve the safety of urban traffic. At present, most of the cities in China allow standard e-bikes to travel on the road, while prohibiting electric motorcycles which is also called non-standard e-bikes traveling. Some cities give electric motorcycles a grace period, such as Guangxi, Sichuan, Guizhou, Yunnan, Gansu, Xinjiang and so on, while other cities further limit the usage of e-bikes in some special areas, such as Beijing, Xiamen, Guangzhou, Shenzhen, Foshan, and Dongguan.

This paper reaches several conclusions. First, the total travel structure of Zhongshan city has a high proportion of two-wheeled transportation (bicycles, e-bikes, and motorcycles), reaching 61.4%. Zhongshan electric bicycle users are usually older, do not have Zhongshan household registration, blue-collar work, low annual income, and those electric bicycle users may not be able to grasp the traffic rules, which is easy to cause unsafe cycling when they ride e-bikes. Most of the electric bicycle travel is for commuting, and compared with other modes of transportation, the proportion of the travel aims to go to school is obviously lower. And the electric bicycle travel has obvious morning and evening peak, with a midday peak. Generally, the time consumption of the electric bicycle is less than 30min, and the average time consumption of electric bicycle is higher than that of walking and bicycle, while lower than that of motorcycle, car, and bus. Besides, the travel of electric bicycle in the space shows a high travel density in the main city, and the distribution of the travel density in other districts is also high. The dynamic changes in the electric bicycle show that the Zhongshan e-bikes usually travel in the same traffic area or adjacent traffic area. And the range of travel activities of e-bikes is similar to that of bicycles and motorcycles, while less than that of cars and buses.

Second, discrete choice models show that the socioeconomic variables, travel variables, attitude variables and built environment variables all have the significant influence on Zhongshan residents' choice of travel mode.

Table 5 Estimated nested logit model of travel mode choice

	Walk			Bike			Motorcycle			Car			Bus		
	Estimate	P value		Estimate	P value		Estimate	P value		Estimate	P value		Estimate	P value	
Intercept	4.88170	< 2.2e-16	***	0.91056	0.0000	***	0.64860	0.0000	***	-1.91050	< 2.2e-16	***	3.11850	< 2.2e-16	***
Gender	-0.12213	0.0000	***	-0.16643	0.0000	***	0.85041	< 2.2e-16	***	1.54990	< 2.2e-16	***	0.18486	0.0000	***
Age	0.00264	0.0149	*	-0.00593	0.0000	***	-0.03632	< 2.2e-16	***	-0.03011	< 2.2e-16	***	-0.03299	< 2.2e-16	***
Huji	-0.14095	0.0000	***	-0.19590	0.0000	***	0.73715	< 2.2e-16	***	1.23020	< 2.2e-16	***	0.33284	0.0000	***
Income	-0.20066	< 2.2e-16	***	-0.30212	< 2.2e-16	***	0.16962	< 2.2e-16	***	0.43336	< 2.2e-16	***	-0.16765	< 2.2e-16	***
Car ownership	0.17567	0.0000	***	-0.13142	0.0088	**	-0.04469	0.2727		2.46270	< 2.2e-16	***	0.18545	0.0005	***
Bike ownership	-0.12398	0.0000	***	-0.17240	0.0000	***	3.36120	< 2.2e-16	***	0.39803	< 2.2e-16	***	0.07078	0.0992	.
Motorcycle ownership	0.22001	0.0000	***	3.58130	< 2.2e-16	***	0.31826	< 2.2e-16	***	0.28144	0.0000	***	0.46831	< 2.2e-16	***
E-bike ownership	-4.10760	< 2.2e-16	***	-4.47180	< 2.2e-16	***	-3.94200	< 2.2e-16	***	-3.99510	< 2.2e-16	***	-3.85460	< 2.2e-16	***
White collar	-0.40863	< 2.2e-16	***	-0.09769	0.0705	.	0.27951	0.0000	***	0.41038	0.0000	***	-0.36262	0.0000	***
Blue collar	-0.45289	< 2.2e-16	***	-0.28532	0.0001	***	-0.00813	0.8762		0.54341	< 2.2e-16	***	-0.61819	0.0000	***
Business owner	-0.58522	< 2.2e-16	***	0.15957	0.0005	***	0.04166	0.2694		-0.44196	0.0000	***	-0.90569	< 2.2e-16	***
Student	0.80561	< 2.2e-16	***	1.35570	< 2.2e-16	***	-0.64516	< 2.2e-16	***	0.53397	0.0000	***	0.81976	< 2.2e-16	***
Commute	-0.30750	< 2.2e-16	***	0.14599	0.0007	***	-0.03844	0.2689		0.00471	0.9213		-0.50904	< 2.2e-16	***
Peak	-0.19167	0.0000	***	-0.09238	0.0027	**	-0.08154	0.0016	**	-0.07525	0.0349	*	-0.20876	0.0000	***
Distance	-0.00010	< 2.2e-16	***	-0.00002	0.0072	**	0.00003	0.0000	***	0.00009	< 2.2e-16	***	0.00013	< 2.2e-16	***
Comfort	0.20197	0.0005	***	-0.07323	0.3062		0.08692	0.1770		1.02140	< 2.2e-16	***	0.01422	0.8701	
Convenience	0.07103	0.0857	.	-0.12902	0.0123	*	0.17057	0.0004	***	0.11793	0.0928	.	0.03818	0.5559	
Safety	0.36321	0.0000	***	0.05553	0.4688		0.20772	0.0028	**	0.99883	< 2.2e-16	***	0.57778	0.0000	***
Money	0.25475	0.0000	***	0.11263	0.0693	.	0.09261	0.1079		-0.04600	0.6023		0.31787	0.0000	***
Improve road	-0.04635	0.0818	.	0.03972	0.2323		0.09388	0.0008	***	0.17269	0.0000	***	0.06414	0.1098	
Improve bus	0.00084	0.9807		0.03480	0.4195		-0.03621	0.3188		-0.08745	0.0604	.	0.20913	0.0001	***

Improve walk	0.11564	0.0000	***	0.07023	0.0403	*	-0.03381	0.2448		0.14130	0.0005	***	-0.06096	0.1477	
Improve bike lane	-0.13508	0.0003	***	0.14622	0.0009	***	-0.06550	0.0957	.	-0.17040	0.0027	**	-0.23732	0.0000	***
Improve parking	0.14374	0.0003	***	0.06937	0.1680		0.06579	0.1126		0.43244	< 2.2e-16	***	0.09480	0.1098	
Origin residential land	-0.07369	0.4955		-0.01592	0.9057		0.11589	0.2873		0.11539	0.4141		-0.09569	0.5105	
Origin industrial land	0.05667	0.7598		-0.06950	0.7623		0.45103	0.0172	*	0.67566	0.0097	**	0.01459	0.9564	
Origin commercial land	-0.24497	0.3953		-0.99468	0.0054	**	-0.38878	0.1838		0.16188	0.6676		0.35138	0.3826	
Origin mixed land	0.10080	0.4354		0.57171	0.0005	***	0.17858	0.1842		-0.21452	0.2389		-0.10065	0.6038	
Destination residential land	-0.19764	0.0591	.	-0.06880	0.5970		-0.01175	0.9107		-0.23975	0.0809	.	-0.31252	0.0273	*
Destination industrial land	-0.09004	0.5735		0.24279	0.2161		0.33519	0.0355	*	0.23652	0.2939		-0.01609	0.9421	
Destination commercial land	-0.02363	0.9263		-0.04284	0.8904		-0.32881	0.2018		-0.12589	0.6981		0.54449	0.1162	
Destination mixed land	-0.49185	0.0000	***	-0.28395	0.0141	*	-0.46492	0.0000	***	-0.44074	0.0030	**	-0.79322	0.0000	***
Origin arterial road	-0.06578	0.0045	**	-0.04464	0.1233		-0.06468	0.0057	**	0.04624	0.1062		-0.00057	0.9842	
Origin subarterial road	0.02238	0.2207		0.05027	0.0272	*	0.06365	0.0006	***	0.01524	0.4988		0.06154	0.0068	**
Origin branch road	0.03103	0.0489	*	0.05728	0.0031	**	0.04333	0.0062	**	0.00238	0.9071		-0.09207	0.0000	***
Origin expressway	-0.05321	0.1417		0.05654	0.1948		0.06501	0.0679	.	0.03085	0.5249		-0.04591	0.3519	
Destination arterial road	-0.03973	0.0856	.	-0.01837	0.5250		-0.05521	0.0178	*	0.06331	0.0254	*	-0.01156	0.6887	
Destination subarterial road	-0.00484	0.7899		0.05183	0.0219	*	0.04916	0.0075	**	0.00944	0.6733		0.07714	0.0006	***
Destination branch road	0.01982	0.2053		0.04205	0.0292	*	0.05163	0.0010	**	-0.00185	0.9272		-0.09939	0.0000	***
Destination expressway	0.00361	0.9204		0.07503	0.0855	.	0.10033	0.0049	**	0.07573	0.1173		-0.02535	0.6078	
Inclusive utility	1.37590	< 2.2e-16	***												

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Log-Likelihood: -126590

McFadden R^2: 0.36576

Likelihood ratio test : chisq =146010 (p.value = < 2.22e-16)

Older people prefer to travel by e-bikes than younger people. Residents who own e-bikes tend to choose e-bikes, while not other vehicles. And the profession of people who prefer to travel by electric bicycle are the white collar and blue collar. About the attitude of Zhongshan residents to choose the way of transportation, the e-bike is considered the least safe, and electric bicycle users are concerned about the improvement of bicycle lanes. Besides, the influence of built environment in the place of origin and the place of destination on the choice of e-bikes is different. In addition, there is a substitution effect between e-bikes and other modes of transportation, but the most obvious substitution effect is between e-bikes and traditional bicycles. As mentioned earlier, e-bikes can achieve longer distance travel and save manpower compared to the traditional bike.

These empirical findings have important implications for transportation policy and urban planning in Zhongshan, as well as other Chinese medium-sized cities. Firstly, residents' travel distance is shorter in medium-sized cities than that in big cities, so motorized transportation and public transportation such as rail usually lag behind in medium-sized cities. Therefore, e-bike has advantages in the transportation system of medium-sized cities, and the government should not prohibit e-bike traveling on the road. Secondly, results about residents' attitude and built environment provide approaches to regulate e-bike. The most impressive points are the relationship between mode choice and concern of safe, and improvement of the bike lane, which suggest the government that improve bike lane or e-bike lane might be an effective way to improve the safety of e-bike.

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