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Which one is more attractive to traveler, taxi or tailored taxi? An empirical study in China

Yujie Zhang^a, Hongwei Guo^{a*}, Cheng Li^a, Wuhong Wang^{a*}, Xiaobei Jiang^a, Yang Liu^b^a*Department of Transportation Engineering, Beijing Institute of Technology, Beijing 100081*^b*Beijing Transportation Research Center, Beijing 100073*

Abstract

Apart from public transit, urban citizens nowadays seek for the personalized travel mode more frequently to satisfy their ever-increasing travel demand. Tailored taxi, based on mobile internet technology, such as Uber in America and Didi-taxi in China, characterizing by its high quality service, is now rapidly expanding its market penetration worldwide. The new emerging tailored taxi challenges the conventional taxi industry. This study concentrates on the personalized travel choices between taxi and tailored taxi. The personalized travel choice is determined by personal characteristic and trip characteristic. Using stated preference technique, a questionnaire is design to acquire data on travel preference. Then the binary logit model is proposed to describe the preferences of traveler's personalized travel behavior. Next, the sensitivity analysis is performed to discuss the influence of different preference factors and individual's characteristics. Finally, the general features of taxi and tailored taxi users are described and the differential development strategies are proposed.

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1. Introduction

Traditional modes of car, bus and taxi are slowly beginning to lose market share to intermediate modes such as shared taxis, lift-sharing schemes and demand responsive transport service [5]. Facing the huge travel demand in urban city area, the newly emerging tailored taxi thrives in many parts of world. Horpedahl [7] gave a definition of

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .

E-mail address: guohongwei@bit.edu.cn, wangwuhong@bit.edu.cn

tailored taxi as follow. Transportation Network Companies, such as Uber Taxi and Lyft are now offering almost taxi levels of service through peer-to-peer models of dynamic lift-sharing operation, whereby ordinary drivers are giving people lifts in exchange for fares. Benefited by advanced internet technology, tailored taxi can be reserved by mobile phone conveniently, which significantly increase the possibility of hiring an exclusive car especially in the rush hour in metropolitan. Apart from reliable accessibility, tailored taxi is also known for its high-quality service and even the lower travel cost comparing to conditional taxi as the subsidy is included. However, the biggest obstacle of wide spreading tailored taxi lies in the confirmation of operating legitimacy. Besides, under the influence of the phase-out mechanism of subsidy in tailored taxi market, the increasing travel cost will inevitably undermined tailored taxi's market penetration. Moreover, there is still vacancy in the law regarding the passenger's right protection while they're travelling by private-owned tailored taxi. What's worse, the Uber's sexual assault case in India further arouses the concern for the passenger's security of tailored taxi. Although it can be found that the strengths and the weaknesses coexist, the fact is that tailored taxi is now deeply threatening the interest of conventional taxi industry. In order to occupy a favorable position, the analysis of travel preferences playing the fundamental role within the increasingly fierce competition between taxi and tailored taxi. Hence, it is necessary to figure out the weights of various preferences when passengers have to choose one type of personalized travel mode between taxi and tailored taxi.

Many studies have been done to the research of conventional taxi. As the tailored taxi is thriving over recent years, this paper mainly reviews the academic research of tailored taxi. Existing studies have evaluated the operation of tailored taxi related services, including legal and illegal types. Gholami et al. [6] analyzed the operation cost of the taxi khattee, which has a fixed route and two fixed stops like jitney, an obsolete and illegal mode of urban transportation in the US. They further put forward a methodology to classify taxi khattee lines so as to replace uneconomical lines with other transport modes. Factor and Miller [9] made a study of transit- taxi, which is similar to bus service however taxi vehicles are used. They reviewed the background and current potential for transit- taxi service implementation in the US and abroad. Cervero and Golub [4] kept an eye on the informal transport services, which is the paratransit-type services provided without official sanction, such as minibus, jitney, vans and station wagons. They discussed the cost and benefits of the informal transport sectors worldwide. Valenzuela et al. [11] surveyed the patrons of camionetas, which are mini-vans privately operated as jitney services, run by immigrants for immigrants throughout cities in the US, Mexico and Central America. They found that camionetas are primarily used by Mexican immigrants with varied socio-economic characteristic who want to travel inter-regionally and transnationally. Brake et al. [3] focused on the existing Flexible Transport Service (FTS), highlighting on Demand Responsive Transport (DRT) services such as UCall in Tyne and Wear, UK or Personalbus in Florence, Italy. They provided accessible and user friendly guideline at policy level for better implementation and development of FTS. Mulley and Nelson [10] pointed out the DRT mainly depended on small low floor buses or taxi to achieve transportation task. They argued that will-implemented FTS had the potential to revitalize bus-based transport services. Nelson et al. proposed to establish the Flexible Agency for Collective Mobility Services (FAMS) which provides an organizational structure and business model for FTS. Atasoy et al. [1] introduced an innovative transportation concept called Flexible Mobility on Demand (FMOD), which is a demand responsive system providing personalized services to passengers. They proved that the FMOD could be applied to different service types including taxi, shared-taxi and mini-bus.

From the literature mentioned above, it could be found that the existing studies mainly discussed on the conceptual level in a quite qualitative way. Actually, the travelers' preference and attitude towards tailored taxi depend on travelers' personal characteristics, especially for the tailored taxi's characteristics, e.g. the service level, charges and safety insurance. On the other hand, the developments of tailored taxi based on model internet also attracted attention of the public, government and scholars. Therefore, a quantitative analysis on travelers' preference and attitude would be very necessary and beneficial. Aiming at exploring the influencing factors behind the travelers' preference to conventional taxi and tailored taxi, a binary logit model with empirical data is proposed and the effects of explanatory variables are analyzed quantitatively. According to the model estimation, some policy suggestions are put forward. The remaining parts of this paper are organized as follows. Section 2 introduces the methodology including binary logit model and data collection. Section 3 describes model construction and estimation. Section 4 discusses personalized travel mode choice under various influential factors together with

proposing some differential development strategies of taxi and tailored taxi. Section 5 demonstrates the conclusions from the study and the expectation for future work.

2. Methodology

2.1. Analysis of travel choice between taxi and tailored taxi

In this study, the taxi represents to taxi cruising on street. In such situation, travelers have to spend uncertain period of time for the taxi service. Besides, the quality and the fare of taxi service are beyond the control of the travelers. On the other hand, the tailored taxi refers to immediate car service ordered by application software. Travelers in this case, can choose different drivers according to the historical evaluations of him or her. At the same time, the travelers could reduce waiting time by arranging the ordered car at a desired fixed time in a particular place. Currently, without thinking about subsidy factor, tailored taxi cost more than conventional taxi. Although there are still legal gaps existing in right protection when traveling by tailored taxi, the tailor taxi is still popular for its high quality service comparing to taxi.

The choices of travelling by taxi or tailored taxi could be somehow associated with the personal characteristics and travel characteristics. The age, gender, education level and household income are chosen as three observation items for personal characteristics. The observation for trip characteristics could be divided into three parts. The first is travel time. The second is commuting trip or elasticity trip. The third comprises of three travel preference evaluations, including convenience, economy and security. Hence, the traveler's choice might be the result of combined consideration with all characteristics mentioned above. Since different people hold varying prospective upon taxi and tailored taxi, they would choose the more satisfying travel mode to better meet their needs. As a result, traveler could get the maximum utility and the travel choice can be explained by the utility maximization theory.

The logit model is used to forecast probability of an event by fitting data, usually representing by some variables, to the logistic curve [8]. As a kind of discrete choice model, the binary logit model is an important traffic behavior model and widely used in transportation predictions [2]. In this paper, we define the occurrence of an event as traveling by tailored taxi. The result of personalized travel mode prediction is either traveling by taxi or tailored taxi. The number of X_i is known while the probability of pro_i remains unknown. The X_i refers to the i th traveler. A total of m traveler samples are collected through the survey. For each traveler sample, a set of variables could be used in predicting the probability of the event (taxi or tailored taxi). Assume that k variables exist, namely x_1, x_2, \dots, x_k . The logit value of the unknown binomial probability is defined as a linear function as follow:

$$\begin{aligned} \text{logit}(\text{probability}_i) &= \ln\left(\frac{\text{probability}_i}{1 - \text{probability}_i}\right) \\ &= \beta_0 + \beta_1 x_1^i + \beta_2 x_2^i + \dots + \beta_k x_k^i \end{aligned} \quad (1)$$

where the unknown parameter β_j is estimated through maximum likelihood estimation, which characterizes the contribution that the j th variable makes to the logit probability value ($j = 1, 2, \dots, k$). Noted that the β_0 refers to an intercept. From the Eq.1, we can easily get the Eq.2.

$$\text{probability}_i = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_1^i + \beta_2 x_2^i + \dots + \beta_k x_k^i)}} \quad (2)$$

Assuming that the utility function could be written as,

$$z = \beta_0 + \beta_1 x_1^i + \beta_2 x_2^i + \dots + \beta_k x_k^i \quad (3)$$

The Eq.2 could be formulated as logistic regression form,

$$f(z) = \frac{1}{1 + e^{-z}} \quad (4)$$

where the $f(z) \in (0,1)$ refers to the probability of an event.

2.2. Data collection

The data collection was completed via a random sampling survey administered in Beijing urban area. Each interviewee received a clear explanation of study purpose and question definition before answering the questions. The contents of the questionnaire included (a) personal profile information (age, gender, income, and education level), (b) preference for choosing personalized travel mode (taxi or tailored taxi), (c) the evaluation of action principle in choosing personalized travel mode (economic, convenience and safety), and (d) the person trip characteristics (travel time and whether it belongs to commute trip). The questionnaire was pretested before real survey to guarantee the clear meaning of each statement. The definition of variables in the scale are declared in Table 1.

Table 1. Definition of the variables in the scale

Variable	Definition	Note
X ₁	Age	Traveler's age
X ₂	Gender	Traveler's gender: 1-male, 2-female
X ₃	Income	Traveler's household income, unit: thousand yuan per month
X ₄	Education level	Traveler's education time, unit: year
X ₅	Economic	The evaluation of moneysaving in choosing personalized travel mode, five-point Likert scale, ranging from 1 (especially unimportant) to 5 (especially important)
X ₆	Convenience	The evaluation of easy access in choosing personalized travel mode, five-point Likert scale, ranging from 1 (especially unimportant) to 5 (especially important)
X ₇	Safety Insurance	The evaluation of legal protection in choosing personalized travel mode, five-point Likert scale, ranging from 1 (especially unimportant) to 5 (especially important)
X ₈	Travel time	The average travel time when choosing the personalized travel mode, unit: min
X ₉	Commuting	The travel is commuting trip (represented by 1) or elasticity trip (represented by 0) when choosing the personalized travel mode
Y	Travel choice	Travel by taxi (represented by 1) or travel by tailored taxi (represented by 0)

After rejecting the incomplete samples, 230 available questionnaires were received. 127 male interviewees and 103 female interviewees participated in the survey. Most of the interviewees were under 50 years old with the mean age of 32. About the household income per month, 27.8% of all participants are lower than ¥3000, 13.5% are between ¥3000 and ¥8000, 26.9% are between ¥8000 and ¥16000, 31.8% are more than ¥16000. The education time indicated majority of interviewees (96.1%) graduated from high school with 35.6% of them had already received bachelor or higher degree. The mean score of economic, convenience and safety are 3.06, 1.98, and 2.59 respectively. As for the travel time, 25.6% spend less than 10 minutes, 42.6% travel between 10 minutes to 20 minutes, while the rest 31.8% spend more than 20 minutes in travel. When the interviewee chose the taxi or tailored taxi, most of their trips (75.2%) were elasticity travel. The survey results showed that 30.4% would choose tailored taxi while the 69.5% would choose conventional taxi.

3. Model Estimation and Validation

3.1. Estimating Model Coefficients

According to the stochastic utility theory, the alternatives have various utilities that will influence the choice. In this paper, two personalized travel modes are considered, including taxi or tailored taxi. At the beginning, we hypothesize the utility functions for each alternative are influenced by all explanatory variables (refer to X_i). The parameters for the explanatory variables are estimated in each utility function by fitting the models to the observed choice outcomes. Maximum likelihood estimation and t-test are adopted in this procedure. If the t-test value of an explanatory variable is greater than 1.96, this variable could remain in the utility function as it could affect the choice making outcome with more than 95% probability. On the contrary, t-test value failing to reach 1.96 would result in the excluding of variable. With the remaining variables, the parameter estimation procedure would be carried out again. As the Table 2 shows, the variable gender, the variable economic and the variable travel time are excluded from the utility function. Then the remainder variables are estimated again and the parameters estimation value is demonstrated in Table 3. The value of estimated coefficient indicates that the older age, higher income and more focusing on safety insurance would lead the traveler to the choice of taxi. On the contrary, higher education level, more focusing on convenience and commuting trip characteristic would lead the traveler to the choice of tailored taxi. Generally speaking, the estimation results in Table 3 lead us to a conclusion that the model is well constructed. First, all explanatory hit the significant level. Second, the chosen variable fit the data well as the adjusted R squared is 0.87.

Table 2. Coefficient Estimation for Explanatory Variable

Variable	Definition	Estimate	Std. Error	T-test
Con	Constant	12.690	4.724	2.686
X ₁	Age	0.145	0.060	2.400
X ₂	Gender	-0.134	1.103	-0.121
X ₃	Income	0.095	0.045	2.096
X ₄	Education level	-1.118	0.248	-4.509
X ₅	Economic	0.244	0.261	0.935
X ₆	Convenience	-2.003	0.748	-2.677
X ₇	Safety Insurance	0.838	0.273	3.073
X ₈	Travel time	0.147	0.083	1.777
X ₉	Commuting	-3.669	1.899	-1.932

Table 3: Coefficient Estimation for valid Explanatory Variable

Variable	Definition	Estimate	Std. Error	T-test
Con	Constant	17.780	4.412	4.030
X ₁	Age	0.121	0.057	2.134
X ₃	Income	0.125	0.044	2.816
X ₄	Education level	-1.146	0.232	-4.946
X ₆	Convenience	-2.274	0.722	-3.151
X ₇	Safety Insurance	0.759	0.250	3.041
X ₉	Commuting	-4.782	1.925	-2.485

3.2. Validating Model Credibility

The survey data was applied to the estimated model. Through comparing the actual and predicted choice outcome, the credibility of choice model is established. In the binary logit model, the alternative with probability more than 0.5 would be considered as the estimated result. Here, if an estimate result is accordance with the survey result, a hit result is defined. Let S_{in} represent the hit result that traveler n chooses travel mode i . Hence, the S_{in} could be expressed mathematically as follow,

$$S_{in} = \begin{cases} 1; & \text{the estimated result is same as survey result} \\ 0; & \text{otherwise} \end{cases} \quad (5)$$

where the $i=0$ refers to the alternative of taxi while the $i=1$ refers to the alternative of tailored taxi. With the define of hit result, the hit ratio could be defined as follow,

$$R_i = \sum_{i=0}^1 \frac{S_{in}}{N_i} \quad (6)$$

$$R = \sum_{i=0}^1 \frac{\sum_{i \in J_m} S_{in}}{\sum_{m=0}^1 J_m} \quad (7)$$

where the R_i refers to the hit ratio of alternative i , R refers to hit ratio of all alternatives, N_i refers to the sample number of alternative i , and J_m refers to the total survey number. The hit ratio of the estimated model is shown in Table 4. The hit ratios indicate that the model can well explain the traveler's personalized travel mode choice.

Table 4: the Hit Ratio of the Binary Logit Model

Alternative	Survey result	Estimated result	Hit result	Hit ratio (%)
Taxi	160	161	155	96.8%
Tailored taxi	70	69	64	91.4%

4. Discussion of personalized travel mode choice

With the aim of analyzing the influence of the personal characteristic and trip characteristic on the choice of taxi or tailored taxi, the sensitive analysis is performed using the proposal model. Theses analyses below are important to understand the traveler's personalized travel mode choice. Besides, differential development strategies of taxi and tailored taxi are discussed based on the results of coefficient estimation and sensitive analysis.

4.1. Effect of Household Income

The household income is an important personal characteristic in predicting the traveler's choice on taxi or tailored taxi. By applying the binary logit model, the sensitive about traveler's household income is analyzed. The Figure 1 indicates that the household income can influence the selection ratio of taxi and tailored taxi significantly. The results show that merely 6.5% travelers will choose tailored taxi as their household income are greater than 70 thousand yuan per month. On the contrary, 31.3% travelers whose household income are less than 5000 yuan per month will choose tailored taxi. The results agree with the facts that tailored taxi is now heavily subsidized and charged much less than conventional taxi when covering the same distance. The low household income travelers are mostly sensitive to the price and have the tendency to choose a relatively cheap travel mode.

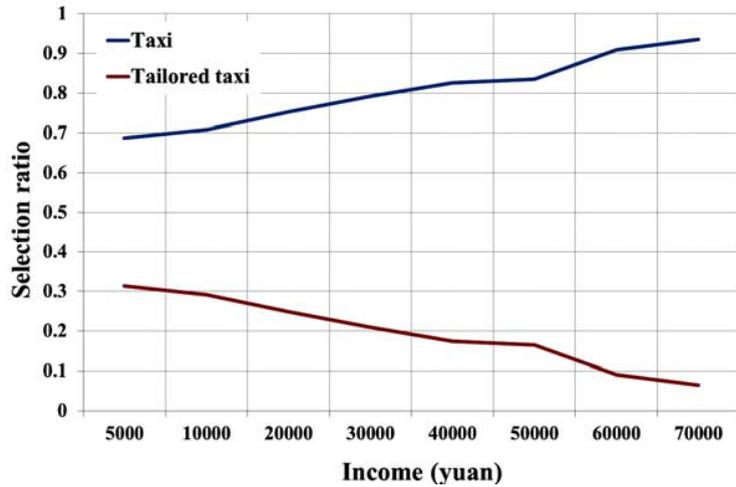


Fig. 1. Probability of each alternative with different household income

4.2. Effect of Convenience evaluation

The evaluation of convenience plays an important role in the decision of travel by taxi or tailored taxi. In order to study the influence of the convenience evaluation, we selection ratios of taxi and tailored taxi are evaluated by the binary logit model and the results are shown in Figure 2. The result indicates that with the importance of convenience increasing, the selection ratio of taxi decreases while the tailored taxi improves. When all people consider convenience is the most unimportant factor, merely 10.4% travelers would choose tailored taxi while 89.6% travelers would choose taxi. However, when all people regard convenience as the most important factor, the selection ratio of taxi and tailored taxi are 46.5% and 53.5% respectively, which doesn't show huge difference. These results are in accordance with the fact that tailored taxi is much convenience than conventional cruising taxi as the tailored taxis are ordered mostly by mobile application software. If a traveler is sensitive to convenience, he or she is most likely to choose tailor taxi as the travel mode.

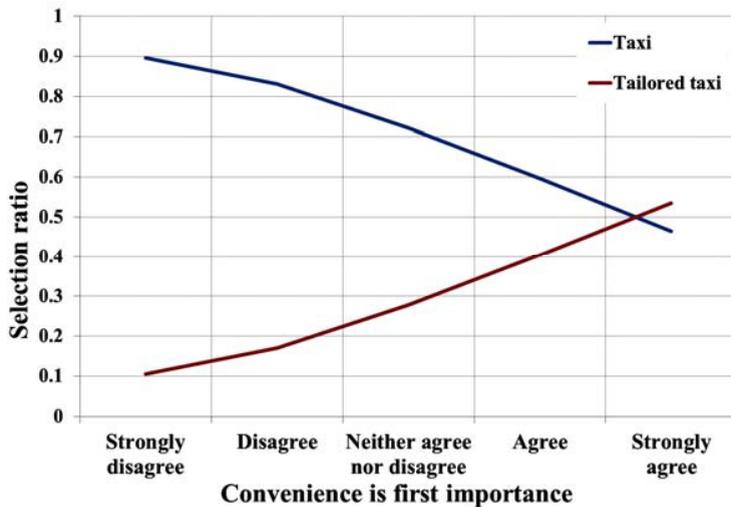


Fig. 2. Probability of each alternative with different evaluation of convenience

4.3. Effect of Safety evaluation

The concern for tailored taxi is most about its safety insurance. As there are still legal gaps existing in right protection when traveling by tailored taxi, the safe evaluation is another important factor which would influence the decision making. The sensitive analysis of safety evaluation is approached by the binary logit model. As the Figure 3 shows, when traveler care more about the safety insurance, the selection ratio of tailored taxi decrease while the taxi ratio increase. However, when traveler regard safety insurance as the most important factor, there are still 23.9% travelers will choose travel by tailored taxi. This might be explained as there are some other advantages that belong to tailored taxi leading the travelers to take advantage of them.

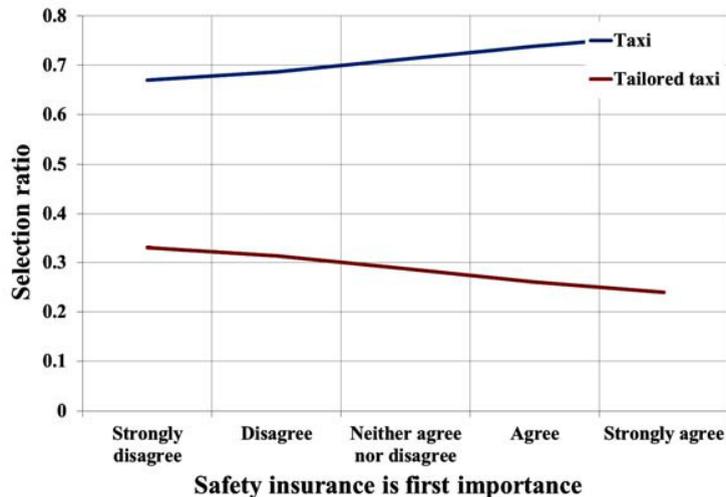


Fig. 3. Probability of each alternative with different evaluation of safety insurance

4.4. Development Strategy of Taxi and Tailored Taxi

Based on the coefficient estimation and sensitive analysis, some differential development strategies for taxi and tailored taxi are proposed as follow.

- According to the model estimation, two significant influencing variables of the action principles include safety insurance, convenience. It means the conventional taxi or new tailored taxi should work hard to improve the service level to attract more consumers. On the contrary, the economy is not the first importance in travelers' preference. Therefore, the taxi industry should try to diversify for diversified demand, e.g. providing luxury vehicles for high-quality service.
- As for the demographic characters, the target market for emerging tailored taxi is the people who are willing to try new things and prefer more comfort and convenient service.
- During the rush hours when most trips are commuting travel, it is time for tailored taxi to take the advantage of its online order feature. In this period, cruising taxi is more inefficient as the congestion in road.
- The conventional taxi should be more convenient to consumers. Improvement method includes allowing ordered online, increasing the total numbers and so on. As for the tailored taxi, more regulations should be launched to protect the rights of passengers.

5. Conclusions

This paper examines the personalized travel mode choice with the consideration of traveler's personal characteristic and trip characteristic. Information is obtained through questionnaire survey in Beijing. A binary logit

model is used to describe the choice of travelling by taxi or tailored taxi. How the influential factors have impact on the personalized travel mode choice is revealed by sensitivity analysis. The following conclusions are drawn based on the result.

- The estimated logit model can describe the personalized travel mode choice well.
- The most influential personal characteristic factor in making a decision to travel by taxi or tailored taxi is education time. The most influential trip characteristic factor is whether the trip belongs to commuting trip or elastic trip. Besides, within the travel preference evaluation, the convenience is the most influential factor in traveler's choice making.
- The results indicate that travelers with old age, high household income, or relatively low education level would prefer to choose taxi as their personalized travel mode. As for the travel preference evaluation, tailored taxi is now considered as a convenient however low security travel mode comparing to conventional taxi.

The findings from paper are expected to help understand traveler's choice of personalized travel mode. Though the personal characteristic and trip characteristic are taking into consideration in binary logit model, there are still some insufficiencies in the work. For example, the neglect of some potential influential factors may result in the fact that the model cannot reflect the effects of variables comprehensively. Additionally, as the tailored taxi is strongly influenced by government's regulation, future research might focus on the regulation factor in traveler's choice between taxi and tailored taxi.

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