Passenger payment behavior analysis of multimodal mobility in MaaS based on Logit model

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Abstract: Urban multi-mode (transfer) transportation is a transportation mode in which different types of transportation (such as bus, subway, online car, shared bicycle, etc.) are configured in a trip. In this paper, we designed the urban multi-mode (transfer) transportation preference questionnaire, collected the data of 371 questionnaires, and constructed a polynomial Logit model. The selection preference relationship among the types of cities, age, gender, job type, income, number of private cars in the family, travel purpose, vehicle type, average number of trips per day, average time per day, travel payment tools and transfer factors, transfer times, transfer payment modes, transfer payment tools, transfer payment packages of the respondents was analyzed. The research shows that 58.22% of the respondents consider travel time as the main consideration of transportation transfer, 88.95% of the respondents can accept an average of 2 or less transfer times a day, 42.86% of the respondents choose the transfer payment mode after the trip, 50.13% of the respondents choose the transportation card as the transfer payment tool. 64.15% choose to use pay-as-you-go transfer payment. Based on the Logit model analysis, we found that: the respondents who are male, have a fixed job, are elderly or have a long average daily travel time are more inclined to consider the time spent on travel as a transfer consideration, while the respondents who have more average daily trips are more inclined to consider the number of transfers as a transfer consideration. Elderly people or those who travel by private car are more reluctant to transfer, while transport card users are more willing to accept more transfers. There is no correlation between the transfer payment mode and the attributes of the respondents; For the preference of transfer payment tools, the elderly and transportation card users are more inclined to transportation card, those with higher income and more private cars are more inclined to mobile ride codes, and the average daily travel time of the elderly are more inclined to face recognition; For the preference of transfer payment packages, older people are more inclined to pay as you go, and male and working people are more inclined to choose annual packages. Conclusion: Multi-mode (transfer) transportation can be accepted by most passengers, and young people without private cars are the main users of multi-mode (transfer) transportation. In the design of MaaS multi-mode (transfer) transportation, the travel time should be optimized, and the pay-as-you-go delivery mode based on the transportation card (smart card) should be optimized.

Keywords: MaaS, Logit model, Multi-mode transportation, Transportation transfer, Preference

1 Introduction

Mobility as a Service (MaaS) is based on active mobility and efficient public transportation systems that integrate different transportation services (such as public transportation, carpooling, car sharing, bike sharing, motorcycle sharing, taxi, car rental, ride-hailing services, etc.) into a single digital mobility service and provide usage services (International Association of Public Transport (UITP), 2022). Since the concept of MaaS was proposed by Sampo Hietanen in 2006, it has gained widespread attention around the world, and numerous MaaS applications have been established and applied (Sampo Hietanen, 2019; Maria et al. 2016; Daniela et al. 2020).

The preference of passengers/users is an important factor affecting MaaS. From the literature, many researchers have analyzed the user preferences of MaaS. Some focus on different passenger/user groups, such as gender, college students, mothers, etc. Some focus on the purpose of travel, such as daily transportation, travel, etc. Some focus on payment methods, such as pay-as-you-go, different packages, etc. Javad et al. (2022) identified the features that impact satisfaction across gender, concluded that app-related features (Update and Release apps) and fare subject features (Ticket and Pass) had the greatest impact on satisfaction to man and app Issues and Tickets had the biggest impact on satisfaction to woman. Willy et al. (2023) analyzed the latent variables based on a survey conducted among college students, and shown that young users prefer to receive a wide range of routing-related information, but environmental and health effects are not among the most wanted factors. Erin et al. (2022) investigated mothers in Brussels, Belgium, and found that the main offers do not seem to be family-oriented, and the multi-modal and digitally literate mothers included in the study did not find shared modes useful, except for shared cars. Chinh et al. (2021) found a substantial market for mobility bundles but PAYG is an option preferred by many, particularly those with varying travel needs. H. Zhou et al. (2023) performed a case study in a metropolitan region in the Netherlands, and show that combining mobility hubs with making sharing services available to the public through MaaS subscriptions is a potential to reduce the number of car trips significantly. Melinda et al. (2021) found age, gender, income, education, and current travel behaviour all play an important role in determining an individual's propensity to purchase MaaS packages. Ching-Fu et al. (2023) conducted a stated choice experiment in Taipei city, and shown that the provision of additional mobility modes (shared bike, shared E-scooter, and taxi) increases choice probability, while price reduces the preference. Valeria et al. (2022) investigated the individual intention to subscribe to MaaS and preferences for bundle configurations in the Netherlands, and indicate that respondents are not yet inclined to subscribe to this new service, public transportation is the most preferred transportation mode. Ioannis et al. (2021) explored the preferences and choices of MaaS demand and willingness to pay based on an online survey in Greater Manchester, UK, and revealed that the most popular plans are the ones that include unlimited public transport and unlimited access to bus services, casual or infrequent car users may be potential MaaS users. Eui-Jin et al. (2021) explored a tourists' preference for tour mode bundle under MaaS in Jeju Island of Korea, and revealed that the trip sequence significantly influences the preference for travel mode in a tour mode bundle, a shared van is the most preferred in both a trip and a tour. Iria et al. (2021) surveyed the key drivers determining the adoption of MaaS in Madrid and Randstad and found that private car users were not significantly attracted by MaaS, but individuals engaged with public transport and shared mobility services did intend to adopt it. Sophia et al. (2022) revealed different sets of socio-economic factors, the impact of Covid-19, and personal travel factors as key predictors of MaaS use for general, social, and work trips. James et al. (2022) found that consumers have preferences for attributes resulting from operator collaboration that can deliver them better door-to-door travel options across the whole transport ecosystem, and the proposed method of institutional integration (MaaS 2.0 or CaaS) creates better value for respondents. Peraphan et al. (2020) expected youth, current public transport users, and flexible travellers to be early adopters of MaaS and transport operators are seen as the most important actors and the most preferred MaaS service integrator. Dong et al. (2022) found that passengers in the short-distance travel scenario are more concerned about the last kilometer walking distance and in-vehicle time, and passengers in the medium-and long-distance travel scenarios are willing to pay a higher price

for improving bus environment. Li Wanying et al. (2022) found that the package sales model combining travel services and tourism services has a large market in China, and subscribing to daily or monthly travel packages is the preferred choice of many respondents. The study of passenger/user preferences in MaaS has made an important contribution to the application and promotion of MaaS. However, insufficient attention has been paid to the payment preferences of multi-modal transport trips in MaaS.

The core idea of MaaS is to integrate different transportation services into one service system. Applications for different transportation systems (such as buses, subways, online ride-hailing, bike-sharing, etc.) are developed, and some applications even integrate multiple transportation systems. However, the service system of multi-mode (transfer) transportation is mainly to serve the trip planning, and cannot completely solve the payment of multi-mode (transfer). This paper mainly discusses the payment preferences of passengers for MaaS multi-mode transportation. Firstly, we designed the urban multi-mode (transfer) transportation preference questionnaire and collected 371 survey data. Then the polynomial Logit model is constructed. The selection preference relationship among the types of cities, age, gender, job type, income, number of private cars in the family, travel purpose, vehicle type, average number of trips per day, average time per day, travel payment tools and transfer factors, transfer times, transfer payment modes, transfer payment tools, transfer payment packages of the respondents was analyzed. Finally, some suggestions for payment design of MaaS multi-mode transportation is proposed.

2 Data collection

In order to investigate the preference of passengers/users on the choice of payment methods for MaaS multi-mode transportation, a questionnaire was designed and the data was collected by online questionnaire.

2.1 Questionnaire Design

The questionnaire is divided into four parts. The first part is the description of the survey, including the purpose of the survey, the filling requirements of the questionnaire and the application of the survey data etc. The second part is the basic information of the respondents, including types of cities, age, gender, job type, income, number of private cars in the family, travel purpose, vehicle type, average number of trips per day, average time per day, travel payment tools etc. The third part is the current situation of multi-mode (transfer) travel of the respondents, such as the main factors considered in transfer, the average number of transfers per day, the average walking time of transfers per day, the average walking distance of transfers per day, the average waiting time of transfers per day, etc. The fourth part is the respondents' choice of multi-mode (transfer) travel. For example, the maximum number of transfers per day, the longest walking time for transfers, the longest walking distance for transfers, the longest waiting time for transfers, the acceptable payment mode for transfers, the acceptable payment tools for transfers, the choice of transfer transportation travel plan for a 10km trip, and the choice of transfer transportation travel plan for a 25km trip, the choice of transfer travel payment package, etc.

For the 10km trip, three transportation options are designed, which are: A) Taxi or Online ride-hailing, 0 transfer, 2 minutes on foot, 20 minutes of travel time, 25 yuan of travel fee; B) Subway, 1 transfer, 10 minutes on foot, 40 minutes of travel time, 5 yuan of travel fee; C) Bus, 2 transfers, 8 minutes on foot, 50 minutes of travel time, 4 yuan of travel fee. For the 25km trip, three transportation options are designed, which are: A) Taxi or Online ride-hailing, 0 transfer, 5 minutes on foot, 40 minutes of travel time, 50 yuan of travel fee; B) Subway, 2 transfer, 20 minutes on foot, 70 minutes of travel time, 10 yuan of travel fee; C) Bus, 3 transfers, 15 minutes on foot, 80 minutes of travel time, 8 yuan of travel fee. Four transfer travel payment schemes are designed, which are: A) pay-as-you-go, that is, on-site payment for each trip; B) Daily package, valid on the same day (24 hours), including 5km free taxi or 1 online taxi, unlimited transfer of city bus and subway, the fee is 20 yuan; C) Monthly package, valid within 1 month (30 days), including taxi or one online car within 5 kilometers per day, unlimited transfer of city buses and subways, the fee is 500 yuan (equivalent to 85% of the daily package); D) Annual package, valid within 1 year (365 days), including a taxi or an online car within 5 kilometers per day, and unlimited transfers of buses and subways within the city, the fee is 5,000 yuan (equivalent to 70% of the daily package).

2.2 Questionnaire Survey

The questionnaire was compiled by WJX APP and distributed by WeChat and email to conduct a nationwide survey in China. The survey was conducted from August 2023 to November 2023 and collected a total of 371 valid questionnaires. Table 1 shows the statistical description of the sample.

Table 1 Statistical description of the sample

Factor	Level	Proportion (%)
Types of cities	Capital city	77.90%
	Other cities	22.10%
Gender	Male	50.67%
	Female	49.33%
Age	<=25	23.45%
	25-36	18.87%
	36-45	21.02%
	45-60	29.11%
	>=60	7.55%
Job type	Full-time work	57.68%
	Free-time work	8.09%
	Student	24.26%
	Retiree	9.97%
Income	<=5000	39.35%
	5000-10000	36.39%
	10000-20000	18.33%
	20000-50000	5.12%
	>=50000	0.81%
Number of private cars	No	13.48%
	Yes	86.52%
Travel purpose	Go to work	60.65%
	Go to school	17.52%
	Others	21.83%
Vehicle type	Private cars	44.20%
	Bus	12.40%

Factor	Level	Proportion (%)
Average number of trips per day	<=2	67.92%
	>2	32.08%
Travel payment tools	Transportation card	63.88%
	Phone (QR code)	27.49%
	Cash	3.50%
	Bank card	2.70%
	Face scanning	1.35%
	Others	1.08%
Factors considered in transfer	Travel time	58.22%
	Travel fee	7.28%
	Number of transfers	4.04%
	Waiting time	12.40%
	Walking time and distance	11.05%
	Vehicle	7.01%
Average number of transfers per day	None	49.06%
	1	34.77%
	2	14.02%
	>=3	2.16%
Average walking time of transfers per day	None	49.06%
	<=2min	4.04%
	2-5min	15.90%
	5-10min	16.44%
	10-20min	10.51%
	>=20min	4.04%
	None	49.06%

	Subway	22.91%
	Taxi	0.54%
	Online ride-hailing	4.04%
	Bike sharing	1.35%
	On foot	5.39%
	Bicycle	8.89%
	Others	0.27%
Average time per day	<=30min	27.76%
	0.5-1.0h	39.35%
	1.0-2.0h	25.07%
	>=2h	7.82%

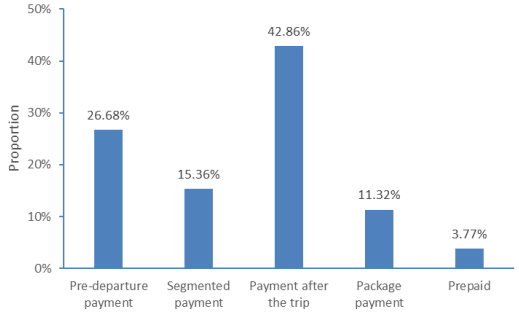
Average walking distance of transfers per day	<=200m	1.89%
	200-500m	19.95%
	500-1000m	18.60%
	10000-2000m	8.36%
	>=2000m	2.16%
Average waiting time of transfers per day	None	49.06%
	<=5min	13.48%
	5-10min	30.19%
	10-20min	5.93%
	>=20min	1.35%

2.3 Descriptive analysis

It can be seen from Table 1: Among the respondents, the proportion of men and women is 1:1, 77.9% Came from provincial capitals, 57.68% in full-time jobs, 75.74% in incomes below 10,000 yuan, 86.52% in families with private cars, 60.65% for go-to-work, and 44.20% trip by private cars. 67.92% of them travel twice or less per day on average, 67.12% of them travel less than 1 hour per day on average, 63.88% of them pay by transportation card, and 58.22% of them take travel time as the main factor of transfer consideration. Among the respondents, 50.94% have no less than one transfer per day, 95.96% have less than 20 minutes of transfer per day, 89.49% have less than 1000m of transfer per day, and 92.72% have less than 10 minutes of transfer per day.

According to the statistics of the survey data, 88.95% of the respondents could accept the average transfer times of 2 or less per day, 93.80% could accept the average transfer walking time of less than 20 minutes per day, 95.42% could accept the average transfer walking distance of less than 1000m per day, and 87.33% could accept the average transfer waiting time of less than 10 minutes per day.

The proportion of transfer payment modes and payment tools selected by the respondents are shown in Figure 1 and Figure 2 respectively. It can be seen from Figure 1 that the transfer payment mode selected by the respondents most frequently is payment after the trip, accounting for 42.86%; The second is pre-departure payment, accounting for 26.68%; The third is segmented payment, accounting for 15.36%; 11.32% chose package payment; Only 3.77 percent chose to prepaid. It can be seen from Figure 2 that the transportation card is the transfer payment tool selected most by the respondents, accounting for 50.13%; The second is the phone (QR code) payment, accounting for 32.88%; Face scanning payment accounted for 11.05%; Other payments (such as bank cards, cash, etc.) do not exceed 6%.



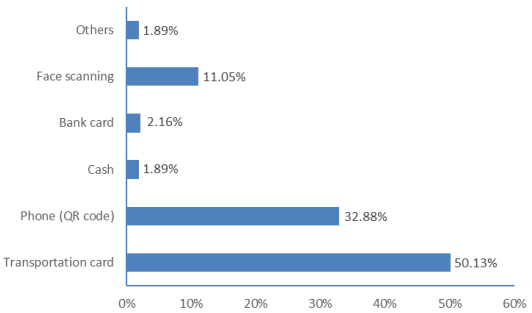


Figure 1 Proportion of transfer payment modes selected by respondents

Figure 2 Proportion of transfer payment tools selected by respondents

It can be seen from Figure 3 and Figure 4 that, regardless of the 10 km trip or 25 km trip, respondents mainly choose plan B (Subway), followed by plan A (Taxi or Online ride-hailing), and finally plan C (Bus). When the trip changed from 10 km to 25 km, the respondents who chose Plan B (Subway) increased.

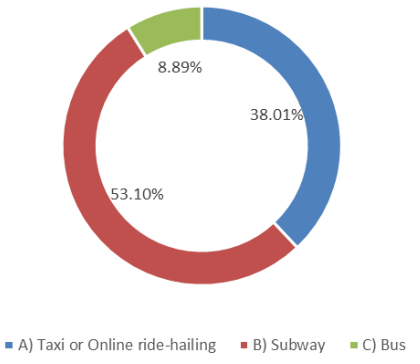


Figure 3 Proportion of transportation plan selection for a 10km trip

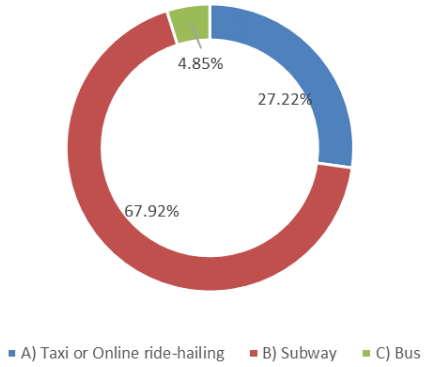


Figure 4 Proportion of transportation plan selection for a 25km trip

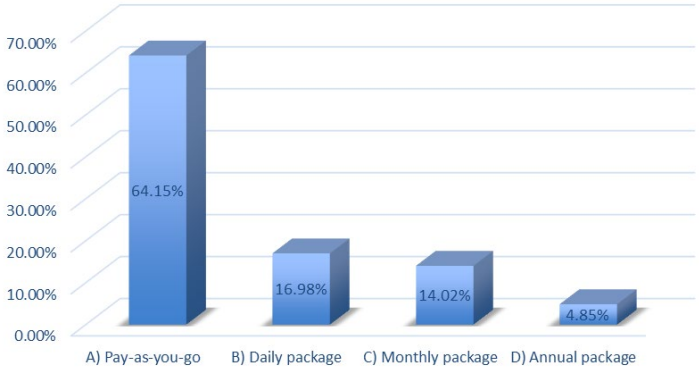


Figure 5 The proportion of transfer travel payment schemes chosen by respondents

It can be seen from Figure 5 that 64.15% of the respondents choose the pay-as-you-go transfer travel payment schemes, while the sum of the people who choose different package payment is only 35.84%. Among them, more people choose daily package than monthly package, and the least people choose annual package. Therefore, for daily travel, most people will be willing to choose a pay-as-you-go option instead of a package payment.

3 Methodology

3.1 Multinomial Logit model

In this paper, Multinomial Logit Model is used to analyze passenger payment preference in MaaS multi-modal transport.Logit model is the earliest discrete choice model, which has been

widely used in the fields of psychology, sociology, economics and transportation, and has derived and developed other discrete choice models, forming a complete discrete choice model system. Such as Probit model, NL model (Nest Logit model), Mixed Logit model and so on.

In statistics, Probability and Odds are employed to describe the likelihood of something happening. Probability describes the ratio of the number of occurrences of an event *A* to the number of occurrences of all outcomes (expressed as *P*). Odds refers to the ratio of the probability *P* of event occurrence to the probability 1-P of event non-occurrence, namely:

$$Odds = \frac{P}{1-P} \tag{1}$$

The logarithm of Odds is called Logit, i.e.

$$Logit = \log(Odds) \tag{2}$$

Logit can be understood as the log of an odd. Since the value range of probability *P* is [0,1], while the value range of Logit is *(-∞, +∞)*, *P* cannot be used as the dependent variable in the regression model. Instead, Logit can be used as the dependent variable to establish the following regression model:

$$Logit = \log(Odds) = \ln\left(\frac{P}{1-P}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_i x_i \ldots + \beta_n x_n \tag{3}$$

Where x_i is the independent variable and β_1 is the coefficient of regression model coefficient, then:

$$Odds = \frac{P}{1-P} = e^{\beta_0+\beta_1 x_1+\cdots+\beta_n x_n} \tag{4}$$

$$P = \frac{1}{1-e^{-(\beta_0+\beta_1 x_1+\cdots+\beta_n x_n)}} \tag{5}$$

When the dependent variable has only two choices, it is a binary Logit model. Multinomial Logit Model should be used for multi-classification multinomial variables with three or more multinomial choices. multinomial Logit model includes standard polynomial Logit model, conditional Logit model and mixed Logit model. The arguments of the standard polynomial Logit model contain only individual properties (independent variables that vary only with individuals), the conditional Logit model arguments contain only properties that vary with choices, and the mixed Logit model arguments contain both individual properties and properties that vary with choices.

Like the binary Logit model, the multinomial Logit model assumes of random utility and utility maximization. The utility function is expressed as:

$$U_{ij} = \boldsymbol{\beta_j X_{ij}} + \varepsilon_{ij} \quad (i = 1,2, \ldots, n) \tag{6}$$

Where U_{ij} is the utility of individual *i*'s choice of option *j*, $\boldsymbol{X_{ij}}$ is the vector of the observable variables associated with individual *i* and option *j*, $\boldsymbol{\beta_j}$is the vector of the preference to be estimated of each observable variable associated with choice *j*, and ε_{ij} is the random error term.

According to utility theory, individual *i* will maximize his utility in the process of making a choice, that is, in the choice set *J*, the probability of choosing option *j* is:

$$P(U_{ij} > U_{ik}) = P(\boldsymbol{\beta_j X_{ij}} + \varepsilon_{ij} > \boldsymbol{\beta_k X_{ik}} + \varepsilon_{ik}) = P(\boldsymbol{\beta_j X_{ij}} - \boldsymbol{\beta_k X_{ik}} > \varepsilon_{ik} - \varepsilon_{ij}), j \neq k \quad (7)$$

If the random term ε_{ij} follows an independent equally distributed generalized extreme value distribution, then the probability of individual *i* choosing option *j* is:

$$P_{ij} = \frac{\exp(\boldsymbol{\beta_j X_{ij}})}{\sum_{j=1}^{J} \boldsymbol{\beta_j X_{ij}}} \quad (8)$$

The maximum likelihood method can be used to estimate the parameters. When the multinomial Logit model satisfies the IIA (Independent of Irrelevant Alternatives) hypothesis, the essence of the multinomial Logit model of *J* classification is *(J-1)* binary Logit model with pairings. Therefore, the multinomial Logit model can only identify *(J-1)* parameters, a base group needs to be selected, and all coefficients are estimated relative to the base group.

3.2 Data Preparation for the Logit Model

According to the survey data in Section 2, 11 individual variables (independent variables) and 5 types of choice variables (dependent variables) are selected to analyze the payment behavior of passengers. The variables and parameters are listed in Table 2.

Table 2 Variables and parameters of Logit model

Variable type	Variable	Declaration of variable	Parameter of a variable
Independent variables	City_type	Types of cities	1-- Capital city; 0--Other cities
	Age	Age	1--<=25; 2--25-36; 3--36-45; 4--45-6; 5-->=60
	Male	Gender	1—Male; 0--Female
	Job	Job type	1-- Full-time work; 0--Others
	Income	Monthly income	1--<=5000; 2--5000-10000; 3--10000-20000; 4-->=20000
	Car_num	Number of private cars in a family	0—0; 1—1; 2—2; 3-->=3
	T_purpose	Travel purpose	1-- Go to work; 0--Others
	T_car	Whether to travel by private car	1--Yes；0--No
	T_counts	Average number of trips per day	1--<=1; 2—2; 3--2-5; 4-->=5
	T_times	Average time per day	1--<=30min; 2--30min-1h; 3--1-2h; 4-->=2h
	T_card	Whether to pay by transportation card	1--Yes; 0--No
dependent variables	T_factor	Preferences for transfer influencing factors	1--Travel time; 2-- Travel fee; 3-- Number of transfers; 4-- Vehicle
	T_trans_counts	Preference for number of transfers	1--None; 2--1; 3--2; 4-->=3
	T_pay_mode	Preference for transfer payment modes	1--Pre-departure payment; 2-- Segmented payment; 3--Payment after the trip; 4-- Package payment or prepaid
	T_pay_tool	Preference for transfer payment tools	1-- Transportation card; 2--Phone (QR code) payment; 3--Face scanning payment; 4--Bank cards, cash et al.
	T_pay_package	Preference for transfer payment packages	1--Pay-as-you-go; 2--Daily package; 3- -Monthly package; 4--Annual package

4 Result analysis

Based on the survey data, one dependent variable and 11 independent variables in Table 2 were

selected respectively, and SPSSAU software was used to analyze passenger payment behavior preference according to multinomial Logit model.

4.1 Preferences for transfer influencing factors

Take City_type, Age, Male, Job, Income, Car_num, T_purpose, T_car, T_counts, T_times, T_card as independent variables and T_factor as dependent variables. A multinomial Logit regression analysis was performed with 371 samples. P = 0.001<0.05, indicating that the original hypothesis is rejected. The independent variables put into the model construction have validity, and the model construction is meaningful.

Table 3 Regression coefficients and Z values of independent variables of T_factor

	Option 2 (Travel fee)	Option 3 (number of transfers)	Option 4 (vehicle)
City_type	-0.554(-1.044)	-0.179(-0.274)	0.464(0.808)
Age	-0.851**(-3.307)	0.225(0.833)	0.356(1.691)
Male	0.243(0.503)	-1.491*(-2.077)	-0.236(-0.504)
Job	-0.445(-0.627)	-1.671*(-2.129)	-0.406(-0.631)
Income	1.112**(3.310)	0.458(1.247)	-0.418(-1.108)
Car_num	0.304(0.910)	-0.205(-0.450)	0.196(0.591)
T_purpose	-1.096(-1.744)	0.644(0.884)	0.916 (1.577)
T_car	-0.725(-1.222)	0.778(1.150)	0.386(0.737)
T_counts	-0.251(-0.828)	0.883*(2.266)	-0.075(-0.258)
T_times	0.168(0.630)	-0.596(-1.575)	-0.773*(-2.523)
T_card	-0.384(-0.810)	0.520(0.826)	-0.034(-0.075)
Intercept	-1.324(-1.332)	-4.741**(-3.075)	-2.044*(-1.975)
Likelihood ratio test		$\chi^2(33)=67.738, p=0.000$	

McFadden *R* square: 0.136; Cox & Snell *R* square: 0.167; Nagelkerke *R* square: 0.226

* $p<0.05$ ** $p<0.01$, The value in parentheses is z.

Table 3 shows the regression coefficients and Z-values of the independent variables of transfer influence factor preferences. Compared with option 1 (Travel time), the regression coefficient of Age in option 2 (Travel fee) is -0.851, and the significance level is 0.001 level (z=-3.307, p=0.001< 0.01), which means that Age has a significant negative influence on T_factor. The regression coefficient of Income is 1.112, and the significance level is 0.001 (z=3.310, p=0.001< 0.01), which indicates that Income has a significant positive influence on T_factor. That is, compared with option 2 (Travel fee) and Option 1 (Travel time), older people are more likely to prefer option 1 (Travel time), while high-income people are more likely to prefer option 2 (Travel fee).

Compared with option 1 (Travel time), the regression coefficient of Male in option 3 (Number of transfers) is -1.491, and the significance level is 0.038 (z=-2.077, p=0.038<0.05), which means

that Male has a significant negative influence on T_factor. The regression coefficient of Job is -1.671, and the significance level of 0.033 (z=-2.129, p=0.033<0.05), which indicates that Job has a significant negative influence on T_factor. The regression coefficient of T_counts is 0.883, and the significance level is 0.023 (z=2.266, p=0.023<0.05), which indicates that T_counts has a significant positive effect on T_factor. That is, compared with option 3 (Number of transfers) and option 1 (Travel time), men and those with full-time jobs are more inclined to choose option 1 (Travel time), and those with more average daily trips are more inclined to choose option 3 (Number of transfers).

Compared with option 1 (Travel time), the regression coefficient of T_times in option 4 (Vehicle) is -0.773, and the significance level is 0.012 level (z=-2.523, p=0.012<0.05), which means that T_times has a significant negative influence on T_factor. That is, compared with option 4 (Vehicle) and option 1 (Travel time), the longer average travel time per day is more inclined to option 1 (Travel time).

4.2 Preference for number of transfers

Take City_type, Age, Male, Job, Income, Car_num, T_purpose, T_car, T_counts, T_times, T_card as independent variables and T_trans_counts as dependent variables. A multinomial Logit regression analysis was performed with 371 samples. P = 0.001<0.05, indicating that the original hypothesis is rejected. The independent variables put into the model construction have validity, and the model construction is meaningful.

Table 4 Regression coefficients and Z values of independent variables of Trans_counts

	Option 2(1)	Option 3(2)	Option 4(>=3)
City_type	-0.578(-0.892)	-0.192(-0.292)	-0.853(-1.118)
Age	-0.297(-1.212)	-0.482(-1.957)	-1.201**(-3.899)
Male	0.015(0.030)	0.508(0.970)	0.444(0.692)
Job	0.368(0.494)	-0.161(-0.215)	-0.977(-1.067)
Income	0.561(1.411)	0.680(1.711)	0.906(1.864)
Car_num	0.039(0.102)	-0.038(-0.101)	0.451(0.985)
T_purpose	-1.102(-1.508)	-1.133(-1.548)	-1.191(-1.415)
T_car	-0.970(-1.558)	-0.727(-1.168)	-1.829*(-2.389)
T_counts	0.139(0.405)	0.474(1.378)	0.544(1.314)
T_times	-0.138(-0.452)	0.120(0.395)	0.508(1.398)
T_card	1.050*(2.108)	1.256*(2.507)	1.291*(2.073)
Intercept	2.660*(2.190)	1.430(1.165)	0.940(0.648)
Likelihood ratio test		$\chi^2(33)=97.912, p=0.000$	

McFadden *R* square: 0.116; Cox & Snell *R* square: 0.232; Nagelkerke *R* square: 0.258

* $p<0.05$ ** $p<0.01$, The value in parentheses is z.

Table 4 shows the independent variable regression coefficient and Z-value of number of

transfers preference. Compared with option 1 (0 transfer), the regression coefficient of T_card in option 2 (1 transfer) is 1.050, and the significance level is 0.035 level (z=2.108, p=0.035<0.05), which indicates that T_card has a significant positive effect on T_trans_counts. In other words, those who use the transportation card prefer option 2 (1 transfer) to option 1 (0 transfer).

Compared with option 1 (0 transfer), the regression coefficient of T_card of option 3 (2 transfers) is 1.256, and the significance level is 0.012 (z=2.507, p=0.01<0.05), indicating that T_card has a significant positive effect on T_trans_counts. In other words, those who use the transportation card prefer option 3 (2 transfers) to option 1 (0 transfer).

Compared with option 1 (0 transfer), the regression coefficient of Age of option 4 (3 or more transfers) is -1.201, and the significance level is 0.001 (z=-3.899, p=0.001< 0.01), which shows that Age has a significant negative influence on T_trans_counts. The regression coefficient of T_car is -1.829, and the significance level is 0.017 (z=-2.389, p=0.017< 0.05), which means that T_car has a significant negative effect on T_trans_counts. The regression coefficient of T_card is 1.291, and the significance level is 0.0038 (z=2.073, p=0.038<0.05), which indicates that T_card has a significant positive effect on T_trans_counts. In other words, compared with option 4 (3 or more transfers) and option 1 (0 transfer), older people and those who travel in private cars are more likely to choose option 1 (0 transfer). Those who use transportation cards are more likely to choose option 4 (3 or more transfers).

4.3 Preference of transfer payment modes

Take City_type, Age, Male, Job, Income, Car_num, T_purpose, T_car, T_counts, T_times, T_card as independent variables and T_pay_mode as dependent variables. A multinomial Logit regression analysis was performed with 371 samples. Then P = 0.211>0.05. After adjusting the number and combination of independent variables, the P-value is greater than 0.05. This indicates that the original hypothesis is accepted, which means that the independent variables put into the model construction are meaningless, so the model construction is meaningless. This may be a transfer payment model (1- pay before departure; 2 - segmented payment; 3-- Pay after the trip; 4-- Package payment or prepaid) preference is relatively discrete, or it may be due to small sample size or unreasonable independent variables leading to little correlation, and further research will be conducted in the future.

4.4 Preference for transfer payment tools

Take City_type, Age, Male, Job, Income, Car_num, T_purpose, T_car, T_counts, T_times, T_card as independent variables and T_pay_tool as dependent variables. A multinomial Logit regression analysis was performed with 371 samples. P = 0.001<0.05, indicating that the original hypothesis is rejected. The independent variables put into the model construction have validity, and the model construction is meaningful.

Table 5 Regression coefficients and Z values of independent variables of T_pay_tool

	Option 2 (Phone (QR code) payment)	Option 3 (Face scanning payment)	Option 4 (Bank cards, cash et al.)
City_type	-0.327(-0.897)	-0.801(-1.645)	-0.244(-0.368)
Age	-0.299*(-2.230)	-0.315(-1.707)	0.453(1.770)
Male	-0.269(-0.892)	0.477(1.161)	1.514*(2.061)
Job	0.491(1.168)	-0.027(-0.046)	-1.492(-1.790)
Income	0.427*(1.974)	0.402(1.445)	0.036(0.103)
Car_num	0.508*(2.238)	0.544(1.778)	-0.289(-0.671)
T_purpose	-0.428(-1.137)	-0.419(-0.781)	-0.468(-0.647)
T_car	-0.168(-0.490)	0.886(1.921)	0.655(1.009)
T_counts	0.258(1.365)	0.092(0.345)	0.380(1.015)
T_times	-0.023(-0.132)	0.503*(2.174)	0.894**(2.834)
T_card	-2.575**(-8.169)	-1.529**(-3.657)	-2.117**(-3.677)
Intercept	0.576(0.878)	-2.072*(-2.223)	-4.949**(-3.262)
Likelihood ratio test		$\chi^2(33)=176.226, p=0.000$	

McFadden *R* square: 0.212; Cox & Snell *R* square: 0.378; Nagelkerke *R* square: 0.423
* $p<0.05$ ** $p<0.01$, The value in parentheses is z.

Table 5 shows the independent variable regression coefficient and Z value of transfer payment tools preference. Compared with option 1 (Transportation card), the regression coefficient of Age in option 2 (Phone (QR code) payment) is -0.299, and the significance level is 0.026 (z=-2.230, p=0.02< 0.05), which means that Age has a significant negative influence on T_pay_tool. The regression coefficient of Income is 0.427, and the significance level is 0.048 (z=1.974, p=0.048<0.05), which indicates that Income will have a significant positive impact on T_pay_tool. The regression coefficient of Car_num is 0.508, and the significance level is 0.025 (z=2.238, p=0.025<0.05), which means that Car_num has a significant positive influence on T_pay_tool. The regression coefficient of T_card is -2.575 and the significance level is 0.001 (z=-8.169, p=0.001< 0.01), which indicates that T_card has a significant negative influence on T_pay_tool. In other words, compared with option 1 (Transportation card), older people and those who use transportation card are more likely to choose Option 1 (Transportation card), and those with higher income and more family cars are more likely to choose Option 2 (Phone (QR code).

Compared with option 1 (Transportation card), the regression coefficient of T_times in option 3 (Face scanning payment) is 0.503, and the significance level is 0.030 (z=2.174, p=0.030< 0.05), which indicates that T_times has a significant positive impact on T_pay_tool. The regression coefficient of T_card is -1.529 and the significance level is 0.001 (z=-3.657, p=0.001< 0.01), which means that T_card has a significant negative influence on T_pay_tool. That is, compared with option 3 (Face scanning payment) and option 1 (Transportation card), those who have a long average travel

time are more inclined to option 3 (Face scanning payment), and those who use transportation card are more inclined to option 1 (Transportation card).

Compared with option 1 (Transportation card), the regression coefficient of Male in option 4 (Bank cards, cash et al.) is 1.514, and the significance level is 0.039 (z=2.061, p=0.039<0.05), which indicates that Male has a significant positive influence on T_pay_tool. The regression coefficient of T_times is 0.894 and the significance level is 0.005 (z=2.834, p=0.005< 0.01), which means that T_times has a significant positive influence on T_pay_tool. The regression coefficient of T_card is -2.117, and the significance level is 0.001 (z=-3.677, p=0.001<0.01), which indicates that T_card has a significant negative influence on T_pay_tool. That is, option 4 (Bank cards, cash et al.) is compared with option 1 (Transportation card), male with a longer average travel time are more likely to choose option 4 (Bank cards, cash et al.), those who use transportation cards are more likely to choose option 1 (Transportation card).

4.5 Preference for transfer payment packages

Take City_type, Age, Male, Job, Income, Car_num, T_purpose, T_car, T_counts, T_times, T_card as independent variables and T_pay_package as dependent variables. A multinomial Logit regression analysis was performed with 371 samples. P = 0.021<0.05, indicating that the original hypothesis is rejected. The independent variables put into the model construction have validity, and the model construction is meaningful.

Table 6 Regression coefficients and Z values of independent variables of T_pay_package

	Option 2 (Daily package)	Option 3 (Monthly package)	Option 4 (Annual package)
City_type	-0.190(-0.522)	0.246(0.557)	-0.455(-0.635)
Age	-0.122(-0.911)	-0.508**(-2.955)	0.592*(2.073)
Male	0.235(0.729)	0.197(0.575)	1.487*(2.385)
Job	-0.053(-0.123)	0.060(0.119)	0.580(0.706)
Income	-0.103(-0.464)	-0.156(-0.619)	-0.820(-1.933)
Car_num	0.169(0.727)	0.001(0.003)	1.016*(2.519)
T_purpose	-0.309(-0.782)	0.699(1.561)	1.795*(2.081)
T_car	-0.265(-0.733)	0.030(0.077)	-0.631(-1.011)
T_counts	0.038(0.191)	-0.076(-0.339)	-0.209(-0.539)
T_times	0.330(1.898)	0.351(1.799)	0.176(0.531)
T_card	-0.340(-1.080)	-0.309(-0.907)	-0.671(-1.176)
Intercept	-1.248(-1.794)	-1.109(-1.453)	-5.483**(-3.721)
Likelihood ratio test		$\chi^2(33)=51.433, p=0.021$	

McFadden *R* square: 0.069; Cox & Snell *R* square: 0.129; Nagelkerke *R* square: 0.149
* $p<0.05$ ** $p<0.01$, The value in parentheses is z.

Table 6 shows the independent variable regression coefficient and Z value of transfer payment package preference. Compared to option 1 (pay-as-you-go), the correlation between option 2 (daily package) and the independent variable is not significant.

Compared with option 1 (Pay as you go), the regression coefficient value of Age in Option 3 (Monthly package) is -0.508 and the significance level is 0.003 ($z=-2.955$, $p=0.003<0.01$), which indicates that Age has a significant negative influence on T_pay_package. That is, Option 3 (Monthly package) is more preferred by older people than Option 1 (Pay-as-you-go).

Compared with option 1 (Pay-as-you-go), the regression coefficient of Age in option 4 (Annual package) is 0.592 and the significance level is 0.038 ($z=2.073$, $p=0.038<0.05$), which indicates that Age has a significant positive influence on T_pay_package. The regression coefficient of Male is 1.487 and the significance level is 0.017 ($z=2.385$, $p=0.017<0.05$), which means that Male will have a significant positive influence on T_pay_package. The regression coefficient of Car_num is 1.016, and the significance level is 0.012 ($z=2.519$, $p=0.012<0.05$), which indicates that Car_num will have a significant positive influence on T_pay_package. The regression coefficient of T_purpose is 1.795, and the significance level is 0.037 ($z=2.081$, $p=0.037<0.05$), which means that T_purpose has a significant positive influence on T_pay_package. In other words, Older, working, and male respondents preferred Option 4 (Annual package) to Option 1 (Pay-as-you-go).

5 Conclusion

Urban multi-mode (transfer) transportation is a transportation mode in which different types of transportation (such as bus, subway, online car, shared bicycle, etc.) are configured in a trip. In this paper, we designed the urban multi-mode (transfer) transportation preference questionnaire, collected the data of 371 questionnaires, and constructed a polynomial Logit model. The selection preference relationship among the types of cities, age, gender, job type, income, number of private cars in the family, travel purpose, vehicle type, average number of trips per day, average time per day, travel payment tools and transfer factors, transfer times, transfer payment modes, transfer payment tools, transfer payment packages of the respondents was analyzed. The main conclusions are as follows：

(1) 60.65% of the respondents travel to go to work, 44.20% of the respondents travel by private car, 67.92% of the respondents travel twice or less per day on average, 67.12% of the respondents travel less than 1 hour per day on average, 63.88% of the respondents pay by transportation card. 58.22% of the respondents consider travel time as the main consideration of transportation transfer, 88.95% of the respondents can accept an average of 2 or less transfer times a day, 42.86% of the respondents choose the transfer payment mode after the trip, 50.13% of the respondents choose the transportation card as the transfer payment tool. 64.15% choose to use pay-as-you-go transfer payment.

(2) Preference for transfer factors: Compared option 2 (Travel cost) with Option 1 (Travel time), elderly people are more inclined to option 1 (Travel time), while high-income people are more inclined to option 2 (Travel cost). Compared option 3 (Number of transfers) with option 1

(Travel time), men and those with full-time jobs are more likely to choose option 1 (Travel time), and those with more average daily trips are more likely to choose option 3 (Number of transfers). Compared Option 4(Vehicle) with option 1(Travel time) , those with a longer average travel time per day were more likely to choose Option 1 (Travel time).

(3) Preference for number of transfers: Compared option 2 (1 transfer) with option 1 (0 transfer), those who use the transportation card are more inclined to choose option 2 (1 transfer). Compared option 3 (2 transfers) with option 1 (0 transfers), those who used the transportation card preferred option 3 (2 transfers). Compared option 4 (3 or more transfers) with option 1 (0 transfers), older people and those who travel by car prefer option 1 (0 transfers), while those who use a transportation card prefer option 4 (3 or more transfers).

(4) For the preference of transfer payment mode, there was no significant correlation among the variables. This may be a transfer payment model (1- pay before departure; 2 - segmented payment; 3-- Pay after the trip; 4-- package or prepaid) preference is relatively discrete, or it may be due to small sample size or unreasonable independent variables leading to little correlation, and further research will be conducted in the future.

(5) Preference for transfer payment tools: Compared option 2 (Phone (QR code) payment) with option 1 (Transportation card), older people and those who use transportation card are more likely to choose Option 1 (Transportation card), and those with higher income and more vehicles in their families are more likely to choose Option 2 Phone (QR code). Compared Option 3 (Face scanning payment) with option 1 (Transportation card), people who travel for a long time per day are more likely to choose option 3 ((Face scanning payment), and those who use transportation cards are more likely to choose option 1 (Transportation card). Compared option 4 (Bank cards, cash et al.) with option 1 (Transportation card), men who travel for a long time per day are more likely to choose option 4 (Bank cards, cash et al.), and those who use transportation card are more likely to choose option 1 (Transportation card).

(6) Preference for transfer payment packages: Compared to option 1 (pay-as-you-go), the correlation between option 2 (daily package) and the independent variable is not significant. Option 3 (Monthly package) is more preferred by older people than Option 1 (Pay-as-you-go). Older, working, and male respondents preferred Option 4 (Annual package) to Option 1 (Pay-as-you-go).

(7) Multi-mode (transfer) transportation can be accepted by most passengers, and young people without private cars are the main users of multi-mode (transfer) transportation. In the design of MaaS multi-mode (transfer) transportation, the travel time should be optimized, and the pay-as-you-go delivery mode based on the transportation card (smart card) should be optimized.

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