Presented at Transportation Research Board 82nd Annual Meeting, Washington D.C, January 2003

Consumer's Perception of Fare When Using Farecard In Urban Railway Route Choice

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- Submission date: 31 July 2002 (Japan's local time)
- Word count: 5,756 words including tables and figures

- **Abstract.** Recently rail operators increasingly introduce a farecard system. This system makes users have richer alternatives of payment modes as well as save their travel time and nuisance to pay. On the other hand, to pay without the cash might paralyze a sense of treating money, and this phenomenon may be observed in the transportation behavior as well. This paper aims to analyze the price perception of travel demand when using the farecard. We analyze the behavior of rail users based on the MNL model for a railway route choice and compare the price perception among various payment modes. The authors set up two hypotheses on the model structure and test them statistically. The one is that a passenger possessing the farecard has a different price perception from a passenger without the farecard. The other is that a passenger has various price perceptions of travel demand when using various types of payment methods even in a route, and her/his price perception when using the farecard is different from that when using the normal ticket. As the results of the tests, we find that the perception does not differ between the farecard holders and non-farecard holders, but that the perception possibly differs between payment methods.

INTRODUCTION

Urban railway operators increasingly introduce a farecard system due to the recent development of information technology. In predicting the response of the market to the introduction of the new system, it is important to know how much the travelers respond to the change of payment method within the rail use. The rail operators also have an interest in how much they need to invest for the new payment system or how much they can earn by the introduction of the new system.

The introduction of the farecard system possibly impacts the behavior of rail passenger. One of the most specific characteristics of using the farecard is that no cash is needed when riding the train. In purchasing the farecard, the travelers get the right to use the railway service in advance, and they consume their right gradually whenever they travel by the railway. Thus, they need not to see nor touch the cash at all when they ride the train. On the other hand, if they do not own the farecard, they have to pay the fare by the cash when riding the train. This characteristics of the farecard influences the consumer's behavior. In this paper, we consider that the consumer's perception of fare may be different between the different payment methods. This is because the consumers may misjudge the price of service when they pay less attention to the price.

There are several studies in the marketing research on the consumer's behavior considering several kinds of payment methods. Bawa et al. (*1*) focused on the coupon and analyzed the purchasing behavior between coupon-prone and non-coupon-prone households. They found that the coupon-prone households tend to have a more educated husband and a higher average income than the non-coupon-prone households. As for the credit card, Hirschman (*2*)(*3*) examined a hypothesis that a consumer possessing only a bank card or a store-issued card will make larger total dollars purchases than a consumer without a bank card or store-issued card. She uses the consumer's data obtained from an interview in several branches of a department store chain and conducted the multiple classification analysis. She concluded that the survey results support the hypothesis. However, since those researches did not consider the price of goods, we still cannot find the empirical evidence on the difference of price perception between payment methods. With regards to the relationship between the fare and the consumer's behavior in public transport market, there are several empirical analyses in a consideration of various types of payment methods (Hensher (*4*); Gilbert and Jalilian (*5*)), but they do not focus on the difference of price perception between difference payment methods. As far as the credit card is concerned, some researchers, such as Doran (*6*), pointed out that many people suffer from wasting much money for purchasing goods due to too much use of credit cards. Some of them even fall into the personal bankrupt. Although this is the extreme case in which the consumers lose control of themselves for the consumption, one of the reasons for this may be regarded as a difference of the perception of price between paying by the cash and paying by the credit card. The cashless payment might paralyze the perception of price of consumers. This phenomenon may be observed in the transportation behavior as well.

In this paper, we examine an idea that the perception of the fare is different between when riding a train with the farecard and when riding the train without the farecard. If this tendency is supported, the value of travel time of passengers may be less in the cashless payment, because the consumers tend to think little of the fare when they do not perceive the price appropriately. For the verification, we collect data on the route choice behavior of urban railway passengers in the Tokyo Metropolitan Area, and apply the MNL model to the behavior. Then we test our hypothesis statistically by the estimated models and finally discuss policy implications of the results.

Scope of the Research

This paper aims to analyze the price perception of transport demand. As the transport demand, we focus on the route choice behavior of the urban railway network in the Tokyo Metropolitan Area. We eliminate the rail passengers commuting to the workplace and the school pupils using the railway from our scope, because they tend to use only commuter passes or seasonal tickets since they travel to their workplaces or schools almost every day. Consequently, we focus on private purpose travels in an off-peak period of a day. The private travel includes visiting friends, visiting relatives, going shopping, going to the theater etc.

As the payment method, as of the year of 2000, the urban railway operators in the Tokyo Metropolitan Area provide four kinds of payment modes: a commuter pass; a farecard; a coupon ticket; and a normal ticket. The commuter pass is so-called a seasonal ticket by which passengers can travel between the fixed origin-destination stations for the certain valid period. The valid period of the commuter passes is categorized into three: one, three, and six months. The passengers can choose the period among them. Next, the farecard is a magnetic card, which can store some money, but cannot be recharged. The coupon is a ticket sold as a unit of ten coupons with some premium. One example of the premium is that ten coupons are sold at a price equal to the price of the eleven normal tickets. Although there are several kinds of coupons provided by the different operators, such as a coupon ticket which can be used for a fixed route, a fixed fare coupon and a fixed time coupon, etc., this paper assumes that there is only one kind of coupon for simplicity, that is, the coupon which is valid for the fixed route. It is expected that this simplification does not influence the result of our analysis, because more than half of the coupon users actually use this type of coupon ticket in the Tokyo Metropolitan Area. Finally, the normal ticket is the one, which is valid for just one riding within the day when it is purchased.

METHODOLOGIES OF ANALYSES

Formulation of Hypotheses

We propose two hypotheses for the passenger's behavior in a travel by rail shown as follows:

H1: A passenger possessing the farecard has a different price perception from a passenger who never possesses the farecard.

H2: The price perception of a passenger is different between when using the farecard and when not using the farecard.

The hypothesis 1 means that railway passengers can be segmented into two kinds of groups. The price perception is different between the farecard-prone passengers and the non-farecard-prone passengers. The hypothesis 1 is quite similar to the hypothesis of Hirschman (*2*), but our hypothesis is based on the price perception of demand whereas the Hirschman's one is based on an amount of purchase or demand itself. The hypothesis 2 means that one passenger can have various price perceptions under various conditions and the perception is determined by what kind of payment method is chosen by the passenger. This is based on the fact that a passenger often uses more than one travel tickets even in a route in the Tokyo Metropolitan Area. Because the commuter pass and the coupon ticket can be used for a fixed section or a fixed OD pair, a passenger has to use two or more kinds of tickets when she/he would like to cross over the section. These two hypotheses are not antinomy. Thus, it is possible that both hypotheses are supported by statistical tests.

Working Hypothesis 1

Suppose that there are more than one alternative routes from an origin station to a destination station, and that passengers can choose a purchase method among the farecard, the coupon, and the normal ticket. Suppose that passengers can be categorized into two groups: the farecard holders and the non-farecard holders. We assume that a utility function of a passenger in a passenger group m (= card or non-card) is

$$U_i^m = \beta_C^m + \beta_T^m T_i^m + \beta_F^m F_i^m + \varepsilon_i^m = V_i^m + \varepsilon_i^m \tag{1}$$

where U_i^m is the utility of route i of a passenger belonging to the group m, T_i^m is a travel time, F_i^m is a travel cost, β_k^m is a k-th coefficient, ε_i^m is an unobserved random variable, and V_i^m is a deterministic portion of the utility. When we assume ε_i^m the identical and independent Gumbel distributed, a probability of choosing an alternative route i, P_i^m, is expressed as

$$P_i^m = \frac{\exp\left(\lambda^m V_i^m\right)}{\sum_j \exp\left(\lambda^m V_j^m\right)} \tag{2}$$

where λ^m is a scale parameter related to a variance of the Gumbel distribution.

We test whether a vector of the coefficients in the utility function of the farecard holders is equal to the vector of the coefficients in the utility function of the non-farecard holders in order to know the difference of the price perception between two groups. A null hypothesis is set up as:

$$H_0^1 : \boldsymbol{\beta}^{card} = \boldsymbol{\beta}^{noncard} \tag{3}$$

where $\boldsymbol{\beta}^m$ is a vector of the coefficients of the passenger group m. For the test of this hypothesis, we apply a part of the procedure proposed by Swait and Louviere (*7*) and Louviere, Hensher and Swait (*8*), which is based on the likelihood ratio test (Ben-Akiva & Lerman (*9*)). This method enables us to compare parameters of the MNL between different data sets by using a standard MNL software. The procedure is described as follows:

STEP1: a scale parameter of one passenger group m (card or non-card), λ^{m1}, is set to one. Then, β^{m1} and $\lambda^{m2}\beta^{m2}$ are estimated separately by the FIML (Full Information Maximum Likelihood) estimates, which is obtained by maximizing the following log likelihood function:

$$\underset{\beta^m}{Max}\, L^m = \underset{\beta^m}{Max}\left[\sum_n \sum_i \delta_{ni} \ln P_{ni}\right] \tag{4}$$

where δ_{ni} is the observed choice result for alternative route i and individual n. Then, the maximum log likelihoods of both groups, L^{m1} and L^{m2}, are obtained.

STEP 2: under a condition of $\beta^{m1} = \beta^{m2}$, a maximum log likelihood L^{λ} is obtained by changing a value of λ^{m2} based on the passengers data of both groups.

STEP 3: whether the null hypothesis can be rejected is tested. Here we use the likelihood ratio test statistic

$$\gamma_a = -2\left[L^{\lambda} - \left(L^{m1} + L^{m2}\right)\right] \tag{5}$$

This test statistic is asymptotically chi-squared distribution with (K+1) degrees of freedom. K is the number of coefficients in the utility function. As Swait & Louviere (*5*) pointed out, this procedure requires that the MNL is the true model that holds the IIA, and systematic sources of difference across decision-makers in the utility function have been accounted for by the inclusion of the appropriate variables in the utility functions.

Working Hypothesis 2

Suppose that a passenger uses two kinds of payment methods in a path from an origin station to a destination station. We assume that the utility function of all passengers is uniform and expressed as

$$U_i = \theta_C + \theta_T\left(T_i^a + T_i^b\right) + \theta_F^a F_i^a + \theta_F^b F_i^b + \varepsilon_i \tag{6}$$

where U_i is the utility of an alternative route i, T_i^j is the travel time of route i with payment method j, F_i^j is the travel cost of route i with payment method j, θ_k is a coefficient, and ε_i is an unobserved random variable. We test whether the coefficient of the travel cost with a payment method j is equal to that with the other payment method j' in order to know whether there is a difference of price perception between payment methods. Consequently, we set up a null hypothesis on the coefficients of the travel cost between the payment method a and b,

$$\theta_F^a = \theta_F^b \tag{7}$$

In order to test the hypothesis 2, we use an asymptotic t test statistic (Ben-Akiva & Lerman (*7*))

$$\frac{\theta_F^a - \theta_F^b}{\sqrt{\mathrm{var}\left(\theta_F^a - \theta_F^b\right)}} \tag{8}$$

and

$$\mathrm{var}\left(\theta_F^a - \theta_F^b\right) = \mathrm{var}\left(\theta_F^a\right) + \mathrm{var}\left(\theta_F^b\right) - 2\,\mathrm{cov}\left(\theta_F^a, \theta_F^b\right) \tag{9}$$

where $\mathrm{var}(\cdot)$ is a variance and $\mathrm{cov}(\cdot,\cdot)$ is a covariance.

VERIFICATION OF HYPOTHESES

Data Collection

We conducted a questionnaire survey for urban railway users in the Tokyo Metropolitan Area. The survey covers the travelers' origin stations, destination stations, chosen routes, possession of the commuter pass, the farecard, the coupon and their individual attributes as well as the reasons why they chose the payment method. These data were collected through a website and the post. The survey was conducted in early November 2001. The share of possession of tickets is shown in FIGURE 1.

From the results of the passenger's attitude for the choice of payment methods, we select variables in the utility function as the travel time, the travel cost, the number of transfers, the number of purchasing the normal tickets. Therefore, the following analyses for tests are based on the models including theses variables.

Analysis: Hypothesis 1

First, we estimate three models by the FIML; based on the data of the whole sample passengers, the data of the farecard holders and the data of the non-farecard holders respectively. The estimated results are shown in TABLE 1. All coefficients have reasonable signs and t-statistics are also good enough. Second, after the scale parameter of the model for the farecard holder is set to be one, the log likelihood function for the whole sample data is maximized by changing the scale parameter of the model for the non-farecard holders. Before the maximization, the coefficients of the two MNL models: farecard holder and non-farecard holders against one to another is graphed as FIGURE 2 to find a range of the scale parameter. FIGURE 2 implies that a co-relationship of coefficients between the two models is very high, and the slope of the regression line seems from 1.2 to 1.4. As a consequence of the maximization we find that the scale parameter maximizing the log likelihood is 1.3, which is shown in FIGURE 3, and the estimated result is shown in TABLE 2. Finally, we test the null hypothesis 1 by the chi-squared statistic with a degree of freedom 5. The statistic is 0.56 when the scale parameter is 1.3. Because the test interval of the scaling parameter is quite much, we calculate the chi-squared statistics when the parameters are 1.2 and 1.4 additionally. Then we obtain them as 0.82 and 0.64. These statistics show that the null hypothesis 1 cannot be rejected statistically.

Analysis: Hypothesis 2

For analysis of the hypothesis 2, we define the fare of each payment method firstly. The fares of the farecard, the coupon ticket and the normal ticket are regarded as the travel cost that a passenger pays actually for his/her travel. This means, for example, that the fare of the coupon ticket is discounted due to its premium. When summing up all fares in a path from an origin to a destination, we apply the existing rail operators' fare regulation to the travel cost of the path. For instance, when a passenger travels from a station in one operator's line to a station in another operator's line, the fare of the latter operator is added to the fare of the former operator. This is because all rail operators in Japan have their own fare systems and they have no coordination of fare system between different rail operators in the Tokyo Metropolitan Area.

With regards to the fare of the commuter pass, we set the following two cases because the travel cost with the commuter pass is possibly regarded as a sunk cost:

1. model 1: the travel cost is regarded as zero
2. model 2: the travel cost is regarded as the saving cost that is calculated by a gap between the travel cost when using the commuter pass and the travel cost when using the normal ticket for a section where the commuter pass is used.

The estimation results of the models are shown in the TABLE 3. Although the t-statistics of the number of purchasing normal tickets in both models are not great enough, the signs of all coefficients are reasonable and the model statistics are also quite good. From the estimated coefficients, we find that the largest absolute value of coefficients is the normal ticket and the second largest is the farecard and the lowest is the coupon ticket. This means that the price sensitivity of the normal ticket is highest and that of the coupon is lowest. This tendency can be found in both models. Then, we test whether the price perception is statistically different among payment modes. First, we calculate the asymptotic t statistics for farecard and normal ticket, and find that we can reject the null hypothesis 1 by 25 % of the degree of significance. As for the relationship between the farecard and the coupon, and the one between the normal ticket and the coupon, we find that the hypothesis 2 can be rejected by 10 % of the degree of significance. From these results, the hypothesis 2 can be rejected statistically to some extent.

DISCUSSIONS

Interpretation of the Analyses Results

The hypothesis 1 is not supported statically. This means that the statement that the farecard-prone people tends to pay more than the non-farecard-prone people might be a myth, at least in the rail route choice. One of the reasons for this result is that the impact of using farecard is quite limited because the rail farecard can be used only for the railway service whereas the credit card can be used for any goods and any service. In addition, the price of the farecard is quite low, at most 5,000 yen (about 45 US$), whereas the credit card can be used for almost unlimited price of goods.

On the other hand, we find that the hypothesis 2 is supported statistically by some degree of significance. This means that a railway passenger recognizes the change of paying methods even in a trip. This change is recognized not when the passenger is traveling but when she/he chooses the payment method and the route in advance of the travel. This means that the railway passengers are so sensitive that they determine a payment method in choosing their rail routes. If we assume that the perception of travel time is common among the different payment methods but the perception of fare is different among various payment methods, we can regard the difference of price perception as the difference of the value of travel time. The values of travel time valuated from the estimated model parameters are 921 [yen/hour] for the farecard use, 1,524 [yen/hour] for the coupon use and 850 [yen/hour] for the normal ticket use. As we expected, the value of travel time in using the normal ticket is the lowest.

We may find the other reason for the difference of the value of travel time among various payment methods, that is, the payment sensitivity depends upon the transaction cost. For instance, when the passenger chooses the normal ticket, they need to go to the vending machine in order to purchase the ticket, but when using the farecard they need not to go to the vending machine nor need not to wait in the queue. The reason why the value of travel time in using coupon is higher than the value in using the farecard may be also the transaction cost, for instance the cost that the passengers have to keep all coupons and pay attention not to lose them. From this point of view, we have tried to consider the transaction cost as the variables of the time of purchasing the normal ticket in the utility function. Since the t-statistics of this variable is not high enough, we cannot judge that the transaction cost is really dominant factors to the passenger's behavior.

Expected Impact of the Different Price Perception Among Payment Methods

The result that the value of travel time when paying by the farecard or the coupon ticket is less than the value when paying by the normal ticket can impact the project evaluation significantly whatever its reason is. First of all, when a market share of the farecard holders increases due to the penetration of the farecard, an average of the value of travel time in the market will decrease as a whole. Then, we expect the change of the behavior of travelers such as they choose a faster but more expensive rail route when the farecard system becomes more popular. In the usual transport demand analysis, we never consider the market share of farecard holders. In the future information-oriented transportation market, we need to consider the impact of the penetration of farecard system more seriously especially when a new payment method such as the smart card will be introduced into the public transport market including the urban railway service.

Second, we need consider the impact of change of price perception when we evaluate the benefit of the new investment. The fact that the value of travel time when purchasing the farecard and the coupon is seemingly higher than that when purchasing the normal ticket will lead to the bias of project evaluation. For example, a project will be evaluated better when more travelers use the farecards than when less consumers use the farecards. Without the consideration of the penetration of the farecards, we may misjudge the impact of the project.

Third, the penetration of the farecard will possibly impact on the profitability of the rail operators. If the price perception of travel demand become lower when the farecard system becomes widespread, passengers tend to choose a route by which they can travel faster even though the travel cost is more expensive. This might increase the profit of railway operators. Moreover, even if a railway operator has to impose an additional fare on passengers, for example, when they start a new railway service extending to the existing line operated by the other operators, a resistance of passengers against paying an additional fee will decrease due to the less price perception. Thus, we need to consider that the rail operators must take account of the impact of the new payment method more seriously.

CONCLUSIONS

In this paper, we analyze the price perception of travelers by the rail route choice and find that the price perception of travel demand do not differ between the farecard holders and the non-farecard holders, but possibly differ between the payment methods. For the further study, we may observe the same phenomenon in other behaviors as well. For instance, we may find the same phenomenon in the electrical toll collection system in an expressway or in the general purchase at stores. As the cashless payment method becomes more popular in the near future, the consumer's purchase of service may change drastically due to the difference of the price perception. Since the result of our examination still has several theoretical problems, we need to examine this problem in more details. In addition, we need analyze how much this phenomenon influences the transportation market in the future.

ACKNOWLEDGEMENTS

We thank the East Japan Railway Cultural Foundation for supporting a research fund to this research. We also thank Mr. Nakajima, Y. for his support to the survey for this research.

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LIST OF TABLES AND FIGURES

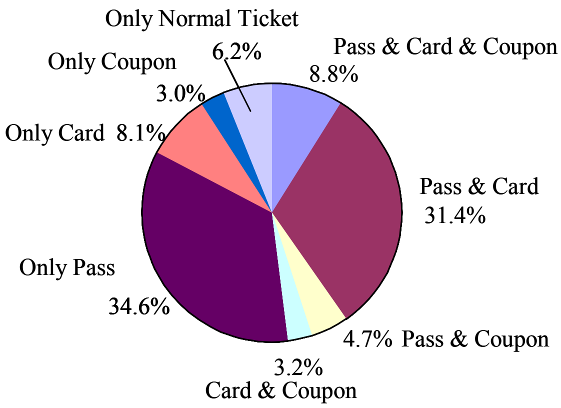

FIGURE 1 Share of Payment Methods for Rail Use in the Tokyo Metropolitan Area.

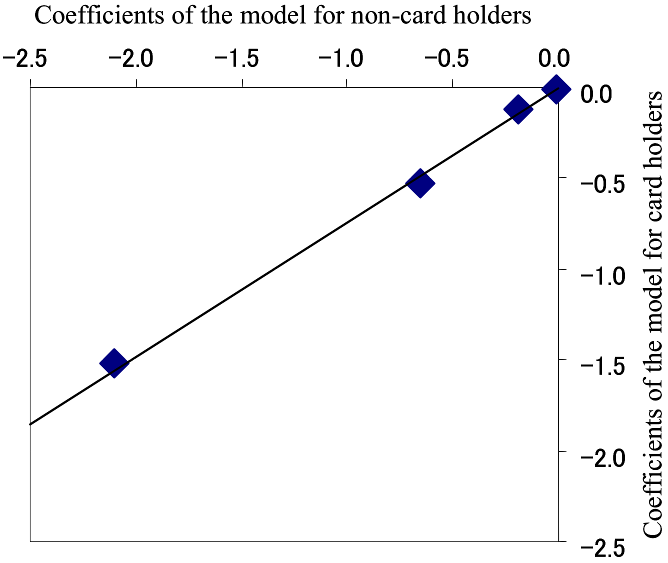

FIGURE 2 Estimated Coefficients: Farecard Holders vs. Non-Farecard Holders.

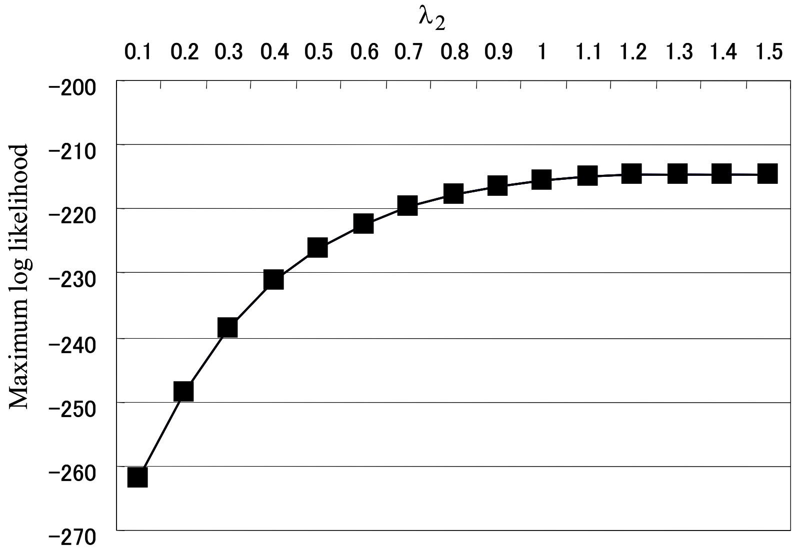

FIGURE 3 Maximum Log Likelihood With Related to λ_2.

TABLE 1 Estimation Results of Models for Test of Hypothesis 1

Variables	Units	Whole samples		Card holders		Non-card holders	
In-vehicle time	minutes	-0.1492	(-5.930**)	-0.1196	(-3.754**)	-0.1913	(-4.629**)
Transfer time	times	-1.7427	(-7.812**)	-1.5149	(-5.391**)	-2.0988	(-5.584**)
Fare	yen	-0.0058	(-3.752**)	-0.0059	(-3.052**)	-0.0060	(-2.389*)
time of purchasing normal tickets	times	0.6091	(-2.626**)	-0.5326	(-1.363*)	-0.6498	(-2.155*)
Number of samples		205		112		93	
Hit ratio	%	60.98		58.93		63.44	
Initial log likelihood		-331.38		-181.53		-149.85	
Maximum log likelihood		-215.52		-127.42		-86.77	
Likelihood ratio		0.349		0.298		0.421	
Adjusted likelihood ratio		0.346		0.292		0.415	

* means significance in 5% degree and ** means significance in 1% degree.

TABLE 2 Estimation Results When Maximum Log Likelihood is Maximized

Variables	Units	$\lambda_2 = 1.3$	
In-vehicle time	minutes	-0.1345	(-6.006**)
Transfer time	times	-1.5706	(-7.881**)
Fare	yen	-0.0052	(-3.851**)
time of purchasing normal tickets	times	-0.4982	(-2.503**)
Number of samples		205	
Hit ratio	%	60.98	
Initial log likelihood		-331.38	
Maximum log likelihood		-214.47	
Likelihood ratio		0.353	
Adjusted likelihood ratio		0.350	

* means significance in 5% degree and ** means significance in 1% degree.

TABLE 3 Estimation Results of Models for Test of Hypothesis 2

Variables	Units	Model 1		Model 2	
In-vehicle time	minutes	-0.1473	(-5.625**)	-0.1497	(-5.646**)
Transfer time	times	-1.8733	(-7.865**)	-1.8984	(-7.826**)
Fare of pass	yen			0.0012	(-0.586)
Fare of card	yen	-0.0096	(-5.574**)	0.0090	(-4.548**)
Fare of coupon	yen	-0.0058	(-1.786*)	-0.0054	(-1.640*)
Fare of normal ticket	yen	-0.0104	(-5.801**)	-0.0098	(-4.768**)
time of purchasing normal tickets	times	-0.1820	(-0.677)	-0.1989	(-0.732)
Number of samples		205		205	
Hit ratio	%	64.88		65.85	
Initial log likelihood		-331.38		-331.38	
Maximum log likelihood		-193.41		-193.24	
Likelihood ratio		0.416		0.417	
Adjusted likelihood ratio		0.412		0.412	

* means significance in 5% degree and ** means significance in 1% degree.