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# USE OF STATED CHOICE ANALYSIS TO DETERMINE ETC IN-VEHICLE TRANSMITTER PURCHASING BEHAVIOR

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An electronic toll collection (ETC) system began operating in Japan in March 2001. However, only a very small percentage of vehicles in Japan have in-vehicle ETC transmitters. This research seeks to determine what sorts of ETC promotion programs and ETC features will motivate drivers to purchase the in-vehicle transmitters. Stated choice experiments were conducted using an Internet-based questionnaire. Several subjective rating questions regarding perceived attitudes on ETC system were also asked in order to categorize respondents with the similar preferences. The relationship between perceived value and purchasing behavior of transmitters are investigated by using an ordered latent class choice model.

***Key Words :*** *ETC in-vehicle transmitter, stated choice analysis, ordered latent class choice model, interactive Internet-based survey, taste heterogeneity*

## 1. INTRODUCTION

Electronic toll collection (ETC) uses various technologies to automate the toll collection process so that drivers do not have to stop to pay cash at a tollgate. ETC service began in Japan on March 30, 2001. The service seeks to alleviate traffic congestion near tollgates; enhance driver convenience by eliminating cash handling; and reduce management costs. Plans call for Japan's ETC system to handle complicated toll systems that charge varying amounts according to the type of vehicle and distance traveled. In addition, by implementing and diffusing ETC services, reduced traffic congestion and emission reduction improvements are expected.

However, the sales data up to 7 May 2002, record only 241,206 cars in Japan equipped with ETC transmitters[1)]. Approximately, this number accounts for 0.3 percent of the total number of cars in Japan[2)] (based on 2001 estimates of approximately 70 million cars). Given the present circumstances, even if flexible toll systems such as distance-based fee system were implemented, only a small percentage of cars in Japan could use and receive the benefits. Thus, road administrators must consider how to best promote ETC transmitters. For example, the Ministry of Land, Infrastructure and Transport (MLIT) declared that the implementation cost of transmitters, including the buying expences and the installation cost, would be reduced by 20%. Another example is the social experiment, which MLIT conducted, where the expressway toll for automobiles with transmitters were reduced[[1]]. In spite of these efforts, the promotion of ETC transmitters has not been doing well.

One of the marketing strategies to promote the diffusion of transmitters effectively is to conduct different policy countermeasures depending on the value orientations of each driver, which may reflect the difference in the propensity of ETC use. In the field of marketing literature, it has been recognized that perceived value on the target product have the significant effects on the consumers' purchase decisions[3),4)]. Each individual, of course, has his/her own vales for ETC use. From a marketing perspective, however, it is useful and cost effective to partition the target drivers of transmitter purchase into several groups in such a way that specific marketing strategies can be implemented to the target segments.

In order to capture these properties in detail, we chose a random utility model incorporating taste heterogeneity, since it allows us to estimate the value respondents place on each attribute for every segmented group. However, due to the small percentage of ETC transmitter users, it was difficult to collect revealed preference data (that is, actual market sales data). Additionally, drivers seem to prefer a variety of transmitter types and attributes. For example, some drivers may feel that transmitters are not that important, while others may perceive them as useful and good to have. Still others might be willing to buy a transmitter if the prices were lower. Consumer tastes for transmitters are likely very diverse.

Given current buying behaviors of ETC in-vehicle transmitter, we thus organized our research around a latent class choice model and a Internet-based survey questionnaire based on the following objectives. First, we sought to explore factors that determine drivers' ETC transmitter purchasing behavior. Second, through the parameter estimation and the elasticity analysis, the relationship between perceived value (attitude) and purchasing behavior of transmitters are investigated. This lead us to capturing preference variation among respondents. Finally, the implications of the results for promoting transmitters are discussed and identified by conducting policy simulations.

This paper begins by describing choice experiment design. Section 2 outlines the data collection process, while Section 3 presents the latent class choice model applied to the transmitter stated choice data. Section 3 further discusses estimation results, elasticities of probability, and policy analysis results. Finally, Section 4 presents conclusions and future research directions.

## 2. EXPERIMENTAL DESIGN AND DATA COLLECTION

### (1) Attributes and Types of ETC transmitters

This research examines individuals' ETC transmitter purchasing behavior with government interests, rather than commercial ETC sellers' profits, in mind. Therefore, most attributes discussed here are those that government is interested in and can control directly and/or indirectly, not attributes of the transmitter design. The four attributes selected for the stated choice experiment were as follows:

(1) Price of unit (yen):
 25,000; 30,000; 35,000; 40,000;
(2) Toll discounts (%): 10, 20, 30, 35;
(3) Reduction in tollgate waiting time (minutes):
 1, 2, 4, 8;
(4) Distance-based toll system: Yes, No.

All attributes have the following four levels, except for the distance-based toll system, which has only two levels. The attributes are defined as follows: (1) Price is the price of a transmitter. In June, 2002, market prices of transmitters range from 30,000 to 50,000 yen. (2) Toll discounts represent discounts given only to transmitter users. (3) Reduction of waiting time at tollgate is the amount of time that respondents could save at tollgates if they installed a transmitter. This indicates the travel time difference between with ETC and without ETC. Finally, (4) A distance-based toll system is a rate system that depends on travel distance rather than a fixed rate, as discussed in the following section.

### (2) Definition of the Distance-based Toll System

Currently, Japan's Road Law classifies toll roads into three types: national expressways, urban expressways, and general toll roads. The Japan Highway Public Corporation (JHPC) constructs and manages national expressways. The Metropolitan Expressway Public Corporation (MEPC), Hanshin Expressway Public Corporation, and designated public corporations build and manage regional urban expressways.

This research targeted car owners in the Kanto region. Thus, we examined urban expressways constructed and managed by the MEPC and national expressways managed by the JHPC.

At present, the toll system applied by the JHPC depends on distance. However, the MEPC charges a flat-rate for three Tokyo, Kanagawa, and Saitama routes. The flat-rate toll system simplifies toll collection, and thus saves time on toll collection and requires no exit gates.

This research examines how a distance-based toll system would impact the MEPC's urban expressways. The present flat rate toll system for the Tokyo area is 700 yen. Thus, we set the maximum fee for distance-based tolls at 700 yen. With this maximum rate, drivers who usually use Tokyo expressways would not have to pay additional money under a distance-based system. We expect that this toll system would promote transmitter use.

The minimum distance-rate toll was set at 200 yen for distances within 5 km. Tolls then increased linearly with distance at a rate of 33.33 yen/km until reaching the 700 yen rate. With this new system, those traveling less than 20 km would pay less than under the current system, while those traveling over 20 km would pay the same amount.

### (3) Stated Choice Experiment Design

The stated choice experiments presented the following three transmitter purchase alternatives to respondents:

1) Hypothetical transmitter option A;
2) Hypothetical transmitter option B;
3) None of the transmitter options.

As shown in **Fig. 1**, "none" choice alternative is explicitly included in the experiment. The preceeding research[5] suggested that the existence of none option in choice experiments might increase the predictive accuracy of choice models if the target product are not well diffused in the marketplace. In the case of ETC transmitters, the market share with respect to the number of automobile is very low. The deployment of none option in the experiment might be helpful to enhance the analytidcal validity and reliability of the model.

The attributes and levels described in Section **2.(1)** were used to create transmitter profiles. Attribute combinations for each transmitter choice were constructed using a $4^3 \times 2$ orthogonal main effects design, which resulted in 16 transmitter profiles. Next, these sixteen profiles were paired with their foldover to create sixteen choice sets[6]. A foldover is a mirror image of the original design (*i.e.*, replace each 0 by 1, and each 1 by 0). This approach guaranteed orthogonality within and between the two transmitter options in the different choice sets[7]. Next, the third choice option of "none" was added to each pair. Then, choice sets in which one profile is superior to another in every attribute were removed. This step reduced the sixteen profiles to fourteen profiles. Since fourteen choice sets is still too many for respondents, we randomly assigned four choice sets to each respondent for evaluation. Each respondent therefore evaluated four pairs of transmitter descriptions. The respondents also had the option of choosing neither transmitter type. The previous works by Zwerina[8] and the Hague Consultancy Group and Steer Davis Gleave[9] explain this type of research design in detail.

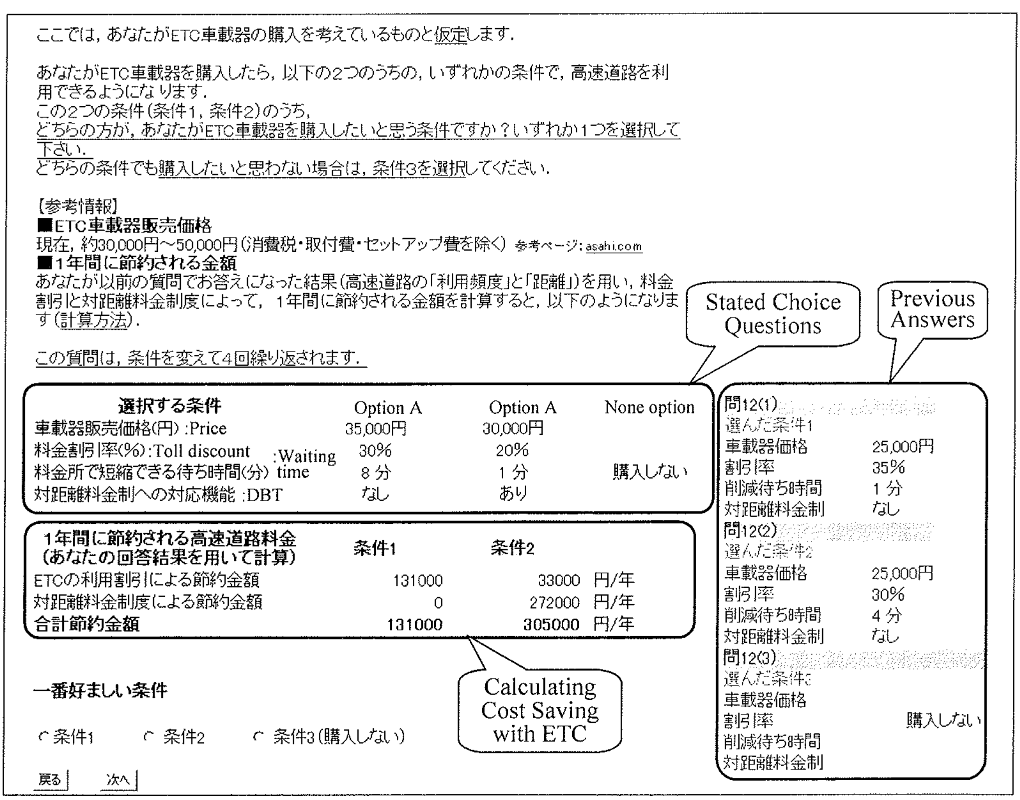



**Fig. 1** An example of stated choice screen on the web

### (4) Survey Questionnaire

Data were collected during a one-week-long Internet-based survey from June 14 to June 21, 2002. The questionnaire design and the development of program code for the Internet were conducted by the authors. The survey was administered by Information Development Center Co.,Ltd[2]. This company has its own registrants for the Internet-based survey they conduct. The company recruited respondents through electronic mailings. Only car owners living in the Kanto region (composed of the Tokyo Metropolitan Area, and Saitama, Gunma, Chiba, Kanagawa, Tochigi, and Ibaraki prefectures) were allowed to answer the survey. Of the 579 respondents, 538 returned usable surveys.

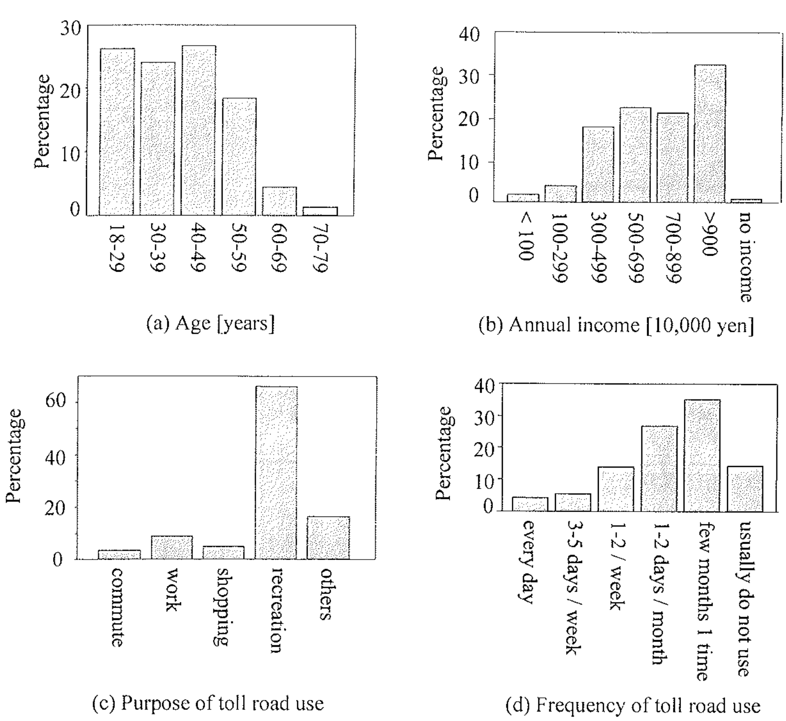
The Internet-based survey consisted of five main pages. Page 1 asked about respondents' toll road use experiences and requested other information related to ETC transmitters. Page 2 consisted of five-point-scale ratings questions with respect to respondents' opinions towards transmitters. Page 3 provided explanations about the effects of transmitter diffusion. Page 4 asked the centerpiece stated-choice questions (see **Fig. 1**). Surveyed respondents were asked to evaluate one choice set at a time and to choose among three alternatives, two of which were transmitter profiles and one of which was a "none" choice. This process was undertaken four times.

The survey's design is distinct from other stated choice experiments [10)-12)] in two main ways. First, previous answer tables accompanied each choice task so that respondents could avoid inconsistent answers. Respondents could also change their answers on a confirmation page after they had answered all survey questions. Second, a table showing savings based on respondents' previous answers for expressway driving frequency and distance, was also presented on the computer screen. By providing more information on ETC-related cost savings, respondents could make decisions more consistently and easily.

Finally, page 5 consisted of a brief questionnaire about individual characteristics (sex, age, marital status, occupation, and income). Pilot tests indicated that the survey required approximately eight minutes to complete and could be entirely self-administered.

### (5) Sample Characteristics

We anticipated that the Internet-based survey would attract mainly young respondents. However, the age range of the respondents was wider than expected; 26% of respondents were between eighteen and twenty-nine, 24% were between thirty and thirty-nine, 26% were between forty and forty-nine, 18% were between fifty and fifty-nine, and 5% were between sixty and sixty-nine. Male and



(a) Age [years]
(b) Annual income [10,000 yen]
(c) Purpose of toll road use
(d) Frequency of toll road use

**Fig. 2** Sample Characteristics

female response rates were approximately equal. The largest income group (32%) had an annual income of more than nine-million yen. The other lower income categories of 3-4.9, 5-6.9, and 7-8.9 million yen per year were about equally represented with 18%, 22%, and 21% response rates, respectively. Approximately half of the respondents, 44%, were office workers and 26% were homemakers. All had their own cars. 59% of respondents were familiar with ETC transmitters, 40% had heard of them, and 1% had no knowledge of them.

Most respondents were not frequent expressway users. More than half, 62%, answered that they use expressways 1-2 times (27%) or 2-3 times (35%) per month. 24% were frequent users. Of those, 4% used the expressways almost everyday, 6% used expressways 3-5 days per week, and 14% used expressways once a week (14%). Respondents answered that their average monthly toll fees were approximately 4,100 yen per month. Most (66%) used the expressways for recreation purposes. Only 3% of respondents had transmitters installed in their cars. In contrast, about one-third responded that they had computer route-navigators in their cars. In stated choice experiments, a high percentage (about 43%) of total respondents chose option three. That is, they chose neither of the transmitter options. The principal sample characteristics are shown in **Fig. 2**.

## 3. MODEL FORMULATION AND ESTIMATION

Respondents seem to have various tastes in ETC transmitters. It is impossible to know in advance how many market segments can be defined for ETC transmitters, since we have so little information about the tastes of respondents and their purchasing behavior. In order to incorporate taste heterogeneity among drivers, we applied a latent class choice model (LCCM)[13)-15)]. The LCCM assumes that each respondent belongs to latent segments, which are unobservable to analysts. Thus, these segments are dealt with probabilistically.

### (1) Individual Choice Model

Suppose the utility (or preference) of alternative $i \in C_n$ for individual $n$ belongs to latent segment $s$ ($s$ = 1, . . . , $S$), which is unknown to the analyst, and defined as

$$U_{in|s} = \beta_s X_{in} + \varepsilon_{in|s}, \tag{1}$$

where $\beta_s$ is a utility parameter row vector for segment $s$, $C_n$ is the choice set and $X_{in}$ is a column vector of alternative and individual characteristics. $\varepsilon_{in|s}$ is an error term. Assuming that the distribution of error terms ( $\varepsilon_{in|s}$ ) is IID Gumbel with scale factor $\mu_s$, the conditional choice probability of choosing alternative $i \in C_n$ for individual $n$ belonging to segment $s$ is found by the following multinomial logit (MNL) model:

$$P_{in|s} = \frac{e^{\mu_s \beta_s X_{in}}}{\sum_{j \in C_n} e^{\mu_s \beta_s X_{jn}}}. \tag{2}$$

When we observe a randomly-selected individual from the population, we cannot observe their segment membership. Instead, we suppose that a latent segment membership scoring function can be observed, as follows:

$$Y_n = \gamma Z_n + \upsilon_n, \tag{3}$$

where $\gamma$ is a parameter row vector, $Y_n$ is a latent membership scoring function, and $Z_n$ is the observed perceptual and attitudinal indicator column vector of the individual $n$ and $\upsilon_n$ is an error term.

In order to define a latent membership indicator, $I_n$ is related to $Y_n$ as follows:

$$I_n = \begin{cases} 1 \text{ if } & Y_n \le \tau_1 \\ 2 \text{ if } & \tau_1 \le Y_n \le \tau_2 \\ \vdots \text{ if } & \vdots \\ S \text{ if } & \tau_{S-1} \le Y_n \end{cases}, \tag{4}$$

where $\tau_s$ $(s = 1,\ldots,S-1)$ are cutoff parameters to be estimated. These $\tau_s$ define the range of $Y_n$ that classifies respondents into each latent segment. It should be noted that in order to construct $S$ classes, an $S$-1 cutoff parameter has to be estimated.

From equation (3), the error term $\upsilon_n$ is assumed to be independently distributed across individuals so that the cumulative density function is

$$G(\upsilon_n) = [1 + \exp(-\upsilon_n)]^{-1}, -\infty < \upsilon_n < \infty. \tag{5}$$

Thus, the segment membership probabilities, $W_{ns} = \Pr(I_n = s)$, *for* $s = 1,\ldots,S-1$, can be calculated as

$$W_{ns} = \Pr(I_n = s) = \begin{cases} G(\tau_1 - \bar{Y}_n) & \text{if } s = 1 \\ G(\tau_2 - \bar{Y}_n) - G(\tau_1 - \bar{Y}_n) & \text{if } s = 2 \\ \vdots & \vdots \\ 1 - G(\tau_{S-1} - \bar{Y}_n) & \text{if } s = S \end{cases}, \tag{6}$$

where $\bar{Y}_n = \gamma Z_n$ (see equation (3)). By assuming that error term $\upsilon_n$ is logistically distributed, the class membership model $W_{ns}$ serves as an ordered logit model. Thus, we call this model an ordered LCCM.

Next, the unconditional probability of observing $n$ choosing $i \in C_n$ can be expressed in terms of the two probability functions as defined in equations (2) and (6), and can be written as

$$P_{in} = \sum_{s=1}^{S} P_{in|s} W_{ns}. \tag{7}$$

The model explained above imposes an ordinal relationship among the latent segments; membership in higher-order segments implies higher values of $Y_n$, and vice versa.

The model used here is based on Swait and Sweeny[14]'s model. In this study, attitude towards having a transmitter (*AH*) and attitude towards transmitter benefits (*AB*) were defined. Both variables are calculated from principal component analysis (PCA), explained later.

Swait and Sweeny[14] and Louviere *et al.*[6] discuss an important aspect of the parameter identification. It is not possible to simultaneously estimate scale factors $\mu_s, s = 1,\ldots,S$ and utility parameters in the model $\beta_s, s = 1,\ldots,S$. Some means of dealing with this problem are as follows:

1. Constrain scale factors as equal but let utility parameters vary across segments (*i.e.*, estimate $\beta_1,\ldots,\beta_s$ and set $\mu_1 = \cdots = \mu_s = 1$);
2. Force utility parameter homogeneity but let scale parameters vary across segments (*i.e.*, estimate $\beta_1 = \cdots = \beta_s = \beta$ and $\mu_1,\ldots,\mu_s$, by normalizing $\mu_1 = 1$).

Each of these possibilities reflects different behavioral assumptions concerning taste heterogeneity and error term variance within latent segments. The first possibility represents the hypothesis that taste parameters differ between latent segments, but have equal variance of error terms. Alternatively, in the second possibility, tastes are assumed to be homogenous across segments, but heterogeneous in terms of error variance. Our main concern is in capturing taste heterogeneity among different segments. Hence, all scale factors are constrained to be equal among segment. Future research should also consider another possibility on the specifitcation of unknown parameters.

The variables used in the latent membership scoring function ($Y_n$) were explained to respondents. In addition to the choice task, respondents also were asked several questions about their opinion towards transmitters, as explained in Section 2.4. The selected variables form $Z_n$ (see **Table 1**). In this set of questions, respondents had to rate their opinion on a five-point scale ranging from strongly-agree to strongly-disagree. These five-scale data were then subjected to PCA to yield the underlying factor structure.

First, we tried to estimate the PCA and the segmentation model (i.e., ordered logit model) simultaneously. However, the estimation results did not converge due to the complexity of the functional form of log-likelihood. For the sake of simplicity in estimation procedure, the PCA result was identified separately from the segmentation model.

The PCA method revealed two factors that accounted for 53% of variation, whereas the contribution ratios of other components are all very low (less than 7% for every component). That is the reason the two factors are regarded as $Z_n$s in the present study. Factor 1 was mainly composed of items No.1-6 and the factor 2 was chiefly composed of items No.7-9 in **Table 1**. By using PCA, the weights of each subjective question are calculated for two factors with the following equations:

$$\begin{aligned} Z_{n1} = 0.395 \times INNO_n + 0.742 \times WITHNCAR_n \\ + 0.723 \times NEARPEOP_n + 0.742 \times SUPERIOR_n \\ + 0.683 \times GOODBAD_n + 0.551 \times DIF_n \\ + 0.191 \times WAIT_n + 0.252 \times WINDOW_n \\ + 0.113 \times ENVI_n, \end{aligned} \tag{8}$$

**Table 1** Questions used for the latent membership scoring function

| No. | Contents (abbreviations for each question) |
|---|---|
| 1. | Are you interested in new products such as in-vehicle navigators or ETC transmitters? (*$INNO_n$*) |
| 2. | The next time you buy a new car, would you like to have a transmitter installed? (*$WITHNCAR_n$*) |
| 3. | If people close to you, such as family members or friends, buy a transmitter, would you be likely to buy one too? (*$NEARPOP_n$*) |
| 4. | Since very few people now have in-car transmitters, do you think owning one would give you a sense of superiority? (*$SUPERIOR_n$*) |
| 5. | Would people close to you (friends and family) agree with your decision to buy a transmitter? (*$GOODBAD_n$*) |
| 6. | Do you think ETC transmitters will become widespread in the near future? (*$DIF_n$*) |
| 7. | Would using an ETC transmitter make you more comfortable, as you would not need to open your car window to pay a toll? (*$WINDOW_n$*) |
| 8. | Do think using an ETC transmitter will considerably reduce your waiting time at toll gates? (*$WAIT_n$*) |
| 9. | Do you think ETC diffusion can contribute to improved environmental conditions, such as reduced air pollution? (*$ENVI_n$*) |

$$Z_{n2} = 0.16 \times INNO_n + 0.281 \times WITHNCAR_n + 0.103 \times NEARPEOP_n + 0.07 \times SUPERIOR_n + 0.205 \times GOODBAD_n + 0.432 \times DIF_n + 0.819 \times WAIT_n + 0.746 \times WINDOW_n + 0.715 \times ENVI_n. \quad (9)$$

We designated the factor 1 as "attitude towards having a transmitter (*AH*)", and the factor 2 as "attitude towards transmitter benefits (*AB*)". The factor scores of factor 1 (*AH*) and factor 2 (*AB*) were used as $Z_n$ in equation (3) to explain the latent segment membership.

**(2) Estimation Results**

The utility functions for the choice-given segment model were specified respectively, with an alternative-specific constant for the "none" option, price, toll discount, waiting time reduction, and distance-based toll system choices. All of these variables were attributes of the stated-choice task.

**Table 2** presents two base models used for comparison with the latent class choice model. The first base model is a simple multinomial logit model (MNL), assuming a single segment in the population (*i.e.* $S = 1$). We call this model the "naïve model" (NM). In this model, we incorporated only the four attributes used in the stated choice task and the one "none" option constant. Several individual characterisitcs regarding automobile use (e.g., trip frequency and trip distance) were tested in the process of model specification. The inclusion of these variables, however, did not improve data fit significantly, contraly to our expectations. An explanatory power of the model is somewhat low, ($\bar{\rho}^2$ =0.087), as shown by the goodness-of-fit statistics. In spite of the low explanatory power of the model, there were signs of parameter correctness, and significance levels were generally high, except for the waiting time reduction variable and the "none" option constant (option 3). In the first base model, we did not incorporate any personal attribute variables. We did so in the second base model by including two PCA-derived factors (*AH* and *AB*) in the MNL utility function specification. This model also maintained the one segment assumption. We labeled the second base model the "base attitude model" (BAM). Adding *AH* and *AB* to the utility functions of transmitters was clearly statistically significant. The likelihood ratio test ($\bar{\rho}^2$) increased from 0.087 to 0.143. Both attitude parameters were significant and positive. This indicates that a person who has high *AH* and *AB* values will be inclined to buy a transmitter, which conforms to our hypothesis.

Since the number of segments for the model estimator is unknown, we used the Akaikes Information Criterion (*AIC*) and the Consistent Akaikes Information Criterion (*CAIC*) to select the number of segments[14)-16)]. Both *AIC* and *CAIC* are based on the log likelihood at convergence (LL). The *AIC* encourages parsimonious selection by penalizing log likelihood improvements that result from increased complexity. *CAIC* is similar to *AIC* but considers sample size as well as the number of parameters. The model with the smallest *AIC* and/or *CAIC* was selected. Statistical tools, however, ultimately only serve as guides, and analysts must make the final decision based on their judgment. The *AIC* and *CAIC* values were calculated as

$$AIC = -2(LL_s - K_s), \quad (10)$$

$$CAIC = -2LL_s + (4S-1)(\ln(2N)-1), \quad (11)$$

where $LL_s$ is the log likelihood at convergence for a model with $S$ segments, $K_s$ is the number of parameters for a model with $S$ latent segments, $S$ is

**Table 2** Estimation results for the naïve- and base attitude- models

| Parameters | Naïve model (NM) Estimates | t-ratio | Base attitude model (BAM) Estimates | t-ratio |
|---|---|---|---|---|
| *Uutility function* | | | | |
| None option constant | -0.123 | -0.65 | -0.159 | -0.85 |
| Price | -0.694 | -11.0 | -0.698 | -11.0 |
| Toll discount | 0.530 | 13.0 | 0.533 | 13.0 |
| Waiting time reduction | $-2.00\times10^{-3}$ | -0.25 | $-2.00\times10^{-3}$ | -0.15 |
| Distance-based toll system | 0.597 | 8.9 | 0.602 | 8.9 |
| Attitude towards having a transmitter (*AH*) | | | 0.771 | 15.0 |
| Attitude towards transmitter benefits (*AB*) | | | 0.164 | 3.5 |
| *Summary statistics* | | | | |
| Initial log likelihood | -2364.2 | | -2364.2 | |
| Log likelihood at convergence | -2152.9 | | -2017.4 | |
| No. of parameters | 5 | | 7 | |
| AIC rho squared | 0.087 | | 0.143 | |
| No. of sample | 2152 | | 2152 | |

the number of segments, and $N$ is the number of samples.

We then estimated the latent class choice model for different numbers of latent segments, ranging from one to four ($S$ = 1,...,4) and graphed $AIC$ and $CAIC$ (**Fig. 3**). It can be seen that $AIC$ and $CAIC$ reach a minimum at $S = 3$. Therefore, we selected the three-segment solution as the best model to express utility parameter heterogeneity among segments (see **Table 3**).

The base attitude model (BAM, in **Table 2**) and the three-segment latent class model (**Table 3**), are non-nested models, thus normal likelihood ratio test statistics cannot be used for comparisons. The modified likelihood ratio test (MLR) was applied to compare the two models[17]. The calculated MLR value was 26.9, which is more than a 1.35 ratio. Therefore, we could safely conclude that the three-segment latent class model is superior to the BAM.

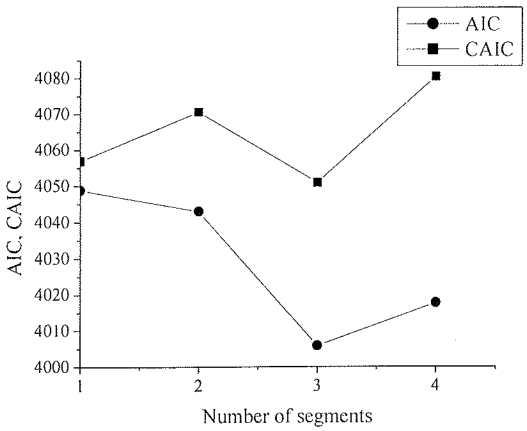



**Fig. 3** AIC and CAIC with respect to the number of segments

We implicitly posit that the coefficient of each attitudinal variable is the same among individuals because the main focus of the paper is to explore the impact of drivers' perceived value on the attitude to ETC system.

From the estimation results (**Table 3**), we obtained the following estimated latent segment membership scoring function:

$$\bar{Y}_n = 3.37 AH_n + 1.74 AB_n, \qquad (12)$$

and cutoff parameters ( $\tau_1 = -2.22$ and $\tau_2 = 2.68$ ). Both $AH$ and $AB$ have significance in the latent segment membership scoring function. Automobile use characteristic were also tested even in the membership function. These variables, however, were not statistically significant. It is mainly because that these variables were highly correlated with the perceived variables for transmitters. That might lead to multicollinearity between covariates. These attributes on car use were exluced in the model specification in such a way that the property of the membership function is currently understood.

If we assume that each respondent belongs to the segment with the highest probability, the identified latent class model can predict the size of each segment: 48.7% for segment 1, 27% for segment 2 and 24.3% for segment 3. Not surprisingly, the largest group (48.7%) was segment 1, the group with

**Table 3** Estimation results for the ordered-logistic latent segment model (3 segment solution)

| | Segment 1 | | Segment 2 | | Segment 3 | |
|---|---|---|---|---|---|---|
| *Parameters* | Estimates | t-ratio | Estimates | t-ratio | Estimates | t-ratio |
| *Utility function* | | | | | | |
| None option constant | 1.072 | 3.2 | -0.775 | -0.55 | -1.28 | -1.2 |
| Price | -0.594 | -6.1 | -0.852 | -3.2 | -0.832 | -2.9 |
| Toll discount | 0.597 | 9.0 | 0.408 | 3.2 | 0.700 | 2.9 |
| Waiting time reduction | 0.0122 | 0.59 | -0.0737 | -0.87 | 0.0804 | 1.5 |
| Distance-based toll system | 0.597 | 5.5 | 0.483 | 1.6 | 0.997 | 3.0 |
| (Predicted segment size) | 48.7% | | 27.0% | | 24.3% | |
| *Class membership function* | | | | | | |
| Attitude towards having transmitter ($AH$) | 3.37 | 4.9 | | | | |
| Attitude towards benefit of transmitter ($AB$) | 1.74 | 5.0 | | | | |
| Cutoff parameter $\tau_1$ | -2.22 | -5.1 | | | | |
| Cutoff parameter $\tau_2$ | 2.68 | 1.6 | | | | |
| *Summary statistics* | | | | | | |
| Initial log likelihood | -2364.2 | | | | | |
| Log likelihood at convergence | -1983.1 | | | | | |
| No. of parameters | 18 | | | | | |
| AIC rho squared | 0.153 | | | | | |
| No. of sample | 2152 | | | | | |

the lowest $AH$ and $AB$ values. Low $AH$ and $AB$ values mean negative attitudes towards having a transmitter and towards transmitter benefits. People belonging to this group (segment 1) are not lilely to want to purchase transmitters. This is consistent with the current situation in Japan, where only a small percentage of total cars have transmitters. The second and the third-largest groups were segments 2 and 3, respectively. The smallest segment was respondents with positive attitudes towards having transmitters and transmitter benefits (*i.e.* high value of $AH$ and $AB$).

**Fig. 4** shows how the three estimated segment membership probabilities (equation (6)) behave as a function of $AH$ and the cutoff parameters, for a fixed average level of $AB$.

As shown in **Fig. 4**, due to the ordinal nature of the segments, low $AH_n$ and $AB_n$ values lead to a high probability of membership of the individual $n$ in segment 1, and large $AH_n$ and $AB_n$ values lead to a high probability of membership in segment 3. Intermediate values of $AH_n$ and $AB_n$ result in a high probability of membership in segment 2.

**Table 3** also suggests that transmitter price has a significant negative effect in all segments, while waiting time reduction is not significantly different from zero for all segments. Low waiting time reductions and the closeness of the reduction categories may account for this result. Waiting time reductions were shown as only one, two, four, and eight minutes. It is assumed that respondents may have feel that waiting time reductions are less important than other attributes (price, toll discounts, and the distance-based toll system). To illustrate this, we compared the two transmitter options. One attribute set the waiting time reduction to eight minutes (the largest reduction presented in the experiment) and priced transmitters at 40,000 yen. Another option set waiting time reduction at two minutes and priced transmitters at 30,000 yen. The comparison among these two sets indicates one possibility that respondents may feel that the six minute time saving difference has less value than the 10,000 yen saving on the cost of the product.

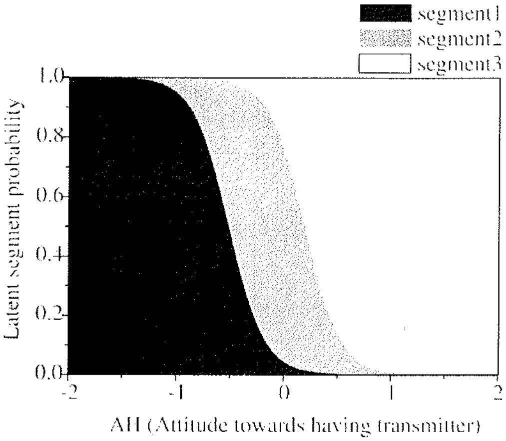



**Fig. 4** Latent segment membership probabilities as a function of the variable $AH$

For segment 1, **Table 3** shows utilities based on all three attributes except waiting time reduction, which was not statistically significant for all segments. This segment has a positive value for the alternative specific constant, or "none" option. Thus, for segment 1, the average effect of unobserved factors on purchasing behavior is negative. This is consistent with this group's negative attitude towards having a transmitter and towards transmitter benefits.

Price had the greatest negative impact on the second segment. This was quite common for all segments. Interestingly, the distance-based toll was not statistically significant for segment 2 so much, though it was strongly significant for segments 1 and 3. This implies that the distance-based toll system policy had less effect on the segment 2 group. Again, the alternative specific constant "none" option was not significant for segment 2. Members in this group can be considered to have a neutral attitude towards having a transmitter and towards transmitter benefits on an average.

In contrast to segment 1, segment 3 showed a low probability of choosing "none." The coefficient of the "none" option constant was less than zero. Only 24.3% of this group chose the "none" option, the smallest percentage of all three groups. The segment 3 population thus displayed a positive attitude towards having a transmitter and towards transmitter benefits. All parameters (price, toll discounts, and distance-based tolls) were significant for this segment.

### (3) Elasticity and Policy Analysis

#### a) Calculating Elasticities

It is important to understand the extent to which transmitter choice probabilities will change in response to factor changes. Elasticity allows us to evaluate the degree to which variables change in response to other variables. In this paper, aggregate elasticities are calculated here with the stated preference data.

In order to calculate aggregate elasticities, elasticities were first calculated for each individual based on the individual's characteristics and the characteristics of the alternatives presented to the individual. The elasticity of $P_{in}$ (probability of individual $n$ choosing alternative $i$) with respect to variable $X_{ink}$, the $k$th variable entering the utility of alternative $i$, was calculated by

$$E^{P_{in}}_{X_{ink}} = \frac{\partial P_{in}}{\partial X_{ink}} \cdot \frac{X_{ink}}{P_{in}}. \qquad (13)$$

Next, the aggregate elasticity for alternative $i$, a weighted average of the individual level elasticities using the choice probabilities as weights, was estimated as

$$E^{\bar{P}_i}_{X_{ik}} = \frac{\sum_{n=1}^{N} P_{in} E^{P_{in}}_{X_{ink}}}{\sum_{n=1}^{N} P_{in}}. \qquad (14)$$

Finally, the aggregate elasticities were calculated by averaging the elasticities of two transmitter alternatives, namely, $(E^{\bar{P}_1}_{X_{1k}} + E^{\bar{P}_2}_{X_{2k}})/2$. The average aggregate elasticities with respect to price, toll discounts, waiting time reductions, and the distance-based toll system were -1.0029, 0.6441, 0.0339, and 0.1669, respectively.

The aggregate elasticity of the probability of choosing a transmitter based on price was the largest of the variables. This implies that a percent change in price may greatly contribute to a percent change in the probability of choosing that alternative. Hence, the three possible policies for promoting transmitter use are (1) reduction of transmitter prices, (2) increasing toll discounts, and (3) implementation of a distance-based toll system. These three policies are arranged in order from the most to least effective, if we assume equal costs for implementing all measures.

**b) Policy Analysis**

To illustrate the effects of the three policies explained above, a base transmitter case was set to approximate the current situation. The base case attributes were given as follows: price equals 40,000 yen, 20% toll discount, two minutes reduced waiting time, and no distance-based toll system. We varied each attribute in the base case and and provided only two choices: buying or not buying a transmitter. The predicted percentage of people who would purchase a transmitter could then be calculated.

The following three policy scenarios were simulated here:

(1) Transmitter price reduction,
(2) Increased toll discounts
(3) Implementation of distance-based toll system.

The scenario of reducing waitng time is eliminated since its coefficients are not statistically significant.

**Fig. 5** plots the percentage share of those who would buy transmitters given transmitter price variations (**Fig. 5 (a)**), toll discount variations (**Fig. 5 (b)**), and the implementation of a distance-based toll system (**Fig. 5 (c)**). In **Fig. 5 (a)**, the price of transmitters ranges from 40,000 yen to 0 yen. As the graph shown in **Fig. 5 (a)** illustrates, respondents, who can belong to setment 3 with the highest probability, would

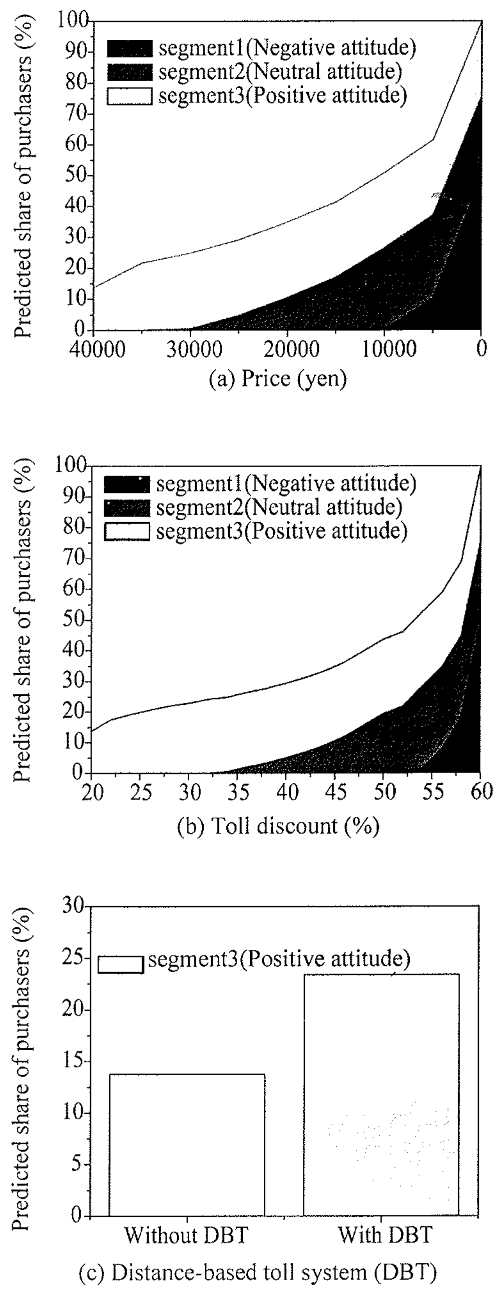



**Fig. 5** Comparison among policy scenarios

purchase a transmitter even if the price were quite high. As for the people belonging to segment 2 or segment 1 with high propensity, they would not purchase until the price was reduced to about 30,000 yen and 10,000 yen, respectively. **Fig. 5 (b)** can be interpreted similarly. Respondents who have high propensity to belonging to segment 3 would still purchase a transmitter even with a low toll discount. People who are probabilistically vested in segment 2 or segment 1, on the other hand, would not purchase a transmitter until the tolls were discounted by about 33% and 53%, respectively. Distance-based toll system implementation is be likely to motivate only the respondents with high positive attitude (i.e., segment 3) to purchase a transmitter.

The iso-lines in **Fig. 6** illustrate how varying price and toll discounts would effect transmitter buying if the distance-rate toll system were implemented. This diagram enables us to understand the effects of policies in which two attributes are simultaneously changed. For example, when the transmitter price are fixed to 40,000 yen, the market share cannot reach 30% even if the toll is reduced by 30%.

It should be noted that the predicted share of transmitters may be exaggerated. In the base case, the percentage share of transmitters was approximately 14%, which differs from the survey situation of less than 1% transmitter ownership. As previously pointed out by literatures, the answer for stated choice experiments can have several kind of response biases, including prominence hypothesis, policy response bias and justification bias[18), 19)]. For example, the survey which we conducted used the following questioned sentence: "If you were considering buying an ETC in-vehicle transmitter, which one would you choose?". This might have had

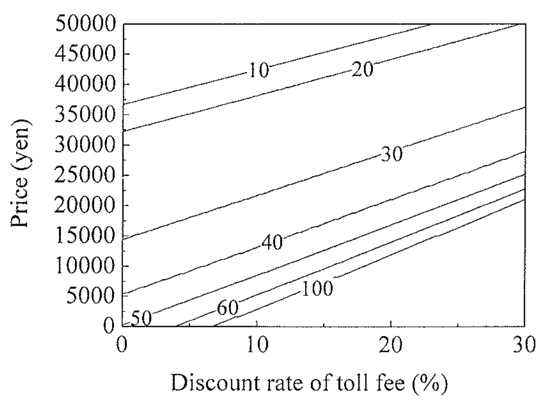



**Fig. 6** Iso-lines of share of transmitter buyers with respect to transmitter price and toll discounts (assuming a distance-based toll were implemented)

a bias towards the buying decision anddiscouraged some respondents from deciding not to buy. That leads to cause an exaggerated prediction. These possible biases should be modified in further works. Neverthless, we believe that the data gathered hear and the empirical analysis are useful in defining attributes that respondents find valuable.

## 4. CONCLUSIONS AND FUTURE RESEARCH DIRECTIONS

This study analyzed individuals' ETC in-vehicle transmitter purchasing behavior. An interactive, Internet-based, self-administered stated-choice survey and ordered logistic latent class choice model were used to fulfill the research objectives.

The ordered logistic latent class choice model divided respondents into segments based on their attitude towards having a transmitter (*AH*) and attitude towards transmitters' benefits (*AB*). As a basis for comparison, we implemented a trinomial logit model with *AH* and *AB* (base attitude model) and without *AH* and *AB* (naïve model). The base attitude model worked much better than the naïve model, and the latent class model yielded improved fit beyond the base attitude model. Therefore, it can be concluded that *AH* and *AB* are useful in determining segmentation. The estimated parameters indicated that for all three segments, reduced waiting time was not statistically significant. In contrast, price coefficients had a high significance value for all three segments.

Elasticities of choice probability with respect to the four main attributes (price, toll discounts, waiting time reduction, and the distance-based toll) were calculated. Three suggested policies for promoting the use of transmitters were: (1) reducing the transmitter price, (2) increasing the toll discounts, and (3) implementing a distance-based toll fee system. Reducing the transmitter price was the most effective option and could increase the probability of transmitter purchase. Policies might also evaluate dual incentives that reduce transmitter prices and increase toll discounts for transmitter users.

For the further work, first, the Internet-based survey format might occur a bias in the sample. Other survey methods should be used to improve the quality of sample data. Second, the stated choice experiments using the interactive Internet-based survey should be examined in more detail. We tried to reduce the resulting bias in statec choice experiments including fatigue effect and state-dependence effect. However, the effects of these treatments remain unspecific. There is a need to evaluate these matters. Third, this research considered taste heterogeneity among individuals by dividing respondents into latent segments dictated by the model itself. We assumed that the unobserved factors that affect decision-makers are independent of the repeated choice. As a result, each choice situation by each respondent was treated as a separate observation. A model such as a mixed logit model[11] that allows repeated choices by each sampled decision-maker should be estimated and compared to the latent class choice model incorporationg the serial correlation among repeated choices.

## NOTE

[1] The details on these countermeasres for promotion can be confiemed in http://www.orse.or.jp/.

[2] The URL of the company is http://www.idcnet.co.jp.

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## 選好表明データを用いたETC車載器購入行動の分析

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我が国では，2001年3月にETCシステムの一般向け運用が開始された．ETC導入による渋滞緩和や環境改善等が期待されているが，車載器の普及が進んでおらず，これらの効果が充分顕在化していない．そこで本研究では，インターネット調査を通じて収集した選好表明データを用いて，個々のドライバーの車載器購入行動をモデル化し，普及促進のための政策について検討した．インターネット調査を通じて，仮想的に作成した車載器プロファイルに対する購入意向を尋ね，嗜好の異なる複数のセグメントを考慮可能な順序型潜在クラス選択モデルを構築した．最後に，同定したモデルに基づいて，車載器価格や道路料金割引率に対する購入確率の感度分析を行った．