between 30 and 50 years old. Respondents with an annual household income of ¥4 to ¥8 million (approx USD 45,000 to 90,000) account for 51.2 percent of the sample. The proportion of respondents with children that are under 19 years old is 49.2 percent and households of more than three people account for 62.3 percent of all. The average car ownership per household is 1.4. Since 87.6 percent of the respondents have a full-time job, the frequency of car usage on both weekdays and at weekends is high, with the percentage of those driving every weekday and every weekend reaching 62.2 and 48.3, respectively. Regarding type of residence, 58.0 percent of the respondents live in detached houses, which might provide them with a better situation for EV charging. Table 1 gives descriptive details of the demographic information.

Table 1. Respondents' demographics

| Item | Category | Frequency | Percentage |
|---|---|---|---|
| Age | Under 30 | 168 | 5.4% |
| | 30 to 39 | 824 | 26.6% |
| | 40 to 49 | 1,134 | 36.6% |
| | 50 to 59 | 663 | 21.4% |
| | 60 and older | 308 | 9.9% |
| Gender | Male | 2,867 | 92.6% |
| | Female | 230 | 7.4% |
| Employment | Working | 2,712 | 87.6% |
| | Not working | 385 | 12.4% |
| Children | Yes | 1,523 | 49.2% |
| | No | 1,574 | 50.8% |
| Annual household income | Up to ¥4 million | 793 | 25.6% |
| | ¥4-8 million | 1,585 | 51.2% |
| | ¥8 million or more | 719 | 23.2% |
| Type of residence | Detached house | 1,796 | 58.0% |
| | Apartment | 1,301 | 42.0% |
| Geographical location | Nagoya city | 1,021 | 33.0% |
| | Aichi prefecture (Nagoya city excluded) | 1,038 | 33.5% |
| | Gifu prefecture | 552 | 17.8% |
| | Mie prefecture | 486 | 15.7% |
| Number of people in household | 3 or more | 1,928 | 62.3% |
| | Up to 3 | 1,169 | 37.7% |
| Car ownership | One car | 2,048 | 66.1% |
| | Two cars | 874 | 28.2% |
| | Three cars | 120 | 3.9% |
| | Four cars | 55 | 1.8% |
| Car usage frequency on weekdays/month | Up to 10 days | 778 | 25.1% |
| | 10 to 19 days | 394 | 12.7% |
| | Every day (20 days) | 1,925 | 62.2% |
| Car usage frequency on weekends/month | Up to 4 days | 378 | 12.2% |
| | 4 to 7 days | 1,224 | 39.5% |
| | Every day (8 days) | 1,495 | 48.3% |

The question regarding EV purchase intentions was asked twice to each respondent.

Each time, the EV was randomly selected from among 27 patterns with different characteristics such as charging time, number of seats, price and range on a full charge (see Table 2). As a result, 1,255 respondents stated that they would like to buy an EV either as an additional car or as a replacement for their currently owned car, while 1,842 respondents stated that they would not buy an EV at all.

Table 2. Description of 27 patterns of EVs

| Pattern | Price/Seats | Range | Charging time/fast charging time | Proportion of gasoline stations with charging facilities |
|---|---|---|---|---|
| 1 | ¥1.5 million (2-4 seats)/¥2 million (7 seats) | 100km | 12hr/30min | 10% |
| 2 | | | 8hr/20min | 33.3% |
| 3 | | | 4hr/10min | 100% |
| 4 | | 200km | 12hr/30min | 33.3% |
| 5 | | | 8hr/20min | 100% |
| 6 | | | 4hr/10min | 10% |
| 7 | | 300km | 12hr/30min | 100% |
| 8 | | | 8hr/20min | 10% |
| 9 | | | 4hr/10min | 33.3% |
| 10 | ¥2.5 million (2-4 seats)/¥3 million (7 seats) | 100km | 12hr/30min | 100% |
| 11 | | | 8hr/20min | 10% |
| 12 | | | 4hr/10min | 33.3% |
| 13 | | 200km | 12hr/30min | 10% |
| 14 | | | 8hr/20min | 33.3% |
| 15 | | | 4hr/10min | 100% |
| 16 | | 300km | 12hr/30min | 33.3% |
| 17 | | | 8hr/20min | 100% |
| 18 | | | 4hr/10min | 10% |
| 19 | ¥4 million (2-4 seats)/¥4.5 million (7 seats) | 100km | 12hr/30min | 33.3% |
| 20 | | | 8hr/20min | 100% |
| 21 | | | 4hr/10min | 10% |
| 22 | | 200km | 12hr/30min | 100% |
| 23 | | | 8hr/20min | 10% |
| 24 | | | 4hr/10min | 33.3% |
| 25 | | 300km | 12hr/30min | 10% |
| 26 | | | 8hr/20min | 33.3% |
| 27 | | | 4hr/10min | 100% |

### 3.2 Psychological Motivations

Apart from the questions regarding EV purchasing intention and sociodemographic information, the respondents answered a set of nine questions relating to environmental consciousness and attitudes to transportation on a 5-point Likert scale with the endpoints defined as “strongly agree” and “strongly disagree”. A further one question addressed attitudes to the future prospects for EVs, with responses ordered on a two-point scale consisting of “agree” and “disagree”. These questions are listed in Table 3.

Based on these questions, motivational constructs fall into four groups. The first group relates to ***environmental consciousness***. This represents the respondents’ perceptions of environmental benefits and compatibility with their green values. This can also be understood as respondents’ environmental concerns and their belief in the positive consequences of reducing car driving. The second group is concerned with the ***automobile dependency***, which demonstrates respondents' associations with auto-dependency. It refers to personal travel habits, infrastructure construction and a self-image that favors automobile travel and sees transportation alternatives as relatively inferior (in this case, the term "automobile" includes cars, vans, light trucks, and SUVs). The third group relates to ***attitudes toward EVs***, which indicates respondents' acknowledgement of the price and the basic requirements for widespread adoption of EVs in the current market. It is also seen as a link to respondents' financial status. The fourth group is concerned with ***attitudes toward the future prospects for EVs***. This is a reflection of respondents' considerations and predictions related to the market share of EVs and how it will change in the future.

Table 3. Psychological questions and scores

| Questions | Scores |
|---|---|
| Using public transportation other than a car helps preserve the environment.<br>I am currently trying my best to reduce car use.<br>An automobile is a necessity for me.<br>Automobiles represent status in society.<br>Public transport is easy to use.<br>EVs are expensive.<br>A network of charging facilities is a prerequisite for the diffusion of EVs.<br>There is no need to reduce car use if I own an EV.<br>There will be a fall in EV prices in the near future. | 5 = strongly agree<br>4 = agree<br>3 = neutral<br>2 = disagree<br>1 = strongly disagree |
| More than half of vehicles in Japan will be replaced by EVs in 20 years. | 1 = agree<br>0 = disagree |

## 4. THE LATENT VARIABLE MODEL (MIMIC)

In order to investigate the relationship between attitudinal questions and four motivational constructs, Cronbach's alpha has been first calcuated under different combinations. However, no desirable results have been obtained, with the highest value of around 0.5. Therefore, a structural equation model (SEM) was constructed by considering the error tems. Note that all demographics data and answers to the attitudinal questions are used as causes and indicators in the SEM, with the properties connected to the four motivational constructs. In addtion, as an important special case of the SEM, the multiple-indicators multiple-causes (MIMIC) model is used to construct the latent (unobserved) variables postulated to be important for the choice model of purchase intention.

### 4.1 Model Estimation

MIMIC involves using latent variables that are predicted by observed variables. The resulting relations between indicators and latent variables as well as several tests of postulated relationships are obtained with the assistance of the software LISREL 8.54. Formally, the MIMIC model consists of two parts: the structural equation model and the measurement model. The structural equation model is given by:

$$\eta_t = B\eta_t + \Gamma x_t + \zeta_t \quad (1)$$

The measurement model represents the link between the latent variable and its indicators, i.e. the latent unobservable variable is expressed in terms of observable variables. It is specified by:

$$y_t = \Lambda\eta_t + \varepsilon_t \quad (2)$$

where $y_t$ is a vector of the ten observable indicator variables, $x_t$ is a vector of the seven exogenous observable variables that cause $\eta_t$, Β, Γ and Λ are matrices of unknown parameters to be estimated, $\zeta_t$ and $\varepsilon_t$ are measurement errors. Figure 1 shows the general structure of the MIMIC model (Buehn and Schneider, 2008). For descriptive information, see Table 4.

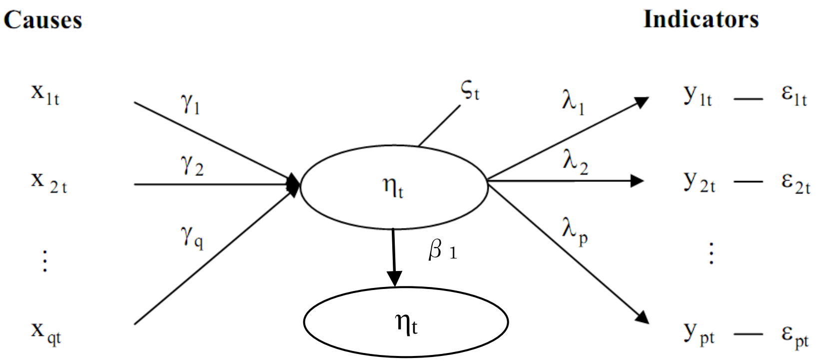



Figure 1. General structure of a MIMIC model

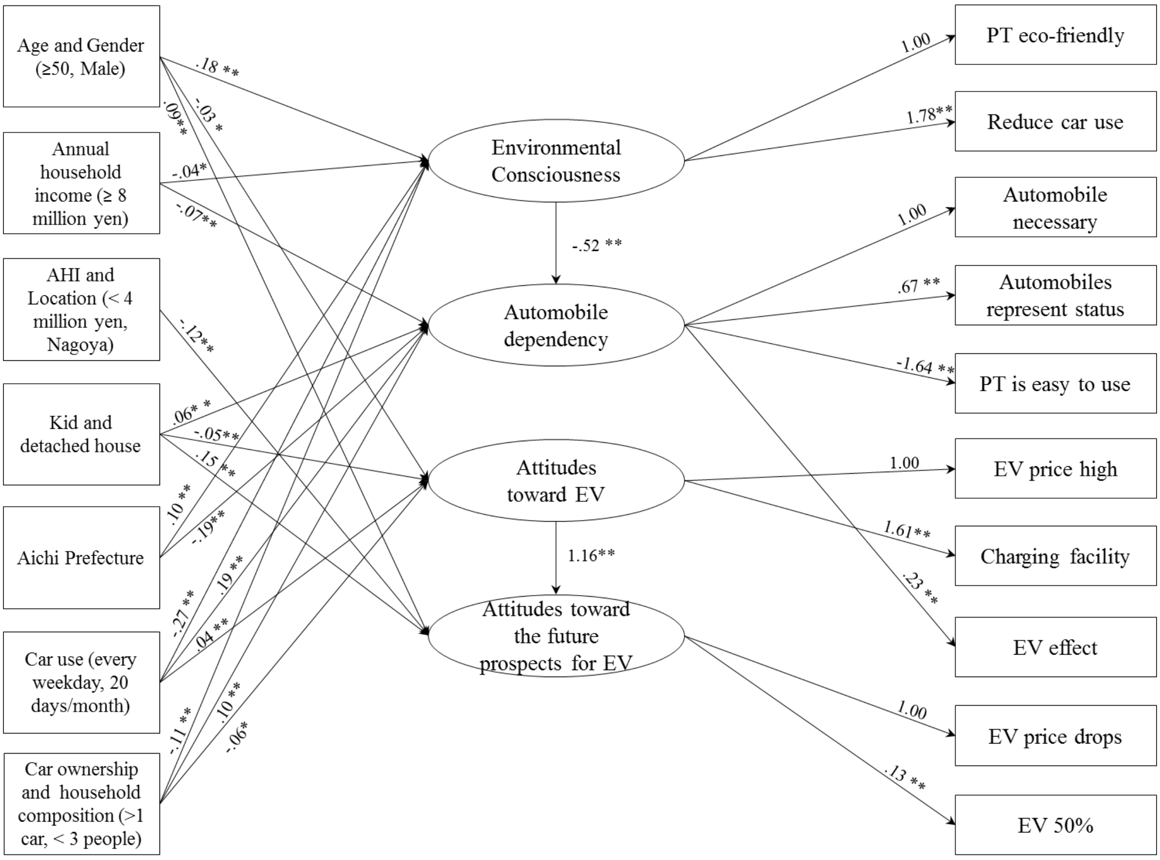
Table 4. Latent variables, indicators and causes

| Variable | Description |
|---|---|
| *Latent variables* | |
| *η1_EnvCs* | Environmental consciousness. |
| *η2_AutoD* | Automobile dependency. |
| *η3_EVatt* | Attitudes toward EVs. |
| *η4_EVfut* | Attitudes toward the future prospects for EVs. |
| *Indicators* | |
| y1_PTE | Using public transportation instead of a car helps preserve the environment. |
| y2_CUS | I am currently trying my best to reduce car use. |
| y3_NEC | An automobile is a necessity for me. |
| y4_STA | Automobiles represent status in society. |
| y5_PTU | Public transport is easy to use. |
| y6_PRH | EVs are expensive. |
| y7_CHG | A network of charging facilities is a prerequisite for the diffusion of EVs. |
| y8_EVE | There is no need to reduce car use if I own an EV. |
| y9_PRD | There will be a fall in EV prices in the near future. |
| y10_EVP | More than half of vehicles in Japan will be replaced by EVs in 20 years. |
| *Causes* | |
| Age/Gender | Dummy variable with value one if the respondent is 50 or older, male. |
| AHI | Dummy variable with value one if the respondent's household has an annual income of ¥8 million or more. |
| AHI/Location | Dummy variable with value one if the respondent's household is in Nagoya and has an annual income up to ¥4 million. |
| Child/House | Dummy variable with value one if the respondent's household includes children (persons younger than 19 years) and they live in a detached house. |
| Aichi | Dummy variable with value one if the respondent's household is in Aichi prefecture (Nagoya city included). |
| Car Use | Dummy variable with value one if the respondent's household uses a car on an everyday basis (weekdays, 20 days/month). |
| Car/People | Dummy variable with value one if the respondent's household includes less than three people and owns more than one car. |

*Note: AHI = Annual Household Income.*

## 4.2 Results of the MIMIC Model

Since no one statistic is universally accepted as an index of model accuracy, in this study a number of indices were computed to explain the fit of the model. The goodness-of-fit index (GFI=0.96), adjusted goodness-of-fit index (AGFI=0.93) and comparative fit index (CFI=0.84) are all close to 1.0, which points to a well-fitting model (Hu and Bentler, 1999). The root mean square error of approximation (RMSEA=0.06) and the standardized root mean square residual (SRMR=0.05) at values likewise confirm that the model produced a good fit to the data (Hooper et al., 2008). Figure 2 depicts the impact of the observed variables on the latent variables, and the impact of one latent variable on others.




$\chi 2$ = 1142, *df* = 86, *p* < .001, *GFI* = 0.96, *AGFI* = 0.93 *CFI* = 0.84, *RMSEA* = 0.06, *SRMR* = 0.05

Figure 2. Results of the MIMIC estimation: coefficients (* p < .10; ** p < .05) and model fit indices

Table 5 shows statistical information of the estimation results. The causes for individuals' latent preferences are the social-demographics of the respondents. All of the variables are classified into two categories (dummy variables). We find that men over 50 years old are more environmentally concerned and have more positive attitudes toward EVs. One possible reason is that the men over 50 years have relatively higher income, which enables them to buy EVs easily. Besides, they have a higher expectation of the future prospects for EVs, compared to other respondents. Thus we would as well recommend that this group of consumers be taken into consideration by auto makers and in policy development to achieve a high acceptance of EVs.

Table 5. MIMIC model for the four latent variables

| | **Latent variable** | | | |
|---|---|---|---|---|
| | *η1_EnvCs* | *η2_AutoD* | *η3_EVatt* | *η4_EVfut* |
| ***Indicator*** | | | | |
| y1_PTE | 1.00 | - | - | - |
| y2_CUS | 1.78(17.8) | - | - | - |
| y3_NEC | - | 1.00 | - | - |
| y4_STA | - | 0.67 (9.87) | - | - |
| y5_PTU | - | -1.64 (-19.2) | - | - |
| y6_PRH | - | - | 1.00 | - |
| y7_CHG | - | - | 1.61 (13.1) | - |
| y8_EVE | - | 0.23 (4.11) | - | - |
| y9_PRD | - | - | - | 1.00 |
| y10_EVP | - | - | - | 0.13 (5.55) |
| ***Cause*** | | | | |
| Age/Gender | 0.17 (7.38) | - | -0.03 (1.92) | 0.09 (2.77) |
| AHI | -0.04 (-1.68) | -0.07 (-3.28) | - | - |
| AHI/Location | - | - | - | -0.12 (-2.37) |
| Child/House | - | 0.06 (3.23) | -0.05 (-2.78) | 0.15(4.92) |
| Aichi | 0.10 (4.16) | -0.19 (-9.02) | - | - |
| Car Use | -0.27 (-10.6) | 0.19 (8.86) | 0.04 (2.57) | - |
| Car/People | -0.11 (-2.55) | 0.10 (2.56) | -0.06(-1.79) | - |

*Note: Variable definitions are given in Table 4. (t-statistics in parentheses). - = data not applicable.*

Households with a higher annual income (more than ¥8 million) are found to be less concerned with the environment and surprisingly less auto dependent. It might mean that households with a higher annual income live in city center where public transportation service are sufficient. Furthermore, we find that households of Nagoya with a relatively lower annual income (less than ¥4 million) take a less positive view of the future prospects of EV. It has been found that households with children and living in a detached house are more automobile-dependent, more positive towards the future of EV, yet have less positive attitude towards EV. Higher car ownership and more frequent car use are coupled with less environmental concern as well as greater dependency on automobile, and the latter are more positive with EV. Finally, it is revealed that respondents living in Aichi prefecture are less dependent on their cars and are more concerned with the environment. This may be partially because of a sound public transport system in Nagoya city which is the largest city in Aichi.

In general, the MIMIC model gives a good account of whether and how individuals' demographics (age/sex), household characteristics (annual household income, house type, household composition, geographical location) and car-use habits affect the predicted structure of latent variables. It is confirmed that the "*environmental consciousness*" factor could partially explain some of the variability in the "*automobile dependency*" factor, and that the "*attitudes toward EVs*" factor could partially explain some of the variability in the "*attitudes toward the future prospects for EVs*" factor.

## 5. THE DISCRETE CHOICE MODEL OF EV PURCHASE INTENTION

### 5.1 Model Estimation

The latent-class nested logit model is employed to investigate the significance of the four latent variables related to environmental consciousness and attitudes to transportation on individuals' intention to purchase an EV. Latent class analysis has become a fairly popular segmentation method for the analysis of individual choice behavior in recent years. It has been used in marketing aimed particularly at explaining heterogeneity in consumer preferences. For example, the latent-class choice model makes it possible to explore the relationship between consumer brand preferences and price elasticity in purchase behavior (Kamakura et al., 1996; Kamakura and Russell, 1989). In the context of household car choice, Zhang et al. (2009) incorporated different types of group decision-making mechanisms as latent classes to enhance model accuracy. Additionally, Wen et al. (2012) applied the latent-class nested logit model to capture flexible substitution patterns among alternatives and preference heterogeneity across individuals to explore high-speed rail access mode choice behavior. Sasaki et al. (1999) applied the latent-class model and SEM model to analyze heterogeneity of travel behavior.

The latent-class model calibrates segment-level parameters to consider preference heterogeneity across individuals. Given a finite and fixed number of segments, $S$, and given that a particular consumer $i$ belongs to segment $s$ ($s$ = 1, 2, … , $S$), the utility function of $i$ for any intended EV purchase choice $m$ in the latent-class nested logit model can be expressed as

$$\begin{aligned} U_{\mathrm{id}m/s} &= V_{im/s} + V_{id/s} + V_{idm/s} + \varepsilon_{im/s} + \varepsilon_{id/s} + \varepsilon_{idm/s}\,, \\ &= \beta'_{im/s} X_{im/s} + \beta'_{id/s} X_{id/s} + \beta'_{idm/s} X_{idm/s} + \varepsilon_{im/s} + \varepsilon_{id/s} + \varepsilon_{idm/s}\,, \\ & \qquad \forall (d,m) \in C_n \end{aligned} \tag{3}$$

where

$V_{im|s}$ = the systematic component of utility common to all elements of $C_n$ choosing intended EV purchase choice $m$,

$V_{id|s}$ = the systematic component of utility common to all elements of $C_n$ choosing intended household car ownership increasing choice $d$,

$V_{idm|s}$ = the remaining systematic component of utility specific to the combination ($d$, $m$),

$\varepsilon_{im|s}$, $\varepsilon_{id|s}$, and $\varepsilon_{idm|s}$ are the random utility components, $X_{im|s}$, $X_{id|s}$, and $X_{idm|s}$ are vectors of observable attributes, and $\beta'_{im|s}$, $\beta'_{id|s}$, and $\beta'_{idm|s}$ are vectors of unknown parameters (Ben-Akiva and Lerman, 1985).

The probability function of the latent-class nested logit model can be expressed as follows:

$$\begin{aligned} P_i(\mathrm{d},m) &= \sum_s P_i(m \mid d,s) \cdot P_i(d \mid s) \cdot H_i(s) \\ &= \frac{\exp\{\mu_m (V_{im} + V_{idm})\}}{\sum_{m' \in M} \exp\{\mu_m (V_{im'} + V_{id'm'})\}} \cdot \frac{\exp\{\mu_d (V_{id} + V'_{id})\}}{\sum_{c' \in C} \exp\{\mu_\mathrm{d} (V_{id'} + V'_{id'})\}} \cdot H_i(s) \end{aligned} \tag{4}$$

$$H_i(s) = \frac{\exp(\omega'_s Z_n)}{\sum_{s'} \exp(\omega'_{s'} Z_n)} \tag{5}$$

The segment membership function $H_i(s)$ represents the probability that traveler $i$ belongs to segment $s$, which is determined using a standard logit formulation as a function of the respondent's characteristics (Wen and Lai, 2010). Within segment $s$, $P_i(d|s)$ is the probability of choosing the intended household car ownership increasing choice $d$, $P_i(m|d, s)$ is the probability of choosing the intended EV purchase choice $m$ given the not increasing car ownership choice $d$, $\mu_m$ is the estimated coefficient of the inclusive term for choosing the intended EV purchase choice $m$ given the not increasing car ownership choice $d$, and $\mu_d$ is the estimated coefficient of the inclusive term for the intended household car ownership increasing choice *d*. The ratio of structure parameters $\mu_d$ to $\mu_m$ must lie between zero and one to satisfy the hypothesis of correlation. If the ratio is equivalent to one, the NL model collapses to the simpler multinomial logit model. In this study, $\mu_m$ is set to one.

Figure 3 depicts the nested structure within segment *s*, where *increase* or *not increase current car ownership of the household* is identified as the upper level, and the two ways of *maintaining the number of cars* (either through buying or not buying an EV to replace the old car) are identified as the lower level.

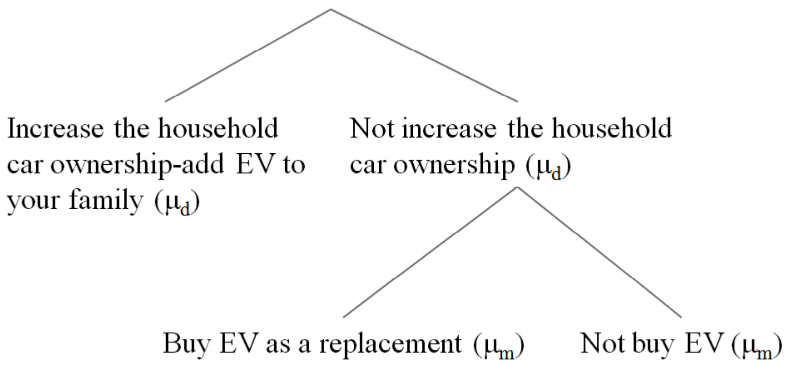



Figure 3. Artificial tree structure for NL estimation

## 5.2 Results of Latent Class NL Model

Table 6 presents consumers' EV purchase intentions. These are the results from the two-segment latent-class NL models. The segments are divided in terms of auto dependency. The consideration for the model structure is explained as follows. The difference in EV purchase attitude was assumed to be related to environmental consiousness and auto dependency. However, it was found difficult to construct the NL models with four segments according to the two latent variables. Instead, reasonable results have been obtained of auto dependency after dividing two segments in the NL models.

### 5.2.1 Psychological variables

The results reveal that most of the latent variables indicating respondents' environmental consciousness and attitudes to transportation are significant in the model.

The segmentation variable is significant for the membership model, *automobile dependency*. The negative value of its coefficient indicates that individuals who are less dependent on automobiles are more likely to belong to Segment 1.

Three other latent variables entered the choice model: *environmental consciousness*, *attitudes toward EVs*, and *attitudes toward the future prospects for EVs*. Except for the last one (a common factor in both Segment 1 and Segment 2), these variables are significant in only one of the two segments, indicating that two classes with almost completely distinct attitudes have been identified.

*Environmental consciousness* is insignificant and negatively associated with the intention to increase household car ownership (buy an EV as an additional car) for the more auto-dependent segment (Segment 2). However, it is significant for the intended choice of buying an EV as a replacement in Segment 2. For people who are more dependent on automobiles, the more concerned they are with the environment, the more likely they will be to maintain present household car ownership. Thus their intention to purchase an EV as replacement will decrease. Although this result is a negative indicator for the wider adoption of EVs, the relevant effect is quite positive from another point of view. Since the ultimate goal is to reduce total greenhouse gas emissions and build a sustainable society, it could be good and helpful if people were to maintain their current consumption status and raise their concern for the environment. In segment 1 (less auto dependent), significant coefficients for environmental consciousness could not be obtained for any utility. This result is different from Flamm's finding that environmental knowledge and attitudes have significant effects on vehicle ownership and usage (Flamm, 2009). This might be because of the segmentation by auto dependency or difference between general cars and EVs.

*Attitudes toward EVs* is significant for the utility of buying an EV as a replacement in the choice model for Segment 2. A higher value of this variable indicates that the respondents are more intrinsically less attracted to EVs and have a negative attitude towards them. As a result, it seems natural that people with a higher value of this variable are more likely not to have the intention of buying an EV as a replacement for the currently owned car, although they are more dependent on automobiles. An interest in EVs is a strong factor in the analysis of consumers' intentions to replace their old cars. This is partly because consumers need experience with a new kind of car, such as an EV, to overcome negativity relating to difficulties with the performance of their old cars.

*Attitudes toward the future prospects for EVs* is insignificant for the choice of buying an EV as an additional car in the two segments. It has a positive sign for the alternative *increasing car ownership (buy an EV as an additional car)* in segment 2.

The picture that emerges from the distinctive latent variables significant to each segment is that neither the environmental consciousness nor the attitudes towards EV places an important role in the conformation of Segment 1's EV purchase intention, while in Segment 2 (the more auto-dependent segment), individuals who are concerned with the environment would have less EV purchase intention, and those who place a lower value on positive attitudes toward EV would reveal more passion in EV purchasing. Overall, the results of the analyses show that consumers' environmental consciousness, automobile dependency and interest in the present of EVs play an important role in the process of forming an intention to purchase an EV.

### 5.2.2 EV-related attributes and demographics

Most of the explanatory variables regarding the attributes of EVs and the respondents' social demographics are significant at the 10% significance level in the choice model. As such, they support our interpretation of Segment 1 as being more price-sensitive and performance-oriented than Segment 2. For example, people in Segment 1 tend to be more cost conscious (0.429) than those in Segment 2 (0.0498). The more expensive a vehicle is, the less affordable it is for a consumer. Note that annual household income level and gender explain consumers' price sensitivity differently in the two segments. For Segment 1, households with lower income are more sensitive to price, whereas for Segment 2, women are more sensitive, which is in accordance with the general situation in Japan that (married) women are normally the secondary workers of the households and are usually engaged in low-paying jobs.

Segment 1 perceives 7-seat vehicles to be a positive factor for the intention of purchasing an EV as a replacement for the currently owned car; interestingly, Segment 2's perception of its effect is negative, although this variable is not significant to Segment 2's intention. Segment 1 perceive vehicles with greater range on a full charge to be superior with regard to replacement intention, with Segment 1 favoring the longer range more strongly than Segment 2. This makes sense in view of the auto-dependency difference between the two segments.

Those who are less keen on travel by private car will pay more attention to a car's attributes (capabilities, power, etc.). It may be attributable to that due to limited car ownership the possibility of buying an EV for frequent daily use has been carefully considered. Whereas, those who are heavily dependent on private cars and have higher car ownership tend to be concerned less with differences in performance between vehicles. This is probably because that individuals who are auto-dependent usually own multiple vehicles, when they consider replacing the second or third car other than the mainly used one, the intention of purchasing rather than the attributes of the vehicle would be a very important reason.

Table 6. Latent-class nested logit model of EV purchase intention

| | **Segment 1** | | **Segment 2** | |
|---|---|---|---|---|
| Variable | Parameter | t-statistic | Parameter | t-statistic |
| **Segmentation model** | | | | |
| Automobile dependency | -0.610* | -1.78 | Base Segment | |
| Constant | 1.106** | 7.25 | | |
| **Segment-specific choice model** | | | | |
| ***Increase household car ownership*** | | | | |
| *Buy EV as an additional car* | | | | |
| Environmental consciousness | | | -0.884 | -0.95 |
| Attitudes toward the future prospects for EVs | -0.049 | -0.026 | 1.160 | 0.89 |
| EV charging facility share[a] | -38.19 | -1.27 | 0.262 | 1.05 |
| Owning a hybrid car (dummy) | | | 0.166 | 0.25 |
| EV 4 seats (dummy) | | | 0.519* | 1.68 |
| Constant of "add" | -0.889 | -0.78 | -0.889 | -0.78 |
| ***Not increase household car ownership*** | | | | |
| *Buy EV as a replacement* | | | | |
| Attitudes toward EVs | | | -12.59** | -3.74 |
| Environmental consciousness | | | -1.337* | -1.89 |
| EV 7 seats (dummy) | 0.374** | 2.82 | -0.223 | -1.04 |
| Range on a full charge (km) | 0.507** | 5.95 | -0.040 | -0.44 |
| Owning a hybrid car (dummy) | | | -2.337** | -2.81 |
| Constant of "rep" | -1.843** | -7.03 | 0.608* | 1.71 |
| *Not buy EV* | | | | |
| EV price (¥1 million) | 0.429** | 6.17 | 0.050 | 0.60 |
| Annual income less than ¥4 million (dummy) | 0.429** | 4.49 | | |
| Female (dummy) | | | 0.211* | 1.74 |
| Scale parameter | 0.910* | 1.77 | 0.910* | 1.77 |
| Segment size | 74.6% | | 25.4% | |
| LL(0) | -6804.79 | | | |
| LL(β) | -4192.13 | | | |
| Rho-square | 0.384 | | | |
| Adjusted rho-square | 0.380 | | | |

[a] *EV charging facility share: the share of gasoline stations with an EV charging facility*
*Note: *Significant at 10% level, **Significant at 5% level.*

Owning a hybrid vehicle is another significant and negative variable in Segment 2's intention to buy an EV as a replacement. This indicates that a respondent's intention to buy is not stronger if the respondent already has good experience of the convenience provided by a vehicle using a new technology, such as a hybrid vehicle. Therefore, with regard to the replacement intention, promotion policies for EV will be more effective to those who do not have hybrid vehicles than the households with hybrid vehicles.

Several other variables (the share of gasoline stations with EV charging facilities, unemployment status, and 4-seat EV) are not statistically significant in the model, indicating that people do not take them into consideration in the decision-making process for the purchase of an EV. For both segments, respondents are found have less preference bias toward buying EVs, either as an additional car or as a replacement for the old car.

## 6. CONCLUSIONS

The aim of this research work is to explore the psychological determinants influencing an individual's intention to purchase an electric vehicle (EV). The literature review section of the paper demonstrates that many researchers have been working on the factors that affect vehicle purchase intentions using various research methods and methodologies. However, very few results have reported on the effects of attitudinal factors in the Japanese context. The approach adopted in this study (of using MIMIC and a latent-class NL model) is similar to other empirical ones, but we use a different dataset so as to model latent variables in the context of EV purchase intention. Specifically for the step of latent-class analysis, and differing from most other empirical studies in which sociodemographic traits are taken as significant segmentation variables (Bhat, 1997; Walker and Li, 2007), we defined our own model specifications using latent variables (automobile dependency) in the membership model. In addition, unlike the common division of an auto market into groups of consumers who are "EV buyers" and "non EV buyers", we divided it into homogenous groups of consumers based on their willingness to increase their current household car ownership. This identifies a further difference between two groups of potential EV buyers – those would increase current household car ownership by buying an EV as an additional car and those would replace the current car with an EV, so not increasing ownership.

A survey carried out using a web-based questionnaire was used to collect demographic data and answers to attitudinal questions. We developed a multiple-indicators multiple-causes (MIMIC) model to estimate the psychological factors (latent variables) that affect individuals' EV purchase intentions. The results of the MIMIC analysis indicated a good model fit. Male householders that are over 50 years old, the households with children and living in a detached house, as well as higher car ownership and more frequent car use are found most actively associated with the latent variables, and a logical explanation for this is developed. Annual household income and car ownership negatively affect environmental consciousness in a consistent way.

We constructed a latent-class nested logit model for EV purchase intention analysis, identified the market segments, and simultaneously modeled their choices. There was one significant variable (the respondent's automobile dependency) in the class membership model, and several variables (including latent variables, EV attributes and social demographics) in the segmented choice models. The auto-dependency variable is significant in dividing the sample data into two segments. Its negative coefficient is evidence that people in one segment are less dependent on automobiles than those in the other. Two latent variables (environmental consciousness and attitudes toward EVs) of the choice model are statistically significant for Segment 2, whereas the other one (the variable of attitudes toward the future prospects for EVs) is significant for neither of the two segments. For people who are more dependent on automobiles, the more concerned they have become about the environment, the more negatively they think of EVs, the less likely they will buy EV as an additional car. In other words, an increase in environmental concern will decrease the intention to increase family car ownership in auto dependent group. In addition to latent variables, EV-related attributes and demographics are also significant shapers of purchase intention.

These results indicate that two groups with quite disparate tastes have been identified. People in Segment 1 tend to be more concerned about the performance and price of an EV before making a purchase decision. Therefore, if the government's strategy for next-generation vehicle usage and the long-term goal of carbon dioxide reduction are to be achieved, more effort has to be made to make sure consumers are well aware of the benefits an EV brings to them as well as to the future vision of an environmentally friendly life.

To summarize, some concrete proposals are made here. First, compared to encouraging the purchase of an EV as an additional car, promoting the replacement of an old car seems to be a fast and efficient way for the Japanese government and auto industry to increase EV use in Japan. Encouraging consumers to adopt a positive attitude toward EVs would be worth a try to achieve this. We would recommend the government and industry to organize publicity campaigns involving television programmes, online newspapers and seminars that draw the attention of potential customers to EVs, increase familiarity with them, and encourage pride in owning one. As a consequence, these people will find EVs a good topic to talk about among friends. In addition, projects such as EV trials should be conducted to provide consumers with an opportunity to experience their benefits first-hand, thereby encouraging more interest and allowing them to see how a low-emission car could work in their life. Furthermore, our results indicate that if better performance (greater range on a full charge and more seats), as well as more acceptable and reasonable pricing could be offered, more people would buy EVs.

Interesting to note is that, in spite of the complexity of the associations between covariates and latent factors as described in the MIMIC model, the correlations between exogenous variables and observed indicators are extremely low, and most of the indicators were predicted by more than one factor. Thus we would recommend extending this research to further develop the proposed psychological constructs and confirm the findings in a broader setting.

In any case, our empirical results do support the hypothesis that environmental consciousness and attitudes to transportation are important with respect to EV purchase intentions. With regard to the Japanese auto market, this is something that has not been reported before to our knowledge and we believe it will prove useful for marketing planners aiming to achieve the goal of establishing a low-carbon society and explore the market for next-generation vehicles.

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