

Influences of Environmental Consciousness and Attitudes to Transportation on Electric Vehicle Purchase Intentions

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ABSTRACT:

This paper examines the influences of environmental consciousness and attitudes to transportation on electric vehicle purchase intentions. A multiple-indicators multiple-causes model and a latent-class nested logit model with two segments were estimated using data obtained through a web-based questionnaire survey in the Chukyo Area of Japan. Results reveal that both environmental consciousness and attitudes to transportation significantly affect an individual's EV buying intentions. Specifically, for the segment of mostly auto-dependent householders, environmental consciousness has strong negative relationships with intention to buy an EV as replacement. The results provide insight for the design of policies aiming at promoting the adoption of EVs.

Keywords: Environmental consciousness, attitudes to transportation, Electric vehicle, Purchase intention, Latent class, Nested logit

1. INTRODUCTION

To meet its commitments under the Kyoto Protocol, Japan set a long-term goal of “halving total global greenhouse gas emissions by 2050 from its current level of emissions” with the aim of establishing a low-carbon society (Government of Japan, 2008). The transportation sector, which accounts for approximately 20% of Japan's carbon dioxide emissions, is in urgent need of transformation. To this end, the Ministry of Economy, Trade and Industry (METI) announced its “Next-Generation Vehicle Strategy 2010”, a formulation of Japan's new strategy for medium- to long-term actions that should be taken by the auto and related industries and society in general (METI, 2010). The development of environmentally friendly cars was identified as a key direction for the auto industry. A target was set for next-generation vehicles to account for up to 50% of new vehicle sales in 2020. Specifically, the government seeks to make electric vehicles (EVs) and plug-in hybrid vehicles (PHVs) account for 15-20% of new vehicle sales in 2020, and for 20-30% of sales in 2030.

Among the many types of environmentally friendly vehicles, the EV attracts great attention for its various merits, such as the important role it plays in reducing emissions of CO₂, air pollutants and noise (particularly for occupants). According to the estimation by National Institute for Environmental Studies (NIES) in Japan, even taking into account the CO₂ emission from power plants, EV may help reduce at least 55% of CO₂ emissions in Japan with comparison to light cars. In the Chinese case, which relies more on thermal power generation, EV may help reduce at least 15% of CO₂ emissions (NIES, 2010). It is widely accepted that widespread use of the EV could make a significant contribution toward the goal

of sustainability.

Early efforts by the nation to encourage the diffusion of environmentally friendly vehicles was described by Japan Automobile Research Institute (JARI) in 2003. These included the establishment of a diffusion goal, subsidies for purchasers, tax incentives, regulation and standardization, and public education (JARI, 2003). To promote the adoption of new, eco-friendly vehicles, Japan's parliament passed the "Green Vehicle Purchasing Promotion Measures" in 2009, so as to provide consumers with incentives to purchase fuel-efficient vehicles. This was expected to also boost EV purchases (JAMA, 2009). By the end of March 2011, ownership of EVs in Japan was over 9,000 (JAMA, 2012), though this represented only 0.6% of total next-generation vehicles, which in turn account for no more than 2% of total car ownership in Japan. Thus, despite the measures taken, EVs are still having difficulty gaining wide acceptance and use. For this reason, there is a need for more efforts to gain a comprehensive understanding of consumer considerations related to the purchase of an EV and how various factors can influence them.

Accordingly, the main objective of this study is to examine the impacts of environmental consciousness and attitudes to transportation on consumer intentions when considering the purchase of an electric vehicle in the Japanese context. To do this, we analyze the results of a questionnaire survey conducted in 2010 and 2011 in the Chukyo Area of Japan.

2. LITERATURE REVIEW

Traditionally, there has been much research interest in identifying the factors that affect consumers' car purchasing behavior. Various models for the choice of vehicle type have been developed, generally focusing on three areas: vehicle attributes (such as operating and capital costs, horsepower, and fuel efficiency); household characteristics (such as number of members, number of vehicles, and household income); and principal driver characteristics (such as age, education, and income) (Golob et al., 1997).

However, in recent years, more and more researchers have found that other constructs, such as attitudinal factors, also relate greatly to purchasing intentions. As Fishbein and Ajzen (1975) wrote, "attitude refers to a person's favorable or unfavorable evaluation of an object, beliefs represent the information he has about the object" and "a person's intention to perform a behavior is determined by two factors: his attitude toward the behavior and his subjective norm concerning that behavior." In this context, many studies investigate the relationship between attitude and intention. The contention that travel attitudes, personality, and lifestyle are important to vehicle type choice has been recently supported, and a disaggregate choice model of vehicle type based on these factors as well as typical demographic variables has been developed (Choo et al., 2004). Specifically related to consumer purchasing intentions for environmentally friendly vehicles, a study focusing on the US and Korean hybrid car markets has shown that self-image congruence and propensity to seek information about green products have strong positive relationships with consumers' intent to purchase (Oliver and Lee, 2010). Analysis and synthesis regarding the impact of expectations and the future on purchase motivations for plug-in hybrid electric vehicles (PHEVs) have been achieved through a household narrative analysis (Caperello and Kurani, 2010). In a study of consumer purchase motivations for hybrid vehicles, the financial benefits related to transport policy were noted as an important factor. Besides, social norms and consumers' willingness to comply with the norms of their groups are found have an influence on purchase decisions (Ozaki and Sevastyanova, 2011).

There is also a great deal of evidence showing that environmental consciousness plays a significant role in vehicle purchasing intention and use. A study on households' intentions to replace an old car has proven that environmental concern together with marital status, number of children, and consumer confidence affect the aspiration level, and this has a direct positive impact on motivation when buying a new car (Marell et al., 2004). As revealed by Flamm's (2009) study, environmental knowledge and attitudes have significant effects on vehicle ownership and use. Households with pro-environmental attitudes own more fuel-efficient vehicles, drive them less, and consequently consume less fuel than do the households of respondents without pro-environmental attitudes. In research into travel mode choice, it has been found that environmental preferences increase the likelihood of choosing an environmentally friendly mode, while the introduction of latent variables of attitudinal and behavior indicator variables enriches the discrete choice model (Johansson et al., 2005). As proved by a German field study (Buhler et al., 2011), environmental concerns and attitudes measured before driving an EV on a regular basis turned out to be significant predictors of acceptance of EVs. Furthermore, through the hearing and analysis of buyers' own stories, Heffner et al. (2007) explored how widely recognized social meanings (denotations) are connected to more personal meanings (connotations) and the effect that both types of meanings have on vehicle purchase and use. Preserve the environment as well as other symbolic meanings (such as *manage personal finances*, *embrace new technology*) are identified as essential symbolic meanings related to hybrid electric vehicles.

To gain a better understanding of consumers' purchase intentions related to EVs, we shall examine factors (such as environmental consciousness and attitudes to transportation) that affect this multi-faceted motivation in greater detail. Building on the empirical studies mentioned above, further investigation of the relationship between EV purchase intention and specific factors will be discussed. In section three, which follows this literature review, we describe the data and the data collection process. In section four, a multiple-indicators multiple-causes (MIMIC) model is developed to investigate the effects of respondents' demographics on four latent variables. In section five, we construct a latent-class nested logit (NL) model to estimate the impacts of the latent variables on EV purchase intentions. Finally, the indications and the direction of future research work are presented in a concluding section.

3. DATA AND METHODOLOGY

The data for this study come from an internet-based questionnaire survey containing questions about vehicle attributes, EV purchase intentions, attitudes to transportation and environmental consciousness, and household characteristics. The surveys were conducted in Aichi prefecture from December 13 to 14, 2010 and in Gifu and Mie prefectures from January 16 to 17, 2011. These regions represent mixed urban and suburban neighborhoods and include the Chukyo Metropolitan Area, which is Japan's third most populous metropolitan area after the Greater Tokyo Area and Osaka-Kobe-Kyoto. They account for roughly 7% of Japan's population. Altogether 2,060 surveys from Aichi prefecture and 1,043 surveys from Gifu and Mie prefectures were completed by householders, for a total of 3,103 responses. After removing invalid responses from the sample, the number of completed surveys dropped to 3,097.

3.1 Demographics

The sample was confined to householders with a driving license and owning at least one car. As a result, 92.6 percent of the sample consists of men and 63.2 percent of the sample is

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.	
I am currently trying my best to reduce car use.	
An automobile is a necessity for me.	5 = strongly agree
Automobiles represent status in society.	4 = agree
Public transport is easy to use.	3 = neutral
EVs are expensive.	2 = disagree
A network of charging facilities is a prerequisite for the diffusion of EVs.	1 = strongly disagree
There is no need to reduce car use if I own an EV.	
There will be a fall in EV prices in the near future.	
More than half of vehicles in Japan will be replaced by EVs in 20 years.	1 = agree
	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 calculated 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 terms. 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 addition, 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 η_t , B , Γ and Λ are matrices of unknown parameters to be estimated, ζ_t and ε_t are measurement errors. Figure 1 shows the general structure of the MIMIC model (Buehn and Schneider, 2008). For descriptive information, see Table 4.

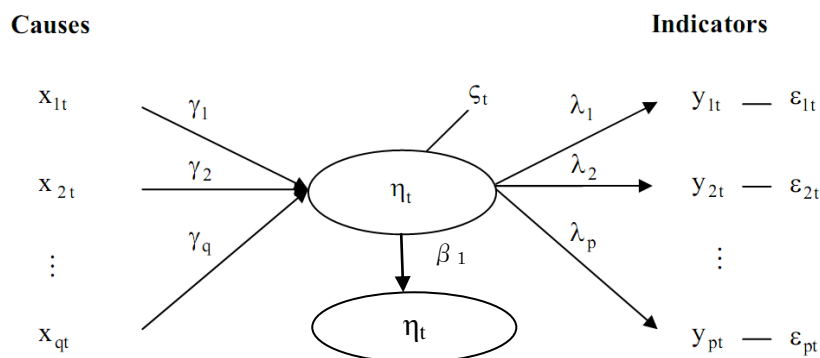


Figure 1. General structure of a MIMIC model

Table 4. Latent variables, indicators and causes

Variable	Description
<i>Latent variables</i>	
$\eta1_EnvCs$	Environmental consciousness.
$\eta2_AutoD$	Automobile dependency.
$\eta3_EVatt$	Attitudes toward EVs.
$\eta4_EVfut$	Attitudes toward the future prospects for EVs.
<i>Indicators</i>	
$y1_PTE$	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.
<i>Causes</i>	
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.

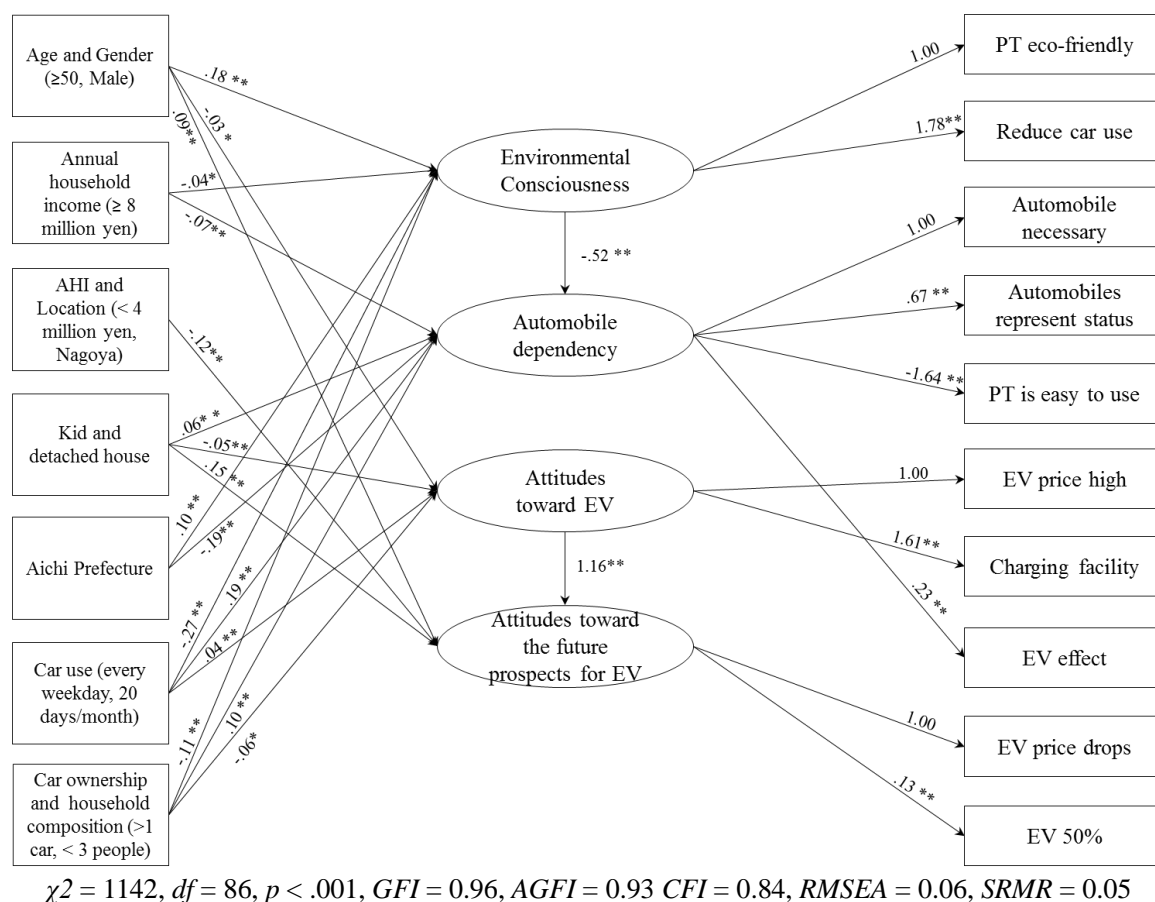


Figure 2. Results of the MIMIC estimation: coefficients (* p < .10; ** p < .05) and model fit indices

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			
	$\eta1_EnvCs$	$\eta2_AutoD$	$\eta3_EVatt$	$\eta4_EVfut$
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 ($s = 1, 2, \dots, S$), the utility function of i for any intended EV purchase choice m in the latent-class nested logit model can be expressed as

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

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:

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

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

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 , μ_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 μ_d is the estimated coefficient of the inclusive term for the intended household car ownership

increasing choice d . The ratio of structure parameters μ_d to μ_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, μ_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.

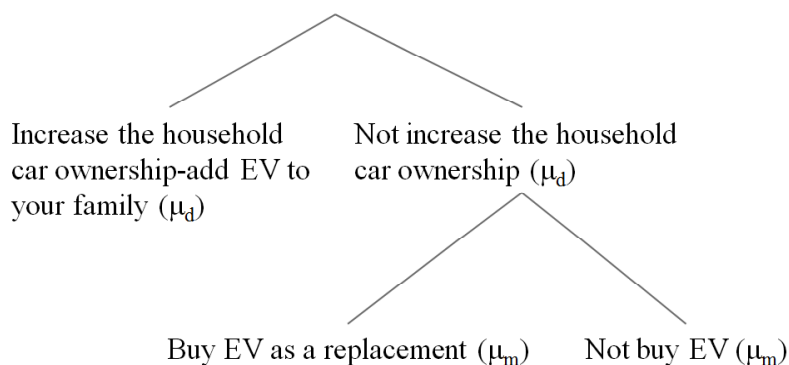


Figure 3. Artificial tree structure for NL estimation

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 consciousness 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 perceives 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

Variable	Segment 1		Segment 2	
	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				
<i>Increase household car ownership</i>				
<i>Buy EV as an additional car</i>				
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
<i>Not increase household car ownership</i>				
<i>Buy EV as a replacement</i>				
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
<i>Not buy EV</i>				
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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