THE INFLUENCES OF ENVIRONMENTAL CONSCIOUSNESS AND TRANSPORTATION ATTITUDE ON ELECTRIC VEHICLE PURCHASE INTENTIONS

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With regard to achieving Japan's long-term goal of reducing 60 to 80 percent of its current level of emissions by 2050, efforts on the adoption of next-generation vehicles is crucial. It is widely accepted that the diffusion of electric vehicle (EV), a zero-emission vehicle, could make significant contribution toward the goal of sustainability. The purpose of this study is to identify the influences of psychological factors, such as environmental consciousness and transportation attitude, on EV purchase intentions. The data comes from a web-based questionnaire survey conducted in Chukyo area of Japan. Drawing from the indications from chi-square test and t-test of the data, we first developed a multiple indicators multiple causes (MIMIC) model to investigate the effects of respondents' demographics on four latent variables, namely "environmental consciousness", "attitudes related to automobile dependency", "attitudes toward EV", and "attitudes toward the future prospects of EV". Then, a multinomial logit (MNL) model was estimated to explore the impacts of latent variables on EV purchase intentions. The results confirmed that environmental consciousness and transportation attitude significantly affect an individual's buying intention for EV. Specifically, environmental consciousness is positively associated with the intention of buying an EV as an additional car and negatively associated with buying an EV as a replacement for the currently owned car. A positive attitude towards the future prospects of EV increases the likelihood of purchasing an EV. The positive effect of latent variables on model estimation process was likewise verified. These findings provide keys toward a broad-scale adoption of EVs.

Key Words : *environmental consciousness, transportation attitude, electric vehicle, purchase intention*

1. INTRODUCTION

To achieve the commitment of the Kyoto Protocol, Japan has 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). Accounting for approximately 20% of Japan's carbon dioxide emissions, transportation sector is in urgent need to be transformed. The Ministry of Economy, Trade and Industry (METI) further announced the "Next-Generation Vehicle Strategy 2010", which was established to formulate Japan's new strategy for medium- to long-term actions that should be taken by auto and related industries and society in general (METI, 2010). The plans identified the development of environmentally friendly cars as a key direction for the auto industry. The diffusion target of next-generation vehicles was set 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 20-30% in 2030.

Among all green vehicles, EV has gained great attention for its various merits, such as the important

role it plays in reducing emissions of CO2, air pollutants and noise of particularly passenger. It is widely accepted that the diffusion of EV, the zero-emission vehicle, could make significant contribution toward the goal of sustainability. Early efforts of the nation to diffuse clean energy vehicles was described by Japan Automobile Research Institute in 2003, including 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, the National Diet of Japan passed the "Green" Vehicle Purchasing Promotion Measures in 2009, so as to provide consumers with incentives to purchase fuel efficient vehicles, which would also boost electric vehicle purchase (JAMA, 2009). Yet EVs are still having difficulty gaining wide acceptance and use. Therefore, it will be necessary to persevere with efforts for the comprehensive understanding of consumer consideration before buying an EV and how factors can influence it.

Accordingly, the main objective of this study is to examine the impacts of environmental consciousness and transportation attitude on consumer intentions for purchasing electric vehicles in the Japanese context. To do this, we analyze the results of a questionnaire survey conducted in 2010 and 2011 in Chukyo area.

2. LITERATURE REVIEW

Traditionally, much research has been interested in identifying the factors that affect consumers' car purchasing behaviors. Various models of vehicle type choice are developed, generally focusing on vehicle attributes (such as operating and capital costs, horsepower, and fuel efficiency), household characteristics (such as number of household 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 much to vehicles purchasing intention. As mentioned by Fishbein and Ajzen (1975), "attitude refers to a person's favorable or unfavorable evaluation of an object, beliefs represent the information he has about the object"; "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., 2002). Specifically to consumer intentions to buy green vehicles, a study concentrated on the US and Korean hybrid car market shows that self-image congruence and propensity to seek information about green products have strong positive relationships with purchase intentions among consumers (Oliver and Lee, 2010). Analysis and synthesis regarding the impact of expectations and the future on plug-in hybrid electric vehicles (PHEVs) buying motivations are achieved through household narrative analysis (Caperello and Kurani, 2010). In a study of consumer purchase motivations of hybrid, the financial benefits related to transport policy are noticed as an important factor in the motivations, and social norms and consumers' willingness to comply with the norms of their groups influence the purchase decision (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' replacement intentions of the old car proves that environmental concern together with marital status, the number of children and consumer confidence affected the aspiration level, which has a direct positive impact on the buying motivation of 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 a research of travel mode choice, it is found that environmental preferences increase the likelihood of choosing an environmentally friendly mode, and the introduction of latent variables of attitudinal and behavior indicator variables enriches discrete choice model (Johansson et al., 2005). As proved by a German field study (Bühler, 2011), environmental concerns and attitudes measured before driving an EV on a regular basis turned out to be significant predictors of acceptance of EVs.

To gain a better understanding of consumers' purchase intention of electric vehicle, we shall examine the factors (such as environmental consciousness and transportation attitude) that affect this multi-faceted motivation in greater detail. Therefore, based on the empirical studies mentioned above, further investigation on the relationship between EV purchase intention and specific elements will be discussed as follows. The third section describes 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 multinomial logit (MNL) model to estimate the impacts of latent variables on EV purchase intentions. Finally, the indications and future research works are given 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, transportation attitudes and environmental consciousness, and household characteristics. The surveys were conducted in Aichi prefecture from December 13th to 14th, 2010, and Gifu prefecture and Mie prefecture from January 16th to 17th, 2011. These regions represent a mixed urban and suburban neighborhood, the Chukyo Metropolitan Area. Altogether 2,060 surveys from Aichi prefecture and 1,038 surveys from Gifu and Mie prefectures were completed by householders, and the overall response rate was 100 percent (number of responses, n=3098). Yet, due to logical errors, one set of answers was removed from the sample size, which makes 3097 the total number of completed surveys.

(1) Demographics

The sample of respondents were confined to the householders with a driving license and own at least one car, which consists to 92.6 percent of men. The sample of age between 30 and 50 years old takes 63.2 percent of the total, and the respondents with an annual household income between 4 to 8 million yen 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 the household of more than 3 people accounts for 62.3 percent of the all. The average car ownership per household is 1.4. Since 87.6 percent of the respondents have a full-time job, the car usage frequency on both weekday and weekend is high, with a percentage of everyday drive reaching 62.2 and 48.3, respectively. Regarding the type of house, 58.0 percent of the respondents are living in detached houses, which might provide them a better condition of EV charging. **Table 1** gives descriptive details for demographic information.

The question regarding EV purchase intentions was asked twice to one respondent. Each time, the EV was randomly selected from 27 patterns, in which the characteristics of EVs are distinct in aspects such as charging time, number of seats, price and running distance after one 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; whereas 1,842 respondents stated that they would not buy an EV at all.

Since consumer themselves is one of the most determining factors affecting EV purchase intention, it is worth determining whether there is a significant association between the two variables. Thus a chi-square test for independence is used and the null hypotheses are stated:

H10. Age and respondents' EV purchasing intention are independent.

H20. Gender and respondents' EV purchasing intention are independent.

H30. The employment and respondents' EV purchasing intention are independent.

H40. Whether there is kid in the household and respondents' EV purchasing intention are independent.

H50. Annual household income and respondents' EV purchasing intention are independent.

H60. The type of house and respondents' EV purchasing intention are independent.

H70. Geographical location and respondents' EV purchasing intention are independent.

H80. Number of people in the household and respondents' EV purchasing intention are independent.

H90. Car ownership and respondents' EV purchasing intention are independent.

H100. Car usage frequency and respondents' EV purchasing intention are independent.

Table 3 gives detailed statistics of the chi-square test. Comparing to the chi square distribution table, and considering our predetermined alpha level of significance (0.05), we would reject all of the null hypotheses except for H10 (age) that there is no relationship between these demographics and purchase intention for EVs. In other words, respondents' motivation of buying an EV is related to most of their socio-demographic factors such as gender, income level, and the type of house and alike. For instance, men are easier to accept EV and buy it than women. The share of the households living in detached houses, or having a more frequent car usage is found greater in the willing to buy EV group than the not willing to buy EV group. Based on the concluding effects demographics on purchase intention, it can be helpful in further study on individual psychographics' relation with EV buying motivation.

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%
Kid	Yes	1,523	49.2%
	No	1,574	50.8%
Annual household income	Up to 4 million yen	793	25.6%
	4 -8 million yen	1,585	51.2%
	8 million yen or more	719	23.2%
Type of house	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 the household	3 people or more	1,928	62.3%
	Up to 3 people	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 weekday / month	Up to 10 days	778	25.1%
	10 to 19 days	394	12.7%
	Every day (20 days)	1,925	62.2%

TABLE 2 Description of 27 patterns of EVs

Pattern	Price/Seats	Running distance	Charging time/Fast charging time	The share of charging stations at gasoline stations
1	1.5 million yen (2-4 seats)/2 million yen (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 yen (2-4 seats)/3 million yen (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 yen (2-4 seats)/4.5 million yen (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%

TABLE 3 Chi-square test of demographics and EV purchase intention

Demographics	Degrees of Freedom	Chi Square
Age	4	5.366
Gender	1	25.540*
Employment	1	12.613*
Kid	1	23.232*
Annual household income	2	22.105*
House type	1	32.779*
Geographical location	3	13.378*
Number of people in the household	1	54.437*
Car ownership	3	52.396*
Car usage frequency on weekday (20 days/month)	2	16.553*
Car usage frequency on weekend (8 days/month)	2	13.758*

*Note: All demographic factors are grouped in the same categories as mentioned early in Table 1. The total samples numbers of respondents would buy and would not buy an EV are 1,255 and 1,842, respectively. *: Statistical significant.*

(2) Psychological Motivations

Apart from the questions regarding EV purchasing intention and socioeconomic questions, the respondents answered a set of nine questions of environmental consciousness and transportation attitude on a 5-point Likert scale with the endpoints defined as "strongly agree" and "strongly disagree". Besides, another question addressed attitude related to future prospects of EV was asked scored on two-point scales of "agree" and "disagree". Based on the questions, motivational constructs fall into four groups. The first group relates to environmental consciousness. It represents the respondents' perceptions of environmental benefits and compatibility with their green values. This can also be understood as respondents' environmental concerns and beliefs in the positive consequences of reducing the car driving. The second group is concerned with the attitudes related to automobile dependency, which demonstrates respondents' associations with auto-dependency. It refers to personal travel habits, infrastructure construction and self-image that favor automobile travel and provide relatively inferior transportation alternatives (in this case, "automobile" includes cars, vans, light trucks, and SUVs). The third group relates to attitudes toward EV, which indicates respondents' acknowledgement of the price and the basic needs for EV adoption 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 of EV. It is a reflection of respondents' consideration and prediction related to the share of EV and the following effects in the future market.

A t-test was used to test whether there is a significant difference in the indicator variables of psychological factors between respondents that would buy an EV and those would not buy EVs. Thus, the null hypotheses of nine variables are stated alike:

H0: There is no difference between the effects that psychological consideration of environment and transportation, as well as EV related issues (e.g., prices and diffusion) has on the purchase intention towards EVs of the two groups of respondents.

Table 4 provides the detailed statistics of two-tailed t-test. Significance level of 0.05 is used for a comparison. Since the t value of y5_PTU and y6_PRH are less than 1.96, we cannot reject the null hypotheses, whereas the other seven hypotheses are rejected with greater t values. Thus it can be interpreted that except for the considerations to the convenience of public transit and the price of EVs, respondents' environmental concern and other transportation attitudes play a significant role in the conformation of EV buying intention, which makes a difference between those would buy and would not buy the electric vehicles.

TABLE 4 T-test of independence of sample stratified by EV purchase intention

	Buy (n=1255)		Not buy (n=1842)		
Variable	**Mean**	**Variance**	**Mean**	**Variance**	**T value**
y1_PTE	3.25	0.83	3.11	0.96	3.88*
y2_CUS	2.70	1.17	2.62	1.23	2.19*
y3_NEC	4.53	0.52	4.39	0.72	4.60*
y4_STA	3.12	1.31	2.92	1.44	4.63*
y5_PTU	2.43	1.30	2.38	1.31	1.35
y6_PRH	4.48	0.47	4.47	0.57	0.57
y7_CHG	4.60	0.35	4.49	0.49	4.67*
y8_EVE	3.09	1.00	2.61	1.00	13.11*
y9_PRD	4.29	0.54	3.97	0.80	10.32*

*Note: Variable definitions are given in Table 5. *: Statistical significant.*

4. THE LATENT VARIABLE MODEL (MIMIC)

All the data of demographics and answers to the attitudinal questions are used as causes and indicators, of which the properties are connecting to the four motivational constructs by a statistical model, the structural equation model (SEM). As an important special case of 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.

(1) Model Estimation

MIMIC involves using latent variables that are predicted by observed variables. The result of relations between indicators and latent variables as well as several tests of postulated relationships are presented by 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:

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

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 ten observable indicator variables of η_t, x_t is a vector of seven exogenous observable variables that cause η_t, 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 5**.

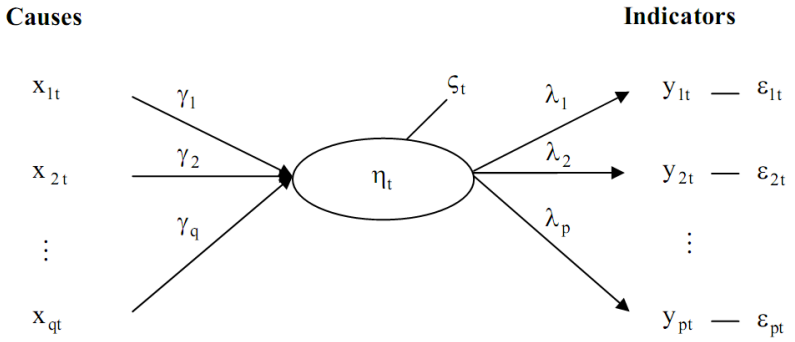


FIGURE 1 General structure of a MIMIC model

TABLE 5 Latent variables, indicators and causes

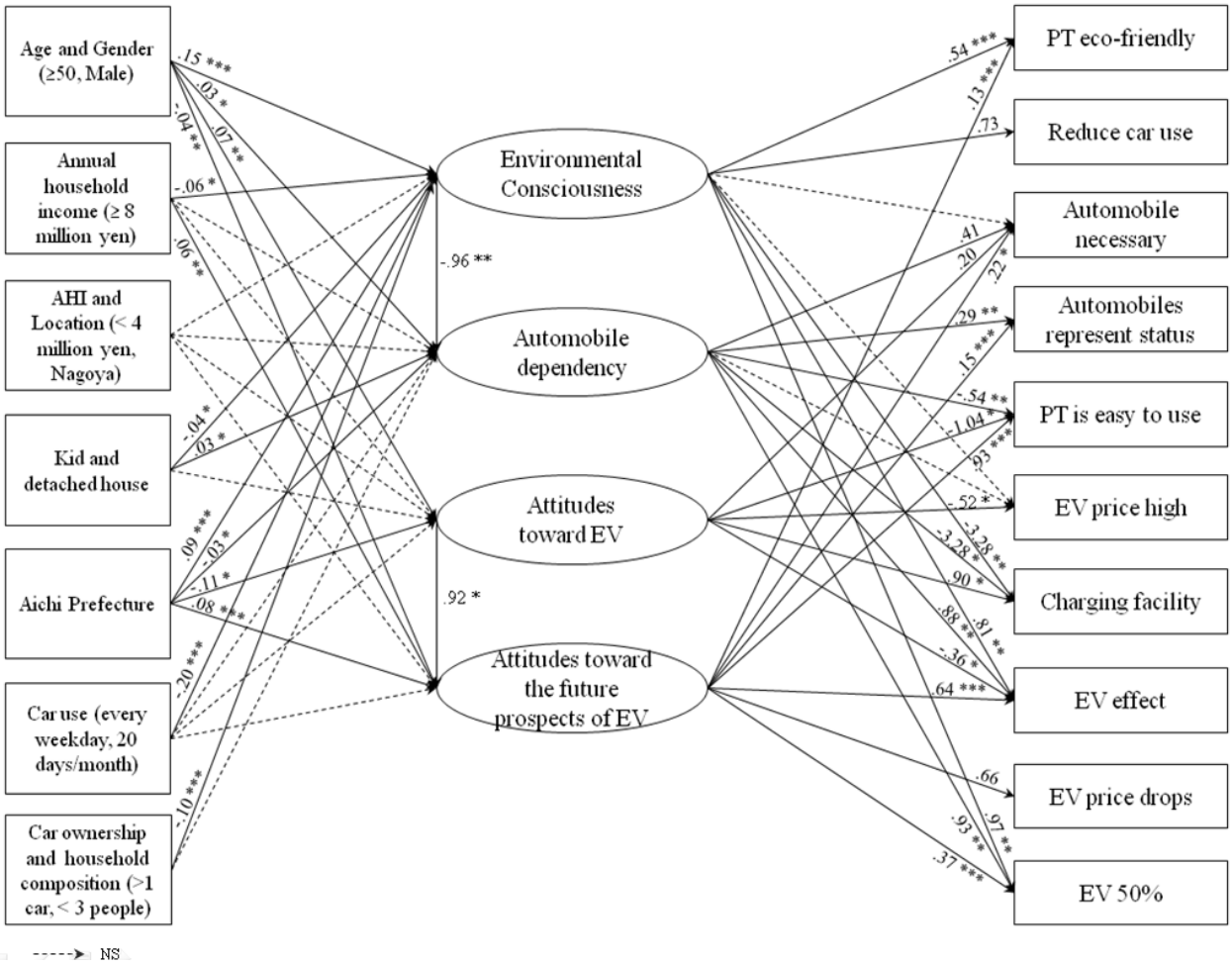
Variable	Description
Latent variables	
η1_EnvCs	Environmental consciousness.
η2_AutoD	Attitudes related to automobile dependency.
η3_EVatt	Attitudes toward EV.
η4_EVfut	Attitudes toward the future prospects of EV.
Indicators	
y1_PTE	Using public transit other than car preserves the environment.
y2_CUS	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	The price of EV is high.
y7_CHG	The construction of charging facilities is mandatory for the diffusion of EV.
y8_EVE	There is no need to reduce car use if I own an EV.
y9_PRD	There would be a price drop of EV in the near future.
y10_EVP	More than half of vehicles in Japan will be replaced by EV 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 yen 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 yen.
Kid/House	Dummy variable with value one if the respondent's household includes children (persons younger than 19 years) and lives 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 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.

(2) Results of the MIMIC Model

Since no one statistic is universally accepted as an index of model accuracy, a number of indices were computed to explain the fit of the model. In this study, the goodness-of-fit index (GFI=.99), adjusted goodness-of-fit index (AGFI=.98) and comparative fit index (CFI=.97) 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=.04) and the standardized root mean square residual (SRMR=.02) at values lower than .05 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 another. and some appear in the text as. C_D, α (*z*) If their

quality is not satisfactory, the manuscript may not be accepted. Numbered equations ((1a) and (1b) for example) should be center-aligned. The equation numbers in parentheses should be placed flush right.



$\chi 2$ = 341.12, *df* = 62, *p* < .001, *GFI* = .99, *AGFI* = .98, *CFI* = .97, *RMSEA* = .04, *SRMR*=.02

Note: NS = Not significant.

FIGURE 2 Results of the estimated MIMIC: coefficients (* p < .05; ** p < .01; *** p < .001) and model fit indices

Table 6 shows the statistical information of the estimation results. The causes for the 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 that are over 50 years old are more environmentally concerned yet more automobile-dependent, and have more negative attitudes toward EV compared to the other respondents. This can be interpreted as the result of a relatively higher education, higher social status, and busier social life. The inertia to their current lifestyle would affect their acceptance of a new product negatively. The more dependent they are on their currently owned cars, the more likely they would underestimate the merits of a new kind of car, the EV. Actually our finding of a relatively high auto dependency of those respondents is also consistent with the findings from Chlond et al.'s research (2012), that they can see an increase in travel demand and car use for elderly travelers. Thus we would as well recommend the policy and auto makers to take this group of consumers into consideration when trying to achieve a high acceptance of EV. The households of a higher annual income (more than 8 million yen) are found less concerned with the environment, although they do have positive attitudes towards the future prospect of EV. Furthermore, we find that the household with children and lives in a detached house is more automobile-dependent, which correspondingly reduces their concern to the environment. Higher car ownership and more frequently car use are coupled with less environmental

concern. Finally, it is revealed that the respondents living in Aichi prefecture are less dependent on their cars, and hold more positive attitudes towards the future prospects of electric vehicles. It is partially because of a sound public transportation system and good publicity of environmentally friendly cars in this area.

In general, the MIMIC model well investigated whether and how individuals' demographics (age/sex), household characteristics (annual household income, house type, household composition, geographical location) and car-use habits affected the predicted structure of latent variables. It is confirmed that the "environmental consciousness" factor could partially explain some of the variability of the "attitudes related to automobile dependency" factor, and the "attitudes toward EV" factor could partially explain some of the variability of the "attitudes toward the future prospects of EV" factor.

TABLE 6 MIMIC model for the four latent variables

	Latent variable			
	η1_EnvCs	*η2_AutoD*	*η3_EVatt*	*η4_EVfut*
Indicator				
y1_PTE	0.54 (20.94)	-	-	0.13 (5.53)
y2_CUS	0.74	-	-	-
y3_NEC	-0.18 (-1.32)	0.41	0.20	0.22 (2.62)
y4_STA	-	0.28 (2.89)	-	0.15 (6.22)
y5_PTU	-	-0.54 (-2.90)	-1.04 (-2.51)	0.93 (3.89)
y6_PRH	-0.40 (-1.78)	-0.41 (-1.64)	0.52 (2.50)	-
y7_CHG	-3.28 (-2.69)	-3.28 (-2.37)	0.90 (2.45)	-
y8_EVE	0.81 (2.79)	0.88 (2.76)	-0.36 (-2.00)	0.64 (6.21)
y9_PRD	-	-	-	0.66
y10_EVP	0.97 (3.30)	0.93 (2.80)	-	0.37 (10.37)
Cause				
Age/Sex	0.15 (10.14)	0.03 (2.44)	0.07 (2.21)	-0.04 (-2.72)
Income	-0.06 (-2.25)	-0.02 (-1.84)	-0.06 (-1.63)	0.06 (2.74)
INC/LOC	-0.07 (-1.86)	-0.01 (-0.89)	-0.03 (-0.77)	0.04 (1.53)
Kid/House	-0.04 (-2.06)	0.03 (2.39)	0.05 (1.83)	-
Location	0.09 (3.62)	-0.03 (-2.01)	-0.11 (-2.16)	0.08 (3.63)
Car Use	-0.20 (-13.59)	0.02 (1.98)	0.07 (1.99)	0.01 (0.81)
Car/People	-0.09 (-3.71)	0.02 (1.92)	-	-

Note: Variable definitions are given in Table 5. (t-statistics in parentheses). - = data not applicable.

5. THE DISCRETE CHOICE MODEL OF EV PURCHASE INTENTION

(1) Model Estimation

A multinomial logit (MNL) model is employed to investigate the significance of the four latent variables related to environmental concern and transportation attitude on individuals' purchase intention of electric vehicles in the conceptual model.

The basic framework for analysis is provided by the random utility model where it is assumed that consumers choose among a discrete number of alternatives to maximize their utility. The general form of MNL is expressed as follows:

The utility function

$$u_{ik} = V_{ik} + \varepsilon_{ik} = \beta X_{ik} + \varepsilon_{ik} \quad (3)$$

The probability function

$$P_{ik} = \frac{exp\,(V_{ik})}{\sum_{k=1}^{M} exp\,(V_{ik})} \quad (4)$$

where Pik is the probability of individual i (i=1,2…,N) choosing alternative k (k=1,2,…, M), uik is the utilities or value of interest for choice al-

ternative k and for individual i, Vik is a function of the observed utilities, ε_{ik} is the random error component associated with choice alternative k and individual i, Xik is the vector of the attributes of the alternative k, β is a vector of parameters.

Note that as mentioned in section 3.1, the question regarding EV purchase intentions was asked twice to one respondent. Therefore, the data set being used to compute the MNL model was doubled consequently, which made 6194 the total sample number of estimation.

(2) Results of the MNL Model

Table 7 presents consumers' purchase intention for electric vehicles. The results from the multinomial logit models with and without latent variables are reported. The model was estimated with three alternatives: C1 if the respondent indicated that he/she would buy an EV as an additional car; C2 if the respondent indicated that he/she would buy an EV to replace the currently owned car; C3 if the respondent indicated that he/she would not buy EVs. The third alternative, C3, was used as the reference choice.

We find that the respondents have a greater preference bias toward not buying EVs. All the explanatory variables regarding the attributes of EVs are significant at the 5% significance level in both the choice model without latent variables and the latent variables enriched discrete choice model. The variables indicating the price and fast charging time of EVs are estimated with expected signs. The more expensive, the more time it takes to charge a vehicle, the less possible it is for a respondent to buy an EV. Note that the variable of female has a positive sign, which indicates that women are more sensitive to the price of automobiles than men. It is in accordance with the general situation in Japan that (married) women are normally the secondary workers of the households and they are usually engaged in low-paying jobs. Two other attributes of the EVs, the number of seats and the share of charging stations at gasoline stations, are also found important to respondents' purchase intention for EV as a replacement for the currently owned car. An increase in the number of seats as well as an increase in the charging station share contributes to an increase in replacement intentions.

Turning to the demographic variables in the model without latent variables, we first notice that men that are over 50 years old are more likely to replace their cars by EVs yet less likely to simply add an EV as a new car to their families. It is also noted that both the variables "Kid and detached house" and "AHI (Annual household income)" are found negatively associated with the intention of not buying EVs. In other words, if a household living in a detached house includes kids, or it has an annual income exceeding 8 million yen, the family members would have stronger preferences for EV purchase. On the contrary, we find that households in Aichi prefecture are coupled with fewer preferences for EV purchase, potentially reflecting the fact that these respondents are satisfied with their current car ownership state and lifestyle.

As the results from the latent variable enriched model revealed, all the four latent variables indicating the respondents' environmental consciousness and transportation attitudes are significant in the model. η1_EnvCs (Environmental consciousness) is found affected the willingness to buy EVs in different ways. This effect would increase the replacement intention yet would decrease the purchase intention for EV solely as one additional car. Those who have greater consciousness on the environment are more likely to control their car use, which makes them less willing to buy new cars, whereas they are also more likely to think of conducting a more environmentally friendly life, which leads them to replace the old cars with green cars. It seems natural that η2_AutoD (Attitudes related to automobile dependency) negatively affect the motive of not buying EVs. The more heavily the respondents are dependent on automobiles, the less likely they would keep from buying new cars. η3_EVatt (Attitudes toward EV) is positively associated with buying an EV as a replacement. η4_EVfut (Attitudes toward the future prospects of EV) has a negative sign for alternative 3 (would not buy EVs) as expected, indicating that those who forecast a positive future of EV tend to have greater purchase intentions for EV.

In general, we would like to point out that positive effect of latent variables on model estimation process was confirmed. The introducing of the variables "environmental consciousness" and "transportation attitude" to the discrete choice model further explains the impact of the respondents' demographic variables on EV buying intention. For instance, as revealed by Figure 2, because men over 50 years old are more environmentally inclined, they exhibit fewer preferences for buying EV as an additional car yet stronger preferences for buying EV as a replacement. In addition, since the households with kids that live in detached houses are more dependent on their cars and are less environmentally concerned, they would accordingly perform less actively in keeping from purchasing EVs. Furthermore, higher incomes are coupled with less environmental consciousness, which consequently decreases the likelihood of not buying EVs.

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TABLE 7 Estimates of the multinomial logit model

Variables		MNL without latent variables		MNL with latent variables	
		Estimated values	***t-statistic***	***Estimated values***	***t-statistic***
EV price (million yen) (C3)	Constant	0.64	20.31	0.64	20.28
	Female	0.22	3.96	0.23	4.15
EV seats (C2)		0.16	9.76	0.16	9.83
EV fast charging time (minute) (C3)		0.59	2.65	0.57	2.60
EV charging station share (C2)		0.24	2.91	0.24	2.93
Age/Gender(≥50, Male) (C1)		-0.22	-1.66	-	-
Age/Gender(≥50, Male) (C2)		0.27	3.83	-	-
Kid and detached house (C3)		-0.33	-5.08	-	-
AHI (≥8 million yen) (C3)		-0.23	-3.24	-	-
Aichi prefecture (C3)		0.15	2.36	-	-
η1_EnvCs (C1)		-	-	-1.69	-3.51
η1_EnvCs (C2)		-	-	0.70	2.36
η2_AutoD (C3)		-	-	-4.52	-2.19
η3_EVatt (C2)		-	-	4.08	5.25
η4_EVfut (C3)		-	-	-5.28	-5.05
Constant1 (C1)		-0.67	-4.84	-1.14	-7.85
Constant2 (C2)		-0.20	-1.41	-0.34	-2.39
Number of samples		6194		6194	
Initial log likelihood		-6804.80		-6804.80	
Final Log Likelihood		-4178.15		-4171.35	
ρ^2		0.386		0.387	
Adjusted ρ^2		0.384		0.385	

Note: Choice 1 (C1) = would buy an EV as an additional car. Choice 2 (C2) = would buy an EV to replace the currently owned car. Choice 3 (C3) = would not buy EVs. (Alternatives in parentheses). - = data not applicable.

6. CONCLUSIONS

The aim of this research work is to explore the psychological determinants influencing individual's intention to purchase electric vehicles. Consumers' considerations of environmental effects and their transportation attitudes relate to the purchase behavior to a large extent.

The brief literature review has presented the findings of different analysis in the same field. The basic information of the web-based questionnaire survey was introduced. The chi-square test and t-test indicated a relationship between respondents' demographics and psychological factors and their purchase intention to electric vehicles. For instance, except for the influence of age, either the consumers' personal characteristics (e.g. gender, employment status, car usage frequency) or the household characteristics (e.g. the annual household income level, the composition of the household, the car ownership, the house type) are strongly associated with the intention of buying an EV. In addition, as revealed by the two-tailed t-test results, association was observed between respondents' psychological considerations and EV purchase motivations. People who stated that they would buy an EV and those would not buy tends to have different attitudes toward the pro-environmental behavior (e.g. reduce car usage and increase public transit usage) and auto-dependency issues (e.g. vote for the statement that a car represents one's social status).

Furthermore, based on the implications mentioned above, we developed a multiple indicators multiple causes (MIMIC) model to estimate the psychological

factors (latent variables) that affect individuals' EV purchase intention. The results of the MIMIC analysis indicated an acceptable model fit. Male householders that are over 50 years old as well as the households in Aichi prefecture are found most actively associated with all the four latent variables, in logical ways. Annual household income and car ownership negatively affect the consciousness on environment in a consistent way.

In addition, we constructed a multinomial logit model for EV purchase intention with and without the latent variables. The results indicated that our latent variables enriched the discrete choice model and increased the goodness of fit indices. Environmental consciousness was identified have opposite effects on the two types of buying intentions. It is positively associated with the intention of buying an EV as an additional car and negatively associated with the intention of buying an EV as a replacement for the currently owned car. We have also identified significant associations between the other three latent variables related to transportation attitudes (η2_AutoD, η3_EVatt, η4_EVfut) and individuals' willingness to buy EVs. For example, there is a high acceptance for EVs as well as a positive attitude towards EV among the respondents that are highly dependent on automobiles. Furthermore, a positive attitude towards the future prospects of EV increases the likelihood of purchasing an EV, either as a new car or as a replacement. If the government's strategy of next-generation vehicle and the long-term goal of carbon dioxide reduction are to be achieved, more efforts have to be done to make sure the consumers are well aware of the benefits EV brings to them as well as a future vision of an environmentally friendly life.

Besides, we would like to point out that by comparing the two discrete choice models (without and with latent variables), the impact of the respondents' demographic variables on EV buying intentions was further explained. The respondents' psychological motivations turned out to be the root cause of their purchase intentions for electric vehicles.

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 the extension of the research to further develop the proposed psychological constructs and confirm findings in a broader setting.

With regard to critical aspects, we have to point out that the respondents' three types of EV buying intention (C1 = would buy an EV as an additional car, C2 = would buy an EV as a replacement for the currently owned car, and C3 = would not buy EVs) are assumed independent, satisfying the independence-of-irrelevant alternatives (IIA) property, and the MNL model was applied for estimation. That is because we believe that these intentions can be further explained as: C1, would enlarge the current car ownership of the household through buying an EV as a new car; C2, would not change the current car ownership thus after buying an EV, a currently owned car would be replaced; C3, would not change the current car ownership of the family. Therefore, one can hardly tell which two of them are more related. And we choose the MNL model for analysis in this research. An interesting issue for future study would be to further investigate the relationship of the three alternatives.

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

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