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Japanese Consumers' Acceptability for Electric Vehicles

Yuki Kudoh[1], Keisuke Matsuhashi[2], Yoshinori Kondo[2], Shinji Kobayashi[2], Yuichi Moriguchi[3]
[1]*Research Institute for Science for Safety and Sustainability, National Institute of Advanced Industrial Science and Technology, 16-1 Onogawa, Tsukuba 305-8569 Japan, kudoh.yuki@aist.go.jp*
[2]*Social and Environmental Systems Division, National Institute for Environmental Studies*
[2]*Research Center for Material Cycles and Waste Management, National Institute for Environmental Studies*

Abstract

Japanese consumers' latest acceptability for electric vehicles (EVs) has been quantitatively evaluated by applying conjoint analysis to the collected respondents data from internet questionnaire survey. Powertrains (battery electric vehicle (BEV), gasoline hybrid electric vehicle (HEV) and gasoline plug-in HEV (PHEV)), vehicle price, vehicle range, driving cost and riding capacity have been chosen as attributes of vehicles and relative importance and its monetary measure of each attribute have been calculated by setting the gasoline vehicle (GV) with typical specifications as baseline. The estimated results indicate that respondents expressed highest importance to riding capacity, followed by HEV and driving cost, whereas the weighting for BEV, PHEV and vehicle range were low or showed no statistical significance. Moreover, 24.2% of the respondents expressed their opinion in the conducted survey that the initial cost for purchasing environmentally friendly vehicles including EVs were expensive compared with conventional GVs. It can be said from the results of this study that the following points should be taken into consideration for further diffusion of EVs: (1) Those EVs whose riding capacity is reduced by mounting electric devices for motor driving would not be accepted. (2) Provision of further and appropriate information for environmental and cost merits is required to gain consumers' recognition especially for BEVs and PHEVs. (3) In addition to subsidy for purchasing EVs, one of the effective way for promoting consumers to buy and hold EVs would be to provide standard information of energy cost or payback time to recover additional initial cost in terms of life cycle cost (LCC) for owning vehicles.

Keywords: Passenger car, Electric drive, Cost, LCC (Life Cycle Cost)

1 Introduction

In Japan, electric vehicles (EVs) are thought to be the promising energy saving, energy diversity and CO2 reduction technology in automotive sector. Vehicle makers are conducting R&Ds upon various kinds of EVs and some of those have already or are ready to put into vehicle market. After the first commercial hybrid electric vehicle (HEV) has been put into Japanese vehicle market in 1997, the number of registered passenger HEVs has been rapidly increasing and it accounts for about 421,000 vehicles at the end of March 2009. The price differences between conventional HEVs and internal combustion engine vehicles (ICEVs) are about 400,000 to 500,000 yen, but Honda[1] had started to sell their new type HEV under 2,000,000 yen from February 2009, whose price difference from ICEV is only about 200,000 yen. There was also a newspaper article that Toyota will slash their current flagship HEV model to the same price as the Honda's new HEV[2] and plans to develop a new low-price HEV below 2,000,000 yen as early as 2011 in Japan[3]. There are also some motivations for commercialisation of battery electric vehicles (BEVs). For example, Mitsubishi Motors Corporation[4] and Fuji Heavy Industries Ltd.[5] are ready for production and sales of small (Japanese Kei car type) passenger BEV beyond 2009. For plug-in HEVs (PHEVs), Toyota says in their sustainability report[6] that they are planning to introduce PHEVs for fleet customers by 2010. It can be expected that these escalating price competitions for HEVs, commercialisation of BEVs or R&Ds of PHEVs would lead to further penetration of EVs and improve environment surrounding passenger vehicles.

There are numerous reports that summarised the environmental performance of EVs. For example, energy consumption and CO2 emissions simulated by various driving schedule test cycles are provided for Japanese[7], US[8] and European[9] conditions. All of these simulation results indicate that environmental performances of EVs prevail over ICEVs. It is assumed in these simulations that EVs have got the same utilities (vehicle size, capacity, etc.) as the baseline gasoline vehicles (GVs) and EVs can achieve almost the same driving performance as GVs. In terms of possession and use of EVs, however, the other aspects apart from driving and environmental performance should be different from ICEVs such as purchase price, fuel cost, vehicle range, etc. Therefore consumers' acceptability for EVs should be different compared with ICEVs. It is important for vehicle makers or governments to understand consumers' acceptability for these vehicles to decide specifications of EVs or policies to promote the use of EVs.

One of the effective ways to analyse consumers' acceptance for products or services is to apply conjoint analysis to consumers' stated preference data. Conjoint analysis is a statistical method mainly developed and used in the fields of environmental economics, computational psychology and marketing research to determine what combination of a limited number of attributes for products or services is most influential upon respondent choice or decision making. A controlled set of potential products or services is shown to respondents and by analysing how they make preferences between these products, the marginal utility of the individual attributes making up the product and total utility of the product can be conjointly determined using multinomial logit model. There are already several studies that had applied conjoint analysis or its closely related methods to evaluate consumers' preferences for alternative fuel vehicles including EVs in US[10][11][12] and in Japan[13][14].

This study aims at evaluating Japanese consumers' latest acceptability for EVs. Based upon the collected data of questionnaire surveys that had been carried out just after the new low-price HEVs have started to be sold and just before Kei car type BEV shall be put into market, a conjoint analysis is carried out to quantitatively estimate consumers' acceptability for EVs. Finally, EV specs that are thought to be important for consumers' vehicle choice or required measures for diffusing EVs will be discussed from the results.

2 Conjoint Analysis

In conjoint analysis, consumers' preference for EVs will be evaluated using a choice experiment (CE). This method is a type of stated preference technique that elicits consumers' preferences directly through questionnaires. In the questionnaire, 4 sets of alternatives (vehicles) consisted of 5 attributes related to vehicles are shown, and the respondents are asked to select the one they most prefer. The details of the questionnaire survey design are described in Section 3.

The collected data are then analysed econometrically using the conditional logit model, which is one of the variations for multinomial logit model. In the model, each respondent is assumed to have a random utility function, which is shown in Eq. (1).

$$U_{iq} = V_{iq}(X_{iq}) + \epsilon_{iq} \tag{1}$$

where U is the total utility, V the observable component of the total utility, ϵ the unobservable component, X the vector of the attributes, i the number of the alternatives (generally called profiles) and q the respondents, respectively. Parameters of the observable utility function V are estimated using the following conditional logit model.

If $U_{iq} > U_{jq} (j \neq i)$, individuals will select alternative i. Hence, the probability of choosing alternative i in the set of all possible alternatives $C = \{1, 2, \ldots, J\}$ by individual q is expressed in Eq. (2).

$$\begin{aligned} P_{iq} &= Pr(U_{iq} > U_{jq} \forall j \in C, j \neq i) \\ &= Pr(V_{iq} - V_{jq} > \epsilon_{jq} - \epsilon_{iq} \\ &\qquad \forall j \in C, j \neq i) \end{aligned} \tag{2}$$

If the error terms ϵ_{jq} and ϵ_{iq} are assumed to be independently and identically distributed with a Gumbel distribution (a type 1 extreme value distribution), probability P_{iq} is calculated as Eq. (3).

$$P_{iq} = \frac{e^{\lambda V_{iq}}}{\sum_{j=1}^{J} e^{\lambda V_{jq}}} \tag{3}$$

where λ is the scale parameter which is conventionally normalised to 1. The Gumbel distribution is used for analytic convenience, which is imposed in many similar models.

The log likelihood function for the maximum likelihood estimate is shown in Eq. (4).

$$\ln L = \sum_{q=1}^{Q} \sum_{j=1}^{J} \delta_{jq} \ln P_{jq} \tag{4}$$

where Q is the number of respondents, δ_{jq} the dummy variable ($\delta_{jq} = 1$ when individual q selects alternative i and $\delta_{jq} = 0$ when individual q selects any other alternative except for alternative i). The utility parameters that maximize Eq. (4) are then calculated.

After the parameters of the utility function are estimated, the marginal willingness to pay (MWTP) of each attribute can be obtained. Assuming additive separability for the utility function, the utility function can be expressed in Eq.

(5).

$$V(X,p) = \sum_n \beta_n x_n + \beta_p p \tag{5}$$

where X is the vector of n attributes ($X = (x_1, x_2, \ldots, x_n)$), p the price of the alternative, β_n the marginal utility of each attribute and β_p the marginal utility of income, respectively. The subscripts for respondents and alternatives i, j and q are omitted here for simplification. The total differential of Eq. (5) is calculated as Eq. (6).

$$dV = \sum_n \frac{\partial V}{\partial x_n} dx_n + \frac{\partial V}{\partial p} dp \tag{6}$$

It is assumed that utility is held constant ($dV = 0$) and all attributes except for x_1 ($dx_i = 0, i \neq 1$) including all non-measured attributes that the respondents perceive are unchanged. Thus the MWTP, the monetary measure for a unit change of x_1, is calculated by Eq. (7).

$$MWTP_{x_1} = \frac{dp}{dx_1} = -\frac{\partial V}{\partial x_1} / \frac{\partial V}{\partial p} = \frac{\beta_1}{\beta_p} \tag{7}$$

3 Questionnaire Survey Design

3.1 Outline of questionnaire survey

Internet questionnaire surveys (pretest and actual survey) have been conducted to obtain CE data for internet monitors of the Nikkei Research Inc. Access Panel from all over Japan that own their own passenger vehicles from the age from 20 to 60. Pretest had been carried out from January 23rd until 27th 2009 (number of respondents collected: 1,323, collection rate: 18.0%) and actual survey from February 13th until 17th 2009 (number of respondents collected: 6,935, collection rate: 32.1%), respectively. Pretest had been conducted to check the adequacy of the configured levels of each attribute (see Subsection 3.2 for details) before conducting actual survey. The estimates shown in Section 4 are based upon the data of actual survey.

In Japan, passenger vehicles are categorized into Kei passenger vehicle and passenger vehicle by law. Kei passenger vehicle is restricted for its physical size, riding capacity, engine displacement and power by regulations and taxes imposed upon owing vehicles are different by two categories. The way how their vehicles are used is different by Kei passenger vehicle and passenger vehicle owners. Indeed, the estimated annual average mileage from our national statistics for vehicle transport[15] and the number of the vehicles held[16] shows different trend between two categories (7,620km/yr for Kei passenger vehicles and 9,146km/yr for passenger vehicles, respectively). In addition, only the Kei passenger vehicle type BEV is announced to be put into market beyond 2009. In this study, consumers' acceptability for EVs is therefore estimated separately by Kei passenger vehicles and passenger vehicles.

Please assume that you are planning to buy a brand-new passenger vehicle within next 3 years. In the following questions, 4 vehicles will be shown at a time. 4 vehicles are different in combination of the following 5 items but the rest of the specs and equipments of the 4 vehicles are assumed to be the same.

1. Powertrain
   GV: Gasoline vehicle
   BEV: Battery electric vehicle
   HEV: Hybrid electric vehicle (with gasoline engine)
   PHEV: Plug-in hybrid electric vehicle (with gasoline engine)
2. Vehicle price [mil. yen]
   Vehicle price without optional equipments and taxes.
3. Vehicle range [km]
   The length that vehicle can drive after filling the tank up or charging the batteries full.
4. Driving cost [yen/km]
   Cost to drive the vehicle 1km.
   If the fuel economy is 10 km/l and fuel price is 100 yen/l, driving cost will be 10 yen/km.
5. Riding capacity [person]
   The number of maximum person that can be carried on the vehicle.

In the following questions, 4 vehicles with the combination of above 5 items will be shown 8 times. Please select one vehicle at a time that you prefer to buy from 4 vehicles like the following example.

<Example>
Please select one vehicle that you prefer to buy from the following 4 vehicles.

	Vehicle A	Vehicle B	Vehicle C	Vehicle D
Powertrain	BEV	PHEV	HEV	GV
Vehicle price	1.5 mil. yen	1.5 mil. yen	3.0 mil. yen	1.8 mil yen
Vehicle range	700 km	250 km	700 km	650 km
Driving cost	12 yen/km	1 yen/km	1 yen/km	7 yen/km
Riding capacity	5 person	2 person	4 person	5 person
	↓	↓	↓	↓
Check the preferred vehicle			√	

Please be aware of the following points.

A. Please select one vehicle in all of the following 8 choise sets with the same format. If there are answer leakages, significant results cannot be obtained.
B. Please select the most preferable one from the 4 vehicles shown at the same time. Do not compare with the vehicles that are shown in other choice sets.
C. Vehile D will be shown in all the 8 choice sets. Vehicle D is a vehicle with typical specs that are estimated from vehicle catalogue data.

Figure 1: Some parts of the vehicle CE question

3.2 CE questions design

Together with some questions related to the specs and usage of their privately owned passenger vehicles and their knowledge for energy saving and CO2 reduction technologies for passenger vehicle, respondents are asked to select one preferable vehicle out of 4 vehicles (profiles) for 8 times considering the balance between each attribute in each passenger vehicles, assuming that they should buy brand-new passenger vehicle within next 3 years and either Kei passenger vehicle or passenger vehicle they would prefer to. Some parts of the CE question are shown in Fig.1.

Table1 shows the assumed attributes and covered levels in this study. We assumed that the following 5 attributes should affect consumers' choice for vehicles: powertrain, vehicle price (without optional equipments and taxes), vehicle range, driving cost and riding capacity.

Based upon the configured attributes and levels, profiles for the CE question have been generated using L25 orthogonal array of attributes and their levels shown in Table 1, which is a special type of fractional factorial design representing the most efficient (in the sense of the lowest number of combinations) set of designs available for the parameter estimation. Excluding 1 from the generated 25 profiles whose combination of level for each attribute is assumed to be impractica-

Table 1: Configured attributes and levels for conjoint analysis

Attribute	Levels
Powertrain	GV, BEV, HEV, PHEV
Vehicle price [mil. yen]	Kei passenger vehicle: 0.8, 1.3, 1.8, 2.3, 2.8 Passenger vehicle: 1.5, 2.0, 2.5, 3.0, 4.0
Vehicle range [km]	Kei passenger vehicle: 80, 200, 400, 600, 800 Passenger vehicle: 100, 250, 450, 700, 1000
Driving cost [yen/km]	Kei passenger vehicle: 1, 2, 3, 5, 8 Passenger vehicle: 1, 3, 5, 8, 12
Riding capacity [person]	Kei passenger vehicle:1, 2, 4 Passenger vehicle: 2, 4, 5, 8

ble for passenger vehicle and that would confuse respondent's choice, a baseline profile has been added to each choice set (Vehicle D in Fig.1). Therefore 8 choice sets with 4 profiles have been generated.

3.3 Provided information for EVs

In order to help the respondents understand the characteristics of the objective EVs, following pieces of general information are provided before the CE questions.

3.3.1 BEV

"BEV can be driven with electric motor and electricity that are charged in the on-board battery.

- You have to charge the batteries of BEV either at your house or at charging stations, like gasoline (or diesel) vehicle needs to be fuelled in filling stations.
- Motor can be driven not only with the charged batteries but also the regenerated energy during braking charged in the battery.
- Energy efficiency of BEV is better than gasoline (or diesel) vehicles. However, since the amount of electricy charged in on-board battery is restricted owing to the current battery technology, the vehicle range will be shorter than gasoline (or diesel) vehicles.
- CO_2 emissions by driving BEV 1km will be about 2$\sim$25% of gasoline vehicle if the emissions by electricity generation are included."

3.3.2 HEV

"HEV can be driven with both gasoline (or diesel) engine and electric motor.

- You have to fuel HEV at filling stations like gasoline (or diesel) vehicle.
- When you are accelerating or driving in congested traffic and energy efficiency of engine is low, it is driven only by motor or by engine assisted with motor. When you are driving in smooth traffic with high speed, it is driven only by engine.
- Motor can be driven not only with the charged batteries but also the regenerated energy during braking charged in the battery.
- Since the energy efficiency (fuel economy) is high, vehicle range will be longer than gasoline (or diesel) vehicles.
- CO_2 emissions by driving HEV 1km will be about 50$\sim$60% of gasoline vehicle if the emissions by refining gasoline are included."

3.3.3 PHEV

"PHEV can be driven with both gasoline (or diesel) engine and electric motor.

- PHEVs have the characteristics of both HEV and BEV. Not only you have to fuel PHEV at filling stations like gasoline (or diesel) vehicle but you can also charge the batteries either at your house or at charging station like BEV.
- It can be driven with motor and charged batteries for short distance. For long distance drive, it can be driven in the same manner as HEVs after the batteries become empty.
- If it is driven in HEV mode and you are accelerating or driving in congested traffic, it is driven only by motor or by engine assisted with motor. When you are driving in smooth traffic with high speed, it is driven only by engine.
- Motor can be driven not only with the charged batteries but also the regenerated energy during braking charged in the battery.
- Energy efficiency (fuel economy) of PHEV is higher than gasoline (or diesel) vehicles. However, since the amount of electricity charged in on-board battery is restricted owing to the current battery technology, the vehicle range driven in BEV mode will be shorter than gasoline (or diesel) vehicles. However, it is expected that the vehicle range driven in HEV mode should be longer than gasoline (or diesel) vehicle.

Table 2: Configuration of baseline profiles

Kei passenger vehicle	Powertrain: GV, Vehicle price: 1.2 mil. yen, Vehicle range: 500 km, Driving cost: 6 yen/km, Riding capacity: 4 person
Passenger vehicle	Powertrain: GV, Vehicle price: 1.8 mil. yen, Vehicle range: 650 km, Driving cost: 7 yen/km, Riding capacity: 5 person

- CO2 emissions by driving PHEV 1km will be about 2∼25% for BEV mode and 50∼60% for HEV mode of gasoline vehicle if the emissions by power generation and refining gasoline are included."

3.4 Setting the baseline profile

In the pretest, a null profile had been shown commonly in every 8 choice sets. If this null profile had been chosen, it means the rest of the 3 profiles included in each choice set had low utility and respondents preferred neither of them. There were so many respondents that had selected this null profile for every 8 choice sets that significant results could not be obtained through the conjoint analysis. This trend can be explained from the fact that since passenger vehicles are expensive, consumers should make a conservative choice for selecting their preferable vehicle.
Consequently in the actual survey, instead of including a null profile, the baseline profiles have been configured and provided commonly in each choice set, which are shown in Table 2. The baseline vehicles are assumed to represent typical GVs and the levels for each attribute have been settled by analysing the catalogue data of the passenger vehicles[17] sold in Japanese market whose model year are after 2000.

4 Estimation of Consumers' Acceptability for EVs

In the questionnaire survey, there were some respondents that had selected all the same choices for 8 times in the CE part. Although it is difficult to distinguish whether they have really chosen the same vehicle by deliberating all the profiles or not in the internet questionnaire survey, the results from the conjoint analysis will be different by including these data or not. In the survey, the time required to answer all the questionnaire items have been measured for each respondent. The minimum value, lower quartile, median, upper quartile and maximum value of the required time for the respondents were 54 sec., 398 sec., 572 sec., 854 sec. and 3,579 sec., respectively. In this study, it is assumed that those 1,731 respondents' data whose required answer time is shorter than lower quartile (398 sec.) had been answered without careful consideration and therefore eliminated from the analysis. Setting the vehicles shown in Table 2 as baseline, utility parameters are estimated using conditional logit model by assuming that the observable components of the random utility function in Eq. (1) can be explained as Eq. (8) by linear combinations of the settled attributes.

$$\begin{aligned} V &= \beta_1 BEV + \beta_2 HEV + \beta_3 PHEV \\ &+ \beta_4(VR - VR_b) + \beta_5(PC - PC_b) \\ &+ \beta_6(RC - RC_b) + \beta_7(VP - VP_b) \end{aligned} \quad (8)$$

where BEV, HEV and $PHEV$ are the dummy variables for each type of powertrains, VR is vehicle range, DC driving cost, RC riding capacity, VP vehicle price and suffix b baseline vehicle, respectively.
One of the indices to measure the goodness-of-fit of the model is the McFadden's likelihood ratio index (LRI), which can be calculated as Eq. (9).

$$LRI = 1 - LL_\beta / LL_0 \quad (9)$$

where LL_β is the log likelihood of the estimated model and LL_0 the log likelihood of the model when all of the coefficients are restricted to be zero. It is said that the model can be regarded to have high goodness-to-fit if LRI is from 0.2 to 0.4[18].

4.1 Kei passenger vehicle estimates

Table 3 shows the estimates for Kei passenger vehicle.
LRI shows that the assumed linear model by Eq. (8) is well fitted for consumers' preference for Kei passenger vehicle.
Each coefficient (utility parameter) in Table 3 stands for the valuation weights of each attribute. For instance, the estimation result shows that a vehicle price increase of 1 mil. yen causes a decrease by 0.0166 in utility on average. Although the utility levels themselves are shown as absolute numbers, they have no specific meaning in themselves and are only meaningful for comparing attributes. For instance, acceptance for HEV is about 3 times higher than that for BEV.
As shown in Eqs. (5)-(7), the valuation weights or the utility parameters can be converted into monetary terms as MWTP. Please note here that the baseline of MWTP has been set to the configured baseline Kei passenger vehicle shown in Table 2.
From the estimated MWTPs in Table 3, a number of implications can be obtained.

- Population respondents evaluate the highest acceptance for unit increase of riding capacity with 0.45 mil. yen from the baseline vehicle. Although the maximum riding capacity for Kei passenger vehicle is restricted for 4 person, this indicate that those vehicles whose riding capacity is reduced by mounting electric devices for motor driving would not be accepted by consumers.

Table 3: Estimates for Kei passenger vehicle

	Coefficient (t-value)	MWTP [mil. yen]
Vehicle price [mil. yen]	-0.0166* (-65.1)	
Powertrain: BEV	0.186* (7.56)	0.112
Powertrain: HEV	0.577* (14.7)	0.348
Powertrain: PHEV	-0.592* (-11.6)	-0.357
Vehicle range [km]	0.00236* (30.6)	0.00143
Driving cost [yen/km]	-0.263* (-44.0)	-0.159
Riding capacity [yen/km]	0.745* (62.4)	0.450
Sample number	2,045	
Log likelihood	-15,018	
LRI	0.338	

* Asterisk denotes significance at 1% level.

Table 4: Estimates for passenger vehicle

	Coefficient (t-value)	MWTP [mil. yen]
Vehicle price [mil. yen]	-0.0105* (-75.5)	
Powertrain: BEV	-0.175* (-7.34)	-0.167
Powertrain: HEV	0.307* (12.7)	0.293
Powertrain: PHEV	-0.0162 (-0.865)	-0.0155
Vehicle range [km]	0.00150* (41.2)	0.00143
Driving cost [yen/km]	-0.185* (-62.2)	-0.177
Riding capacity [yen/km]	0.313* (51.7)	0.300
Sample number	3,158	
Log likelihood	-29,549	
LRI	0.156	

* Asterisk denotes significance at 1% level.

- For the MWTP of powertrains, HEV shows the highest value, followed by BEV and PHEV. This can be explained from the fact that consumers now widely recognise the merits and environmental friendliness of HEVs that have been already provided in vehicle market and that they know Kei passenger vehicle type BEVs are ready to put into market. On the other hand, MWTP of PHEV is estimated to be negative value compared with the baseline GV. Although respondents are asked to read the provided basic characters for PHEV in Subsection 3.3 before they choose their preferable profile from each choice set, this indicates that either they didn't get the merit of choosing PHEV compared with HEV and BEV or they couldn't imagine what PHEV would be like from the provided information.

- Respondents' valuation for unit driving cost decline from the baseline cost of 6 yen/km was 0.159 mil. yen. In other words, a unit decline of driving cost is worth 0.159 mil. yen rise in vehicle price from the baseline vehicle.

- Although the coefficient for vehicle range shows statistical significance, its valuation weight and MWTP are estimated to be low compared with other attributes, which means that either they don't care for vehicle range or that they couldn't imagine that the vehicle range would be shorter than the baseline vehicle, especially for BEV, from the provided information described in Subsection 3.3.

4.2 Passenger vehicle estimates

The estimates for passenger vehicle is summarised as Table 4.

LRI for passenger vehicle indicates that instead of assuming the linear model by Eq. (8), other types of utility functions such as log or logistic function should be applied to or other attributes that are not adopted in this study should be included to evaluate consumers' preference for passenger vehicles.

However, the estimated 0.293 mil. yen MWTP for HEV from the baseline GV indicates that further diffusion of HEVs can be expected with the price difference of 200,000 yen between the new low-price HEVs and ICEVs.

MWTP of BEV for Kei passenger vehicle was positive value but that for passenger vehicle is negative. It may be that respondents did not make an affirmative powertrain choice for passenger vehicle type BEV, for the provided pieces of information for BEV commercialisation are only for Kei passenger vehicles.

Moreover, the estimated coefficient for PHEV has no statistical significance. Although they should know the concept and merits of PHEV from the provided pieces of information described in Subsection 3.3 but lacking concrete information for its commercialisation, chances are that they held their judgment for choosing PHEV when they are asked to choose and buy a new passenger vehicle within this 3 years.

The rest of the estimates in Table 4 show almost the same trend as in Table 3.

4.3 Consumers opinions for vehicle ownership

At the end of the conducted internet questionnaire survey, respondents are asked to express their free opinions for relationship between vehicles and the environment, if any. Among the total of 5,203 respondents whose data are used for conjoint analysis, 1,257 respondents (24.2% of the total) have described such similar opinions that although they would like to own an environmentally friendly vehicle, they cannot afford to buy it with too expensive vehicle price compared with conventional passenger vehicles, or that they will purchase it if the initial cost of these vehicles falls. In spite that the life cycle cost (LCC) for holding a vehicle can be described as the sum of initial, driving and maintenance costs, this indicates that consumers would consider them separately and they especially pay high attention to initial cost for purchasing vehicles. As 52 out of 1,257 respondents had mentioned in their free opinions, governmental subsidy for consumers to help reduce paying initial cost of purchasing those vehicles should be required for widespread of EVs.

In Japan, energy-efficiency standards for some machineries and equipments are provided in the Energy Conservation Law (ECL) by implementing the Top Runners Approach, which aims to establish energy-efficiency standards that meet or exceed the best energy-efficiency specifications for a product in industry[19]. Top Runner target machineries and equipments are obliged to display their energy-efficiency by the ECL. For some objective machineries and equipments, the "Uniform Energy-Saving Label" that shows their energy-saving performances, expected annual energy cost and other pieces of information is also displayed at the retailers to promote consumers to purchase and use these products. For passenger vehicles, whether they have achieved the Top Runners Approach energy standards or not can be distinguished by the window sticker on the vehicles but the label program that provides energy cost information has not yet been implemented.

It is quite difficult to provide precise information of energy cost or LCC for using and holding a vehicle owing to the following reasons. The results from our previous studies show that there is a gap between fuel consumption of a vehicle measured by driving schedule test cycle and actual fuel consumption[17] and that the actual fuel consumption depends upon the average travel velocity that varies by the places where we drive[20][21]. In addition, driving range of a vehicle differs by where and how consumers use their vehicles. Moreover, it is difficult to set the discount rate to calculate LCC.

It is true that commercialisation of HEVs and providing pieces of information for Kei passenger vehicle type BEVs commercialisation have played an important role for enhancing consumers' environmentally awareness of EVs, whose effect has been reflected to the estimates in Tables 3 and 4. In addition to provide appropriate information of the environmental merits for using EVs or subsidy for EV purchase, another effective way for further promoting consumers to buy and hold EVs would be to provide standard information of energy cost or payback time to recover additional initial cost in terms of LCC for owning EVs.

5 Summary

In this study, internet questionnaire surveys have been conducted just after the new low-price HEVs have started to be sold and just before Kei car type BEV shall be put into market. Based upon the collected data of the survey, Japanese consumers' latest acceptability for EVs has been quantitatively evaluated using conjoint analysis.

The estimated results show that population respondents evaluate the highest preference for riding capacity, which means that those EVs with less seats by mounting electric devices for motor driving would not be accepted by consumers. In terms of weighting or MWTP for each type of powertrain, they show highest acceptance for HEVs followed by Kei passenger vehicle type BEV. Since the price difference between the new low-price HEVs and ICEVs is lower than the MWTP for HEVs from the baseline GV, further diffusion of HEVs can be expected with this price difference. On the other hand, respondents express less preference or held their judgment for choosing other types of vehicles. It is estimated that they also weight importance upon driving cost reduction but not for driving range. From these findings, it can be said that further and appropriate information for environmental and cost merits should be required to gain consumers' recognition especially for BEVs and PHEVs.

From opinions expressed in respondents' free opinions for relationship between vehicles and the environment, it can be said that they pay special attention to initial cost for purchasing vehicles, although LCC for holding a vehicle can be described as the sum of initial, driving and maintenance costs. This suggests that another effective way for promoting consumers to buy and hold EVs should be to provide standard information of energy cost or payback time to recover additional initial cost in terms of LCC for owning vehicles in addition to subsidy for purchasing EVs.

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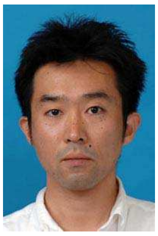
Authors



Yuki Kudoh, Dr.-Eng., Research Scientist, Material and Energy Sustainability Assessment Group, Research Institute of Science for Safety and Sustainability, National Institute of Advanced Industrial Science and Technology.

Keisuke Matsuhashi, Dr.-Eng., Senior Researcher, Transportation and Urban Environment Section, Social and Environmental Systems Division, National Institute for Environmental Studies.

Yoshinori Kondo, Dr.-Eng., Senior Researcher, Transportation and Urban Environment Section, Social and Environmental Systems Division, National Institute for Environmental Studies.

Shinji Kobayashi, Dr.-Eng., Transportation and Urban Environment Section, Social and Environmental Systems Division, National Institute for Environmental Studies.

Yuichi Moriguchi, Dr.-Eng., Director, Research Center for Material Cycles and Waste Management, National Institute for Environmental Studies. He is also appointed as Visiting Professor, Graduate School of Frontier Sciences, The University of Tokyo.