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Asymmetric Preferences on Electric Vehicles from the Relative Importance Point of View

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Abstract

In Jeju Island of Korea, approximately 500 electric vehicles (EVs) have come into use so far, and Jeju Special Self-Governing Province has invited public participation of 1,500 EVs dissemination recently. Imported car makers as well as domestic car makers have a strong will to sell their EVs to people in Jeju Island. Among the previous literature, the research about the gap between consumer expectations and EV realities has performed by Deloitte Survey. However, there has rarely exists the research about the gap between the EV consumer expectations and EV expert expectations even though the EV market has been emerging to us. Thus, this paper examines if there exists any gap in EV selection criteria between EV consumers and EV experts. We adopted the amount of battery, charging methods, purchase reasons, and billing methods as the measuring factors. And then, we performed Conjoint analysis for fulfilling our research goals. By showing the gap between the experts and the consumers, this research can give the EV experts the idea that leads them to the desirable way to develop future EVs.

Keywords: Smart Grid, Electric Vehicle, Conjoint Analysis, Preference Analysis, Production Strategy

1 Introduction

Forecasting is a scientific process of using historic data to determine the direction of future trends. Every forecast is based on a selected model and by different approaches of dynamic variables it will have different strengths and weaknesses. Forecasting performance often fail to spot the result of 100 percent accuracy. However, they provide the best basis for scheduling available. Considering several variables is vital when developing model of forecasts [1]. Recently, neural network becomes more popular as an automotive engine diagnose or a specific engine activities forecasting. A number of researches have been carried out using different methodology on engine diagnose [2][3][4]. The current study proposed a modeling and forecasting of the car speed based on HMLP with MRPE as the training algorithm. After preliminary study, injected fuel (liter/hour) has been selected as neural network input, while the speed (km/h) is the output. With several dynamic combinations of input and output variables, they become an essential ingredient in the formation of unbiased and adequate modeling and forecasting.

The 2nd International EV Expo was held in Jeju Island of Korea last March. A lot of domestic and international EV manufacturing companies and experts participated in the Expo for promoting their products and for further research [1]. At the same time, the number of consumers who are willing to buy EVs in the near future increases. Like other product, the EV consumers also want to have an EV that can go farther, have less charging time, and be less expensive than the EV makers can offer [2]. However, the EV expert expectations and the EV consumer expectations can be different because their interests are quite different with each other. Thus, we researchers should find the gap between the experts' research direction and the consumers' expectations for the successful EV market at this moment.

In fact, the introduction of EVs into the market has brought up many technical problems. Thus, many research related to the EVs has been proposed for many years [3][4]. In particular, the development of battery management methods [5][6] and the implementation of efficient charging algorithms [7][8] are still hot issues in the EV technologies. Due to the recent EV dissemination policies, the EV market will be opened wider to the public this year in Korea. However, the research considering the EV researchers and the consumers who are interested in EVs together has rarely been existed. Recently the research [9] performed a survey on the visitors who attended the 2nd International EV Expo held in Jeju Island. But, the survey only focused on the Expo participants. Thus, we need to extend the survey to the people who live in Jeju Island at this time. In this research, we present how different the EV experts and the future EV consumers are when they choose an EV as their personal car. By performing this research, we would like to provide the consumers' preferences and their worries about the EVs to the experts. Then, the experts can lead the EV market successful.

In order to achieve our research goals, we performed Conjoint analysis, which can estimate the part-worths of a set of the sub-factors for a given factor. A factor is a component of a product (or a service) and is also composed of a few set of sub-factors. Conjoint analysis can measure consumers' integrated preference about the given product (or the given service) [10][11]. We also evaluated the relative importance of the factors for the product (or the service). The analyzed result helps to fix the misconception about the consumers' thought of the EVs [9]. For Conjoint analysis, we extracted the factors of a given product, and determined the sub-factors for each factor. And then, we made a set of profiles (cards) that are combinations of the sub-factors. We used the set of profiles in order to determine the preferences of respondents [10][11]. In this research, we chose 4 factors such as the amount of battery, charging methods, purchase reasons, and billing methods as EV selection criteria. The numbers of the sub-factors for the 4 factors are 3, 3, 2, and 2 respectively. Therefore, the total number of the possible combinations (profiles) is 3*3*2*2 (= 36) in this research [9]. We surveyed 100 people, some of them are the residents in Jeju Island and others are the participants of the 2nd International EV Expo. Among 100, we collected only 78 answers from the respondents.

2 Related Works

In the research [9], 26 males (70.3%) and 11 females (29.7%) participated. The 11 respondents (29.7%) had no plan to purchase an EV, whereas the 26 respondents (70.3%) had a plan to buy an EV. However, there was no one who would buy an EV within 6 months. The 17 respondents (45.7%) answered that they would purchase an EV more than 2 years later [9].

As the results of the survey, the orders of the preferences on the 4 factors for the experts were the amount of battery (63.2%), the charging methods (21.2%), the billing methods (9.3%), and the purchase reasons (6.3%). On the other hand, the orders of the preferences of the 4 factors were the amount of battery (88.0%), the charging methods (8.2%), the purchase reasons (2.4%), and the billing methods (1.4%) for the consumers. Even though two groups ranked the amount of battery in the first place, the consumers consider the amount of battery more importantly than the experts. Also, the experts considered the charging methods as another important factor for an EV selection unlike the consumers [9]. In a Deloitte Survey [2] in 2011, the key considerations when evaluating EVs were range (battery amount), charging time, purchase price, fuel price, and fuel efficiency. However, the paper neither indicated when the people buy nor the maintenance factors.

3. Experiments

In this paper, we adopted the same EV selection criteria used in the research [9]. Table 1 shows the 4 factors as the EV selection criteria. There are a lot of criteria beside the 4 factors of this paper. However, the amount of batter and the charging method are the keys in EV technology. And, the purchase reason and the maintenance cost are the most important in the buyer's perspective. In 2014, the range of the mileage of a domestic EV lay between 91km and 148km. Thus, we chose 200km, 300km, and 400km drive as the alternatives for the amount of battery. Next, for the charging methods, we have slow charging method, fast charging method, and batter swap currently. For the purchase purpose, we divided it into 2 such as commute purpose and family use. Also, we divided the billing methods into 2 such as monthly billing and instant billing.

Table 1. EV Selection Criteria [9].

Criteria	Alternatives
The amount of battery	▪ 200km-drive with one full charging ▪ 300km-drive with one full charging ▪ 400km-drive with one full charging
The charging methods	▪ Charging in a long-term parking area such as House and APT (slow charging) ▪ Charging in a short-term stop or parking area such as street and charging stations (fast charging) ▪ Battery swap
The purchase reasons	▪ For commute ▪ For family use
The billing methods	▪ To pay the monthly bill ▪ To pay the bill immediately

By using the 12 profiles mentioned above, the respondents determined the ranking from 1 to 12. And then, we performed a Conjoint analysis based on their answers. In most statistical methods, the desirable sample size is 30 at least because of the Central Limit Theorem. However, Conjoint analysis can perform individual analysis, whereas others perform aggregated analysis. Thus, it can allow the analysis of small number of experts with a set of various types of profiles.

4 Results and Discussion

We firstly present the characteristics of the respondents of the survey. We had 55 (70.5%) males and 23 (29.5%) females in the survey. Also, we had 1 teenager, 32 20s, 16 30s, 20 40s, 8 50s, and 1 60s. The respondents were college students, graduate students, university's employees, and some others. Among the respondents, 51 (65.4%) people answered that they have a plan to buy an EV in the future. We divided the purchasing time into 4 such as within 6 months, within 1 year, within 2 years, and after 2 years. Two respondents answered that s/he had a plan to buy an EV within 6 months. 12 respondents and 37 respondents answered that they will buy EVs within 2 years and after 2 years respectively. It means that the respondents wanted to delay the purchasing time 1 or 2 year later even though they had a plan to buy one. The 62 respondents (79.5%) came from Jeju Island and 16 came from other cities who attended the 2nd International EV Expo. Next, the preference differences are described in Table 2. The Pearson's R in Table 2 represents the correlation coefficient between the observed and the estimated preferences, whereas the Kendall's τ represents how well the ranks of the observed preferences coincide with the rank values of their estimated part-worths.

Table 2. The Asymmetric Preferences.

Factors Sub-factors		Part-worths			Relative importance		
		W	E	C	W	E	C
The amount of battery	200km	-2.15	-1.928	-2.092	71.84%	54.64%	82.85%
	300km	.502	.656	.463			
	400km	1.603	1.272	1.629			
The charging methods	Slow charging	.473	.623	.296	21.96%	31.95%	13.54%
	Fast charging	.199	.616	.016			
	Battery swap	-.672	-1.248	-.312			
The purchase reasons	For commute	-.007	.020	-.039	0.27%	0.68%	1.74%
	For family use	.007	-.020	.039			
The billing methods	Monthly billing	-.156	-.373	-.042	5.97%	12.73%	1.87%
	Instant billing	.156	.373	.042			

W: the whole, E : the expert, C : the consumer W: R=.996 (p <.001), τ=.970 (p <.001), E: R=.998 (p <.001), τ=.879 (p <.001), C: R=.991 (p <.001), τ=.931 (p <.001)

In Table 2, all the Rs and all the τs are statistically significant. This means that the estimated values represent the observed values well. As shown in Table 2, the amount of batter was the most important factor for the whole respondents when they select an EV. However, the consumers thought more important about the amount of battery because the relative importance ratio of the consumers (82.85%) was much bigger than that of the experts (54.64%). For the sub-factors of the amount of battery, 400km-drive was the best with one full charging. However, this does not mean that the bigger, the better. Also, this does not mean that 400km is not the exact number for the amount of battery. Anyhow, among the alternatives, the biggest amount of battery was selected for the whole respondents.

Next, the charging method was the second factor for the whole respondents. But, the experts preferred both slow charging method and fast charging method, whereas the consumers preferred slow charging more. For the purchase reasons and the billing methods were not that attractable to the whole respondents. However, the experts cared more than the consumers about the billing methods. From the results mentioned above, we found that the experts considered various kinds of factors of the EVs more than the consumers. Thirdly, we examine if the differences between the experts and the consumers are statistically meaningful with t-Test. Table 3 shows the mean values of the relative importance of the 4 factors for the experts and the consumers. In order to get the t values of the 4 factors, we calculated the relative importance values of each factor *i* for a respondent *j*, $value_{ij}$, as shown in the below expression.

$$value_{ij} = \frac{(\max\_\,partworth_{ij} - \min\_\,partworth_{ij})}{\sum_i (\max\_\,partworth_{ij} - \min\_\,partworth_{ij})},$$

where i=1, 2, 3, 4 (1)

and j=1, 2, …, the number of the respondents

We compared the mean relative importance of the sub-factors of the 4 main factors. According to Table 3, only the preferred charging method was statistically different between the experts and the consumers (p=.050). From Table 2, we already saw that the relative importance for the charging methods were quite different between the experts and the consumers. The experts considered the slow and the fast charging methods together unlike the consumers. In addition, for the sub-factors of the charging method, the consumers preferred slow charging method more than the experts. Thus, the difference was partially meaningful statistically ($p < .1$). For the sub-factors of the amount of battery, the consumers preferred the 200km-drive with one full charge more than the experts statistically ($p < 0.01$).

Table 3. The Mean Values of the Relative Importance of the 4 Factors.

Factors	Group	Mean	SD	t/df	p
The amount of battery	Expert	39.42	21.30	-.98	.330
	Consumer	44.60	22.00	76	
The charging methods*	Expert	37.74	20.97	2.00	.050
	Consumer	28.38	18.62	76	
The purchasing purposes	Expert	11.05	14.01	-1.52	.134
	Consumer	16.72	17.93	59.19	
The billing methods	Expert	11.79	11.68	.53	.601
	Consumer	10.30	11.69	76	

Finally, we divided the consumers into 2 groups. One is the visitor group and the other is the university employee group. We performed an ANOVA about the relative importance ratio for the 4 factors. There were 23 Expo visitors and 30 university employees. The preference difference in the charging method among the 3 groups (the experts, the visitors, and the employees) was significant (df=2, F=3.63, p=.031). The preference difference in the amount of battery among the 3 groups was partially significant (df=2, F=2.96, p=.058). Based on the post hoc tests with Tukey, the experts and the visitors were statistically different when choosing a charging method (p=.025). From this result, we knew that the charging methods were different based on their purposes on the usage of an EV. For the visitors, the shorter charging time was important because of their mobility.

5 Conclusions

In the previous research [9], the EV experts and consumers both considered the amount of battery as the most important key factors when purchasing an EV. This result was similar to this research. In addition, from the statistical point of view, for the 4 factors (the amount of battery, the charging methods, the purchasing purposes, and the billing methods), the charging methods were only different between the experts and the consumers. We can explain this phenomenon with the characteristics of the respondents. In fact, a lot of portion of our respondents was filled with the university employees. Thus, many consumers were interested in long term parking easily. However, for the experts, various kinds of charging methods are important to consider. If we expand the respondents more in the future, the result may be different from this research.

Next, even though two groups ranked the amount of battery in the first place, the consumers consider the amount of battery more importantly than the experts. However, unlike the consumers, the experts considered the charging methods as another important factor for an EV selection. This result was similar to the one of the research [9]. In addition, the experts wanted to purchase an EV for the commuting purpose. However, the consumers had the opposite preference in the purchase reason. They wanted an EV for family use. The experts and the consumers preferred the instant billing method. It may be influence by the existing billing method in gas stations.

However, this research has a few limitations. Firstly, we had limited number of respondents. Also, the respondents skewed to workers. If we survey visitors or other people who have different jobs, then we might have different results. Secondly, even though the factors we chose in this research came from the previous research works, there exist a lot of factors for evaluating EVs. In this research, we only chose 4 factors. In the near future, we should extend the factors and determine the factor level equally. However, from this research and the previous literature, we can guess that EVs can penetrate successfully to the automobile market by performing preference analysis at the early stage of a new product development with Conjoint. The understanding of the consumers' relative importance of many factors of EVs can give a new direction to successful development of EVs. In particular, there exists a difference between two consumer groups in this research. Thus, more careful consumer analysis is needed in the near future.

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