Transportation Research Part D 36 (2015) 96–106

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

# Factors affecting electric vehicle sharing program participants' attitudes about car ownership and program participation

Daejin Kim [a], Joonho Ko [b,*], Yujin Park [c]

[a] Department of Transportation System Research, The Seoul Institute, Seoul 137-071, Republic of Korea
[b] Megacity Research Center, The Seoul Institute, Seoul 137-071, Republic of Korea
[c] Department of Rural Policy Research, Korea Rural Economic Institute, Seoul 130-710, Republic of Korea

ARTICLE INFO

*Article history:*
Available online 13 March 2015

*Keywords:*
Electric vehicle
Car sharing
Satisfaction
Ordered probit
Factor analysis

ABSTRACT

There are growing concerns on traffic congestion, climate change and parking problems in major cities. Faced with these concerns, policy makers have sought sustainable transportation options including electric vehicle sharing programs (EVSPs). The city of Seoul with 10 million people also has recently launched an EVSP to provide citizens with an alternative travel mode. This study attempts to explore factors affecting the EVSP participants' attitudes about car ownership and program participation. To do this, a web-based survey was conducted for the participants of the Seoul EVSP, asking their satisfaction levels for the components of the EVSP. Then, using 533 responses of 1772 EVSP members (a response rate of 30%), ordered probit models were developed for three types of attitudes: (1) willingness to dispose of a car, (2) willingness to purchase an EV and (3) willingness to continue participating in the EVSP. The estimated models suggested that participants' social and economic perspectives were the most important factors affecting the participants' attitudes. In addition, the attitudes varied depending on personal characteristics such as gender, age and income. Although this study was conducted in the early stage of an EVSP, its results are expected to provide insights into a better EVSP design.



## Introduction

Electric vehicles (EVs) have become widely recognized as an environmentally friendly mode of transport. Along with this aspect, most car manufacturers have started to develop and commercialize EVs, especially targeting the urban market (Sierzchula et al., 2012). Some previous studies have shown that EVs can reduce local air pollution and traffic noise (Brady and O'Mahony, 2011; Hawkins et al., 2013), and may improve the sustainability of the road transportation sector which is responsible for the largest share of transportation carbon emissions (Brouwer et al., 2013).

In recent years, the popularity of car-sharing has grown in several large cities (Stasko et al., 2013) due to its benefits such as saving the costs of car purchase and maintenance and reducing parking demand (Efthymiou et al., 2013). Car-sharing can be classified into three types: neighborhood car-sharing, station cars and multi-nodal shared use vehicles (Barth and Shaheen, 2002). Appropriate models can be selected depending on the conditions of the city. Martin and Shaheen (2011a) reported that there are some positive effects of car-sharing operations. They insisted that car-sharing can induce people to abandon their cars by giving access to an automobile only when needed, and providing some benefits from eliminating costs of owning a private vehicle. They also argued that the service improves fuel efficiency because vehicle fleets for

* Corresponding author. Tel.: +82 2 2149 1127; fax: +82 2 2149 1120.
*E-mail address:* jko@si.re.kr (J. Ko).

http://dx.doi.org/10.1016/j.trd.2015.02.009
1361-9209/

car-sharing tend to be composed of more fuel efficient cars such as hybrid cars. A more comprehensive review on car-sharing including its history is found in Shaheen and Cohen (2007) and Shaheen et al. (1998).

Since EVs are typically well-suited for use in cities, many city governments are attempting to implement EV sharing initiatives in numerous ways by providing financial supports (Bakker and Trip, 2013). Some cities in European countries such as Barcelona, Paris, Berlin, Hamburg, Rotterdam and Stockholm are implementing EV car-sharing programs (IEA, 2012). Since the use of EVs for car-sharing is a recent application, most EVSP-related studies utilize data from experimental level small programs rather than a city-wide scheme (Luè et al., 2012; Nakayama et al., 2002). The EV car-sharing program allows many people to gain experience with driving EVs, which may be useful for educating the public about the technology and its usability. In accordance with these trends, the city of Seoul, the biggest city in South Korea, had just officially started an EVSP in May 2013. The program aims (a) to mitigate traffic congestion; (b) to take actions on climate change; and (c) to alleviate parking problems by reducing car-ownership of citizens. Since the beginning of the EVSP, many citizens have registered their membership and experienced EVs through the service.

To help policy makers, this study investigates which factors affect the EVSP users' attitudes about environment-friendly and sustainable travel mode choices after participating in the EVSP and experiencing EVs. For this, this study conducts a survey asking the EVSP users about their satisfaction degrees for each EVSP component. Then, the components are grouped by using a factor analytic technique in order to figure out which factors are closely related. Next, to analyze which factors will affect the EVSP users' attitudes, ordered probit models are estimated with dependent variables of three types of intentions: willingness to dispose of a vehicle, to buy an EV and to continue using shared EVs. The paper discusses the implications on the findings and provides recommendations for future research and policies. The results of the investigation are expected to be useful for policy makers who are to efficiently operate and expand an EVSP, formulate EV transportation systems and promote citizens to purchase EVs.

## The electric vehicle sharing program in Seoul

In Seoul, public transit is the most frequently used transportation mode as suggested by the mode shares: 24.1% of passenger car, 28.1% of bus, 36.2% of metro, 7.2% of taxi, and 4.4% of others as of year 2010. However, still a significant portion of trips are made by personal cars because of the lack of accessibility to public transit for some areas, aggravating traffic congestion (Kim et al., 2014). In addition, parking problems are very severe for some old residential areas where developers failed to provide sufficient parking spaces meeting the sharply increased car-ownership. Under this circumstance, the city government has strengthened parking requirements. For example, 20 years ago, developers did not need to provide parking lots for houses with a floor area of less than 200 $m^2$, but now they must provide at least one parking lot even for those houses. In spite of the measures, some communities with old houses still face a severe problem of parking supply shortage. In the case of Gangbuk-gu, an old residential area, the ratio of the numbers of parking lots to registered cars is only 0.64 as of 2011.

To mitigate these problems, Seoul Metropolitan Government (SMG) contracted with four private companies for the operation of an EVSP and officially launched the program in May 2013 after a ten month pilot test. During the pilot test period, the EVSP was widely promoted to citizens and the renting systems became stabilized. SMG together with the central government supported the companies by providing an EV purchase subsidy (about 15,000 USD for each government), enabling them to buy the vehicles at the same level of cost as conventional vehicles. In addition, SMG allowed the use of city-owned parking spaces for their car-sharing stations with a discounted parking rate of 50%. At the initial stage, the EVSP deployed 132 all-electric vehicles (Kia Ray EVs, one single EV model at the time of deployment) with 59 car-sharing stations as seen in Fig. 1. The Ray EVs are equipped with a 16.4 kW h lithium ion battery that allows an all-electric range of 138 km depending on driving conditions. Their charging time is about six hours for standard chargers and 25 min for high-speed chargers. The drivers can recharge the EVs using 160 free public chargers including 28 high-speed battery chargers installed at car-sharing stations and some public buildings such as city hall.

At the end of the year, the EV fleet size increased to 184 with 87 car-sharing stations. Most car-sharing stations are located near metro stations in the business or commercial areas so as to provide public transit users with good accessibility to and from the shared EVs, filling the gap between personal cars and public transit. The members of the EVSP can access the shared EVs at any time with a reservation through the EVSP website or smart-phone applications. The online system provides the members with the real-time information about the battery charge state of the shared EVs to be rent as well as their availability. The rental fee is assessed by adding two elements: basic fare (about 5.0 USD per hour including insurance) and distance-based fare (15 cents per kilometer). If a member travels 13 km (the average trip length of a Seoul citizen) using a shared EV within an hour, the rental fee is about 7.0 USD, which may be compared with a taxi fare of 10.0 USD and a public transit fare of 1.1 USD for the same distance trip.

## Data

### *Survey*

The research team developed a website for conducting a questionnaire-based survey to identify participants' attitudes about the EVSP. The web-based survey is advantageous in that it minimizes the occurrences of missing answers by advising

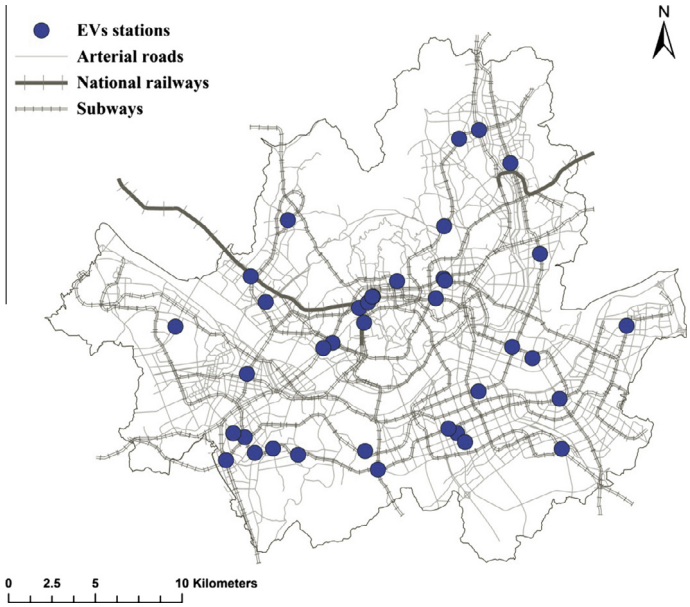


**Fig. 1.** EV sharing stations in Seoul.

respondents to check all questions. In addition, a well-designed framework of a survey website may help respondents fully understand the purpose of the survey and answer questions properly. More importantly, the online contact with the participants is the only way to conduct the survey because the EVSP is operated on a basis of self-service. After obtaining participants' e-mail addresses with the cooperation from the EVSP operating companies, the research team sent the participants e-mails, asking for their participation in the survey. The staff of the operating companies also helped the research team design the questionnaire and reviewed the appropriateness of the question items. Of the 1772 participants that the emails were sent to, 533 participants completed the survey, resulting in a response rate of 30%. This survey was conducted for a length of one month in June of 2013.

In the survey, respondents were asked about their (a) travel patterns with the EVSP including main trip purposes, average number of trips, renting and returning hours, and sharing stations; (b) the level of satisfaction degrees for each EVSP component on a 5-point Likert scale from one (terrible) to five (excellent); (c) attitudes about car ownership and future plans for using the EVSP with 5-point Likert-type answers from one (not willing to do) to five (willing to do); and (d) demographic information such as household size, household income, gender, age, marital status, number of children, car ownership, occupation and home address. The EVSP component is composed of 15 items including EV characteristics such as noise, speed and driving range and renting and charging system related issues. In addition, user perceptions (e.g., whether the participation of the EVSP contributes to improving the environment, reduces concerns about car maintenance and parking and makes a positive impression on others) were included in the EVSP component.

*Characteristics of respondents*

Table 1 illustrates the demographic characteristics of the participants who responded to the web-based survey. As suggested by the table, most respondents are male (86.9%) and within the age group of 20s and 30s (77.9%), indicating that at this early stage of the EVSP the program seems to be preferred by the group of male and younger citizens. Concerning car ownership, 68.1% of the respondents are car owners, which is comparable with the car ownership rate of 32% for the age group of 20 years and older in Seoul. This situation is somewhat counter-intuitive in that car-sharing programs are designed to provide transportation service to citizens who do not have available cars. Potential reasons for the situation are as follows. First, intended EV users are more likely to be car owners since they have enough car driving experience, and thus are more ready to accept a new transportation mode, EV. Second, the EVSP is a new program in its early stage so even the car owners may want to experience the new system. Third, the car-sharing program in Seoul may be useful even to the car owners for non-commute trip purposes because of severe traffic congestion during peak hours and parking shortages or high parking prices in business areas. They usually commute using public transit, leaving their cars home. Furthermore, the participants' high car ownership rate implies that the major clients of the EV car-sharing program are not necessarily people who do not have a car. Thus, the objective of a car-sharing program, second-car replacement or disposal of a car seems to be important for the EVSP.

The respondents' household income appears to be rather evenly distributed, with the middle-income group between 2 and 5 million KRW (1.0 USD = 1100 KRW) having the portion of 58.2%. This household income level may be closely

**Table 1**
Characteristics of respondents.

| Variable | Description | Frequency | ($n$ = 533) Percentage (%) |
|---|---|---|---|
| Gender | Male | 463 | 86.9 |
| | Female | 70 | 13.1 |
| Age | 15–19 | – | – |
| | 20–29 | 191 | 35.8 |
| | 30–39 | 224 | 42.0 |
| | 40–49 | 97 | 18.2 |
| | 50–59 | 20 | 3.8 |
| | Over 59 | 1 | 0.2 |
| Monthly household Income (Million KRW) | Below 1 | 18 | 3.4 |
| | 1–2 | 55 | 10.3 |
| | 2–3 | 128 | 24.0 |
| | 3–4 | 91 | 17.1 |
| | 4–5 | 91 | 17.1 |
| | 5–6 | 57 | 10.7 |
| | Over 6 | 93 | 17.4 |
| Car ownership | 0 | 170 | 31.9 |
| | 1 | 298 | 55.9 |
| | 2 | 57 | 10.7 |
| | 3 | 6 | 1.1 |
| | 4 | 2 | 0.4 |
| Marital status | Single | 334 | 62.7 |
| | Married | 199 | 37.3 |
| Occupation | Office worker | 336 | 63.0 |
| | Non-office worker | 63 | 11.8 |
| | University Student | 95 | 17.8 |
| | Others | 39 | 7.3 |
| Main trip purpose for car-sharing participation | Commuting to work or school | 29 | 5.4 |
| | Business | 95 | 17.8 |
| | Shopping | 26 | 4.9 |
| | Leisure | 262 | 49.2 |
| | Personal activity (e.g. banking and religious activity) | 94 | 17.6 |
| | Others | 27 | 5.1 |

associated with such sample characteristics as age, marital status and occupation. Most respondents are single and office workers with 62.7% and 63.0%, respectively. Regarding the primary purposes of using the EVSP, the largest portion of respondents revealed that they use the shared cars for leisure (49.2%), followed by business (17.8%) and personal activity (17.6%). In summary, the representative respondents can be characterized by single young males who own a car, work at offices and use the sharing cars for leisure.

## Analytical approach

### *Factor analysis*

Factor analysis is a multivariate statistical technique designed to produce uncorrelated factors and to reduce the number of variables, adequately describing the data (Asfahani, 2014). Factor analysis has been used in some transportation-related studies to uncover groupings in variables (Hill and Boyle, 2007; Westerman and Haigney, 2000). In this study, factor analysis is utilized as a way to group various EVSP's attributes into new variables that have similar satisfaction ratings.

The factor analysis model is formulated by expressing $m$ variables $X_1, \ldots, X_m$ with means $\mu_1, \ldots, \mu_m$ as linear functions as presented in the following (Washington et al., 2011):

$$\begin{aligned}
X_1 - \mu_1 &= l_{11}F_1 + l_{12}F_2 + \ldots + l_{1n}F_n + \varepsilon_1 \\
X_2 - \mu_2 &= l_{21}F_1 + l_{22}F_2 + \ldots + l_{2n}F_n + \varepsilon_2 \\
&\vdots \qquad\quad \vdots \qquad\quad \ddots \qquad\quad \vdots \\
X_m - \mu_m &= l_{m1}F_1 + l_{m2}F_2 + \ldots + l_{mn}F_n + \varepsilon_m.
\end{aligned}$$

In the equation with $n$ observations, $F$ and $l$ represent factors and factor loadings, respectively. The error term $\varepsilon$ is associated only with the variable.

The appropriate number of factors was determined using a scree plot (Lattin et al., 2003). For the analysis, a maximum likelihood factor analysis was conducted with a Varimax rotation which maximizes the sum of the variances of the factor loadings (Kaiser, 1958; Asfahani, 2014). This rotation technique is designed to produce factors that are uncorrelated and to reduce the number of variables on which a factor highly loads in order to better distinguish between factors. Each question was then assigned to a factor, and the factor was named based on the questions that were grouped together (Hill and Boyle, 2007). An interpretation of factor analysis is straightforward. Variables that have high factor loadings (the maximum value is one) are thought to be highly influential in describing the factor, while variables with low factor loadings (minimum value is zero) are less influential (Washington et al., 2011).

*Ordered probit model*

Ordered probit models have been popularly used when dependent variables are ordinal (Li et al., 2012; Erdem et al., 2010). According to the typical form of an ordered probit model (Greene, 2012), a latent variable $Y$ representing the degree of EVSP users' willingness to take an action is introduced as:

$$Y = X'\beta + \epsilon$$

where $X'$ is a vector of explanatory variables, $\beta$ is a vector of coefficients, and $\epsilon$ is a normally distributed random error term. The probability of dependent variable $Y$ taking on each of the willingness values, $j = 1, \ldots, J$ is:

$$P(Y = 1) = \Phi(\tau_1 - X'\beta)$$
$$P(Y = j) = \Phi(\tau_j - X'\beta) - \Phi(\tau_{j-1} - X'\beta)$$
$$P(Y = J) = 1 - \Phi(\tau_{J-1} - X'\beta)$$

where $P(Y = j)$ is the probability of willingness taking a specific level $j$, $J$ is the number of levels (in this case, $J = 5$), $\Phi(\cdot)$ is the standard normal cumulative distribution function, and $\tau_j$ is the threshold parameter (cut-off points) to be estimated for each level.

In an ordered probit model, the coefficient associated with each explanatory variable indicates the impact of the variable on the willingness value. However, it does not directly quantify the impact on the variable and cannot be intuitively interpreted, especially for intermediate willingness levels. Thus, the marginal effect is calculated for each variable to quantify its impact on each willingness level. For a $k$th explanatory variable $x_k$ of $X$, its marginal effect for the $j$th response, $\delta_{kj}$ is given by (Mallick, 2009)

$$\delta_{kj} = \frac{\partial Prob[y = j|X']}{\partial x_k} = \left[\Phi\left(\tau_{j-1} - \sum_{k=1}^{K}\beta_k x_k\right) - \Phi\left(\tau_j - \sum_{k=1}^{K}\beta_k x_k\right)\right]\beta_k.$$

It determines how a change in $x_k$ changes the distribution of the outcome variable, i.e. all outcome probabilities.

For a continuous variable, the marginal coefficient illustrates the change of probability of willingness level by a one unit increase in the variable while keeping all other variables at their mean values. For a dummy variable, the marginal effect for willingness level is computed by comparing the outcome when the variable takes a value of one with the one when the variable takes a value of zero, keeping all other variables at their means (Li et al., 2012).

## Results

*Satisfaction level and attitudes about the EVSP*

The average scores and 99% confidence errors for the 5-point Likert scale questions about EVSP users' satisfaction with each EVSP component are presented in Fig. 2. As suggested by the average score of 3.86 at a 5.0 scale, the members seem to be generally satisfied with the EVSP. In particular, the members were found to be most satisfied with the properties of shared vehicles such as less noise, speed and comfort of EVs as seen in the figure. In addition, participants tend to report higher scores on such benefits of EV operations as saved travel costs, reduced environmental and overall concerns. Meanwhile, respondents tend to be less satisfied with charging and the limited number of renting stations.

Furthermore, participants were asked to rate their levels of willingness to change their behavior after experiencing the shared EVs and participating in the EVSP. Fig. 3 shows the distributions of the marked rates for the three questions. Concerning the question about their willingness to dispose of their vehicles or abandon to buy a new car, most respondents replied that they are less likely to do that. In fact, positive replies for the question occupy only 11.1% while negative ones are 57.2%. At least at the initial stage of the EVSP, the program seems not strong enough to change participants' car ownership behavior. Regarding the EV purchasing intention, neutral responses occupy the largest portion (40.0%). However, slightly more respondents revealed that they would not buy EVs (32.6% of 'not to buy' vs. 27.4% of 'to buy'). For the question about intention to continue using the EVSP, only 13.9% of the respondents negatively replied while more than half of the respondents (51.0%) expressed their intentions to use the EVSP. Based on these results, it may be concluded that the participants are likely to continue using the shared vehicles, but more or less reluctant to change their car owning behavior. Nonetheless, the

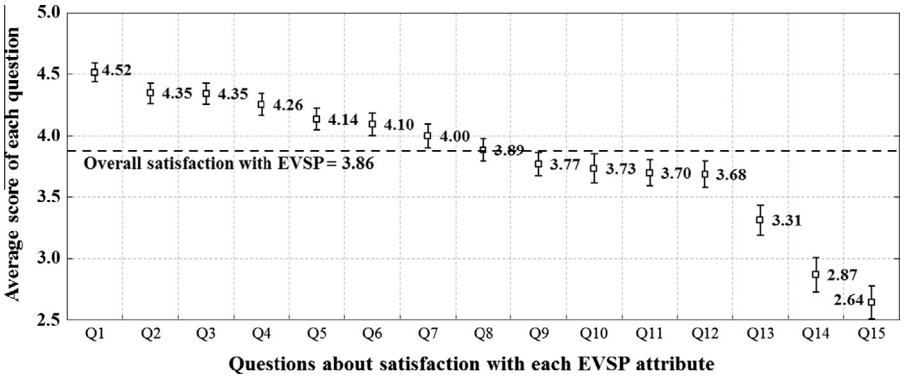


**Fig. 2.** Satisfaction scores for EVSP components. Squares indicate the sample mean values for each question; error bars indicate 99% confidence limits in the mean. The labels on the *x*-axis of the figure above represent the followings: Q1 = vehicle noise, Q2 = environmental concerns, Q3 = vehicle speed, Q4 = vehicle comfort, Q5 = reduced concerns (e.g. regular vehicle check-up), Q6 = travel cost savings, Q7 = Booking system (e.g. web-site, smart-phone application), Q8 = cleanness of vehicle, Q9 = making a positive impression on others, Q10 = renting hour availability, Q11 = membership and payment system, Q12 = annual membership fee and booking fare, Q13 = ease of using EVs and charger system, Q14 = renting station availability, Q15 = driving range.

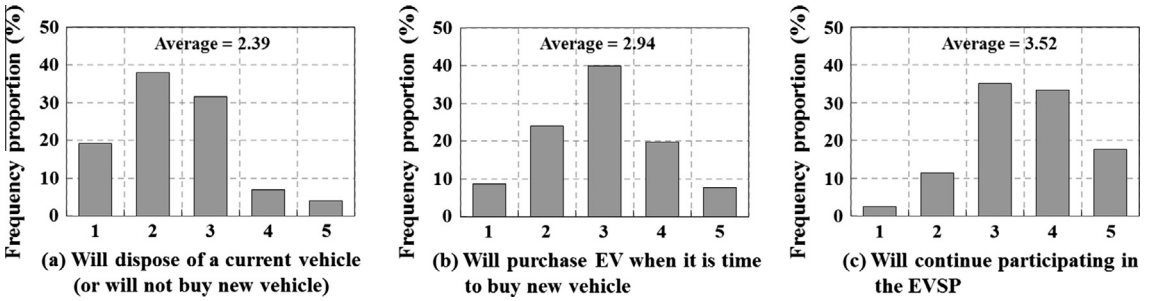


**Fig. 3.** Frequency distributions of EVSP users' intentions. Labels on the *x*-axis of the histograms above represent the followings: 1 = strongly will not do, 2 = will not do, 3 = moderate, 4 = will do, 5 = strongly will do.

EVSP seems to be still meaningful in that some users revealed their intentions to reduce car ownership and purchase EVs. The identification of such users' characteristics would be helpful for a better EVSP and the wider use of EVs.

*Factor analysis*

Based on a scree analysis, the variables were grouped into four factors that account for 17.5%, 16.3%, 14.5%, and 12.0% of the variance, respectively as seen in Table 2. Factor 1, labeled as 'shared EVs', includes factors associated with EVs' speed, comfort, noise and cleanness. As for the cleanness of shared EVs, the factor loading value for Factor 3 is slightly higher than that of Factor 1 (0.42 vs. 0.40). However, the variable was assigned to Factor 1 because the vehicle cleanness seems to be more directly related to general vehicle characteristics. Factor 2, named as 'booking, fee and payment', explains the degree of satisfaction concerning fees for annual membership and rental and systems for payment and booking. Factor 3, named as 'renting, charging and driving', represents the satisfaction degrees about the ease of using EVs and chargers, renting station and hour availability and driving range of EVs. Factor 4 includes reduced concerns for not owning a car, travel cost savings and environmental concerns. In addition, making a positive impression on others is a part of this group. Factor 4 was named as 'social and economic perspective'. In general, the four factors seem to be reasonably structured, observing that all the variables, except for vehicle cleanness and booking system, were strongly associated with just one of the factors.

*Ordered probit models*

Three ordered probit models were estimated as presented in Table 3 for the EVSP users' three intentions: (1) to dispose of a car (or not to buy a car), (2) to purchase an EV and (3) to continue participating in the EVSP. In the modeling process, insignificant variables at a significance level of 0.1 were excluded by using a stepwise method (Stata Press, 2013). The modeling results show which factors are significantly associated with the intentions. For example, in Model 1 (dependent variable: will dispose of a current vehicle), seven variables were identified as significantly related to the dependent variable, including Factor 2, Factor 4, age, income, car ownership, marital status and occupation.

**Table 2**
Factor loading for the 15 EVSP user satisfaction levels.

| EVSP user satisfaction levels | Factor | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| *Factor 1: Shared EVs (17.5% of variance, λ = 5.0)* | | | | |
| Vehicle speed | **0.87** | 0.19 | 0.10 | 0.11 |
| Vehicle comfort | **0.82** | 0.09 | 0.12 | 0.19 |
| Vehicle noise | **0.81** | 0.21 | 0.00 | 0.04 |
| Cleanness of vehicle | **0.40** | 0.22 | **0.42** | 0.17 |
| *Factor 2: Booking & Fee & Payment (16.3% of variance, λ = 1.6)* | | | | |
| Annual membership fee and rental fee | 0.20 | **0.84** | 0.09 | 0.13 |
| Membership and payment system | 0.28 | **0.82** | 0.11 | 0.09 |
| Booking system | 0.27 | **0.44** | 0.43 | 0.01 |
| *Factor 3: Renting & Charging & Driving (14.5% of variance, λ = 1.3)* | | | | |
| Ease of using EVs and charger system | 0.17 | −0.03 | **0.74** | 0.13 |
| Driving range per charging | 0.12 | 0.04 | **0.66** | 0.10 |
| Renting station availability | −0.08 | 0.44 | **0.60** | −0.01 |
| Renting hour availability | 0.08 | 0.43 | **0.55** | 0.17 |
| *Factor 4: social and economic perspective (12.0% of variance, λ = 1.2)* | | | | |
| Reduced concerns (e.g., maintenance) | 0.13 | 0.17 | 0.08 | **0.77** |
| Environmental concerns | 0.22 | −0.01 | 0.15 | **0.67** |
| Travel cost savings | 0.06 | 0.55 | −0.05 | **0.59** |
| Making a positive impression on others | 0.28 | 0.15 | 0.31 | **0.51** |

λ is the eigenvalue for that factor.
The bold underlined numbers indicate that the question item is strongly associated with the factor.

Among the factor variables, only Factor 4 was included in all the three models with positive coefficients. This result indicates that an increase in the level of satisfaction with 'social and economic perspective' has positive effects on EVSP users' likelihood to change their attitudes about car ownership and the EVSP participation. Overall, an increase in age is also likely to increase the probabilities of EVSP users' willingness to change their attitudes. This result looks rather counter-intuitive because young people are usually believed to be early adopters of new technology and tend to easily change their behavior under new circumstances. However, this phenomenon seems to be plausible since the survey was addressed to EVSP participants, not the general public. In other words, it is likely that only the old participants who have a strong will to change their car use patterns are to be included in the survey sample. Because of the same reason, the sample size for older participants is rather small. Further studies may be required to prove this phenomenon using a different survey design. Meanwhile, an increase in household income showed opposite results as suggested by the negative coefficient values for the variable. The lower income group's larger willingness to change their behavior may be induced by the lower costs of the EVSP. Moreover, the government's EV promotion policies such as the EV purchase subsidy and lower electricity rate for EVs seem to be able to attract even lower income groups to the EV market. In fact, Korea's government set special electricity rates for EV promotion which range between 5 cents and 18 cents per kilowatt hour according to peak load pricing. The car ownership variable is rather unique in that it affects the intentions in a different direction. More specifically, car owners are less likely to dispose of a car but more likely to purchase an EV.

Through the ordered probit model estimation, the marginal effects of contributing factors are estimated as seen in Table 4. A positive marginal coefficient indicates the increased probability of a willingness level for a one unit increase in an input variable, i.e., a 10-year increase for the age variable in Model 1 can decrease the probability of levels 1 and 2 by 5.0% and 2.5%, while increasing the probabilities of levels 3–5 by 4.2%, 1.9% and 1.4%, respectively.

### *Willingness to dispose of a current vehicle*

Some previous research efforts reported that car-sharing can cut the needs to own a car, resulting in reducing household vehicle ownership (Martin and Shaheen, 2011a; Glotz-Richter, 2012). In this study, however, the average score for the 5-point Likert scale question about disposing of a vehicle (or abandoning to buy a new vehicle for those who do not have an available vehicle) is only 2.39 which is below the moderate value three. This result implies that the EVSP does not have an influential effect on car ownership behavior changes. Considering that the survey respondents had limited experience (including the pilot test period) with the EVSP and EVs, the result may not be necessarily discouraging. Researchers may need to keep tracing the participants' attitudes according to EVSP's deployment stages considering fleet size, EV performance, fee levels and so on.

The result of Model 1 suggests that some factors may affect participants' intentions to dispose of a car or not to buy a car. Among the four factor variables, only Factor 4 was included in the model at a significance level of 0.01 while Factor 2 was included only at a level of 0.1. This result indicates that the willingness to dispose of a vehicle (or abandoning to buy a new vehicle) is substantially affected by the participants' social and economic perspectives. Model 1 shows that young participants are less likely to change their car ownership as suggested by the positive sign of the age variable. The coefficient

**Table 3**
Estimated results of ordered probit models.

| Variable | Estimated coefficients | | |
|---|---|---|---|
| | Model 1 (Willingness to dispose of a current vehicle) | Model 2 (Willingness to purchase an EV) | Model 3 (Willingness to continue participating in the EVSP) |
| *User satisfaction level* | | | |
| Factor 1: Shared EVs | – | 0.126*** | 0.138*** |
| Factor 2: Booking & Fee & Payment | 0.087* | – | 0.268*** |
| Factor 3: Renting & Charging & Driving | – | 0.156*** | 0.226*** |
| Factor 4: Social and economic perspective | 0.162*** | 0.187*** | 0.298*** |
| *Demographic* | | | |
| Female | – | – | 0.294** |
| Age [a] | 0.190*** | 0.132** | 0.187** |
| Income [b] | −0.068** | −0.068** | −0.056** |
| Car owner [c] | −0.285*** | 0.223** | – |
| Single | 0.266** | – | 0.209* |
| *Occupation* | | | |
| Office worker | | | |
| Non-office job | 0.368** | – | 0.380** |
| University student | – | – | 0.355** |
| *Trip purpose* | | | |
| Commuting to work or school | | | |
| Leisure | – | – | 0.332*** |
| Personal usage | – | – | 0.302** |
| Threshold $\tau_1$ | −0.651 | −1.184 | −1.763 |
| Threshold $\tau_2$ | 0.466 | −0.228 | −0.755 |
| Threshold $\tau_3$ | 1.565 | 0.862 | 0.457 |
| Threshold $\tau_4$ | 2.112 | 1.730 | 1.569 |
| *Summary statistics* | | | |
| L(c) | −727.57 | −766.40 | −734.70 |
| L(β) | −699.94 | −744.72 | −666.18 |
| $-2(L(c) - L(\beta))$ | 55.25 | 43.35 | 137.03 |
| *P*-value | $P < 0.001$ | $P < 0.001$ | $P < 0.001$ |

* 0.10 level.
** 0.05 level.
*** 0.01 level.
[a] 10-year increase in age.
[b] One million KRW increase in monthly household income,
[c] Car owners those who have at least one available car.

value for the household income variable indicates that an increase in household income will likely decrease the possibility to dispose of a vehicle (or abandon to buy a new vehicle). Furthermore, single participants who do not need to take care of their family members are more likely to abandon cars than married participants.

The estimated model also suggests that car owners are less likely to dispose of their cars. The marginal effect of the coefficient provided in Table 4 shows that car owning respondents will be more likely to rate level 1 (strongly will not do) and level 2 (will not do) than the other respondents by 7.1% and 4.2%, respectively. When interpreting this situation in a different manner, the result implies that the respondents without a car are more likely to give up purchasing a car after experiencing the EVSP.

When it comes to the occupation variable, non-office job workers were found to be more likely to abandon their cars, compared to office workers. It seems that non-office job workers' characteristics such as less car dependency, more flexible work schedules and lower incomes may allow them to have more chances to dispose of a car. The main trip purpose of car sharing appeared not to affect the car ownership behavior change as no significant variables were found for the trip purpose variable.

### *Willingness to purchase EVs*

As an effort to reduce greenhouse gas emissions in the transportation sector, the Korean government has tried to invigorate the EV market. However, the penetration level of EVs in the city of Seoul falls behind other pioneering cities such as Paris, London and Hamburg. In order to vitalize the EV market, research on demands of potential EV customers is essential. Some previous studies (Axsen and Kurani, 2013; Jensen et al., 2013) suggested that the choice of alternative fuel vehicles is influenced by several factors such as vehicle design, purchasing price, charger availability, vehicle images and functional

**Table 4**
Marginal effects of variables in the ordered probit models.

| Variable | Level 1 (strongly will not do) | Level 2 (Will not do) | Level 3 (moderate) | Level 4 (will do) | Level 5 (strongly will do) |
|---|---|---|---|---|---|
| *Model 1: Willingness to dispose of a current vehicle* | | | | | |
| Factor 2: Booking & Fee & Payment | −0.023 | −0.012 | 0.019 | 0.009 | 0.006 |
| Factor 4: Social and economic perspective | −0.042 | −0.021 | 0.036 | 0.016 | 0.012 |
| Age | −0.050 | −0.025 | 0.042 | 0.019 | 0.014 |
| Income | 0.018 | 0.009 | −0.015 | −0.007 | −0.005 |
| Car owner* | 0.071 | 0.042 | −0.060 | −0.030 | −0.023 |
| Single* | −0.071 | −0.032 | 0.059 | 0.026 | 0.019 |
| Non-office job* | −0.083 | −0.063 | 0.070 | 0.041 | 0.035 |
| *Model 2: Willingness to purchase an EV* | | | | | |
| Factor 1: Shared EVs | −0.018 | −0.027 | 0.004 | 0.025 | 0.017 |
| Factor 3: Renting & Charging & Driving | −0.023 | −0.033 | 0.005 | 0.031 | 0.021 |
| Factor 4: Social and economic perspective | −0.027 | −0.040 | 0.005 | 0.037 | 0.025 |
| Age | −0.019 | −0.028 | 0.004 | 0.026 | 0.017 |
| Income | 0.010 | 0.015 | −0.002 | −0.014 | −0.009 |
| Car owner* | −0.034 | −0.047 | 0.010 | 0.044 | 0.028 |
| *Model 3: Willingness to continue participating in the EVSP* | | | | | |
| Factor 1: Shared EVs | −0.004 | −0.020 | −0.030 | 0.024 | 0.031 |
| Factor 2: Booking & Fee & Payment | −0.008 | −0.040 | −0.058 | 0.046 | 0.060 |
| Factor 3: Renting & Charging & Driving | −0.007 | −0.034 | −0.049 | 0.039 | 0.050 |
| Factor 4: Social and economic perspective | −0.009 | −0.045 | −0.064 | 0.052 | 0.066 |
| Female* | −0.007 | −0.039 | −0.069 | 0.042 | 0.073 |
| Age | −0.005 | −0.028 | −0.040 | 0.032 | 0.041 |
| Income | 0.001 | 0.008 | 0.012 | −0.009 | −0.012 |
| Single* | −0.006 | −0.032 | −0.043 | 0.037 | 0.045 |
| Non-office job* | −0.008 | −0.048 | −0.090 | 0.049 | 0.098 |
| University student* | −0.008 | −0.047 | −0.083 | 0.049 | 0.089 |
| Leisure activity* | −0.010 | −0.049 | −0.071 | 0.056 | 0.074 |
| Personal usage* | −0.007 | −0.041 | −0.070 | 0.044 | 0.074 |

* Discrete change of dummy variable from 0 to 1.

limitations (i.e., driving range, top speed, fuel cost and battery life). In addition, the study of Jensen et al. (2013) found that environmental concerns have a positive effect on the preference for EVs.

This study found that the average scores regarding the satisfaction with EV characteristics, including noise, speed and comfort, were higher than the other EVSP aspects. Despite the EVSP users' higher satisfaction with the EV characteristics, it does not seem to directly lead people to buy EVs for their next vehicles (the average score of willingness to buy an EV is just below the neutral point, 2.94). Model 2 presents some determinants which will prompt the EVSP users' motivation for purchasing EVs. They include Factor 1, Factor 3, Factor 4, age, income, and car ownership. The variables of Factor 4, age and income show similar effects as Model 1. More specifically, the respondents with higher personal satisfaction with 'social and economic perspective' and older and lower income group are likely to purchase EVs. Similar to the previous studies as cited above, Factor 1 which represents the satisfaction with EV characteristics seems to be an important factor on purchasing EVs. In addition, Factor 3 was found to be an influential factor. Especially, the respondents who are satisfied with the ease of using EVs and chargers and driving range per charging seem to be more likely to purchase EVs as suggested by their higher factor loadings in Table 2.

Unlike Model 1, the coefficient of car ownership was found to be positive, suggesting that car owners are more likely to purchase EVs. This situation implies that for EV promotions, more policy actions should be taken targeting car owners. Meanwhile, there were no significant relationships found for the variables of marital status, occupation and trip purpose.

### *Willingness to continue participating in the EVSP*

In the early stage of an EVSP operation, increasing the number of the participants in the program is a critical issue for the success of the program. Regarding this issue, one of the major concerns of policy makers would be on how many citizens will join the EVSP, who will frequently rent the shared EVs or for what purposes the program will be used. Fig. 3 illustrates that a considerably large portion of the respondents replied that they have an intention to use the EVSP when cars are needed. In fact, about fifty percent of them expressed that they are likely to use the EVSP and the average score for the willingness is 3.52, which is much higher than those for the other questions.

Model 3 suggests who will be likely to participate in the EVSP. The inclusion of all the factor variables in Model 3 implies that satisfaction with shared EVs and several EVSP components are all important factors to attract people to the EVSP. The comparison among the estimated coefficients indicates that Factor 4 influences the decision most significantly and is least affected by Factor 1. Similar to the other models, this result suggests that the user's social and economic perspectives are critical elements for continuing the participation. Concerning the demographic characteristics of the respondents, female users seem to have a higher propensity to use the EVSP than male, which matches with the finding revealed in Caulfield (2009). This result seems to be reasonable in that women usually do not heavily rely on vehicles and try to avoid the burden of car maintenance. Indeed, this aspect is the major benefit of a car-sharing program in which operating companies are responsible for car maintenance. Older (survey respondents are all under sixty years old except only one respondent) and single users are likely to continue using the EVSP. Meanwhile, users with higher household income are less likely to continue participating in the EVSP. Of occupation variables, non-office job workers and university students were found to have positive coefficients, illustrating their more willingness to participate in the program. This may be attributed by their lower income level and less car dependency (or non-regular basis of car using).

Different from Model 1 and Model 2, Model 3 included the variables related with the trip purposes of the EVSP. In particular, the variables of leisure and personal purposes were included in the model, presenting positive coefficient values. It is analogous to the result of Martin and Shaheen (2011b) which insisted that car-sharing is generally used to complete non-compulsory trips, e.g. leisure and shopping. These results indicate that the participants who use the EVSP mainly for non-compulsory trips are likely to keep retaining their program membership but there is little chance for them to change their car ownership behavior.

## Conclusions

An exploration of EVSP users' attitudes is important since it may direct the EVSP toward a success by helping policy makers effectively operate and expand the program. In fact, the policy makers may be interested in some practical issues such as how many citizens will make use of the EVSP. In addition, they may wonder if the program can replace a significant portion of conventional vehicle trips with EV trips, and those who have experienced EVs through an EVSP will dispose of their current vehicles or purchase EVs for the next cars. This study is intended to provide policy makers with some implications about the issues using a questionnaire-based survey addressed to EVSP participants.

The survey results indicated that the participants are rather reluctant to change their car ownership but have intentions to continue participating in the EVSP as suggested by the average 5-point Likert scale scores: willingness to dispose of their current vehicles (or abandon to buy a new vehicle) = 2.39; willingness to purchase EVs = 2.94; willingness to continue using the shared EVs = 3.52. Further, ordered probit models were estimated to identify which factors affect EVSP users' attitudes. For the modeling, 15 EVSP components, for which satisfaction levels were asked, were grouped into four factors using factor analysis, and employed as independent variables. Notably, the factor associated with the users' social and economic perspectives were found to significantly affect the car ownership behavior and EVSP participation. Willingness to dispose of cars (or abandon to buy a new vehicle) appeared to be affected by car-sharing fee and payment system although the association was rather weak. In addition, the purchase of EVs seemed to be affected by EV characteristics and systems of charging and renting. These findings indicate that car ownership behavior changes toward enhancing sustainability can be achieved more or less through customer education as well as the improvement of EV and charger performance.

Variables of age and household income were found to significantly affect the behavior changes. Older participants showed higher chances of car ownership change and continuous participation, which is rather counter-intuitive in that early adopters are generally believed to be young people. However, this appeared to occur because the survey was addressed to the EVSP participants with a strong will to change their travel modes, not the general public. On the contrary, the participants with higher household income were found to be less likely to change their behavior, which might imply that the current level of economic benefits is not satisfactory for the group. Car owners tended to be less likely to give up their cars, but likely to purchase EVs. Thus, at the current stage, the EVSP appears not to be sufficiently effective for reducing car ownership. Single participants showed a higher chance of disposing a car and continuing participation in the EVSP. Gender and main trip purposes using the shared cars affected only the willingness to continue the participation.

Overall, the study results suggest that policy makers should carefully design an EVSP so that the program can contribute to the establishment of sustainable urban transportation systems. The design should consider the characteristics of program participants and components of the EVSP. Customized services or policy tools and effective educations are expected to substantially encourage participants to change their behavior in a more sustainable direction. Meanwhile, cares should be taken in interpreting the results of this study since the survey was conducted during the relatively early phase of an EVSP. In this situation, the participants might not be fully aware of the substantive effects of the EVSP. Further studies are encouraged to conduct when the system of EVSP becomes stable and most participants properly recognize its effects. In addition, the EVSP studied might not be able to effectively reflect a variety of consumers' needs and preferences since the program deployed only one single EV model and a limited number of car-sharing stations. When the future EV markets and programs are expanded, the participants' attitudes can be substantially altered. The conditions of a city where an EVSP is deployed can be a critical factor that influences participants' attitudes since program operational approaches are to be developed fully reflecting the conditions. It should be cautious that the findings of this study may not be easily transferred to other cities with different conditions than Seoul.

## References


Asfahani, J., 2014. Statistical factor analysis technique for characterizing basalt through interpreting nuclear and electrical well logging data (case study from Southern Syria). Appl. Radiat. Isotopes 84, 33–39.

Axsen, J., Kurani, K.S., 2013. Hybrid, plug-in hybrid, or electric – what do car buyers want? Energy Policy 61, 532–543.

Bakker, S., Trip, J., 2013. Policy options to support the adoption of electric vehicles in the urban environment. Transport. Res. Part D 25, 18–23.

Barth, M., Shaheen, S.A., 2002. Shared-use vehicle systems: framework for classifying carsharing, station cars, and combined approaches. J. Transport. Res. Board 1791, 105–112.

Brady, J., O'Mahony, M., 2011. Travel to work in Dublin. The potential impacts of electric vehicles on climate change and urban air quality. Transport. Res. Part D 16 (2), 188–193.

Brouwer, A.S., Kuramochi, T.K., van der Broek, M., Faaij, A., 2013. Fulfilling the electricity demand of electric vehicles in the long term future: an evaluation of centralized and decentralized power supply systems. Appl. Energy 107, 33–51.

Caulfield, B., 2009. Estimating the environmental benefits of ride-sharing: a case study of Dublin. Transport. Res. Part D 14 (7), 527–531.

Efthymiou, D., Antoniou, C., Waddell, P., 2013. Factors affecting the adoption of vehicle sharing systems by young drivers. Transp. Policy 29, 64–73.

Erdem, C., Şentürk, İ., Şimşek, T., 2010. Identifying the factors affecting the willingness to pay for fuel-efficient vehicles in Turkey: a case of hybrids. Energy Policy 38 (6), 3038–3043.

Glotz-Richter, M., 2012. Car-sharing – "car-on-call" for reclaiming street space. Proc. Soc. Behav. Sci. 48, 1454–1463.

Greene, W., 2012. Econometric Analysis 7/E. Prentice Hall (International Edition).

Hawkins, T.R., Singh, B., Majeau-Bettez, G., Strømman, A.H., 2013. Comparative environmental life cycle assessment of conventional and electric vehicles. J. Ind. Ecol. 17 (1), 53–64.

Hill, J.D., Boyle, L.N., 2007. Driver stress as influenced by driving maneuvers and roadway conditions. Transport. Res. Part F 10 (3), 177–186.

IEA (International Energy Agency). 2012. EV City Casebook. <http://www.iea.org/publications/freepublications/publication/EVCityCasebook.pdf>.

Jensen, A.F., Cherchi, E., Mabit, S.L., 2013. On the stability of preferences and attitudes before and after experiencing an electric vehicle. Transport. Res. Part D 25, 24–32.

Kaiser, H.F., 1958. The varimax criterion for analytical rotation in factor analysis. Psychometrika 23 (3), 187–200.

Kim, D., Lee, J., Choi, S., 2014. Balancing mobility and $CO_2$ reduction by a mode share scheme: a comparison of Los Angeles and Seoul Metropolitan areas. Int. J. Urban Sci., 1–14

Lattin, J.M., Carroll, J.D., Green, P.E., 2003. Analyzing Multivariate Data. Thomson Brooks/Cole, Pacific Grove, CA.

Li, Z., Wang, W., Liu, P., Ragland, D.R., 2012. Physical environments influencing bicyclists' perception of comfort on separated and on-street bicycle facilities. Transport. Res. Part D 17 (3), 256–261.

Luè, A., Colorni, A., Nocerino, R., Paruscio, V., 2012. Green move: an innovative electric vehicle-sharing system. Proc. Soc. Behav. Sci. 48, 2978–2987.

Mallick, D., 2009. Marginal and interaction effects in ordered response models. Technical Report, School of Accounting, Economics and Finance, Deakin University, Burwood.

Martin, E., Shaheen, S. 2011a. The impact of carsharing on household vehicle ownership. Access: The magazine of the University of California Transportation Center, vol. 38, pp. 22–27.

Martin, E., Shaheen, S., 2011b. The impact of carsharing on public transit and non-motorized travel: an exploration of North American carsharing survey data. Energies 4 (12), 2094–2114.

Nakayama, S., Yamamoto, T., Kitamura, R., 2002. Simulation analysis for the management of an electric vehicle-sharing system: case of the Kyoto public-car systems. J. Transport. Res. Board 1791, 99–104.

Shaheen, S.A., Cohen, A.P., 2007. Growth in worldwide carsharing: an international comparison. J. Transport. Res. Board 1992, 81–89.

Shaheen, S.A., Sperling, D., Wagner, C., 1998. Carsharing in Europe and North America: past present and future. Transp. Quart. 52 (3), 35–52.

Sierzchula, W., Bakker, S., Maat, K., van Wee, B., 2012. The competitive environment of electric vehicles: an analysis of prototype and production models. Environ. Innovat. Societal Transit. 2, 49–65.

Stasko, T.H., Buck, A.B., Oliver Gao, H., 2013. Carsharing in a university setting: impacts on vehicle ownership, parking demand, and mobility in Ithaca, NY. Transp. Policy 30, 262–268.

Stata Press, 2013. Stata Reference Manual, Release 13. A Stata Press Publication, College Station, Taxas, pp. 2222–2231.

Washington, S.P., Karlaftis, M.G., Mannering, F.L., 2011. Statistical and Econometric Methods for Transportation Data Analysis. CRC Press.

Westerman, S., Haigney, D., 2000. Individual differences in driver stress, error and violation. Personality Individ. Differ. 29, 981–998.