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Article

Households' Willingness to Pay for Interactive Charging Stations for Vehicle to Grid System in South Korea

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Abstract: The South Korean government intends to construct interactive charging stations (ICSs) for a vehicle to grid (V2G) system that uses electric vehicles as a type of energy storage system. This article employs contingent valuation (CV) to examine households' willingness to pay (WTP) to construct the ICSs. To this end, a CV survey of 1000 people was performed using the one-and-one-half-bound dichotomous choice questioning as the elicitation method for the WTP. To check if the response effect incurred by the questioning exists, a single-bound model, which partly uses the responses from the questioning, was also applied. Furthermore, a spike model which can model WTP observations with lots of zeros was adopted. The single-bound spike model, finally chosen for further analysis, produced some results securing statistical significance. The average household WTP is estimated as KRW 4017 (USD 3.51) per annum. A national version of the yearly WTP is derived as KRW 85.48 billion (USD 74.65 million). Considering that the occurrence period of the annual WTP is 10 years, the total present value as of the end of 2022 is computed as KRW 676.4 billion (USD 590.7 million). This study has significance in two aspects. First, quantitative information on household WTP is explicitly provided. Second, to the best of the authors' knowledge, the household WTP is empirically dealt with for the first time in the literature. In addition, the implications of this value from a policy perspective, as well as four challenges to be solved for constructing ICSs for a V2G system, are discussed.

Keywords: interactive charging station; vehicle to grid; willingness to pay; energy storage system; contingent valuation

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1. Introduction

The number of electric vehicles (EVs) is scheduled to rise from 0.23 million in 2021 to 3.62 million by 2030, to reduce air pollutants and greenhouse gas (GHG) emissions in South Korea [1]. As of the end of June 2021, 12,789 fast EV chargers and 59,316 slow EV chargers were in operation, and the number of EVs per charger was 2.4. The number of EVs per charger in China, Japan, France, and the United States was 6, 10, 10, and 16, respectively [2]. Therefore, compared to other countries, South Korea seems to have an excellent level of EV charging infrastructure. Moreover, the government plans to build 12,000 fast EV charging stations and 500,000 slow EV charging stations by 2025 [3].

South Korea has been trying to increase renewable energy (RE). Recently, the country has established a plan to significantly augment the share of RE in total power generation from 5% in 2019 to 30.6% by 2036 [4]. Solar and wind power will account for most of the RE. However, they are typically variable RE (VRE) sources in the country [5]. Currently, the ratio of solar to wind power is approximately nine to one, and this situation is expected to continue for the time being. Thus, energy storage systems (ESSs) to help overcome the problem of variability and intermittence involved in VRE are widely needed [6–10]. The frequent curtailment of RE generation will emerge as a social issue [11–13].

Two representative types of ESSs under discussion in the country are pumping-up power generation and batteries. The government decided to build three new pumping-up power plants with a 1.8 GW capacity, and is considering further construction of such plants. However, they not only incur high costs, but also require a suitable large-scale site. Local residents and environmental groups are bitterly opposed to the additional construction of pumping-up power plants. This is because the construction of a pumping-up power plant damages forests. Moreover, a battery ESS (BESS) is quite vulnerable to fire. In fact, many installed BESSs have not been operable in the country due to frequent BESS fires.

Consequently, the government is considering another kind of ESS, an interactive vehicle to grid (V2G) system that use EVs. An interactive V2G means supplying power stored in the EV battery to consumers through the grid [14,15]. EVs are charged during times when power demand is low or curtailment of VRE generation is needed. Power is transmitted from the EVs to the grid at times when power demand is high. According to an empirical study, 100,000 EVs can play a role as great as a power plant with a capacity of 1 GW [16].

As of 2021, the average daily mileage of passenger cars in the country is 37.2 km per car [17]. According to the Ministry of Land Infrastructure and Transport [18], a total of 1.59 million eco-friendly cars, including EVs, were registered in South Korea as of 2022, accounting for 6.2% of the total number of registered cars. It would be more useful if there were specific performance data related to the driving of EVs, but the data have not yet been found in South Korea. Therefore, in this study, it is assumed that the driving performance of EVs will be similar to the statistics of general passenger cars in South Korea.

Assuming that the average driving speed of a passenger car is 50 km per hour, the average driving time per day is 0.74 h. In other words, most cars are parked for more than 90% of the day. Thus, if an infrastructure that can transmit the power stored in EVs to the grid is established, parked EVs can be used as a power supply source. For the interactive V2G system to succeed, two things are required. First, active participation of EV owners in the system is needed. The government intends to introduce a system that differentiates EV charging rates according to changes in power demand during the day, and pay a certain amount when returning power from EVs to the grid. The charging rates should be high when power demand is high, and the rates should be low when power demand is low. Second, interactive chargers that connect EVs and the grid should be constructed.

The establishment of a government-led interactive charging station (ICS) infrastructure demands a large investment of money. The investment will eventually be financed by the general public. For this reason, information on the public acceptance of bearing the cost incurred by constructing an ICS infrastructure for V2G is needed. Thus, the main objective of this article is to examine households' willingness to pay (WTP) to construct an ICS infrastructure for a V2G system using contingent valuation (CV). This research has significance in two aspects. First, quantitative information on household WTP is explicitly provided to the government for policy making and decisions. Second, to the best of the authors' knowledge, the household WTP is empirically dealt with for the first time in the literature.

In other words, the purpose of this paper is not to develop innovative methodologies or creative ideas, but to secure and present evidence to carry out government-led ICS construction. The subsequent composition of this article consists of four sections. The method applied in this study is explained in Section 2. Section 3 describes the results, and Section 4 presents a discussion. Conclusions and policy implications are presented in Section 5.

2. Methodology

2.1. Method: CV

One representative method that can be applied to obtaining households' WTP for a commodity is CV. Of course, there are other methods that can measure WTP in addition to CV, but this study applies CV for two reasons. Firstly, CV is the most frequently employed technique in evaluating WTP to consume a good not traded in the market. This kind of good is called a nonmarket good; the ICS for a V2G system is such a case. There are many studies applying CV [5,19–22], among which, the main results of research cases related to renewable energy or eco-friendly vehicles similar to this study are summarized in Table 1. Secondly, the reliability and validity of the CV technique using observations gathered from a survey of people are well-verified in previous research [23,24]. In short, CV is not only well-established in theory, but is also useful and frequently applied in empirical studies.

Table 1. Summary of literature review of studies evaluating eco-friendly vehicle infrastructure or renewable energy using contingent valuation.

Sources	Countries	Main Results
Bigerna and Polinori [19]	Italy	The additional willingness to pay (WTP) for the introduction of the hydrogen bus was EUR 2.01 to 2.44 per single-trip bus fare.
Yang et al. [20]	South Korea	The public's WTP for expanding hydrogen stations from 20 in 2016 to 100 by 2020 was KRW 2258 (USD 2.04) per household per year.
Lee et al. [21]	South Korea	The mean willingness-to-accept for vehicle-to-grid service was KRW 9821 (USD 8.83) per month, per vehicle.
Kim et al. [5]	South Korea	The mean WTP for introducing power-to-heat was KRW 4348 (USD 3.59) per household per year.
Kowalska-Pyzalska [22]	Poland	The mean WTP for green electricity was PLN 2.83 (USD 3.5 USD) per month.

The application of CV is largely standardized in the literature. The process of applying CV consists of three main steps, which are shown in Figure 1. A questionnaire is prepared in the first step with great caution. The employment of CV requires a survey of individuals with a well-prepared questionnaire. Thus, a CV questionnaire should be adequately prepared and modified so that respondents can read it without difficulty, and can easily understand it [25–28]. In the second step, data are collected from conducting the CV survey. For the purpose of obtaining reliable observations in applying CV, the guidelines given in the Korea Development Institute [29], Johnston et al. [30], and Sajise et al. [31] must be carefully followed. The collected data are statistically analyzed to derive some necessary information in the third step. Among the various models to deal with CV data, a model widely accepted and applied in the literature should be adopted [32].

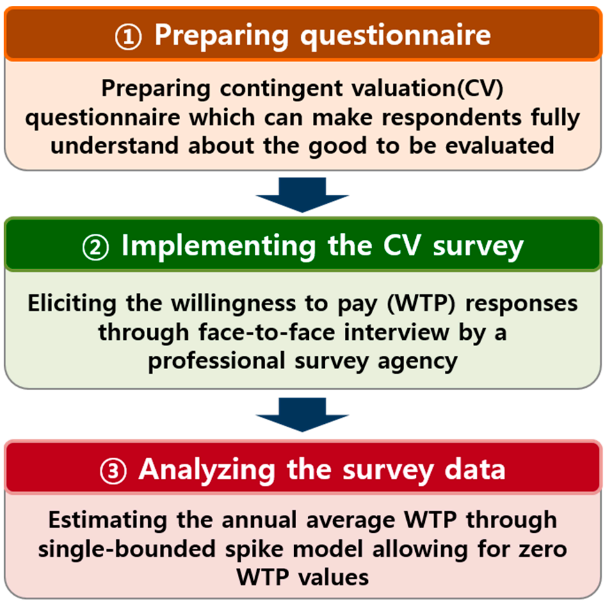

Figure 1. Process of applying contingent valuation in this study.

2.2. Step 1: Questionnaire Preparation

The important points in the first stage, questionnaire design, are summarized in three ways. First, the goods to be evaluated must be clearly presented. In this study, the reference state (Q_0) is that there are no ICSs, and only 512,000 EV charging stations (12,000 fast EV charging stations and 500,000 slow ones) by 2025. The target state (Q_1) is that all 512,000 EV charging stations will be built with ICSs by 2025. The goods to be evaluated should be explicitly a move from Q_0 to Q_1. In particular, sufficient explanations of constructing ICSs for a V2G system should be provided to the respondents so that they can understand the goods without any difficulties. Consequently, the goods to be evaluated were described to the respondents in the questionnaire as follows:

"For compensating the intermittence and variability involved in the VRE, the government has the intention of introducing a V2G system that utilizes EVs as a type of ESS. With the introduction, there is no need to construct additional ESS, power plants, and transmission lines in preparation for suspension of RE supply, which can save costs and prevent social conflicts such as resident opposition. In addition, since there is a lot of traffic in the downtown area, the V2G system has an advantage as a distributed power source. However, to introduce the V2G system, it is necessary to build an ICS infrastructure that connects EVs and the grid, which has a high cost".

Moreover, four effects expected from constructing ICSs for a V2G system were explained to the respondents. First, VRE resources can be efficiently utilized because it is not necessary to curtail the power from VRE, or at least the frequency of such curtailments is drastically reduced. Second, this reduces the demand for additional construction of fossil fuel-based power plants, which in turn can reduce emissions of GHGs and air pollutants. Third, energy security can be enhanced by curbing the importation of fuel needed for fossil fuel-based power plants. Fourth, the stability of the supply of power may be improved by shaving the peak demand for power.

Second, the WTP induction method and the payment vehicle are determined. The open-ended question format asks respondents directly about the magnitude of the WTP. Respondents may be embarrassed when an open-ended question is asked, which may increase their objection to the survey itself or the probability of reporting protest responses. On the other hand, the closed-ended question format, which asks respondents about whether they are willing to pay a presented bid, can avoid this problem. A dichotomous choice (DC) questioning method was applied to induce the WTP. That method has the advantage of preventing protest bid responses and inducing an incentive-compatible response, as it asks whether or not the respondent has the intention of paying a predetermined bid amount instead of plainly asking the size of the WTP [33].

Specifically, of several kinds of DC questioning methods, the one-and-one-half-bound DC (OBDC) one was chosen to elicit the respondents' WTP. As mentioned earlier, the government tries to cover the costs associated with the construction of an ICS infrastructure with taxes, which are public resources. Therefore, the income tax was selected as a payment vehicle, considering that it is concerned with the goods under investigation and is familiar to the respondents. In addition, the unit of payment was clearly presented as a household, the frequency of payment was annual, and the payment period was set as 10 years.

Third, the entire contents of the questionnaire should be easily understood and well-accepted by the respondents. To this end, a preliminary draft questionnaire prepared by the authors was reviewed by the supervisors from the polling company and a focus group comprising 10 people. As a result, all parts that were considered incomprehensible or inaccurate could be adequately corrected. In addition, color photographic data were also provided to the respondents to help them figure out the goods to be valued. In other words, color visual cards were used in the survey along with the final revised questionnaire.

2.3. Step 2: Survey Implementation

The decisions to be made for the second step, the survey implementation, can be summarized in four points. The first point concerns the method of conducting the survey.

In this study, the face-to-face interview method was selected. Other interview methods using the Internet, telephone, or mail have difficulty avoiding sample selection bias, and it is not easy to explain to respondents the purpose of the survey and the main survey contents sufficiently. The second point is the unit of survey. This was determined as the household rather than the individual, considering that the payment vehicle selected was income tax per household. Therefore, the number of households, not the number of individuals, should be used when calculating a national version of the WTP.

The third point is who will extract the respondents and interview the extracted respondents in the CV survey. The first option, of course, is the authors. However, they lack experience in sampling and interviews. Regarding sampling and interviews, it is reasonable to obtain help from a company specializing in public opinion polls. Accordingly, the authors entrusted the entire process of the survey to a specialized polling company. The final point is the sample size. This was determined to be 1000. Ordinary public opinion polls in South Korea are urged to use this figure by the Korea Development Institute [29]. Moreover, this size was supported by Arrow et al. [34].

2.4. Step 3: Data Analysis

The utility difference model given by Hanemann [35] was basically adopted to analyze the DC CV data. The model notes that if the response to the WTP question is "yes," the utility ensuing from paying the bid amount is greater than that ensuing from not paying it. That is, the difference between these two utilities is greater than zero. This point enables us to model the probability of answering "yes" to a bid amount, P. Two bid amounts, P^U and P^L, have to be determined beforehand in applying the OBDC model. P^L is lower than P^U. Half of all respondents were presented with a lower bid amount, P^L, first, and the other half were presented with an upper bid amount, P^U, first. If the answer to P^L is "no" or the answer to P^U "yes," no other questions are required. However, if the answer to P^L is "yes" or the answer to P^U is "no," P^U or P^L are additionally presented, respectively. Thus, some people face two WTP questions, while others face only one WTP question. As a result, there are a total of six possible cases, as follows:

(i) If the response is "no", WTP $\leq P^L$,
(ii) If the response is "yes-no", $P^L <$ WTP $\leq P^U$,
(iii) If the response is "yes-yes", $P^U <$ WTP.
(iv) If the response is "no-no", WTP $\leq P^L$,
(v) If the response is "no-yes", $P^L <$ WTP $\leq P^U$,
(vi) If the response is "yes", $P^U <$ WTP.

From (i) to (iii) are cases where the lower bid (P^L) is presented first, and from (iv) to (vi) are answers derived when the higher bid (P^U) is presented first.

Furthermore, respondents who answer "no" to the lower amount, P^L, should be identified if they have positive or zero WTP. To this end, a question of whether or not they intended to pay a penny was additionally offered to them. Finally, the WTP of each respondent, W, corresponds to one of the following four cases.

$$\begin{cases} W = 0 \\ 0 < W < P^L \\ P^L \leq W < P^U \\ P^U \leq W \end{cases} \tag{1}$$

where $G_W(\cdot)$ is the cumulative distribution function of W.

The probability of accepting the payment of P is $Pr(P \leq W) = 1 - G_W(P;\theta)$ where θ is a parameter vector of $G_W(\cdot)$. Looking at Equation (1), the first case means point data, and the other three cases imply interval data. Therefore, it is required to apply a specially designed model to deal with point data and interval data in one configuration. Taking this into account, the spike model developed by Kriström [36] is applied in this study. This is because it has been found in empirical studies that the model is useful, as well as most widely applied to dealing with data on WTP with many zero observations [37]. Let θ be (θ_0, θ_1). In the spike model, $G_w(P;\theta)$ is often formulated as:

$$G_w(P;\theta) = \begin{cases} 0 & \text{if } W < 0 \\ [1+\exp(\theta_0)]^{-1} & \text{if } W = 0 \\ [1+\exp(\theta_0 - \theta_1 P)]^{-1} & \text{if } W > 0 \end{cases} \quad (2)$$

If covariates concerning the characteristics of a respondent are additionally penetrated into Equation (2), θ_0 can be replaced by $\beta\prime c$ where β is a parameter vector that matches the covariate vector, c. The spike, meaning the probability of $W = 0$, is $[1+\exp(\theta_0)]^{-1}$. The average of W is derived as $\left(\frac{1}{\theta_1}\right)\ln[1+\exp(\theta_0)]$.

3. Results

During March 2021, the CV survey was conducted nationwide. Respondents had no particular difficulty in responding to the WTP questions. If some items were not answered, or it was judged that they were not sincere in filling out the questionnaire, the questionnaire was boldly discarded and further investigation was conducted on other respondents. Finally, the survey of 1000 households was completed. Table 2 summarizes the answers to the bid amounts offered to the respondents. The upper and lower panels of the table show the answers when P^L and P^U are presented first, respectively. Overall, it can be seen that as the bid presented first increases, the number of "yes" answers decreases. In the second column from the right, "no-no" and "no-no-no" answers indicate a WTP of zero. That is, the number of respondents with $W = 0$ is 590 (= 281 + 309).

Table 2. Summary of answers to each set of bids.

Bids [a]		Number of Answers				
First	Second	"Yes-Yes"	"Yes-No"	"No-Yes"	"No-No"	Totals
1000	3000	20	20	3	29	72
2000	4000	8	23	8	33	72
3000	6000	9	14	9	39	71
4000	8000	5	17	5	44	71
6000	10,000	3	13	11	44	71
8000	12,000	4	8	13	46	71
10,000	15,000	4	11	11	46	72
	Totals	53	106	60	281	500
First	Second	"Yes"	"No-Yes"	"No-No-Yes"	"No-No-No"	Totals
3000	1000	19	8	3	41	71
4000	2000	24	13	5	30	72
6000	3000	12	6	4	50	72
8000	4000	12	4	10	45	71
10,000	6000	9	3	15	44	71
12,000	8000	9	2	14	46	71
15,000	10,000	7	2	10	53	72
	Totals	92	38	61	309	500

[a] The unit is Korean won (USD 1.0 = KRW 1145 at the time of the survey).

Although the survey was conducted in March 2021, about two years ago, the scenario set in this study is still significant in two respects. First, it is the stability of the government's EV supply plan. In South Korea, a plan to supply eco-friendly vehicles is being established every five years under the 'Eco-friendly Vehicle Act'. Electric cars are representative eco-friendly vehicles. In the future, the supply of eco-friendly vehicles will increase, and EVs will be responsible for most of the supply. As a result, the deployment of V2G systems will increase, and the government is still very interested in public WTP for ICSs for V2G. Second, ICS construction for the introduction of V2G systems is still in the empirical research stage due to technical limitations. In other words, since there is no ICS established so far, and the policy for introducing the V2G system is still in the preimplementation stage, the current state and target state scenarios set in the CV survey of this study are still valid. Therefore, the authors think that the analysis results of the data collected two years ago still provide useful implications for policy officials.

One more thing that needs to be emphasized is that the beneficiaries of the benefits arising from the ICSs for V2G covered in this study are not limited to EV owners, but to the entire population. This is because ICSs for V2G will primarily benefit EV owners, but ultimately create positive effects such as efficient use of surplus electricity produced from VRE, reducing greenhouse gas and air pollutant emissions, improving energy security, and improving power supply stability. Therefore, EV owners were not only considered in selecting survey subjects. Respondents from all over the country were randomly selected. Of course, the construction of the ICSs for V2G allows EV owners to gain financial benefits from power transactions, but this is not the focus of this study. The subject of evaluation of this study is the various benefits to the entire people due to the construction of ICSs for V2G.

It is necessary to check if a response effect involved in the OBDC questioning method takes place or not. The response effect is related to the second question. Thus, a model that does not use the answers to the second question can be considered. To this end, the single-bound DC (SBDC) model using the response to only the first question was also applied. If there is no significant distinction between the results from OBDC and SBDC models, it can be accepted that the response effect does not occur. Otherwise, since there exists the response effect, it is desirable to adopt the estimation results from the SBDC model. Table 3 shows the estimation results of both models.

Table 3. Results from estimating the models.

Variables	One-and-One-Half Bounded Model [d]	Single-Bound Model [d]
Constant	−0.3651 (−5.71) #	−0.3719 (−5.80) #
Bid amount [a]	−0.1810 (−17.68) #	−0.1305 (−13.47) #
Spike	0.5903 (38.15) #	0.5919 (38.25) #
Yearly average household willingness to pay	KRW 2912 (USD 2.54)	KRW 4017 (USD 3.51)
t-values	15.32 #	12.52 #
95% CI [b]	KRW 2574 to 3316 (USD 2.25 to 2.90)	KRW 3462 to 4715 (USD 3.02 to 4.12)
Log-likelihood	−1133.67	−928.76
Wald statistics (*p*-values) [c]	422.49 (0.000)	261.66 (0.000)
Sample size	1000	1000

[a] The unit is KRW 1000 (USD 0.87). [b] It means confidence interval computed using the method given by Krinsky and Robb [38]. [c] The null hypothesis is that the model is mis-specified. [d] The values shown in the parentheses next to the coefficient estimates are *t*-values. # Implies that the estimate holds statistical significance at the 5% level.

Statistical significance at the 1% level is secured for the estimated coefficients for the constant term and the bid amount of the two models. Particularly, the coefficient for the bid amount has a negative sign. This implies that as the size of the bid increases, the probability of accepting the payment of it diminishes. Thus, the respondents appropriately provided WTP responses in the CV survey. The null hypothesis for the Wald statistic is that the coefficients are all zero. The hypothesis can be rejected in both models. The estimates found in the two models for the spikes, 0.5903 and 0.5919, respectively, were statistically significant. As mentioned above, the sample proportion of zero WTP observations was 59.0%, which is almost equal to the spike values. Consequently, the spike models were reasonably estimated.

By putting the estimates of the two models into the average WTP formula presented by Kriström [36], KRW 2912 (USD 2.54) and KRW 4017 (USD 3.51), respectively, were statistically significantly discovered for the yearly average WTP per household in the two models. Interestingly, the latter is much greater than the former. The gap is KRW 1105 (USD 0.96), accounting for 37.9% of the average WTP from the OBDC model. We are faced with the challenge of choosing one of these two and using it in the further analysis.

In this regard, an overlap test is adopted to examine whether the gap is significant. The test takes two steps. First, the 95% confidence intervals (CIs) are constructed for the average WTP estimates. In this research, the technique given by Krinsky and Robb [38] is used. Second, it is checked if the 95% CIs overlap each other or not. As shown in Table 2, the CIs do not overlap. It appears that a response effect as reported by Bateman et al. [39] exists in the OBDC model. Furthermore, the response effect significantly lowers the average WTP estimate. Consequently, the SBDC model is preferred to the OBDC model in this research. The SBDC model forms the basis of the following discussion.

4. Discussion of the Results

Three aspects will be discussed in relation to the above results. First, the effect of several variables related to the respondent on the WTP response can be explored. Five individual characteristics were selected for the exploration. Table 4 presents information about these. Specifically, there are two variables, Education and Knowledge, related to the individual characteristics of the respondent, and three variables, Income, Metro, and Solar, related to the respondent's household.

Table 4. Description of variables used in the model.

Variables	Definitions	Mean	Standard Deviation
Education	The respondent's education level in years.	14.24	2.13
Income	The respondent household's monthly income (unit: million Korean won).	4.88	1.98
Metro	The respondent's residence (0 = non-Seoul Metropolitan area; 1 = Seoul Metropolitan area).	0.53	0.50
Knowledge	Whether the respondent recognizes the vehicle-to-grid system before seeing the questionnaire (0 = no; 1 = yes).	0.05	0.22
Solar	Whether there is a solar power facility in the respondent's house (0 = no; 1 = yes).	0.03	0.18

Table 5 reports the estimation results of the SBDC model including the covariates. All of the coefficient estimates have statistical significance. Incidentally, their signs are all positive. For instance, the respondent's level of education or income is positively correlated to the probability of responding "yes" to a bid. Coefficients for other variables can be interpreted similarly. The estimated yearly average WTP for the construction of an ICS infrastructure is KRW 3522 (USD 3.08) per household, of which, the t-value is 12.50. Therefore, it is distinguishable from zero at a significance level of 1%. The Wald statistic computed under the null hypothesis that all of the parameter estimates are jointly zero is 156.21, and its p-value is 0.000. Thus, the hypothesis can be rejected at a significance level of 1%. The estimate for the spike is 0.5977, which is close to the sample proportion of 0.5900 and has statistical meaningfulness.

Second, the sample version of the average WTP can be extended to the population version of WTP. In the extension, two points are important. The first point is to determine the appropriate size of the population. When the survey was performed, South Korea had 21,278,321 households [40]. This number is used for the size of the population. The second point is the representativeness of the sample. In this respect, a specialized polling company implemented the sampling while maintaining consistency with the characteristics of the population. Thus, the extension can be attempted without causing much controversy. In this study, the population becomes the whole of South Korea. The average household WTP for the construction of an ICS infrastructure obtained above was KRW 4017 (USD 3.51) per annum. The yearly national WTP becomes KRW 85.48 billion (USD 74.65 million).

Table 5. Results from estimating the single-bound model with covariates.

Variables [a]	Coefficient Estimates [e]
Constant	−2.9602 (−6.12) #
Bid amount [b]	−0.1461 (−13.49) #
Education	0.1105 (3.26) #
Income	0.0670 (2.05) #
Metro	1.0598 (7.33) #
Knowledge	1.2989 (4.32) #
Solar	0.9878 (2.74) #
Spike	0.5977 (36.40) #
Yearly average household willingness to pay	KRW 3522 (USD 3.08)
t-value	12.50 #
95% CI [c]	KRW 3028 to 4142 (USD 2.64 to 3.62)
Log-likelihood	−862.37
Wald statistic (*p*-value) [d]	156.21 (0.000)
Sample size	1000

[a] They are described in Table 4. [b] The unit is KRW 1000 (USD 0.87). [c] It means confidence interval computed using the method given by Krinsky and Robb [38]. [d] The null hypothesis is that the model is mis-specified. [e] The values shown in the parentheses next to the coefficient estimates are *t*-values. # Implies that the estimate holds statistical significance at the 5% level.

Third, the present value of the population version of the annual WTP needs to be computed. The duration of the occurrence of the annual WTP was suggested to be ten years from 2022 to 2031 in the CV survey. Currently, an appropriate social discount rate is recommended to be 4.5% by the government. With these two pieces of information, the total present value as of the end of 2022 can be computed as KRW 676.4 billion (USD 590.7 million). To check the economic feasibility of the construction of an ICS infrastructure, this value can be compared with the cost corresponding to it. However, it is difficult to obtain specific information on the total cost of this construction project. This is because the V2G system is still in the empirical research stage and there is no case where an ICS has been built.

Thus, the government budget invested in related projects in the past can be considered as a proxy for the cost. The relationship between the government budget and the WTP derived in this study can be explained in two main aspects. First, since the construction of the ICSs for V2G is promoted by the government, not by the private sector, all of the costs related to its construction are filled by the government budget. In other words, ICSs for V2G are built by the government with financial resources raised by taxes. Second, it is desirable that the appropriate level of budget allocated to a specific project set by the government does not exceed the economic benefits generated by the project. The public WTP for ICS construction derived from this study can be interpreted as an economic benefit arising from the construction. Therefore, it would be desirable for the government budget for ICS construction projects not to exceed the total WTP amount derived in this study. Although the construction cost of ICSs for V2G has not yet been accurately calculated, it can be compared to the results of this study if the cost is calculated in the future.

The total budget invested by the government for the ten years from 2011 to 2020 to build an EV charging station infrastructure in the early stage of introducing EVs was KRW 668.9 billion (USD 584.2 million). Since constructing an ICS infrastructure means attaching an interactive charger to an existing EV charger, the construction is expected to cost less than the cost invested in building the infrastructure for the initial EV charging stations. The total present value is larger than the total budget invested by the government to build the infrastructure for EV charging stations over the past ten years. It seems that constructing the ICS infrastructure is socially beneficial. Of course, after obtaining accurate cost information, the work of more strictly comparing the value obtained in this study with it should be followed.

However, there are still issues to be resolved for the successful introduction of a V2G system, and especially, the opinions collected in this survey can be largely summarized into four categories. First, it is necessary to introduce a charging and discharging rate system exclusively for V2G. There is still only an EV charging rate system in South Korea, and no discharge rate. In addition, it is necessary to prepare a differentiated charging and discharging rate system by time and season. Second, specific methods of participating in the V2G system should be disclosed. Since the public's overall understanding of the V2G concept is still at a low level, various information such as ICS location, real-time price, and mandatory access time must be provided to users, including potential users, easily and clearly for the successful introduction of the V2G system.

Third, appropriate incentives should be provided to V2G system participants. The benefits of providing power reserves due to the V2G system will be enjoyed by the entire nation. Therefore, in consideration of the social benefits, V2G system participants should be provided with incentives for participating in the system, in addition to the profits from energy arbitrage. This can be an effective inducement to sufficiently secure EVs required to activate the V2G system. Fourth, it is necessary to resolve public concerns and distrust about the possibility of fire and shortening the life of EVs due to frequent battery charging and discharging. It is necessary to promote and improve public awareness that the fire and life shortening problems can be prevented through several means such as a battery management system.

As mentioned earlier, the purpose of this paper is not to develop innovative methodologies or creative ideas, but to evaluate the benefits of certain policies that the South Korean government intends to pursue. In other words, in a situation where an ESS is needed due to the expansion of VRE, this paper attempts to quantitatively analyze the economic benefits of ICS construction for the introduction of V2G, one of the ESS alternatives, using CV. CV has been widely applied for the valuation of nonmarket goods, and Table 6 summarizes the results of this study and the results of similar previous studies. Although the same methodology was applied, it is difficult to compare the results of each study with each other because the previous research cases and this study differ in five main aspects: evaluation target, sample size, survey method, survey time, and model.

Table 6. Summary of the results of previous studies and this study using contingent valuation.

Sources	Countries	Object to Be Valued	Mean Willingness to Pay
Bigerna and Polinori [19]	Italy	Introduction of hydrogen bus	EUR 2.01 to 2.44 per single-trip bus fare
Yang et al. [20]	South Korea	Expanding hydrogen stations	KRW 2258 (USD 2.04) per household per year
Lee et al. [21]	South Korea	Vehicle-to-grid service	KRW 9821 (USD 8.83) per month, per vehicle
Kim et al. [5]	South Korea	Introducing power-to-heat	KRW 4348 (USD 3.59) per household per year
Kowalska-Pyzalska [22]	Poland	Green electricity	PLN 2.83 (USD 3.5 USD) per month
This study	South Korea	Construction of interactive charging stations	KRW 3522 (USD 3.08) per household per year

Since the methodology used in this study has already been developed a long time ago and its framework has been established to some extent, it is difficult to say that it is innovative. Nevertheless, the implications of this paper can be useful in three aspects. First, to the extent that the authors know, this study is the first attempt in the literature to evaluate the public WTP for ICS construction for the introduction of V2G. There have been quite a few research cases in which CVs have been applied to energy issues, but it is difficult to find cases in which CVs have been applied in evaluating the economic value of infrastructure construction for V2G. Second, policy officials were provided with basic data to determine the budget for the ICS construction project or to evaluate the economic feasibility of the project. The government was demanding information on economic benefits for the construction of ICSs, which is preemptively necessary for the introduction of V2G systems, but this information has not been available so far. Third, other countries that are planning policies similar to South Korea may refer to their findings.

5. Conclusions

The government is considering introducing a V2G system to overcome the problem of variability and intermittence involved in VRE. For its introduction, an ICS connecting EVs and the power grid is required, and the government intends to construct the infrastructure by investing public funds. In this regard, this research attempted to quantitatively examine household WTP for the construction by using CV. For the sake of eliciting the WTP response, the OBDC model was adopted. For comparison, the SBDC model, which uses only the response to the first question in the OBDC model, was also applied. A spike model with a considerable plausibility that could explicitly deal with zero WTP responses was employed. Consequently, the estimation results of the SBDC model were used for further policy analysis. The average household WTP was statistically significantly derived as KRW 4017 (USD 3.51) per year. Its population value was KRW 85.48 billion (USD 74.65 million) per annum. The present value corresponding to ten years' payment was KRW 676.4 billion (USD 590.7 million) as of the end of 2022. This value is clearly significant, and appears to be greater than the cost involved in constructing the ICSs for V2G.

Of course, the construction of an ICS infrastructure does not guarantee the successful introduction of a V2G system. As can be seen from the four issues discussed above, a systematic system necessary for operating the V2G system and a support policy for participants should be established. If the 30.6% RE supply target is achieved by 2036, it will be a key task to stably include intermittent RE in the power system. Accordingly, various types of flexible resources are required. The EV resources can be used in downtown areas with a high demand for electricity, and can contribute to stabilizing RE output by being used as reserve power. Therefore, for the introduction of a V2G system, efforts such as system preparation, infrastructure construction, and public awareness improvement are necessary.

The results obtained from this research have three policy implications. The first implication is that the upper limit of the government budget invested in constructing an ICS infrastructure for a V2G system was quantitatively calculated. The estimated total benefit can be interpreted as the upper limit, and the government can refer to this information when allocating the budget. The second implication is that among the individual characteristics of the respondents, factors affecting the WTP response were identified. When the government selects target areas for constructing ICSs, it can give priority to places where a group with a high preference resides. The third implication is that 59.0% of all respondents had no intention of paying for the construction. This indicates that more than half of all households are negative or indifferent to the construction. Therefore, in order for the government to successfully promote the construction project and introduce a V2G system, it is necessary to persuade the public through publicity about its effectiveness or institutional improvement and support.

To complement the implications of this study more abundantly, three further studies can be conducted in the future. First, it is necessary to evaluate the public's acceptability of the charging and discharging rate system exclusively for a V2G system. Second, as the WTP for constructing ICSs can vary from region to region, it can be estimated by region by obtaining a greater budget for the survey and increasing the sample size. Third, it would also be meaningful to try experiments related to CV data analysis. For example, a comparison of results using various DC questioning methods. In this study, the OBDC model and the SBDC model were compared, but the double-bound DC model may be considered additionally.

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