CHEMICAL ENGINEERING TRANSACTIONS
VOL. 97, 2022
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Jeng Shiun Lim, Nor Alafiza Yunus, Jiří Jaromír Klemeš

ISBN 978-88-95608-96-9; **ISSN** 2283-9216
DOI: 10.3303/CET2297023

Wider Benefits of Eco-Friendly Transportation Projects with Contingent Valuation Method

Donggyun Ku[a], Soonwook Kweon[b], Jooyoung Kim[c], Seungjae Lee[a,]*
[a]Department of Transportation Engineering, University of Seoul, Korea
[b]Department of Transportation Engineering/Department of Smart Cities, University of Seoul, Korea
[c]Department of Transportation Policy, Korea National University of Transportation, Korea
sjlee@uos.ac.kr

Various eco-friendly transportation projects are being planned in line with the 2050 carbon neutrality policy. These projects are mainly for pedestrians. It is difficult to evaluate these projects because the method for calculating transportation benefits mainly considers the travel time-saving effect of vehicles. The purpose of this study involves evaluating eco-friendly projects by reflecting on the pedestrians-friendly effect. Specifically, transportation benefits are evaluated by the contingent valuation method (CVM). It is based on willingness to pay (WTP) reflecting landscape effects. The target of this analysis is "The Generalization Project of the Gyeong-in Expressway". This project involves a plan to build an underground road with the same scale as that of the existing road and change the existing road to a pedestrian-friendly park. This project is ineffective in terms of timesaving. When reflecting CVM, Benefit-Cost (B/C) is 0.96 and when not reflecting CVM, B/C is -0.21, negative benefits are calculated. Benefits are generated due to a decrease in capacity. If the landscape effect is added, then the willingness to pay for constructing a park is 19,210 KRW/y, which corresponds to a benefit of 8,277 billion KRW/y. This method, which reflects the landscape and walking connectivity effects for pedestrians, can calculate the characteristics of pedestrians for evaluating transportation projects. It can contribute to expanding eco-friendly transportation projects.

1. Introduction

The eco-friendly transportation business mainly contains pedestrian-friendly characteristics. Large cities around the world are also systematically reorganizing related laws and actively carrying out projects to improve the pedestrian environment (Lee et al., 2020). These are evaluated by benefits including vehicle operation costs, travel time costs, traffic accident costs, and environmental benefits (Shang et al., 2004). These benefits are focused on the saving of time and distance effects. The effects of pedestrian-friendly projects such as parks in the road project can be missed by existing evaluation. This means that an eco-friendly evaluation method such as CVM is needed (Kim et al., 2012). This study aims to present pedestrian-friendly indicators through the combination between existed evaluation model and CVM. This method is expected to overcome the limitations of the existing evaluation method. It is in line with the 2050 eco-friendly project.
CVM is a concept widely adopted in the analysis of the value of public goods, such as reduced CO2 emissions (Adamanc et al., 2011). CVM is analyzed by WTP in a non-market system. It is the population subject to evaluation that plays an important role in calculating total benefits in CVM. CVM assessment target refers to the extent of the region in which the conditional goods are traded and live in The affected market area (Dong et al., 2021). Furthermore, It is also conducted in consideration of the consumers contributing to traffic improvement and the quality of the residential environment (Park et al., 2017). CVM is being reviewed in a double-questioning fashion.
The process of this study is as follows. Limitations of CVM and how to apply this concept in transportation projects are reviewed in the literature review. In the methodology part, a case study is introduced. The survey design and sample setting for calculating WTP are presented. In the result part, various results contributed to

Paper Received: 31 May 2022; Revised: 23 August 2022; Accepted: 1 September 2022
Please cite this article as: Ku D., Kweon S., Kim J., Lee S., 2022, Wider Benefits of Eco-Friendly Transportation Projects with Contingent Valuation Method, Chemical Engineering Transactions, 97, 133-138 DOI:10.3303/CET2297023

this study are presented. These are included sample size, WTP, benefits using the CVM model, and B/C. In conclusion, a discussion of the results and limitations of this study are presented.

2. Literature Review

The social overhead capital (SOC) business should be evaluated with quantitative benefits. Various benefits are reviewed including benefits that can be additionally considered such as CVM. Here SOC projects are all or part of construction resources from the private sector for the efficient construction of public facilities. The environmental benefits of existing SOC project evaluations have focused on the amount of carbon emitted (Choi et al., 2021). It means that eon-friendly projects are evaluated only by the effect based on speed and distance (Ku et al., 2021).

CVM has strengths to evaluate eco-friendly projects. First, it can reflect the effect of landscape and connectivity for pedestrians. It means that it is possible to calculate the characteristics of pedestrians in transportation projects. Fein (2012) used CVM to evaluate Boston's Big Dig, which is represented by an eco-friendly project.

Second, it can describe a virtual market system. Kumar et al. (2021) used a virtual market system to extract acceptance intent for WTP or environmental effects. Perni et al. (2021) showed how the conditional valuation (CV) method is used in the market CVM. It is the development of research methodologies to overcome the unobservable parts of respondents' choices with changes in supply levels that are included (Zhang et al., 2022). According to the double boundary dichotomy CVM method, WTP and related specific payments were derived to obtain necessary data (Ikeuchi et al., 2013). The minimum condition for using this proposed probability utility model is the respondent.

In a previous study appeared limitations. First, the minimum conditions were not met. This means that citizens were not willing to pay it. It corresponds to the fact that it detects changes in the level of public goods based on monetary income and individual characteristics given as an indirect utility function (Palanca et al., 2020). The problem of selecting the number of samples also appeared. Sample sizes are not subdivided by region showing a large range of errors or do not indicate WTP. It is calculated to determine the advantages of the same layer. This may cause statistical bias in respondents' willingness to pay (Vaughan and Darling, 2000). Another limitation in previous studies, there is no existing benefit with CVM. It is applied incidentally. (Lipinska et al., 2019).

In this study, the existing benefits were calculated using the results of CVM. This result can be directly applied to the actual SOC business. Respondents' influence rights were subdivided in the questionnaire survey. In the survey, respondents' sphere of influence was subdivided. The price adjustment factor was calculated and corrected as a sample setting for direct and indirect users. This result can minimize the statistical bias of CVM results. It was confirmed that the landscape effect and the pedestrian-friendly effect were converted to WTP and were items of the same hierarchy (Park et al., 2017). Indirect benefits such as CVM methodology should be activated in the evaluation items of transportation projects. In addition, it is necessary to develop a methodology that can accurately estimate the environmental benefits of transportation projects.

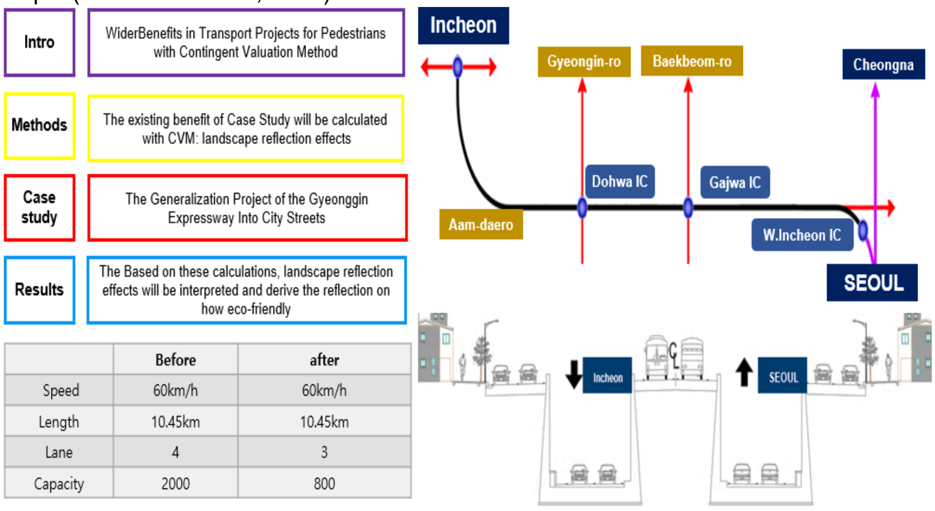
3. Methodology

This study's purpose is to evaluate the feasibility of eco-friendly projects that have not been reflected in existing benefits. It was calculated by adding CVM to the existing profit. Economic analysis uses B/C, Internal Rate of Return (IRR), and Net Present Value (NPV) methods. The benefits are calculated through Bureau of Public Road (BPR) and WTP. CVM reflects the effect of accessibility and walkability corresponding to indirect benefits. Although it is expected that there is no economic feasibility when calculating existing benefits, economic feasibility is expected to be secured via CVM. Figure 1 shows the framework and case study for analyzing CVM results. The analysis target is the Gyeong-in Expressway project. This project has the same speed, extension, and lanes. There is only an increase in travel time due to capacity reduction. In reality, it is almost impossible to estimate the WTP of individuals in the target population CVM is apply non-market valuation techniques. The non-market evaluation technique was calculated as shown in Eq (1).

$$gross\ annual\ income\ on\ benefits = N \cdot TV = N \cdot \overline{WTP} \tag{1}$$

where $\overline{WTP}$(= $(\sum_{i=1}^{n} WTPi)/n$) denotes the sample average (or median) of willingness to pay per household (or per person) In this study, the household on was calculated and investigated.

In the CVM survey design, first, the area of the virtual market and target population are set, and then the target goods are selected, and scenarios are prepared. Virtual market CV questions were presented so that respondents could understand trading products well and reveal preferences through surveys. A payment method is selected based on the presented questions. Respondents asked questions to make it easier to understand trading products and virtual market CV questions. Questionnaires are pre-survey, analysis, and result format. To estimate the benefits, Mitchell and Carson (1989) suggested the willingness to pay function presented by (bid function). The calculation formula is used for estimating the function and benefit because it is simple (Hanemann et al., 1991).



	Before	after
Speed	60km/h	60km/h
Length	10.45km	10.45km
Lane	4	3
Capacity	2000	800

Figure 1: Framework of the study and Explanation of Project of the Gyeongin Expressway

The probability utility models presented in this study are based on the neoclassical economic theory of maximizing utility under budget constraints. It was assumed that survey respondents knew the level of utility when creating green spaces and cultural facilities. It was used to represent theoretical politics. Based on their monetary income and personal characteristics, the following Indirect utility function can be postulated: $(v(j, m; S))$. Analysts cannot observe all the factors that influence the view on the creation of green spaces and cultural facilities in the central part of the Gyeongin expressway. Hence, it is reasonable to assume that this model followed the probability utility function as Eq (2) and Eq (3):

$$v_i(i, m; S) = u_i(j, m; S) + \epsilon_i \quad (2)$$

$$Here, \epsilon_i \sim i.i.d. nomal\ distributioni = 1, \ldots..n. \quad (3)$$

If a respondent answered yes to the question of whether he/she is willing to pay amount A, then the utility function of the individual is $u(1, m, S) \geq u(0, m; S)$. Specifically, the $i = 1$ is represents a situation in which the Gyeongin Expressway generalization project is completed, and various services can be implemented, and $i = 0$ represents a situation in which it has not been implemented.

This implies that with respect to presentation amount A, it can be expressed as $u_i(1, \mathrm{m} - \mathrm{A}; \mathrm{S}) + \epsilon_i > (U_I(0, \mathrm{m}; \mathrm{S}) + \epsilon_i)$. This can be represented by the following linear utility difference function: Eq (4) (linear utility difference function).

$$\Delta v = u_i(1, \mathrm{m} - \mathrm{A}; \mathrm{S}) - u_i(0, \mathrm{m}; \mathrm{S}) > \epsilon_{i,0,} - \epsilon_{i,1} = \epsilon$$
$$= \alpha + \beta A + \gamma S > \epsilon \quad (4)$$

The probability that the respondent will say yes to the given offer amount A is as Eq (5):

$$\Pr(yes) = \Pr(\Delta v > \epsilon) = 1 - \emptyset(A, S) \quad (5)$$

This can be expressed as $\in_i = n_i/\sigma_p \sim N(0,1)\ \emptyset(\cdot)$, which denotes the cumulative standard normal distribution. To indicate respondents' preference for a given CVM question as a quantitative choice, the utility difference function presented as Eq (4) or Eq (5) can be estimated using the maximum likelihood estimation method.

First, (single-bounded dichotomous choice) respondents responded with a 'yes/no to a given scenario and the amount presented in the question. The logwood function for these response patterns of respondents can be expressed as Eq (6):

$$ln\, L = \sum_{i=1}^{N} [I_i \cdot ln\, \emptyset(ln\, A, S) + (1 - I_{i)}. ln(1 - \emptyset(ln\, A, S))] \quad (6)$$

Where $\emptyset(\cdot)$ denotes the standard normal cumulative probability function, $\ln A$ is the log form of the suggested amount presented to each respondent, and S represents high-variable variables and includes a constant term. Given that the economic benefits of the affected population are measured according to the purpose of this CVM survey, the probability utility function is estimated using the logwood function in Eq (6), and the sample WTP is measured using estimates. Although the sample means have the disadvantage of being influenced by outliers, it is a necessary statistic if the sample WTP measure is used as part of the cost-benefit analysis of public works projects. For example, if the presented amount in the probability utility function (2) is included in a linear form, then the sample WTP sample mean and median are of the same order as that in Eq (7):

$$WTP_{average} = \frac{\alpha+\gamma S}{\beta} = WTP_{median\ value} \qquad (7)$$

4. Results

It presents an evaluation of the feasibility of undergrounding the "The Generalization Project of the Gyeong-in Expressway" Project. The existing benefits and benefits including CVM were compared with the existing benefits. The existing benefit is -0.21B/C, and the benefit including CVM is 0.96B/C. Therefore, economic analysis was possible. Based on the results, it can be judged that there is business feasibility only when the environmental benefits of CVM are reflected. This business can be considered suitable for eco-friendly businesses.

4.1 CVM result

The survey covered 1,000 people. Standard sample sizes are recommended from 200 to 2,500. The sample size was calculated according to Eq (8) as below.

$$N = [Z_{\alpha/2}\, \sigma/E]^2 \quad (8)$$

In Eq (8) N is desired sample size. Z is the 95% confidence interval statistic (1.96) at significance level α = 5%, 2-sided test. σ is the standard deviation of income. E is an acceptable error in the sample estimate of the population mean WTP obtained as one-tenth of the census estimate of average household income (i.e. a 10% error). Vaughan and Darling (2000) suggested an acceptable error within 10%. This can be confirmed by applying the mean and standard deviation for income. In Korea, the average income is 49.36 million KRW/m, and the standard deviation is 47.79 million KRW/m (Kim et al., 2021). The sample size is calculated at 466 within a 10% acceptable error. WTP is the most important factor in this study. To improve reliability, the sample size was calculated as 1,000. This is an acceptable error of 7%. The ratio of men to women in the sample is 5:5. Various estimations of probability utility Models for this project are shown in Table 1.

Table 1: Estimation of Probability Utility Models for The Generalization Project of the Gyeong-in Expressway

Variable identifier		Probability utility function	
		Model (1)	Model (2)
intercept		0.348 (3.59)**	0.246 (2.39)***
Presented amount		-0.0264 (-4.73)***	-0.0272 (-4.84)***
a pile of Incheon residents			0.290 (3.07)***
N		757	757
X^2 statistic		22.3***	32.2***
Intent to pay per sample individual	Total Sample WTP Average	13,197 KRW	-
	Incheon City residents	-	19,728 KRW
	Residents of Seoul and Gyeonggi Province	-	9,043 KRW

1) ( ) is the t statistic, meaning, *** p<0.001.

The results of the survey showed that 243 individuals did not intend to pay taxes for this project. The respondent's answers are the same, but the sampling area is different because it is divided into three areas: Incheon, Seoul, and Gyeonggi. This response was interpreted as resistance to taxes, lack of information, or distrust of collection methods, excluding the 757 respondents. Excluding the respondents analyzed to estimate the linear utility gap function using a single bisected probit model, the average WTP was measured using an estimate.

Model (1) was estimated as a simple linear model using only the constant term and the suggested amount as explanatory variables. Model (2) included dummy variables including residents of Incheon to distinguish the affected area, which is an important sample design variable. In results of Table 1, represents a 95 % confidence interval calculated from the sample mean WTP, where the standard error is calculated using the delta method Oehlert (1992).

The following are the results of the survey. Individuals aged 20 or older were selected for recruitment. The question of the survey is whether you are willing to pay taxes. The model used for the Gyeongin Expressway generalization project is a probability utility model.757 people, excluding those who responded to CV item resistance, were used as analysis data included in the estimation of the intention to pay the sample. The potential population for calculating the annual benefit of this project was calculated by considering the CV question-answer participation rate as the ratio of the target population willing to pay taxes for the general project. The CV question response rates were 74 % for Incheon residents and 77 % for Seoul and Gyeonggi residents. The base year for the case study is 2016. The response consumer price index is 2018. The consumer price index has been adjusted again as of 2016. It also adjusted the WTP. The adjusted consumer price index is 0.974. The adjusted annual WTP households are estimated to be 19,210 KRW/p for Incheon residents and 8,805 won/p for Seoul and Gyeonggi residents. Overall results are shown in Table 2.

Table2: WTP after adjusting the consumer price index

Sortation	2018 WTP	Price adjustment factor	WTP as of 2016
A resident of Incheon	19,728 KRW	0.974*	19,210 KRW
Seoul City, Gyeonggi Province Residents	9,043 KRW		8,805 KRW

Note*: The consumer price adjustment was calculated using the CPI in April 2018 and CPI in December 2016.

4.2 Comparison of results (with or without CVM benefit)

The adjusted WTP estimate is multiplied by the number of target populations and the CV response participation rate. This is used to calculate the annual benefit of the Gyeongin Expressway generalization project as shown in Table 2. The annual benefit was estimated at 32.81 billion KRW for Incheon residents and 54.32 billion KRW for Seoul and Gyeonggi residents. The combined annual benefit of the two groups was 87.13 billion KRW. Specifically, the results of the population by group and annual benefit are listed in Table 3. It is classified according to whether the CVM result is included.

When calculating WTP benefits, the social discount rates for present value were 4.5 % of the total benefit from 2018–2022 (five years), which occurs for 30 y from 2025. As shown in Table 3, the total salary of -64.8 billion KRW was specifically calculated at -7.8 billion KRW every year from 2018 to 2021, and the effect of total discount benefits gradually decreased since 2021, and the total discount benefit of -64.8 billion KRW (Calculated by summing up 30 years in economic analysis) is generated every year In the case of the convenience calculation result and transportation convenience, when calculating the existing benefits excluding CVM, the total benefit was -130.9 billion KRW, the total cost was 3,688, the total discount benefit was -64.8 billion KRW, the total cost of B/C was -0.21 billion KRW, and NPV was -3774.14. When the CVM effect is reflected, the WTP value calculated via the CVM survey was 13,197 KRW, which was calculated as 301.2 billion KRW /y when converted into benefits. The total benefit was 8,277 billion KRW, the total cost was 3,688, the total discount benefit was 3,012 billion KRW, and the total cost of B/C was 0.96 billion KRW, and NPV was -114.20. When comparing the difference between the results, the result including CVM increased by 9586, the total discount benefit increased by 3,660, B/C increased by 1.17, and NPV decreased by -3,659.94. This application of CVM showed the necessity of conducting the transportation business in the case study. It was concluded that the CVM methodology can lead to eco-friendly business with the feasibility of the road business.

Table 3: Comparison of results (with or without CVM benefit)

	Gross benefit	Total cost	Total discount benefit	Total Discount Cost	B/C	NPV
Without CVM	-1,309	3,688	-648	3,126	-0.21	-3,774.14
With CVM	8,277	3,688	3,012	3,126	0.96	-114.20
Results	+9,586	0	+3,660	0	+1.17	-3,659.94

5. Conclusion

Many eco-friendly transportation projects have pedestrian-friendly characteristics. These projects are difficult to evaluate with existing traffic evaluation methods that mainly focus on timesaving. This study presented the existing time-saving benefit and pedestrian-friendly benefits through CVM. This is the effect of improving the landscape from transportation projects. The WTP for landscape effects was calculated through the case study. This result is fused with the existing time-saving effect. It presents a direction to overcome the limitations of existing evaluation methods for transportation projects.

This study has several limitations. First, eco and pedestrian-friendly benefits can be evaluated in various ways, but this result suggested only landscape effects. This case study includes the development of a park, so the walk disconnection disappears. these effects can be improved by developing an urban network analysis index for finding the effect of walking disconnection. Second, the minimum number of samples was calculated and analyzed. This WTP is the result of at least 1,000 samples. For the evaluation of existing transportation projects, large-scale data surveyed at the national level were used. This means that the number of samples varies depending on whether the CVM effect is reflected. This can be improved when a budget for evaluating eco-friendly transportation projects is secured. The main contribution of this study is to present quantification of the eco-friendly effect that was suggested as a limitation of the evaluation of the transportation project. It is expected that this will help the 2050 carbon neutrality policy.

Acknowledgments

This work was supported by the Ministry of Education of the Republic of Korea, the National Research Foundation of Korea (2019K1A4A7A03112460), and financially supported by the Korea Ministry of Land, Infrastructure, and Transport (MOLIT) as an ´Innovative Talent Education Program for Smart City.

References

Adaman F., Karalidotless N., Kumbaroĝlu G., Or I., Özkaynak B., Zenginobuz Ü., 2011, What determines urban households' willingness to pay for CO2 emission reductions in Turkey: A contingent valuation survey. Energy Policy, 39(2), 689–698.

Choi M., Ku D., Lee S., Lee S., 2021, Environmental Impact of Personal Mobility in Road Managements. Chemical Engineering Transactions, 89, 331–336.

Dong Y., 2021, Comparing the willingness to pay for the ecological compensation and recreation value of the urban inland rivers based on CVM method, a case study of Nanyang urban inland rivers. SSRN Electronic Journal, 28, 1.

Fein M., 2012, Tunnel vision: "Invisible" highways and Boston's "Big Dig" in the age of privatization. Journal of Planning History, 11(1), 47–69.

Hanemann M., Loomis, J., Kanninen B., 1991, Statistical Efficiency of Double-Bounded Dichotomous Choice Contingent Valuation. American Journal of Agricultural Economics, 73(4), 1255–1263.

Ikeuchi A., Tsuji K., Yoshikane F., Ikeuchi U., 2013, Double-bounded Dichotomous Choice CVM for Public Library Services in Japan. Procedia - Social and Behavioral Sciences, 73, 205–208.

Kim J., Kang S., Kim K., Kang Y., 2012, A Study on Estimating the Benefits by Pedestrian Environment Improvement Using CVM. Journal of Korean Society of Transportation, 30(4), 7–19.

Kim T., Kim E., Shin H., Lee H., Park M., Lee H., 2021, Income gaps and imbalances by regionally, Balanced Development Monitoring & Issue Brief 7, Sejong Special Self-Governing City, Korea.

Ku D., Kim J., Yu Y., Kim S., Lee S., Lee S., 2021, Assessment of Eco-Friendly Effects on Green Transportation Demand Management. Chemical Engineering Transactions, 89, 121–126.

Kumar A., Prakash G., Kumar G., 2021, Does environmentally responsible purchase intention matter for consumers? A predictive sustainable model developed through an empirical study. Journal of Retailing and Consumer Services, 58, 102270.

Lee S., NA S., KU D., KIM J., 2020, Wider Benefits in Transport Projects Using an Impact Analysis Evaluation Method. EJournal of Korean Society of Transportation, 38(3), 208–217.

Lipinska H., Klopotowska A., Wlosek D., 2019, The Contingent Valuation Method in the Study of Ecosystem Services on the Example of the Urban Natural System of Lubartów. IOP Conference Series: Materials Science and Engineering, 603(5).

Mitchell R.C. (Ed), 1989, Using Surveys to Value Public Goods : The Contingent Valuation Method, Resources for the Future Publishing Limited, New York, USA.

Oehlert G., 1992, A Note on the Delta Method, The American Statistician, 46(1), 27–29.

Palanca Tan., 2020, Willingness to pay of urban households for the conservation of natural resources and cultural heritage in a neighboring rural area: A CVM study. Philippine Journal of Science, 149(2), 363–373.

Park J., Lee D., Park C., Kim H., Jung T., Kim S., 2017, Park accessibility impacts housing prices in Seoul. Sustainability (Switzerland), 9(2), 185.

Perni Á., Barreiro J., Martínez P., J M., 2021, Contingent valuation estimates for environmental goods: Validity and reliability. Ecological Economics, 189, 107144.

Shang J., Tjader Y., Ding Y., 2004, A unified framework for multicriteria evaluation of transportation projects. IEEE Transactions on Engineering Management, 51(3), 300–313.

Vaughan W., Darling A., 2000, The Optimal Sample Size for Contingent Valuation Surveys Chapter In : Vaughan W, The Standard approach to survey sample size determination Vol 28, Inter-American Development Bank, American, 1–46.

Zhang S., Yang B., Sun C., 2022, Can payment vehicle influence public willingness to pay for environmental pollution control? Evidence from the CVM survey and PSM method of China. Journal of Cleaner Production, 365(May), 132648.