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ENVIRONMENTAL ECONOMICS FOR CONSTRUCTION

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ABSTRACT: This study aims to propose an assessment model on environmental economics which will provide useful information in making a decision for the implementation of pro-environmental and economical construction projects. To meet the objective, this study suggests a procedure to estimate environmental cost of construction projects. The model combines environmental load assessment and environmental value assessment. The environmental cost of pollutant generated from the construction project was estimated utilizing the Contingent Valuation Method (CVM) which is a value assessment method borrowed from economic science. The devised model is expected to provide a useful methodology that will scientifically support the planning and management of sustainable construction not only in the environmental aspect but also in the economical aspect.

Keywords: Environmental cost, Environmental Economics, LCA, Construction project, CVM

1. INTRODUCTION

With increased attention being given to such issues of sustainable development, the industrial ecology of construction is a subject of considerable interest worldwide (Hendrickson and Horvath, 2000). As construction projects have become complicated and diversified, a number of new principles and values have emerged. Of them, the environment is regarded as one of the most important values. Accordingly we are entering into the paradigm of environment-economy coexistence, which means that the environment and economy should be considered together. The necessity has arisen to conduct research which can support efficient decision-making in an environmental economic perspective through numerical measurement of costs and values of environmental change caused by construction projects.

Hence this study aims to suggest an integrated assessment model that is composed of assessment of environmental load and valuation of the environmental load. The cost of environmental good (which is non-commodity output) is predicted by utilizing the environmental value assessment methodology adopted in economics. In addition, through case analysis, assessment of environmental economic efficiency is explored.

2. BACKGROUND

For the purpose of seeking opportunity of environmental improvement, Life Cycle Assessment (LCA) is utilized in the construction sector as a decision-making tool that enables evaluation of environmental function through quantifying environmental load (such as contamination, waste water, and fugitive dust) generated during the complete life cycle of a construction project. LCA is a process of assessing the environmental impacts that arise from the use of such energy and material. It helps find improvement methods for such environmental function. Implementation of LCA suggested in ISO 14040 series is composed of four phases: 'Goal and Scope Definition,' 'Inventory Analysis,' 'Impact Assessment,' and 'Interpretation' (ISO, 2004).

3. METHODOLOGY

In order to analyze the degree of economic damage caused by pollutants from construction projects, the amount of dollar cost for each unit of damage by a standard pollutant is estimated by utilizing Contingent Valuation Method (CVM) which is combined with the concept of Utility Theory. CVM is a method for estimating a monetary value of intangible assets or public goods (ex: the environment, patents, new technology). For tangible goods and services, the fair market price is the value. For intangible assets or public goods, however, prices cannot be determined in the market and indirect analysis through the surrogate market is difficult. As a result, CVM assumes a hypothetical, not a real, market and through questionnaire survey, inquires Willingness-To-Pay (WTP) to protect the goods and the willingness to accept compensation for the loss of the resource. CVM can be defined as a method of measuring directly the values given by people to specific public goods or environmental goods which are not transacted in the market.

To assess environmental value, this study adopted the method of expressing the improvement of environmental impact into utility and calculating WTP on the utility. For this purpose it is necessary to discern various categories of environmental impact caused by construction projects. According to ISO 14040 criteria, total eight categories were reviewed in this study.

4. ASSESSMENTS MODEL ON ENVIRONMENTAL ECONOMIC

This study proposes an assessment model on environmental economics integrating environmental impacts and economic effects brought by a construction project. For this purpose, this study suggests a formula of calculating total environmental cost in which environmental loads per environmental impact category are converted into monetary value, like the following.

$$EC_{TOTAL} = \sum_i \{ \sum_j [(Load_j \times eqv_{ij})] \times EC_i \} \quad \text{----- (Eq. 1)}$$

Here, EC_{TOTAL} = Total environmental cost ($) incurred by a construction project

i = Category *i* of environmental impact

j = Inventory item j

$Load_j$ = Environmental load of inventory item j

eqv_{ij} = Equivalency factor value of inventory item j that belongs to environmental impact category i

EC_i = Environmental cost for unit of standard pollutant per environmental impact category i

The suggested assessment model on environmental economics consists of environmental load assessment and environmental value assessment. Here, inventory items mean diverse sources contributing to environmental problems belongs to each environmental impact category. Equivalent factors (UN 1997) are factors used to convert the toxicity of an individual pollutant into a common accounting unit for each environmental impact category. The toxicity of the individual pollutant may vary orders of magnitude. With the equivalent factors, the toxicity of the individual pollutants can be expressed in a common accounting unit for the purpose of assessing contributions to environmental problems from diverse sources.

4.1 Environmental Load Assessment

The life cycle of a construction project extends from the production of construction materials, execution, operations of the constructed facility during its endurable life span, and maintenance to dismantling and disposal of the wastes. Environmental load assessment is the process of calculating quantitative environmental load generated from major materials (e.g. cement, ready-mixed concrete, electricity, section steel, rebar, asphalt concrete, timber) and equipment operation (e.g. light oil) that have a large effect on the environment during the life cycle of a construction project. Environmental impacts caused by contaminants per environmental impact category suggested in ISO 14040 series are analyzed. It also defines standard environmental goods (e.g. CO_2, CFC, Ethene, SO_2, PO_4, DCB, etc.) per environmental impact category and calculates discharged representative material for valuation of the environmental cost (Fig. 1)

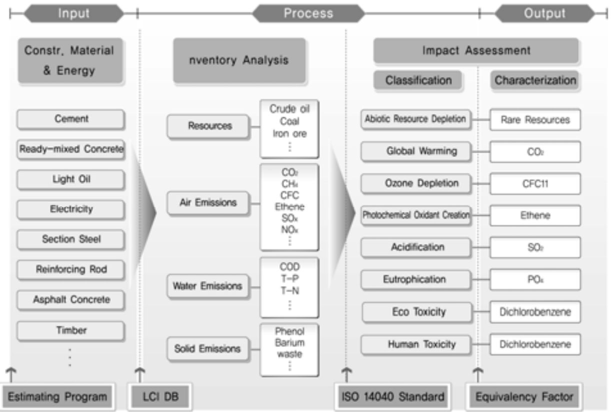

Figure 1. Items composing environmental load assessment

4.2 Environmental Value Assessment

Environmental value assessment is a process of calculating WTP for environmental goods in order to estimate the environmental cost. At the preparation stage, contingent valuation scenario is designed and statistical analysis is carried out. For this work, the definition of object material such as attribute, assessment unit and utility boundary was made for 8 environmental impact categories. A sample group is determined for the questionnaire survey. Through survey, the allowable scope of utility per attribute (category) and WTP are measured. The data measured are analyzed to calculate WTP per unit improvement of each category, and then the quantity of the standard pollutant of each category matching with the unit improvement of the category is identified. Lastly, through comparing the quantity of the standard pollutant with the computed WTP for unit improvement of the category, the environmental cost of each standard pollutant per category is estimated. With the estimated environmental costs, and also by measuring the environmental load of the construction project, the total environmental cost during the whole life cycle could be calculated using Eq. 1.

5. DESIGN OF CONTINGENT VALUATION SCENARIO

The Contingent Valuation Method (CVM) utilizes survey questions to elicit consumer preferences for public goods. In the survey, respondents are basically presented with the following material and questions (Mitchell and Carson 1989):

1. A detailed description of the good(s) being valued and the hypothetical circumstance under which it is made available to the respondent.
2. Questions which elicit the respondents' willingness to pay for the good(s) being valued.

3. Questions about respondents' characteristics (for example, age, income), their preferences relevant to the good(s) being valued, and their use of the good(s).

Based on the requirements above, a scenario of a hypothetical market was formed in this study to assess the value of attributes. Then, a questionnaire survey on the career, job title, damage experience, gender, household income, and WTP was performed and the results were analyzed using SPSS.

5.1 Sampling and Questionnaire Method

For the study, the population is the whole households of Korea because the environmental impacts generated from construction projects are nationwide. For sampling, 200 people were chosen. The sampling is designed to reflect the profile of the population on the advice of an expert. Questionnaire survey was performed by direct individual interviews to communicate clear objective of the survey and to help understand on the questionnaires. With the definition of objective material, the questionnaire survey included a full description of WTP for a better understanding on the part of the respondent. Out of 200 responses, 30 responses were unclear in their answers and removed in final analysis. The survey was conducted from April 29 2008 through May 6 2008.

5.2 Definition of Object Material to Measure

At CVM, the first step of full-scale questionnaire survey is to set goods as an object of the survey. In this study, the eight categories (i.e. abiotic resource depletion, global warming, ozone depletion, photochemical oxidant creation, acidification, eutrophication, eco toxicity, and human toxicity) were assumed as objects of assessment, and estimation of monetary value payable to renovate these factors was performed. To help understand clearly the environmental impacts caused by a construction project, particularly in respect to the 8 categories (or attributes), each environmental impact was defined by referring to the studies done by a research institution under MOE (2001), Environmental Textbook Study Society (2003) and Choi (2008) as well as related impairment phenomenon which is a state of fog setting in fine weather. The number of occurrences of such visibility impairment was set as an assessment unit for the category, with 60 days as its maximum.

5.2.5 Acidification

Acid rain under pH 4.5 falls in large cities and industrial complexes in Korea. The pH concentration of acid rain was assumed in this study as the unit to assess the category of acidification. The assessment scope was determined in the range of pH 7.0 (normal) ~ pH 3.0 considering various research results on the expected level of damage from acidification.

5.2.6 Eutrophication

Due to pollutants discharged from infrastructure (road, bridge, etc.), water contamination in some lakes and swamps is a serious condition. According to Korean water quality standard, grade I is classified as statistical data. The unit and scope of assessment to evaluate the contents and attributes were defined as follows.

5.2.1 Abiotic Resource Depletion

The rate of dependency on energy resources for domestic consumption has reached nearly 90% in Korea, and the rate of worldwide dependency on fossil fuel has exceeded 85%. Therefore, the survival of the human race will be threatened without countermeasures against energy resources depletion. Additional dependency rate (%) for crude oil, coal and iron ore was assumed as the unit of assessment, and 10% was set as the maximum assessment scope.

5.2.2 Global Warming

According to a research result, if the density of carbon dioxide (which is the principal cause of global warming) becomes double the present level, then rice production in Korea will fall by 40% due to abnormal weather caused by global warming. The decrease rate (%) in rice production was set as the unit to assess the category of global warming, while 40% was established as the extent of assessment (i.e. the maximum decrease rate).

5.2.3 Ozone Depletion

If the ozone layer is destroyed, harmful ultraviolet rays will flow into the globe, threatening living things on earth. In particular, a 1% decrease of ozone will cause a 2% increase of harmful ultraviolet rays, leading to a 5% rise in the skin cancer development rate. Excessive ultraviolet light breaks down the chemical combination of materials and detaches DNA molecules (which are the essence of life), causing skin cancer and cataracts in the eye. The occurrence rate (%) of skin cancer due to ozone depletion was established as the unit to assess the attribute of ozone layer destruction, with 5% assumed as the maximum assessment scope.

5.2.4 Photochemical Oxidant Creation

Due to photochemical smog phenomenon, Korea reportedly suffers around 60 days each year of visibility

oligotrophic, grade II ~ III as mesotrophic, while grade IV as eutrophication. Grade I of the water quality standard means a clean state (no to very low pollution), grade II low pollution, grade III moderate pollution, grade IV considerable pollution, grade V severe pollution which causes displeasure in daily lives, and grade VI excessive pollution in which fish cannot survive. The level of water quality affected by contamination was set as the unit to assess the category of eutrophication, with the scope of assessment established in the range of I ~ VI.

5.2.7 Eco Toxicity

Major industrial cities of Korea have seen mass mortality of aquatic animals as environmental water in the areas was contaminated by discharged chemical materials. The result of much research has discovered that aquatic animals die when exposed to toxic material for a prolonged time. Hence the death rate (%) of aquatic animals in environmental waters due to toxicants was used in this study as the unit assessing the eco toxicity, with 5% established as the maximum scope of assessment.

5.2.8 Human Toxicity

From the old days human beings have suffered disease or perished due to various kinds of environment pollution. Many of the diseases which led to death due to such pollution were developed through respiratory organs. In this study, the unit of assessment for the category of human toxicity was set with the deaths caused by Dichlorobenzene (standard material of human toxicity). The number of deaths exceeding the ordinary level was used. As for the assessment scope, 50 deaths per one million of population were established which reflects various research results.

5.3 Evaluation of Allowable Level for Categories

For the question 'What is the maximum and minimum allowable level of category (attribute)? The expectation that most respondents will choose both side extreme values of the suggested scope was upset. Many respondents preferred Interior Extremes. The survey results on minimum allowed level and maximum allowed level per category were averaged and shown in Table 1.

5.4 Estimation of Monetary Value for Categories

In order to identify the monetary value for each category (attribute), the respondents were questioned about "How much are you willing to pay (WTP) for unit level improvement of each category?" The WTP amount surveyed for each category was averaged. The average figure can be the representative value of WTP for each category.

It is also desirable to establish confidence interval considering uncertainty, rather than accepting the figure as it is. This study established confidence interval for the data obtained from the questionnaire survey in view of uncertainty. The result is shown in Table 2 below.

Table 1. Comparison of Main Features between Mixed-use and Single-use Projects

Category	Assessment Unit	Ass. Scope	Min. Allowed Level	Max. Allowed Level
Abiotic Resource Depletion	Dependence rate on overseas resources (%)	0~10	2.1	8.1
Global Warming	Rice production decrease rate (%)	0~40	6.5	31.9
Ozone Depletion	Skin cancer developed rate (%)	0~5	0.6	4.1
Photochemical Oxidant Creation	Visibility impairment occur date (days)	0~60	7.9	44.7
Acidification	Acid rain concentration (pH)	7.0~3.0	6.6	4.1
Eutrophication	Water quality level (level)	□~□	1.4	4.7
Eco Toxicity	Eco animal death rate (%)	0~5	0.6	3.9
Human Toxicity	Additional death toll (person)	0~50	5.0	34.7

Table 2. Monetary value per category

Category	Degree of Improvement	Average WTP ($)
Abiotic Resource Depletion	Dependence rate on overseas resources decreased by 6.0%	320.83 (51.61~590.05)
Global Warming	Rice production drop rate improved by 25.4%	319.73(194.90~444.57)
Ozone Depletion	Skin cancer rate decreased by 3.5%	129.22 (0~271.03)
Photochemical Oxidant Creation	Visibility impairment reduced by 36.8 days	60.00 (0~568.25)
Acidification	Acid rain concentration improved by 1.9pH	54.00 (0~171.87)
Eutrophication	Water quality improved by 3.4 level	8.33 (1.16~15.50)
Eco Toxicity	Eco animal death rate decreased by 3.3%	136.67 (0~505.40)
Human Toxicity	Additional death toll dropped by 29.7 person	449.95 (179.46~720.44)

Table 3. Environmental cost per pollutant

Environ. Impact Category	Standard Pollutant	Environ. Cost ($/ton)
Abiotic Resource Depletion	Rare Resources	316.04
Global Warming	CO_2	56.64
Ozone Depletion	CFC11	160.46
Photochemical Oxidant Creation	Ethene	23.12
Acidification	SO_2	65.83
Eutrophication	PO_4	1.25
Eco Toxicity	Dichlorobenzene	0.93
Human Toxicity	Dichlorobenzene	70.48

5.5 Estimation of Environmental Cost of Pollutants per Environmental Impact

Like the above, the values of environmental impact categories have been measured in a currency unit using CVM based on Utility Theory. The measured values will enable estimation of monetary value for each unit of environmental pollutant utilizing the Concentration-Response Function. The ISO 14040 series (2004) suggests each representative material that can account for most of the potential environmental damage among the various environmental pollutants. Hence each representative pollutant can be a standard material for each environmental impact category (attribute). The quantity of the standard pollutant matching to the unit improvement of environmental impact category is calculated, and then, monetary value for each unit of the standard pollutant for each category is estimated.

Table 3 shows the standard pollutant per environmental impact category and the result of analyzing their economic value through price ($/ton) estimation of their discharges. These values were calculated by using WTP average for each category.

The above result of computing the environmental cost per pollutant shows that the environmental cost affecting abiotic resource depletion is the largest with 316.04 ($/ton), followed by the environmental cost for human toxicity (Dichlorobenzene) with 70.48 ($/ton). This analysis on monetary value for each unit of environmental pollutant might be the first trial to estimate the unit cost for an environmental impact category, and hopefully it will be utilized for future related research.

6. CONCLUSIONS

This study proposed the assessment model on environmental economics which combines environmental load assessment and environmental value assessment. To formulate the assessment model, the unit and scope of assessment for the environmental impacts in respect to the 8 categories were defined, and a methodology to combine environmental load and environmental cost was suggested. In order to support estimating the monetary value of environmental impact which can be applied in assessing environmental economy of construction projects, CVM (Contingent Valuation Method) combined with the concept of Utility Theory was utilized.

This study estimated cost of pollutant per environmental impact category. It is concluded that 316.04 ($/ton) is incurred for each unit of abiotic resource depletion, 56.64 ($/ton) for global warming (CO_2), 160.46 ($/ton) for ozone depletion (CFC11), 23.12 ($/ton) for photochemical oxidant creation (Ethene), 65.83 ($/ton) for acidification (SO_2), 1.25 ($/ton) for eutrophication (PO_4), 0.93 ($/ton) for eco toxicity (Dichlorobenzene), and 70.48 ($/ton) for human toxicity (Dichlorobenzene).

By utilizing the proposed assessment method on environmental economics, the engineers can identify environmental damage cost with large weight, and it is expected environmental cost can be saved.

Acknowledgments : This research was supported by a grant (06 CIT A03) From Research Policy & Infrastructure Development Program funded by Ministry of Construction & Transportation of Korean government.

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