AN ASSESSMENT SYSTEM OF ECO-FRIENDLINESS OF CONSTRUCTED FACILITY IN THE DESIGN PHASE USING VALUE ENGINEERING

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ABSTRACT: The new paradigm called 'Low Carbon Green Growth' involved in reducing greenhouse gas is on the rise as a critical issue worldwide. The essential of Kyoto protocol issued in 1997 is to achieve the sustainable economic growth environments by converting existing production system to eco-friendly one. The protocol imposes the liability to reduce greenhouse gas to the countries joined to it. The paradigm is directly involved in the energy consumption and environmental pollution caused by construction activities. Value Engineering which are mainly applied in the design phase in practice is a measure to improve the value of a constructed facility by analyzing and/or appraising the functions and costs of it. However, an appropriate method which assesses eco-friendliness of constructed facility has not been propose by researchers. This paper proposes a method which assesses the performance involved in eco-friendliness of constructed facility using Value Engineering (VE) in the design phase. The method estimates the environmental cost relative to the amounts of energy consumption and environmental pollution occurred over the entire project life cycle. The database called "Life Cycle Inventory DB", which stores information about the amounts of environmental pollution, is used. The algorithm which retrieves the amounts of environmental pollutions from the DB and converts them into environmental costs is developed. The algorithm is implemented into a system which quantifies the eco-friendliness of constructed facility in the design phase using VE.

Keywords: Greenhouse gas, Value Engineering, environmental pollution, LCI Database, and environmental cost.

1. INTRODUCTION

The new Paradigm known as 'Low Carbon Green Growth' is on the rise as a critical issue in an effort to reduce greenhouse gas worldwide. The Kyoto protocol issued in 1997 aims to convert existing production system into eco-friendly and sustainable economy system. The new production system is achievable by imposing the liability to reduce greenhouse gas to the countries joined to it. The paradigm is directly involved in reducing the energy consumption and environmental pollution occurred by construction activities in construction community. Therefore, it is important to assess the eco-friendliness of design alternative in the early stage of project life cycle.

This paper introduces a method which assesses the eco-friendliness of constructed facility using Value Engineering (VE) in the design phase. This study uses VE which has been used to improve the values of a constructed facility by analyzing and appraising the functions and costs of design alternative. A method which assesses the eco-friendliness of design alternative was developed using VE. The eco-friendliness was measured by estimating the environmental cost relative to the energy consumption and environmental pollutants occurred over the entire project life cycle.

The algorithm which retrieves the information relative to the amounts of environmental pollutants from a DB named LCI and computes the corresponding environmental cost is presented. It is implemented into a system which quantifies the eco-friendliness of a design alternative using VE. LCI DB maintains information involved in the amounts of energy consumption and environmental pollutants.

2. CURRENT STATE OF ECO-FRIENDLINESS ASSESSMENT IN DESIGN PHASE USING VE

VE has been used to maximize the value, that is, rate of return. it is a decision making technique which selects an optimal alternative by evaluating the planning, design, and construction method alternatives using experts' knowledge in each phase of project life cycle. The relationship among Value Index, Function, and cost defined by Eq.1 is well accepted in VE arena.

$V = F / C$................................ Eq.1

Where, V: Value Index, F: Facility's Functions demanded by construction owner, C: Life Cycle Cost (LCC).

Value Index improvement is achievable by improving functions or reducing costs. Four strategies such as value innovation, value improvement, function improvement, and function maintain, and cost reduction strategies are exist to improve Value Index theoretically. However, two approaches are preferred to increase Value Index in practice. One is to achieve maximum functions, while holding the cost to a certain fixed cost. The other is to minimize the costs, while acquiring the function predefined. VE in design phase is consisted of two folds, evaluating function performance and cost performance. Function performance factor includes two categories of dimensions. First, the general dimensions such as constructability, environmental consideration, and safety, etc. Second, project specific dimensions attributed by the design of facility. On the other hand, cost performance factor includes the Life Cycle Cost(LCC) of each phase over a project life cycle.

The validity of the function performance evaluation has been a question because it mostly depends on the experts' opinions and knowledge which may be somewhat arbitrary. That is way, many researchers have put research efforts on the research agenda. Specifically, AHP(Analytic Hierarchy Process) method which objectify the experts' arbitrary opinions is applied by computing the relative weights of each function dimension to complement the reliability issues. Nevertheless, the necessity to develop a method which quantifies function performance has been an issue. As shown in the function assessment diagram of Fig.1, the assessment of environmental dimension is evaluated along with other functional factors such as constructability, stability of traffic flows, etc in arbitrary assessment base. Therefore, this study aims to develop which quantify eco-friendliness of facility.

Category			Initial	Alternative 1	Alternative 2
Function Performance Evaluation Diagram					
Function Performance (F)			695	853	747
Initial Investment (0.1 billion won)	budget	construction cost	102	88	94
		Land cost	20	17	4
		subtotal	122	105	98
	design and inspection cost		3	2	3
	subtotal		125	107	101
maintenance cost			25	24	31
LCC			150	131	132
Relative LCC			1.00	0.87	0.88
Value Index			695	980	849
Acceptance				○	

Fig. 1 A case of VE in design phase

3. ASSESSMENT SYSTEM OF ECO-FRIENDLINESS OF FACILITY

This system retrieves the information relative to environmental pollutants generated over project life cycle to quantify the eco-friendliness of constructed facilities from LCI DB. The information retrieval process, called "Appraisal of environmental influence", is executed according to ISO 14040 which uses Life Cycle Assessment(LCA). Then, the environmental cost appraisal process, which converts the equivalent monetary value to the environmental stress to environmental cost, is executed. As part of this process, a survey was administered to investigate how much cost is allowable to spend to reduce environmental stresses. Contingent Valuation Method CVM) was used to calculate the environmental cost.

3.1 Appraising environmental influence

The appraisal of environmental influence is a process to identify the items, which influence on environment, such as the ones exhausting natural resources, warming global, disrupting the ozone layer, eutrophicate soil, and toxic ecology compiled from Life Cycle's contents analysis. Four steps are defined by ISO 14040 to appraise environment. First, Classification assigning the contents to influence categories, Second, Characterization representing environmental influences within influence category, Third, Normalization setting the local and time standard according to the relative size of environmental influence, and Fourth, Weighting which adds up the result of characterization.

Since this study aims to compute the environmental cost using the amount of environmental stresses and environmental influence for each category, normalization and weighting steps were skipped.

1) Classification

Classification is a process gathering the items identified by the contents analysis. It is consisted of two folds. The first fold is find out the contents to which environmental influence has relevance using the facts known in literatures. for example. CO_2 is identified as to have relevance to global warming. because it is a cause of global warming in literature. The second fold is to collect all the similar contents into pertinent environmental influence category. For example, the contents such as CO_2, CH_4, CFC, NO_X, and etc are categorized into environmental influence category called global warming. After these classification steps, the correlation between these categories and environmental influence are identified. this classification. As this classification process is based on scientific approach, it is relatively clear process.

2) Characterization

Characterization is a process which quantify the influence on each categories by the contents identified. The contents are classified to environmental influence category in classification. However, The magnitude of influence was not quantified. That is way, it is necessary to quantify the magnitude of influence.

Characterization is consisted of two folds. The first fold is to quantify the magnitude of influence on each categories by classified contents. The second fold is to add up the influences of all contents which belongs to a specific category. Eq.2 (ISO 14040, 2004) formulates the second fold as follows:

$C_{ij} = Load_j \times eqv_{ij}$ ………………Eq.2

Where,

- $Load_j$: the magnitude of environmental stresses of content j (g/f.u).
- eqv_{ij}: the equivalency factor of content j which belong to category i (g-eq/g)
- C_{ij}: the size of influence that content j influence on category I.

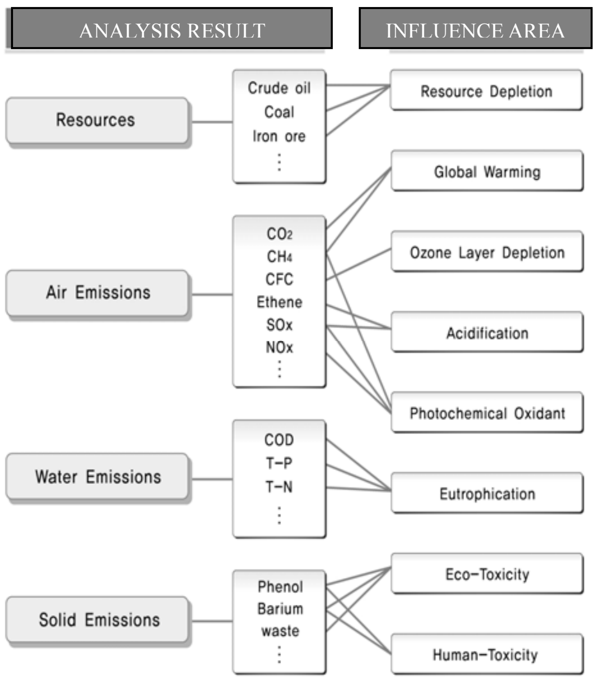

Fig. 2 Classification

The characterization model is used to quantify the magnitude of influence on environmental stresses of the contents classified into a category. C_i is the magnitude of influence by the i^th item on the environmental category. The environmental category includes all the item that are classified into a specific category i. C_i is described as follows.

$C_i = C_{ij} = (Loadj \times eqv_{ij})$ …………Eq.3

Table 1 represents the appraisal of global warming in disposal phase. It was obtained by applying the classification and characterization defined by ISO 14040. process. Environmental parameters are the factors which influence on global warming. They are obtained from LCI DB using construction resource variables. Equivalency factor is the relative ratio of other parameters according to CO_2 ratios. The magnitude of environmental stresses of content j ($Load_j$) is the magnitude of a category, which affect to global warming, corresponding to gas emissions amount from gasoline consumption. The magnitude of influence on global warming, which is obtainable from the classification and characterization process, in disposal phase is 4.51E+00 as shown in the most right and bottom cell. In addition, the magnitude of influence on global warming in construction, operation and maintenance phases were calculated using the same process as shown in Table 2.

Table 1. the appraisal of global warming in disposal

Environmental Parameter	Equiv.Factor(kg)[equiv$_{ij}$]	Inventory Result			Character. Result(C_{ij})
		Diesel		sum(quantity× LCI DB)[$Load_j$]	
		quantity(ton)	LCI DB		
HCFC-22	1.70E+03	14.1	1.34E-08	1.89E-07	3.22E-07
Nitrous Oxide(N_2O)	3.10E+02	14.1	9.74E-03	1.37E-01	4.26E-02
CFC-11	4.00E+03	14.1	5.71E-08	8.06E-07	3.22E-06
Methane(CH_4)	2.10E+01	14.1	0.00E+00	0.00E+00	0.00E+00
CFC-114	9.30E+03	14.1	5.85E-08	8.25E-07	7.67E-06
HFC-134a	1.30E+03	14.1	0.00E+00	0.00E+00	0.00E+00
Carbon Dioxide(CO_2)	1.00E+00	14.1	3.17E+02	4.47E+03	4.47E+00
CFC-13	1.17E+00	14.1	7.71E-09	1.09E-07	1.27E-06
CFC-12	8.50E+03	14.1	1.23E-08	1.73E-07	1.47E-06
TOTAL					4.51E+00

Table 2. LCA of each environmental influence category

Influence Area	**Mark**	**Construction Phase**	**Running Phase**	**Demolition Phase**	**LCA**
Abiotic Resources Depletion	ARD	8.96E+01	3.55E+02	3.63E+00	4.48E+02
Global Warming	GW	6.27E+03	1.30E+05	4.25E+01	1.36E+05
Ozone Depletion	OD	4.50E-04	9.04E-05	1.38E-04	6.78E-04
Photochemical Oxidant Creation	POC	1.04E+01	9.26E-01	1.39E-02	1.13E+01
Acidification	AC	1.41E+01	2.20E+02	3.85E-01	2.34E+02
Eutrophication	EU	5.52E-02	9.11E-02	1.49E-03	1.48E-01
Eco Toxicity	ET	1.02E+05	1.13E+04	4.63E+02	1.13E+05
Human Toxicity	HT	2.03E+03	5.74E+00	1.93E+02	2.23E+03

3.2 Environmental costs of categories

Contingent Valuation Method(CVM) is used compute economic loss contributed by each environmental pollutants in a category in project life cycle. In addition, the method is based on Multi-Attribute Utility Theory(MAUT) and converts Willingness To Pay(WTP) per unit loss to environmental cost. In addition, CVM is a method estimating the value to which public attach to certain public goods or environmental ones and quantifying the magnitude of environmental influences caused by construction activities.

The environmental influence was categorized using the environmental pollutants defined by ISO 14040 to calculate environmental costs. To calculate the costs, eight environment influence categories such as exhaustion of natural resources, global warming, disruption of the ozone layer, producing photochemical oxide, acidification, eutrophication, ecological toxicity, and human toxicity are defined as environmental influence category. The standard environmental goods for each categories are identified and the amount of standard materials(e.g., CO_2, CFC, Ethene, SO_2, PO_4, DCB, etc) in propotion to environmental stresses. Then, WTP which calculate environmental costs is computed and applied.

Data collection, processing, and analysis are carried out using Contingent Valuation Method(CVM) that is based on Multi-Attribute Utility Theory(MAUT). The environmental cost per unit standard materials(EC_i) was obtained from CVM. Table 3 shows the costs calculated by CVM (Kwon, 2008).

Table 3. The environmental cost per unit standard materials(EC_i)

Influence Area	Criteria Pollutant	Level Improvement Degree	Eco Cost(Won)(EC_i)
Abiotic Resources Depletion	Rare Resources	6.0% Reduction of the dependency on importing resource.	316,042
Global Warning	CO_2	25.4% improve rice production	28,321
Ozone Depletion	CFC11	3.5% reduction of skin cancer occurrence rate	160,458
Photochemical Oxidant Creation	Ethene	36.8 days reduction of administration obstruction	23,119
Acidification	SO_2	1.9pH reduction of acid rain	65,829
Eutrophication	PO_4	3.4 grade improvement of water quality	1,250
Eco Toxicity	Dichlorobenzene	3.3% reduction of ecological animal death ratio	929
Human Toxicity	Dichlorobenzene	29.7 reduction of dead people	70,483

3.3 Calculating Total Environmental Cost

The magnitude of environmental stress of each category was retrieved from LCI DB. The environmental cost was computed using CVM and Total Environmental Cost(EC_{TOTAL}) was calculated. It is not necessary to carry out all these steps each time.

The eco-economics evaluation model (Kwon, 2008) which calculates total environmental cost, provides an easy-to-use and quick method. It uses the major materials and energy source which are widely used in the delivery of infrastructure such as roads, bridges, etc as a medium. The model is more than acceptable in that the eight major materials and energy source cover most of the range of construction resources, albeit it is limited in that the model dose not include all type of materials and energy source for all type of projects.

Fig. 3 provides the process computing environmental cost in eco-economic evaluation model. The only thing that users have to is inputting the amount of materials and fuels. Then, the model provides environmental categories, corresponding parameters of each category, and the values of LCI DB, and etc. The total environmental cost demanded for delivering a construction project is obtainable using the Eq.4 according to the environmental cost computation process in Fig. 3.

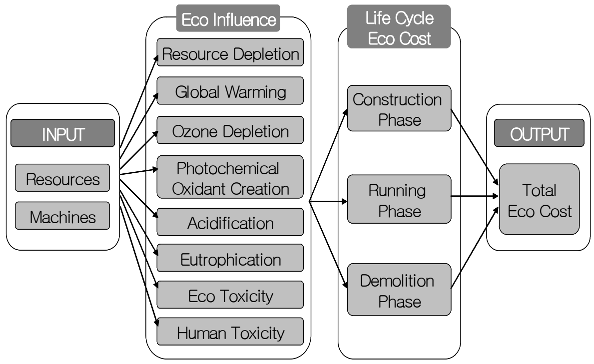

Fig. 3. The environmental cost computation process

$EC_{TOTAL} = \{(Load_j \times eqv_{ij}) \times EC_i\}$ …………….. Eq.4

Where,

- EC_{TOTAL} = Total environmental costs demanded for delivering a construction project
- i = Environmental influence category
- j = The contents of a category
- $Load_j$ = The magnitude of environmental stresses of content j
- eqv_{ij} = The equivalency factor of content j of category I
- EC_i = The unit cost of a standard materials i

4. ECO-FRIENDLINESS MEASURMENT MODEL IN DESIGN

The environmental assessment was considered as the Function part in existing VE at design phase. However, the new method assigns the sum of total environmental cost (EC_{TOTAL}) and life cycle cost (LCC) to the Cost part in Eq.5. The Eco-friendliness measurement model in VE analysis of Design phase is defined as follows;

V(Value Index) = F / C(LCC+EC_{TOTAL}) ……..Eq.5

Where,

- V: Value Index,
- F: facilities' functions demanded by construction owner, and
- C: the sum of Life Cycle Cost(LCC) and Total environmental costs (EC_{TOTAL}).

The comparison between the outputs obtained from conventional VE and the new VE considering eco-friendliness was compared using the case shown in Fig. 1. The outputs are presented in Table 5 and 6. As shown in Table 4, the case study is involved in designing road intersection which is consisted of road and bridge. The environmental evaluation is considered in cost part rather than function part of the equation of Value Index. When the two methods were used, there was no difference in the rank of the alternatives. However, it was identified that the new method retains its' merits. It appears that the reason why the results is contributed by smallness of EC_{TOTAL} comparing with LCC.

Table 4. Information of Case study

Category	Original	Alternative 1	Alternative 2
Road(m)	850	1,250	1,000
Bridge(m)	670	480	520
sum	1,520	1,730	1,520

Table 5. Results obtained by the VE considering eco-friendliness

Unit: 100 million Korean Won

Category	Original	Alternative 1	Alternative 2
FUNCTION	610	753	677
LCC	150	131	132
Total Env. Cost (EC_{TOTAL})	31.8	33.2	30.2
LCC+EC_{TOTAL}	181.8	164.2	162.2
Relative cost(C)	1.000	0.90	0.89
Value (V=F/C)	610	834	759

Table 6. The comparison of existing and new system

Category	Existing VE		Eco-friendly VE		Difference
	Score	Best	Score	Best	
Original	695		610		85
Alternative 1	980	○	834	○	146
Alternative 2	849		759		90

5. CONCLUSION

The existing production system is demanded to reformulate into eco-friendliness one. That is why, the construction community needs a method which quantifies eco-friendliness in design phase. This paper reports that an environment-economic assessment system that quantifies the eco-friendliness of facility in design phase was developed by using VE. It retrieves the magnitude of environmental pollutant over the project life cycle from LCI DB and computes environmental cost using the information retrieved earlier.

It was found that there was not much difference in Value Index between the results obtained from the existing VE and the new system. However, it appears to the authors that the new system quantifies more objectively eco-friendliness, albeit the existing VE system depends on appraiser's subjectivism. in addition, It would be a good addition, if other types of construction materials are accommodated in later version of the system.

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