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Development of Eco-VE Function for Construction

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Abstract

Recently accepted "Paris Agreement" has restricted the Earth temperature increase to be below 1.5 degrees Celsius contrast to previous industrialization. To follow this agreement, there should be efforts such as carbon emission reduction and eco design etc. One of these efforts is development of eco-VE function that applied eco-friendly concept on VE which is commonly used at design phase. Concept of this model includes carbon productivity concept and potential environment pollution index that reflects eco-VE function on original VE. The carbon productivity concept is a cause of production increase that offset production decrease factor depending on green-house gas reduction. The potential environment pollution index presents the possibility of environment pollution through construction phase. The carbon productivity is 'Construction cost/Carbon emission'. The construction costs are consisted of material, equipment, labour cost and indirect expenses. Carbon emissions are calculated by emission for material production and equipment fuel consumption. The potential environment pollution index is composed of environmental pollution and conservation cost. The environmental pollution cost includes environmental damage and destruction cost. The environmental conservation cost includes environmental pollution prevention cost, waste treatment cost, environmental pollution compensation, environmental pollution test research funds and law cost.

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Keywords: Eco VE; Eco Cost; carbon productivity; potential environment pollution index;

These costs can't be calculated directly because it is not occurred yet. While designing it is calculated by comparing original plan to alternative about possibility of environment pollution. The value of VE increases when the cost is low and the performance is high. The value of eco-VE is 'Carbon productivity/Potential environment pollution index'. If

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the eco-VE function is applied to VE for alternative development at design phase, there will be big impacts on greenhouse gas reduction.

1. Introduction

1.1 Background & Purpose

December 12, 2015 is the signing date of the Paris Agreement that was the most historic conference in the history of humankind for the joint efforts of correcting the mistakes made by humans. Gather in Paris, delegates from 196 n ations across the world came to an agreement with a plan to make efforts to cope with climate changes resulting fro m rising global temperatures since the Industrial Revolution.

The Paris Agreement includes a temperature restriction of below 1.5 degrees compared to that before the industria lization Heo, [6].

Industrial advancement is needed for life of abundance but sustainable development is required. Accordingly, rela ted regulations are being reinforced.

In accordance with such trend, various efforts are needed also in the construction field that occupies 40% of total e nergy consumption of Korea. According to Park [14] construction industry is the 3rd highest industry with most carb on dioxide emissions of the 28 industrial classifications. For solving such issue, use of eco-material and construction method and energy efficiency maximization of heavy equipment are needed.

One of these efforts is the development eco-VE model in which the eco-friendly concept has been implemented in the area of VE (value engineering) that is being widely used in the design phase. The concept of this model is reflecting the eco-VE function in the existing VE and the eco-VE function includes carbon productivity concept and potential environment pollution index. The carbon productivity concept is a productive increase factor offsetting the productivity reduction factor resulting from greenhouse gas reduction. The potential environment pollution index indicates the possibility of environmental pollution that could occur when construction facilities are constructed. The potential environment pollution index consists of environment pollution ratio and environment conservation ratio and the environmental pollution ratio consists of environment damage cost and environment destruction cost. The environment conservation cost consists of environmental pollution prevention cost, waste disposal cost, environmental pollution compensation cost, environmental pollution test & research cost and legal & institutional cost. These costs cannot be directly estimated since they have yet to occur. Accordingly, they are estimated in the form of index by comparing the possibility of environmental pollution between the original design plan and alternative. The purpose of this study is to develop eco-VE function that can be used in the application of eco-VE to develop design alternatives.

1.2 Scope & Method

The scope of this study will be the parts of existing VE Job Plan for developing eco-VE function for the definition of environmental performance, establishment of the environmental costs concept, implementation of potential envir onmental costs and development of eco-VE function incorporating these components.

The procedure and method of the study is as shown in Fig. 1 and existing researches on environmental performance, environmental costs and potential environmental costs needed to develop eco-VE function will be reviewed. For defining environmental performance, eco-requirements of project implementer and user will be identified. For eco-items to be reflected in the design, functional analysis will be conducted to define the final purpose and method of facilities. In addition, correlation between functions performed with the facilities will be examined with eco-design items.

For establishing the concept of environmental costs, accounting classification & definition of environmental costs consisting of explicit/implicit environmental costs, VE related environmental costs and carbon productivity concept will be analyzed. One of the characteristics of environmental costs is that it is cost that has yet to occur. Reflecting such characteristic, the concept of potential environmental costs index is implemented. Namely, potential environmental costs are defined through a method of comparing design alternatives and assessing the possibility of causing environmental costs to express its size in index.

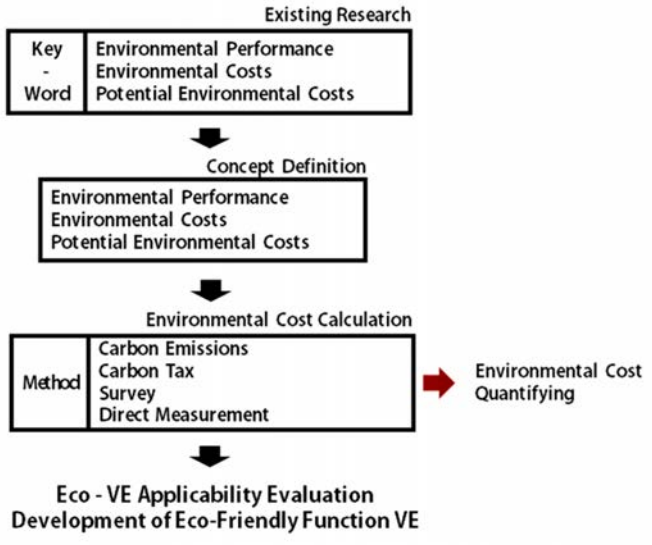

Fig 1. Study method.

The definition of environmental costs that can be used in the design phase may vary depending on the environmental costs estimation method. Carbon dioxide emission and emissions trading price methods, survey and direct measurement methods were examined to assess their applicability to eco-VE in the design phase.
The eco-VE function accordingly defined will be applied to the basic concept of VE namely, formula with value proportional to function and inversely proportional to LCC (life cycle cost) to develop new eco-VE function.

1.3 Existing research trend

Various researches on environmental costs are being actively conducted throughout all industrial areas in Korea. I n the case of construction industry, various efforts are being made recently for estimating environmental costs comp ared to the past where researches on environmental load were conducted.
Cho performed LCA (life cycle assessment) of various apparatus including landscape lightings designed for high-rise multipurpose building to analyze the environmental costs of 11 types of greenhouse gas including CO_2, [4]. Jang examined environmental costs in construction projects using carbon tax, [7]. In addition, Oh [13] analysed the environmental costs of air pollutants that occur while demolishing apartment, Cha conducted a study on the CO_2 emission and environmental cost estimations of construction wastes, [2].

Researches on the environmental costs in the case of domestic construction projects were mostly limited the deduc tion of environmental costs on CO2 through LCA.
In regards to studies on eco-VE, Kim and Kim developed NIA model for quantifying the eco-friendly sense of project owner [9]. Kim et al. conducted LCA and inter-industry analysis for railroad alignment design to quantitatively estimate environmental pollution emissions and estimated CO2 costs in railroad construction projects based on carbon emission trading price [10]. Kim and Lee conducted a study on eco-friendly design for increasing the energy efficiency of high-rise multipurpose building [8]. In addition, Lee presented systematic procedures and standards to prevent any omission of VE proposals during evaluation through green VE proposal evaluation procedures & standards [12]. Song analysed the existing VE selection method to propose green VE selection model for selecting eco-friendly elements that need to be considered in project [15]. However, studies on eco-VE are lacking applicable to public works with significant costs and resources. Accordingly, this study aims to develop eco-VE function through the indexing of potential environmental costs difficult to measure during the early design phase and carbon productivity that has not been examined in existing VE researches to develop eco-VE function in the application of eco-VE for overcoming the limitation of environmental costs deduction method limited to CO_2 and developing design alternatives.

2. Theoretical consideration

2.1 VE (Value Engineering)

In construction industry, VE can be defined as an organized effort given to the functional analysis and design of construction system for achieving necessary function with the lowest LCC (life cycle cost). The value to be achieved by performing VE consists of cost, performance and time components for creating optimum value by maintaining an appropriate balance. For achieving optimum value through VE activity, it is necessary to conduct quantitative analysis with specific numerical figures instead of through qualitative approach. Quantitative formula is as shown in Formula 1,

$$\text{Value} = \frac{Function}{Cost} \tag{1}$$

where Cost = Life Cycle Cost.

In addition, development of eco-VE function of this study occurs during a design VE process. The design VE can be defined as a process of creating a plan of improvement and the best plan to select structure, material, machine, construction method and system according to the function, performance and quality level required from facilities during the design phase. Expected cost-savings and performance improvement effect is significant with significant possibility of improvement and low activity costs when VE is applied earlier than later. Accordingly, importance of design VE is all the more significant [12].

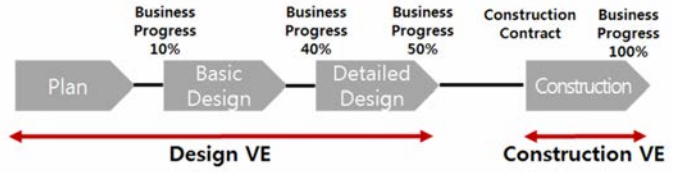

Fig 2. Design and Construction VE, [12].

2.2 Environmental Costs

Environmental costs are the type of costs companies or nations take on to avoid issues that could occur or revert to previous state environmental issues that serve as major policy of national industrial advancement and cross-border e nvironmental disputes, along with simple environment issues such as localized or international level global warming occurring as a result of industrialization [3].

Environmental costs include explicit cost companies or nations that discharge pollutant directly spent to reduce po llutants in compliance with environmental policy and social implicit cost occurring as a result of various social rippl e effects caused by pollutant emission.

Explicit/implicit cost estimation is performed through a quantification method using damage cost from air pollutio n, earmarked tax cost for ecological damage and emissions trading costs for emissions. In the case of explicit cost, h owever, there are not that many research cases that reflect it since it is difficult to measure air, water quality and soil damage costs. However, implicit cost can be measured within the research scope such as environmental pollution pre vention cost, environmental pollution compensation cost and legal expenses [7].

2.3 Carbon Productivity

Carbon productivity is a GDP increasing factor offsetting a GDP decreasing factor according to greenhouse gas reduction and it was first presented by McKinsey Global Institute [1]. It is a crucial concept that we need to focus on in the era of green growth with the emphasis on greenhouse gas reduction and sustainable growth. Accordingly, carbon

productivity is being perceived as an important concept in this era of green growth where greenhouse gas reduction and sustainable growth are being emphasized [11].
For sustainable growth, it is necessary to also consider carbon emissions as a production element in addition to labour and capital in the production function based on added value. It is because it would be necessary to take on the cost of greenhouse gas emissions, along with the formation of carbon prices in the case where carbon tax or greenhouse gas emission trading scheme is implemented that will inevitably lead to the implementation of carbon productivity concept for greenhouse gas reduction. Accordingly, it would be necessary to increase carbon productivity to offset the cost burden and profit decrease resulting from greenhouse gas emission [2].

Table 1. Method of Calculating Environmental Cost.

Division	Estimation Method
Substitute Evaluation Method	In the case where the value of measurement object cannot be directly measured, It is a method of meas uring value that can indicate the same effect or cost of measurement object.
Prevention Cost Estimation Method	A method of using the cost required to prevent damage as the substitute of actual cost
Analytical Method	A method of extracting information from various source data
CO2 Emissions Trading Price Method	A method of estimating environmental costs by multiplying CO2 emissions by carbon emissions tradin g price
Contingent Valuation Method	A method of extracting the payment costs of respondents regarding hypothetical change of environmen t quality upon eliciting the value of public property or environmental goods
Survey	A method of estimating environmental costs with information obtained through field survey, questionn aire, interview, etc.
Restoration Cost Method	A method of estimating costs required to restore environmental damage to previous state or avoid dama ge that could occur

2.4 Potential Environmental Costs

Environmental costs can be divided into environmental pollution costs such as environmental damage & destruction costs and environmental conservation costs such as environmental pollution prevention cost, waste treatment cost, environmental pollution compensation cost and legal & institutional costs. In regards to the estimation methods of environmental costs, they include survey method, analytical method, prevention cost estimation method, restoration cost estimation method and economic incentive & preventive systems. However, they are not being widely used due to their complexity of calculation method and difficulty of data collection. In addition, environmental damage & destruction costs and environmental pollution compensation cost are calculated once they have actually occurred and they are type of costs that cannot be used when developing alternatives during the early stage of design. Namely, they are potential costs that have not occurred yet.

3. Deduction of EV (Eco-Value)

3.1 Establishment of Eco Function Standard

Eco function (EF) refers to eco design items and they will be used in this study by analysing and revising the eco evaluation items being used in the building eco certification system of Korea, the LEED (Leadership in Energy and Environmental Design) certification system of the USA and the BREEAM (Building Research Establishment Environment Assessment Method) of the UK. The eco evaluation item is a system of inducing eco-friendly & sustainable development by implementing eco performance evaluation of building, design method and eco design guidelines [16].
The eco performance standard in eco VE is a device for increasing the eco performance of facilities by adding function to general VE and the eco performance standard to be applied may vary depending on the facility characteristics.

In addition, it may be exempted in the case where the project organization does not cover the subject of corresponding item and weighted value may be given to each index depending on the region. Table 2 shows some of the eco evaluation items of the LEED & BREEAM.

Table 2. Eco-Friendly Evaluation Items.

	LEED	BREEAM
Evaluation Items	Building Materials	Maintenance
	Building Waste Management	Health & Wellness
	Energy Countermeasure	Energy
	Number of Existing Buildings	Traffic
	Indoor Air Quality	Water Efficiency
	Landscape / Exterior Design	Building Materials
	Installation of Recycling Equipment	Garbage
	Operational and Administrative Facilities	Site Plan
	Prohibited Use of Ozone-Depleting Substances	Ecological Environment
	Site Selection	Pollution
	Traffic Relationship	Innovation
	Water Conservation	
	Water Quality	

3.2 Deduction of Potential Environmental Pollution Index

Considering that potential environmental costs are difficult to directly calculate during the early design stage and they are costs that have yet to occur, it would be reasonable to apply an indirection estimation method of comparing between two plans.

It would be appropriate to consider a method of quantitatively expressing the possibility of causing greater costs by comparing between original plan and alternative with each sub-classification items related to environmental pollution cost and environmental conservation cost.

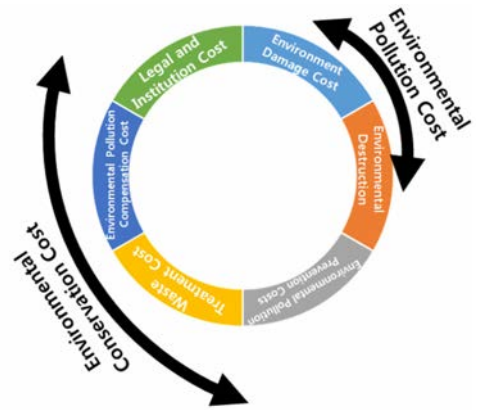

Fig 3. Design Parameters Evaluating of Environment.

Environmental pollution cost is a currency assessment of the damage resulting from discharged wastes and environmental conservation cost refers to cost for preventing environmental pollution and destruction caused by corporate production activities.

For deducing potential environmental cost, potential environmental pollution index is deduced using an indirect comparison method between original plan and alternative during eco VE design. First off, AHP (Analytic Hierarchy Process) that provides objective mathematical model is used for examining subjective or individual preference of individual or group to calculate the weighted value of 7 types of environmental evaluation standards appropriate for eco VE project by the VE team [5].

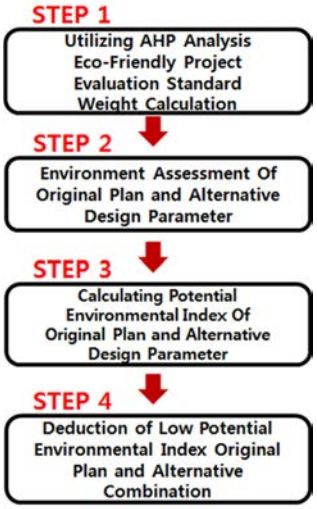

Fig 4. Deduction process of Potential Environmental Index.

In addition, environmental evaluation is performed according to the design items of original plan and alternative to calculate potential environmental index by using the evaluation table shown in Fig. 4. In regards to the calculation method, the VE team measures the seriousness of environmental pollution cost of the environmental evaluation standard in the 7-point scale, which could occur upon the construction of facilities in the original plan and alternative according to design items. In addition, potential environmental pollution index of each design item is calculated by multiplying by the weighted value of the environmental evaluation standard obtained through AHP to deduce original plan and alternative with low index value. Lastly, added value between the design item combination of alternative and original plan with low potential environmental index is used as potential environmental index in Formula 2.

3.3 EV Formula

Existing VE value evaluation formula can be revised according to eco VE concept and presented as shown in Formula 2. This formula includes eco evaluation item, carbon productivity concept of McKinsey Global Institute and potential environmental cost based on existing VE. Necessary coefficients of this formula are as follow.

Function (F) is expressed as a reason for existence of facility or its performance and its value increases as the numeric value increases. Environment Function (EF) is determined according to the facility characteristics among the evaluation items of eco certification system and its value also increases as the numeric value increases.

Life cycle cost (LCC) consists of design cost, construction cost, operation & maintenance cost and demolishment & disposal costs and its value increases as numeric value decreases. CO_2 emission is referring to the amount of carbon dioxide discharged from materials and equipment used to construct facility. It is calculated using individual estimation method of estimating environmental load by-product from the type and quantity of every material used to make product based on the product and system blueprint and estimate sheet and inter-industry method of calculating the amount of energy consumption and environmental load ultimately caused by final demand amount of industry. In the case where there are various products or system processes such as building, there is matching method of calculating step-specific environmental load. It is expected that CO_2 emission amount can be estimated by revising individual estimation method, inter-industry method and matching method according to eco VE and reflecting them in this model.

In regards to potential environmental pollution index (PEPI), possibility of the occurrence of environmental cost can be quantified by comparing between original design plan and alternative through the PEPI Evaluation Sheet, shown in Fig. 4, since it is difficult to measure environmental costs that could occur upon the construction of facility.

$$EV = \frac{F \times EF}{LCC \times CO_2 Emission \times PEPI}, \tag{2}$$

where: F: Function
EF: Environment Function
LCC: Life Cycle Cost
PEPI: Potential Environment Pollution Index.

Table 3. Potential Environmental Cost Sheet.

Main Category	Sub Category	Original Plan	Alternative
Environment Damage Cost	Air		
	Water		
	Land		
	Pesticide		
	Radiation		
	Thermal Cracking		
	Toxicology		
	Odour Emissions		
Environmental Destruction	Noise		
	Vibration		
	Industrial Waste		
	Subsidence of Land		
	Sunlight Infringements		
	Adding Harmful Food		
	Water Shortages		
	Destruction of Natural Landscapes		
Environmental Pollution Prevention Costs	Environmental Pollution Prevention Equipment		
	Operation Maintenance of Environmental Equipment		
	Factory Planting		
	Environmental Remediation		
	Raw Material Conversion and Pollution Avoidance		
	Non-Pollution Public Relation		
	Environmental Pollution Prevention Training		
	Environmental Pollution Measure		
Waste Treatment Cost	Waste Incineration		
	Waste Burial Treatment		
	Effective		
Environmental Pollution Compensation Cost	Compensation		
	Animals and Plants Compensation		
Environmental Pollution Test research cost	Improvement of the Manufacturing Method		
	Reduction of Pollution Control		
	Development of By Products and Joint Products		
	Etc.		
Legal and Institution Cost	a. Contractor charges		
	b. Environmental pollution fine		
	c. Environmental pollution charges		
	d. Other institutional relation costs		
Evaluation Scale	1 2 3 4 5 6 7 Not likely to occur ↔ Highly likely to occur		

4. Conclusion

This study aimed to deduce eco design plan by changing existing VE that is being applied to design into eco VE function. Eco VE includes the carbon productivity concept and potential environmental pollution index. In regards to the eco VE function EV, F value through the functional analysis of design item and EF value reflecting eco evaluation element were placed as numerator, while placing CO_2 emission based on LCA and material production, CO_2 emission from the fuel consumption of equipment operated and PEPI as denominator to allow eco value of facility to increase as function & performance increase and CO_2 emission, LCC and PEPI decrease.
As for follow-up study, it would be necessary to verify the eco VE function model by performing simulations using facility that been designed through eco VE.

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References

[1] McKinsey Global Institute (2008), “The Carbon Productivity Challenge: Curbing Climate Change and Sustaining Economic Growth”
[2] Cha, K. W. (2011), A Study on the Calculation of CO2 Emissions and Environmental Cost according to Construction Waste Types on the basis of LCA, Master Thesis, Kyungpook National University (in Korean).
[3] Cho, K. H., Chun, H. C., Choi, D. S. (2012), "Integrated Environmental Cost Computation Method in Domestic Construction Industry", Journal of The Korean Society of Living Environmental System, Vol. 19, No.5, pp.605-614 DOI: 100491763 (in Korean).
[4] Cho, S. Y., Ahn, J. W., Kim, Y. S. (2009), "A Case Study and Model Development of Environmental Costs in the Global Worming", Proceedings of Korea Institute of Construction Engineering and Management, pp. 274-280 (in Korean).
[5] Choi, J. W., Jung. H. Y., Jang, S. Y. (2011), " Development of Decision Making Model of Measures on the Decrease of Traffic Accident Following Implementation of Intra-city Bus by using AHP", Journal of Korean Society Civil Engineers, Vol. 31, No. 5, pp. 649-687 (in Korean).
[6] Hur, S. S. (2016), “Climate Change and Concerted Actions by Mankind”, Journal of Korean Social Trend and Perspective, Vol.96, No.2, pp. 214-220 (in Korean).
[7] Jang, W. S., Jeong, W. Y., Park, H. D., Han, S. H. (2010), "An investigation and a suggestion for considering environmental costs in construction project - Carbon Tax and Emission Trading Cost", Proceedings of Korea Institute of Construction Engineering and Management, pp. 265-266 (in Korean).
[8] Kim, H. Y., Lee, H. N. (2013), "A Study On Environment-Friendly Planning In The Super High-Rise Mixed-Use Building For Energy Saving", Journal of The Korean Housing Association, pp. 223-228. (in Korean).
[9] Kim, J. S., Kim, B. S. (2016), "A Proposal of NIA Model for Eco-VE Decision of Construction Facilities", Journal of Korean Society Civil Engineers, Vol. 35, No. 6, pp.1377-1385 (in Korea).
[10] Kim, S. Y., Kim, H. B. (2010), "A Study on the Improvement of Korea Green Building Certification System by the Comparison with BREEAM and LEED", Journal of Architectural Institute, Vol. 26, No. 12, pp.271-278. DOI: 82496584 (in Korean)
[11] Kim, Y. K. (2010), "Carbon productivity status, trends and implications in Korea", Korea Institute for Industrial Economics & Trade Publications, Vol. 407, No, 2, pp.1-11. (in Korean).
[12] Lee, H. G. (2012), A Study of the Measurement of Environmental Accounting in formation in Corporations, Master Thesis, Han-Yang University (in Korean).
[13] Oh, M., Kim, H. S., Lee, K. H. (2000), " A Qualitative approach to assessment of the CO_2 emission and the energy consumption during the construction", Journal of Architectural Institute, Vol. 20, No. 1, pp. 461-464 DOI: 3378683, pp.461-464 (in Korean).
[14] Park, P. J., Kim, M. Y., Lee, I. S. (2009), "Analysis of CO2 Emission Intensity per Industry using the Input-Output Tables 2003", Korea Environmental Economics Association, Environmental and resource economics review, Vol. 18, No. 2, pp. 279-311 DOI: 76551656 (in Korean).
[15] Song, C. Y., Moon., H. S., Hyun, C. T. (2011), "Subject Selection Model of Green VE for Sustainable Design", Journal of Construction Engineering and Management, Vol. 12, No. 3, pp.42-52. DOI: 100926962 (in Korean).
[16] Yoon, J. E., Lim, Y. H. (2011), "Study on Correlation of Green Building Certification System and Guidelines - Focused on LEED and Sustainable Building Guidelines in the US", Journal of Architectural Institute, Vol. 27, No.11, pp.155-164. DOI: 82729015 (in Korean).