TITLE: IMPROVEMENT OF THE EVALUATION METHOD FOR VE ALTERNATIVES USING THE RISK ASSESSMENT PROCESS

AUTHOR: JINHO PARK[1], ZHENGXUN JIN[2], CHANGTAEK HYUN[3], HYUNJOO KIM[4]

1) Kumho Engineering & Construction Co., Staff Member, Master, Email: rokmarin8548@uos.ac.kr
2) Ph.D Candidate, Dept. of Architectural Engineering, Univ. of Seoul, Seoul 02504, Korea, Email: rlawjdgns52@uos.ac.kr
3) Professor, Dept. of Architectural Engineering, Univ. of Seoul, Seoul 02504, Korea, (Corresponding Author) Email: cthyun@uos.ac.kr
4) Associate Professor, Dept. of Global Construction, International School of Urban Sciences, Univ. of Seoul, Seoul 02504, Korea, Email: hkim01@uos.ac.kr

ABSTRACT

Value engineering (VE) is one of the fundamental techniques of the construction management, and it is part of a systematic effort devoted to the functional analysis of facilities designed to achieve the necessary functions at a minimum life cycle cost. Since the success or failure of VE projects depends on the participants' capabilities, it is important to follow systematic procedures. However, although an alternative is suggested in accordance with the current VE procedures in the actual VE task, very often the case is that the alternative is not executed in the following stages, but instead reverts to the original plan. This seems to imply that VE alternatives are not specifically analyzed and evaluated in terms of risk management basis. In this regard, this study proposed a risk assessment process that can systematically analyze the VE alternatives to improve the efficiency of tasks through the prevention of returning alternatives in VE improvement activities.

The procedures of this study are as follows. A total of 20 VE results reports were analyzed while expert interviews were performed to analyze VE application status. Based on the results, the problems of evaluation on the VE alternatives were derived, and four improvement directions were set to solve them. Following this, a risk assessment process for VE alternatives was proposed through the introduction of risk assessment procedures, specific factor analysis of the alternatives and IPA techniques. Then, their applicability was verified by applying the proposed risk assessment process for VE alternatives to actual cases and performing expert interviews. The verification results confirmed that the efficiency of VE tasks could be improved by reducing the repetitive work for the returning alternatives.

INTRODUCTION

Among the core techniques of the construction management, VE is a systematic effort devoted to the functional analysis of facilities designed to achieve the necessary functions at a minimum life cycle cost (Kim et al. 2005). Since the success or failure of VE projects depends on the capabilities of participants, including owners, construction managers, architects, general contractors and VE experts, it is important to follow systematic procedures (Choi and Kim 2005).

The Ministry of Land, Infrastructure and Transport in Korea laid the foundation for the systematic implementation of VE tasks by providing a standard VE implementation manual. The VE process of Korea is largely divided into the preparation stage, analysis stage and execution stage. The analysis stage consists of various phases, such as functional analysis, idea generation, rough evaluation and idea concretization, and concretization of alternatives and detailed evaluation (The Ministry of Land, Infrastructure and Transport 2013). However, it is often the case that only a rough evaluation is performed, or the rough and detailed evaluations are integrated in actual VE tasks. In this case, it is difficult to analyze and evaluate alternatives in terms of risk, even for the important alternatives. This in turn leads to the so-called returning alternatives where the alternatives proposed in the preceding stage are returned to the original plans in the following stage, and thus the repetitive work for the alternatives often decreases the efficiency of the VE task.

In this regard, this study seeks to propose a risk assessment process for VE alternatives in order to minimize the occurrence of returning alternatives based on the systematic analysis and evaluation of VE alternatives.

LITERATURE REVIEW

Risk Management

Definition of Risk

Risk has been defined by several institutions and researchers. According to the PMI (Project Management Institute), project risk is defined as "an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective" (PMI 2009). The WSDOT (Washington State Department of Transportation) defines risk as "uncertain factors that may affect one or more of the project objectives" (WSDOT 2014).

Many researchers in Korea have also defined risk in various ways. JaeGyeong Cho defined it as "the implication of uncertainty on the risk with variability of results through the prediction of the future outcomes" (Cho 2012). Kang et al. defined it as "an uncertain event or situation in the future that can affect the project objectives", and risk in project management was defined as "a concept that includes the possibility of both negative threats and positive opportunities" (Kang et al. 2016).

To sum up, risk can be defined as 'positive or negative factors affecting the project objectives with certain probabilities'.

Classification of Risk

Risk needs to be classified so as to manage the risk of project efficiently. There are no specific criteria for classifying risks, but risks are generally classified into negative or positive risks, individual or collective risks and external or internal risks, depending on the nature of the risks.

In particular, individual risks and collective risks are similar to VE alternatives and VE projects/construction projects, respectively. Individual risks refer to "specific events or conditions that have an effect on the project objectives". Collective risks are defined as "the impact of uncertainty over the entire project" (PMI 2009).

IPA Analysis

The Importance Performance Analysis (IPA) technique proposed by Martilla and James has been utilized in a variety of fields since the management diagnosis technique of the automobile industry was suggested through a customer opinion survey (Oh 2016). The IPA technique is useful for comparing the importance and satisfaction levels, determining the priority of the performance factors, and thus deriving the investment and improvement areas of the project (Oh 2016).

First, a survey is conducted in order to evaluate the satisfaction and importance of each criterion at the same time. Then, one of the total average, median, standard deviation and arbitrary value based on the survey results is adopted to divide the space made up of the X axis and Y axis into four areas. The results are then analyzed according to the position of each criterion.

PROBLEM AND IMPROVEMENT PLAN FOR EVALUATION OF VE ALTERNATIVES

Analysis for VE status

In order to investigate the problem for evaluation of VE alternatives and the occurrence of returning alternatives, a total of 20 VE results reports were analyzed, and expert interviews were carried out. An analysis was conducted regarding the VE results reports from 2008 to 2016, which consisted of eight preliminary design phases, ten detailed design phases and two construction phases in ten construction projects. In particular, two results reports in different phases for each project were analyzed so as to examine the presence of returning alternatives.Table1 shows the VE status analysis results.

[Table 1] VE Status Analysis Results

Division	Detailed Description
Presence of rough and detailed evaluations	13 projects were found to undergo only the rough evaluation, six projects underwent both the rough and detailed evaluations, and one project did not undergo any evaluation.
Considerations in the comparison/evaluation of existing plans and alternatives	The comparison and evaluation of the existing plans and alternatives are mainly focused on an increase or decrease of the initial investment costs. The Life Cycle Cost is mainly considered in the field of mechanical or electrical equipment. In addition, advantages and disadvantages are analyzed to compare and evaluate the existing plans and alternatives.
Selection of criteria	Elements with comprehensive meanings, such as maintenance efficiency, workability, economic feasibility and safety are selected as criteria used for the rough and detailed evaluations. These criteria are selected subjectively by VE project participants based on the characteristics of the construction project.
Application of detailed evaluation technique	A matrix evaluation technique has mainly been applied as a detailed evaluation technique. It was applied to 12 cases out of a total of 20 VE results reports. However, the matrix evaluation technique was applied not to all of the alternatives, but to some of them.
Occurrence of returning alternatives	Returning alternatives occurred in six construction projects. The total number of alternatives proposed in six construction projects was 281, and that of returning alternatives was 12, accounting for about 4%. Meanwhile, the amount of the total proposals was 16,064 million won, and that of the returning alternatives was 1,571 million won, accounting for about 9%. This shows that the frequency of returning alternatives is relatively low, but their impact is high in terms of cost.

Problems for Evaluation of VE Alternatives

Through the analysis of 20 VE results reports and expert interviews, the problems of evaluation of VE alternatives were derived as shown in Table 2.

[Table 2] Problems of Evaluation of VE Alternatives

Division	Detailed Description
Lack of concretization in the analysis of alternatives	Since only the disadvantages and advantages of the alternatives over the existing plans are investigated, there is insufficient analysis and evaluation considering the effects of the alternatives in terms of the project objective, design and construction.
Insufficient detailed evaluation	Detailed evaluations are conducted only for some alternatives.
Evaluation by the same criteria	Since all alternatives are evaluated with the same criteria, the characteristics of each alternative are not taken into consideration.
Inadequate segmentation of qualitative evaluation	Since, in some cases, evaluators make evaluations only using ‘○, △, ×’, which mean ‘good, medium, and bad levels’, there is a lack of in-depth evaluation of the alternatives.

Improvement Plans for Evaluation of VE Alternatives

Each problem of evaluation of VE alternatives has in common that it is difficult to specifically analyze and evaluate the VE alternatives on a systematic basis. Therefore, in order to specifically and systematically analyze and evaluate the VE alternatives, improvement plans for evaluation of VE alternatives from four aspects were established as shown in Table 3.

[Table 3] Improvement Plans for Evaluation of VE Alternatives

Division	Detailed Description
Concretization of alternatives considering effects on the project objective	The concretization of VE alternatives needs to be performed by considering the effects of the alternatives on the construction project.
Concretization and evaluation considering the characteristic of alternatives	There is a need for procedures where alternatives are concretized and evaluated by considering the characteristics of each alternative
Complement of evaluation procedures	There is a need to complement the evaluation procedures of VE alternatives to improve the efficiency of VE tasks based on the specific analysis and evaluation of the alternatives on a systematic basis
Subdivision of evaluation scores	There is a need for methods to evaluate alternatives more quantitatively through the introduction of 5-point, 7-point or 9-point scales

RISK ASSESSMENT METHOD FOR VE ALTERNATIVES

Risk Assessment Process for VE Alternatives

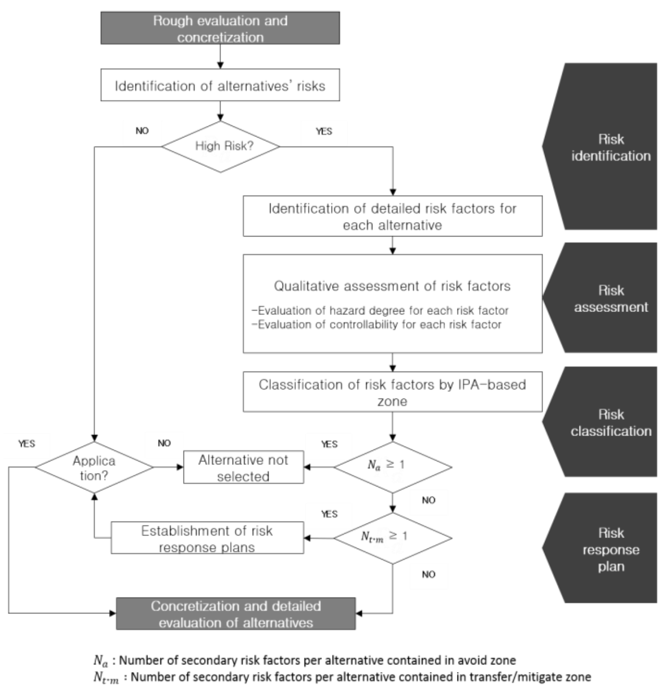
Based on the aforementioned improvement plans for evaluation of VE alternatives, a risk assessment process was developed through the introduction of risk evaluation procedures, analysis of specific factors of the alternatives and application of IPA techniques. In order to specifically analyze and systematically evaluate the alternatives, the risk assessment process was added just before the concretization of the alternatives as shown in Fig.1. The implementation method for each step is as follows.

Identification of alternatives’ risks

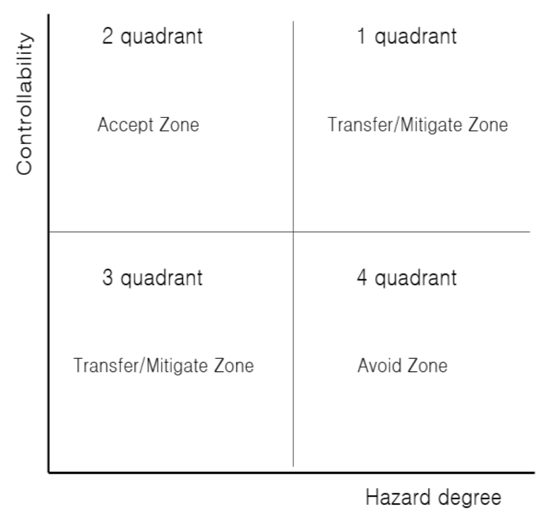
Among the proposed alternatives, those with a high risk of becoming returning alternatives are selected by experts’ intuitions in the risk identification step. The degree of risk of becoming returning alternative means the possibility that the proposed alternative will be returned to the existing plan since it is thought to have a negative effect on the cost, schedule or quality at the implementation stage. A high-risk alternative refers to an alternative with a high risk of becoming a returning alternative based on the experts' intuitions. Meanwhile, the PI technique, AHP technique or FMEA technique can be applied to more quantitatively identify alternatives' risks.

Identification of detailed risk factors for each alternative

In this step, the detailed factors of risk are grasped with respect to the alternatives selected as high-risk ones. For specific analysis of the alternatives, the primary risk factors are investigated and then developed into the secondary risk factors. In the analysis of the primary risk factors, the 'noun + verb' method is used for defining the risk of high-risk alternatives. In the analysis of the secondary risk factors, the primary risk factors are subdivided and developed as specific risk factors.



[Fig. 1] Risk assessment process for VE alternatives



[Fig. 2] Controllability and hazard degree

Qualitative assessment and classification of risk factors

The next step is to assess the hazard degree and controllability of the secondary risk factors and decide whether to adopt alternatives based on the zone where the secondary risk factors are located in the IPA-based zones. The IPA-based zones are classified into the Accept Zone, Transfer/Mitigate Zone, and Avoid Zone as shown in Fig. 2. In this study, the X-axis and Y-axis refer to the hazard degree and controllability, respectively. The7-point scale was used to assess the hazard degree and controllability. In addition, for the classification of IPA-based zones, each zone was classified based on point 4, which are intermediate values of 1 to 7 points. The Avoid Zone is characterized by low controllability and a high hazard degree, and although only one of the secondary risk factors for alternatives is included in this zone, the alternatives are not adopted. The Transfer/Mitigate Zone have similar controllability and hazard degrees to each other, and risk response plans are established with respect to the included secondary risk factors. The Accept Zone is a region with a low hazard degree but high controllability, and the secondary risk factors included in this zone can be utilized for project management with the constant recognition.

Establishment of risk response plans for transfer/mitigate zone

Risk response plans are established for the secondary risk factors included in the Transfer/Mitigate Zone. For planning the risk response, appropriate response plans should be established through brainstorming or other proper tools carried out by VE team members. However, this step is performed for alternatives that do not have secondary risk factors included in the Avoid Zone.

VERIFICATION BY CASE STUDY

In order to verify the risk assessment process for VE alternatives, a case study was conducted with the case of 'Design VE for OO Railway Roadbed Construction'. In this study, the risk assessment process of VE alternatives was performed through interviews and surveys of VE experts participating in the case application project. The application results of each step are as follows.

Identification of alternatives' risks

In the case of 'Design VE for OO Railway Roadbed Construction', a total of 38 alternatives were proposed in the roadbed area. Of these, 14 alternatives were rejected through consultation with the owner, and alternatives' risks were identified with respect to the remaining 24 cases. Five experts who participated in the case application project were interviewed to derive high-risk alternatives. As a result, 'the optimization of support patterns and blasting specifications of the tunnel section', and 'the deletion of stairs outside the station' were derived as high-risk alternatives.

Identification of detailed risk factors for alternatives

The detailed risk factors were analyzed through interviews with five VE experts in relation to the two alternatives selected as high-risk alternatives. Table 4 and Table 5 summarize the detailed/secondary risk factors for each high-risk alternative, respectively.

[Table 4] Analysis Results of Detailed Risk Factors of H1

Alternative Name (Classification Code)	Optimization of Support Patterns and Blasting Specifications of the Tunnel Section(H1)		
Primary risk factors	Classification code	Secondary risk factors	Classification code
Difficulties of standardization work	H1F1	Impossible to apply support pattern standards due to uncertain phenomena of faults	H1F1R1
		Need for additional reinforcement in the tunnel section	H1F1R2
		Need to change excavation methods according to the status of surrounding areas and construction efficiency	H1F1R3

[Table 5] Analysis Results of Detailed Risk Factors of H2

Alternative Name (Classification Code)	Deletion of Stairs Outside the Station(H2)

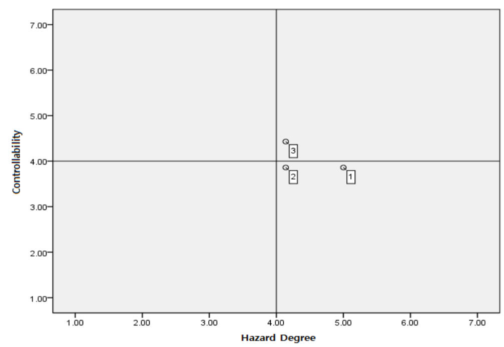
Primary risk factors	Classification code	Secondary risk factors	Classification code
Small construction cost saving effects	H2F1	Little contribution to construction cost savings	H2F1R1
Increase in escalator capacity	H2F2	Civil complaints caused by the reduction of facilities	H2F2R1
		Possibility of casualties due to the reduction of evacuation method in case of fire	H2F2R2

Qualitative assessment and classification of risk factors

Three secondary risk factors were derived for each of the high risk alternatives, that is, ‘the optimization of support patterns and blasting specifications of the tunnel section’ and ‘the deletion of stairs outside the station’. In this step, ‘controllability’ and ‘hazard degree’ were evaluated for each of the three secondary risk factors. For the assessment of the controllability and hazard degree, a survey was conducted on seven VE experts who participated in the case of ‘Design VE for OO Railway Roadbed Construction’. The following Table 6 and Table 7 show the controllability and hazard degree assessment results for the secondary risk factors of H1 and H2. Each result value was calculated by the mean value of the respondents. Based on this, the IPA-based zone classification is schematized as shown in Fig. 3 and Fig. 4.

[Table 6] Assessment results for the secondary risk factors of H1

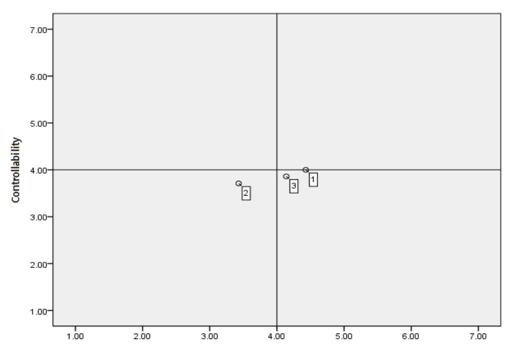
Secondary risk factors	Controllability	Hazard Degree	Number in Figure 3
H1F1R1	3.86	5.00	1
H1F1R2	3.86	4.14	2
H1F1R3	4.43	4.14	3



[Fig. 3] Assessment results for the secondary risk factors of H1

[Table 7] Assessment results for the secondary risk factors of H2

Secondary risk factors	Controllability	Hazard Degree	Number in Figure 4
H2F1R1	4.00	4.43	1
H2F2R1	3.71	3.43	2
H2F2R2	3.86	4.14	3



[Fig. 4] Assessment results for the secondary risk factors of H2

Results of case study

As a result of the case study, 'the optimization of support patterns and blasting specifications of the tunnel section' and 'the deletion of stairs outside the station' were derived as high-risk alternatives, and three secondary risk factors were ascertained, respectively. Then, the controllability and hazard degree for each of the secondary risk factors were assessed, and the results were analyzed according to the location of the quadrant. The H1 was not adopted because the secondary risk factors such as H1F1R1 and H1F1R2 were included in the Avoid Zone. The H2 was also not adopted because the secondary risk factor of H2F2R2 was included in the Avoid Zone.

Through the case study, it was possible to specifically and systematically analyze and evaluate the alternatives selected as high-risk alternatives. Therefore, it is expected that the practical application of the risk assessment process for alternatives will minimize the occurrence of returning alternatives.

Verification by expert interviews

In order to verify the practical applicability of the risk assessment process for VE alternatives proposed in this study, interviews with four VE experts were performed. The results of the expert interviews are summarized from four aspects as shown in Table 8.

[Table 8] Verification Results through Expert Interviews

Division	Detailed Description
Specific analysis of VE alternatives	The current evaluation of VE alternatives is limited to such items as workability and maintenance, and therefore it is difficult to specifically evaluate the alternatives on a systematic basis. Meanwhile, if the risk assessment process of VE alternatives proposed in this study is applied, the VE alternatives will be evaluated more specifically.
Complement of VE procedures	Since the VE task is performed with the creative idea generation of many stakeholders, the continuous improvements of the VE procedures are required for efficient VE tasks. The proposed risk assessment process can give a contribution to this.
Utilization	The risk assessment process can be utilized in VE tasks of various delivery methods, such as the Design Build, CM at Risk, IPD, etc.
Limitations on practical application	It is somewhat complicated to apply the risk assessment process for VE alternatives of this study.

CONCLUSION

This study proposed a risk assessment process for VE alternatives through the risk evaluation procedures, specific analysis of alternatives and the introduction of IPA techniques. The risk assessment process has its significance in that it specifically evaluates the VE alternatives on a systematic basis, and thus can minimize the occurrence of returning alternatives. It is thus expected to reduce the repetitive work for the returning alternatives, thereby contributing to improving the efficiency of VE tasks. In addition, it can be utilized as one of the application methods for risk management, which is an important area of construction project management.

Meanwhile, there is a need for research to quantitatively verify the improvement degree of VE task efficiency by minimizing the occurrence of returning alternatives through the risk assessment process proposed in this study.

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