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Applying the Integration of Value Engineering and Risk Management in Road Construction Projects (Case Study: Qazvin, Alamut, Tonekabon Section 5 Main Axis Project)

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Abstract

Value management is a systematic approach to achieving project goals. This process involves evaluating the project goals and the strategies to achieve them. It should be noted that value management is different from risk analysis. Risk analysis attempts to identify the uncertainties in the project implementation process. Combining value management with risk analysis provides a powerful tool for ensuring a project's success. Risk analysis attempts to identify the uncertainties in the project implementation process. Combining value management with risk analysis provides a powerful tool for ensuring a project's success. After identifying the strengths and weaknesses of the two management techniques, the need to combine them is stated. Using a Value Engineering (VE) workshop, risks in mass-production projects were identified, and a questionnaire was prepared accordingly. By distributing questionnaires among managers of mass-producing companies, information was collected about the risks in these projects. SPSS and LISREL were used to analyze and summarize the results for the research questions. The AHP method was used with Expert Choice software to rank the existing risks. In this thesis, the risks in construction projects were identified, and the results of this research show that the ranking test was conducted using the AHP technique. First, the inconsistency index k was calculated to be less than 0.05, indicating that the pairwise comparisons were correct and acceptable. Therefore, there is no need to revise the weights and comparisons made. Secondly, among the risks in the implementation of road construction projects, the priority of risks is in the following order: (risk arising from economic factors, risk arising from implementation, risk arising from the employer, risk arising from human resources, risk arising from natural factors, risk arising from political factors - risk arising from the design factor, risk arising from scheduling factors, risk arising from environmental factors, risk arising from legal issues, and risk arising from procurement).

Keywords: Value engineering, Risk management, Integrated model, Project management.

1 | Introduction

With the increasing growth of infrastructure projects and their increasing technical, financial, and time complexity, the need to use new management approaches to improve efficiency and reduce costs is increasingly felt [1]. Road construction projects, especially in mountainous and difficult-to-access areas, always

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face challenges such as resource constraints, environmental risks, economic fluctuations, and design changes [2].

Meanwhile, the two approaches of VE and Risk Management (RM), as efficient tools in project management, can be combined to optimize decision-making, increase productivity, and reduce direct and indirect project costs [3], [4]. VE analyzes the functions of project components and suggests alternative solutions to achieve goals at lower cost, aiming to improve performance and reduce costs without compromising quality [5].

On the other hand, RM helps reduce uncertainties and increase confidence in achieving project objectives by identifying, assessing, and controlling potential risks [6]. Combining these two methods can synergistically address each method's weaknesses and yield better results in the decision-making process for construction projects [7].

Several international studies have examined the combined application of these two approaches in construction projects [8]. The results of these studies show that integrating VE and RM at different project stages, especially during the design and planning phases, leads to reduced costs, improved quality, and shorter implementation delays [9].

Also, the use of these approaches in road construction projects has led to better identification of critical factors and optimization of technical and economic solutions [5]. The Qazvin-Alomt-Tonkabon main axis project, especially its fifth section, which is located in a mountainous area with complex geological conditions, is a prime example of projects that require integrated project management approaches [10]. The purpose of this research is to investigate the effect of using a combination of VE and RM on cost, time, and quality optimization in this specific project [5].

2 | Delphi Method

The present study examines the effectiveness of scientific theories in RM-VE integration. Given the research questions and prior research in this field, the Delphi method is among the best scientific methods for this study. In this way, first a questionnaire is designed and then distributed (the first stage of implementing the Delphi technique), after which the questionnaires are collected and reviewed. After studying and reviewing, several questionnaires were returned for corrections. Then the questionnaires are collected and reviewed again, and the influential factors are extracted. After the revised questionnaires are reviewed, the second stage of implementing the Delphi technique begins. In this way, the questionnaire is designed and distributed again.

Then, the questionnaires are collected, and the most important factors are extracted. The Delphi method is conducted with the participation of individuals with knowledge and expertise in the research topic. These people are known as the Delphi panel. The Delphi method is iterative. It is used to collect and use experts' opinions through questionnaires distributed with feedback. Questionnaires are designed to focus on problems, opportunities, solutions, and predictions. Each new questionnaire is created based on the previous one. This process stops when a consensus or agreement is reached or when sufficient information has been exchanged. The flexibility of the Delphi method is evident in its application. The basis of the Delphi method or technique is that the opinions of experts in each field of practice are the most authoritative in predicting the future.

Therefore, unlike survey research methods, the validity of the Delphi method does not depend on the number of participants. The validity of the Delphi method depends on the scientific credibility of the experts participating in the research. Participants in a Delphi study include 5 to 20 people. The minimum number of participants depends on the research method.

3 | Literature Review and Related Works

Several researchers have investigated the application of Value Engineering (VE) and RM either separately or in combination within construction projects. Shen and Liu [1] emphasized that VE helps identify critical success factors in construction by optimizing functions at reduced cost without sacrificing quality. Similarly, Munier [11] studied different risk analysis techniques in engineering projects and concluded that structured risk assessment improves decision-making reliability in complex environments.

Abdelalim et al. [12] proposed a risk-based decision-making framework for VE, highlighting that risk identification enhances the efficiency of value studies in large-scale projects. Banaitiene and Banaitis [5] examined RM in construction and argued that integrated approaches are essential to address both technical and financial uncertainties. Ismail et al. [13] provided a case study of a highway project in which VE and RM were applied together, showing that integrated models improve safety margins while controlling costs.

Despite these contributions, most previous studies have focused on general construction projects or industrial settings, with limited attention to road infrastructure in mountainous, geologically complex areas. Therefore, this research extends the literature by analyzing the combined use of VE and RM in the Qazvin-Alamut-Tonekabon project, which represents a highly challenging environment for project managers. This case study provides novel insights into the practical benefits of integrating VE and RM for infrastructure development.

4 | Analytical Hierarchy Process Model

One such common mathematical model is the Analytic Hierarchy Process (AHP). This is a mathematical method for determining the importance and priority of criteria in the evaluation and decision-making process. The AHP is a flexible and robust method used for decision-making in situations where conflicting decision-making criteria make choosing between options difficult. In evaluating any issue, we need a measurement criterion with an index. Choosing the right index allows us to make accurate comparisons between alternative variables.

But when several indicators are considered for evaluation, the evaluation task becomes more complex. The complexity of the task increases when several or more criteria are together in space and of different types. At this time, the task of evaluation and comparison goes beyond the simple analytical mode the mind is capable of. In this case, a powerful practical analysis tool will be needed. One of the powerful tools for such situations is the AHP. This method is used for leveling and grading.

Sometimes it may also be used for social and economic analysis. In this method, before any work, we must standardize the data for each location. The three steps are: 1) Creating a hierarchy tree, 2) Pairwise comparison, and 3) Determining the final score of the options and checking the consistency of the judgments.

5 | Analytical Hierarchy Process Technique

The AHP technique was first proposed by Saati [14]. This technique has been widely used to design and implement evaluation models that consider the relationships among effective criteria. This technique is one of the most comprehensive systems designed for decision-making with multiple criteria. This method was first widely used in industry. Today, this method is also used in other areas of decision-making. The AHP process can:

I. It allows modeling the decision problem as a hierarchical structure.

II. It provides a place to consider quantitative and qualitative criteria simultaneously.

III. It involves different options in decision-making.

IV. It is based on pairwise comparisons that facilitate judgment and calculations.

V. It shows the degree of compatibility and incompatibility of the decision.

VI. It has a strong theoretical basis.

6 | Identifying Risks

Risk identification is the most important step in the project RM process. In this process, all potential project risks are identified and listed. These risks are then prioritized after analysis, and appropriate actions are taken.

Since Hilson's definition of the risk structure in Risk Failure, this structure has been an efficient and useful tool for structuring RM processes and is used in many risk standards, such as the PMBOK. The risk failure structure is a resource-oriented hierarchical structure for categorizing risks in a project. As you move down the failure structure, the amount of detail about the sources of project risk increases; therefore, the risk failure structure, or hierarchical structure of potential risks, can be a valuable aid in determining the risks facing the project.

This structure has been used as a framework for determining RM processes. By using the risk failure structure obtained at the end of this research, we achieve a single framework for examining risks in construction projects. This reveals common, general risks and allows preventive action in future projects. In the first stage, using articles and interviews with experts in the field, the level one risk failure structure was divided into 2 internal categories, and at level two, it was divided into 10 areas, as shown in the figure below.

6.1| Justification of Tools and Methods

The choice of Delphi, AHP, and supporting software tools (SPSS, LISREL, and Expert Choice) was based on their complementary strengths in addressing the objectives of this study. The Delphi method was selected because it enables structured expert judgment and consensus-building in situations with high uncertainty, which is particularly relevant for risk identification in large construction projects.

SPSS was used to analyze the questionnaire results, providing descriptive and inferential insights. LISREL was employed to test structural relationships among risk factors, enabling deeper interpretation of the interdependencies among risk and value parameters. Finally, Expert Choice software was used for multi-criteria decision-making using AHP, which helped prioritize risks with high accuracy and consistency.

These tools together ensured methodological rigor by combining expert-driven insights with robust quantitative analysis. The integration of qualitative and quantitative approaches strengthened the validity and reliability of the findings, making the adopted framework suitable for complex decision-making in road construction projects.

7 | Disadvantages of Separate Implementation of Value and Risk

Experience with applying VE and RM separately shows that, although the purpose of both approaches is to optimize the project, in practice, RM practitioners are more focused on increasing safety and reliability in the system. In practice, they often impose costs on the project to address potential risks in the form of preventive costs or increased safety factors in design. As a result, RM is considered a costly approach. On the other hand, the VE approach seeks to reduce costs further. However, lower-cost solutions usually come with more risks and hazards. As a result, it seems that combining these two methods can achieve a real approach to cost optimization, rather than an incremental or decremental approach.

8 | Benefits of Combining Value and Risk

There are four main advantages to combining value and risk:

I. This combination enables simultaneous assessment of value and risk from the initial stages of the project, providing a comprehensive picture for decision-makers to develop a concept of opportunities and uncertainties.

II. This combination is more effective not only because of the method's quality, but also because it results in fewer workshops and more favorable outcomes.

III. Using this integrated tool eliminates inappropriate and inconsistent use. As a result, it creates a shared understanding within the team and a structured approach to identifying the client's goals. This reduces levels of confusion and makes it easier for the team facilitator and other members of the project workshop.

IV. The tool can be simple or advanced. Any type of value management, value analysis, and related RM tool can combine the situation and the conditions in a desirable way.

9 | Limitations and Future Research

This study was limited to a single case, which may limit the generalizability of the findings. The statistical tools used were limited to AHP, SPSS, and LISREL. Future research should explore the use of advanced techniques such as Fuzzy AHP, ANP, or Monte Carlo simulations. Additionally, the model could be validated across various infrastructure projects to establish broader applicability under different economic and environmental conditions.

10 | Managerial Implications

The results of this research offer significant insights for project managers. The integrated approach of VE and RM helps optimize engineering decisions, budget control, and project timelines. Managers are advised to conduct regular performance and risk evaluation meetings to minimize resource waste and increase efficiency. Moreover, implementing this model during the design phase can ensure better strategic decisions are made before execution begins.

11 | Implementation Framework

A step-by-step implementation framework for applying the integrated VE-RM model is as follows:

I. Define project objectives: identify performance metrics (cost, quality, time).

II. Perform a function analysis to determine the value of key project components.

III. Identify risks: use standard techniques such as PESTEL, SWOT, or RBS.

IV. Integrate VE and RM workshops by conducting joint analysis sessions.

V. Decision-making using AHP: evaluate and prioritize proposed alternatives.

VI. Execution and monitoring: implement selected solutions and monitor results.

This framework ensures a replicable, practical approach to utilizing VE and RM across various construction projects.

12 | Literature Review

Several international and national studies have investigated the integration of VE and RM in construction projects. For instance, Štilić andPuška [15] used AHP to analyze risks in engineering projects and demonstrated the effectiveness of combining VE with Multi-Criteria Decision-Making (MCDM) methods. Similarly, Wu et al. [16] presented a case study on highway construction in Taiwan, where the integrated use of VE and RM led to a 15% cost reduction.

In the Iranian context, studies such as “Formulating sustainable urban development strategies using SWOT, ACEPT, TOPSIS techniques (Case study: Kermanshah city)” by Ahmadi [17] emphasize the importance of combining modern approaches to enhance project management decisions. These findings confirm that simultaneous analysis of costs and risks can significantly improve decision quality and project outcomes.

13 | Discussion

The results of this research align with previous international studies on the integration of VE and RM. For example, Shen and Liu [1] demonstrated that applying VE leads to significant cost savings, while Munier [11] showed that risk analysis improves control over project uncertainties. The findings of the present study confirm that combining these two approaches not only enhances decision-making quality but also minimizes delays and unexpected costs in road construction.

From a practical perspective, the integrated framework can be applied by government agencies, consultants, and contractors as a systematic decision-making tool. For instance, project managers in road construction can use the model to prioritize risks related to economic fluctuations, environmental challenges, and technical complexities, while simultaneously identifying opportunities for value improvement. This ensures better resource allocation and greater project sustainability.

Moreover, the study suggests that employing the integrated VE–RM model supports more transparent communication among stakeholders, leading to stronger consensus in the planning and implementation phases. For future work, it is recommended that this model be applied to other types of infrastructure projects, such as tunnels, bridges, and urban transportation systems. Comparative studies across different contexts would further validate the framework's generalizability and refine its application in practice.

14 | Conclusion

In this research, the aim was to improve the performance of road construction projects and reduce costs and potential risks by examining the combination of two approaches, VE and RM. A case study on the main axis project in the fifth section of Qazvin-Alamot-Tonkabon showed that the simultaneous application of these two approaches can effectively identify low-value activities, reduce unnecessary costs, increase resource efficiency, and better manage uncertainties and potential threats to the project. The analyses showed that integrating VE and RM increased the accuracy of engineering and implementation decisions, enabling the correct prioritization of risks and the analysis of activity value, thereby providing more optimal solutions for the implementation of construction projects. It was also found that using this combined approach, in addition to reducing direct costs, also leads to improved quality, increased safety, and reduced project delays. Finally, it is suggested that employers and consultants of construction projects, especially in infrastructure projects such as road construction, utilize this integrated approach as an efficient tool in project management to achieve project goals with better quality and cost by improving productivity and reducing risk.

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Data Availability

All data supporting the results of this study were collected through field investigations, expert questionnaires, and the analytical methods outlined in the paper. Additional processed data may be provided by the corresponding author upon reasonable request.

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