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Research on the Path of Engineering Value Realization and Risk Control under the Guidance of Practice Orientation

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ABSTRACT

This thesis conducts an in-depth exploration of the value and risks of engineering, analyzing the diverse values created by engineering in economic, social, and environmental fields, while also dissecting various risks present in engineering practices. By integrating some practical cases, it studies strategies for realizing the positive value of engineering, explores effective methods for risk control, and focuses on the analysis of the definition, assessment, and management of acceptable risks. The aim is to provide theoretical guidance for engineering practices, promoting the maximization of positive value under the premise of ensuring safety.

KEYWORDS

Engineering value; Engineering risks; Risk control; Acceptable risk

1. INTRODUCTION

As an important practical activity for human beings to transform nature and promote social development, engineering runs through the development of human civilization [1]. From ancient water conservancy projects and construction projects to modern transportation projects, energy projects, information projects, etc., projects continue to create great value. However, while the project brings positive benefits, it also comes with many risks, such as safety accidents, environmental pollution, and social conflicts [2]. How to balance the value and risk of the project, realize the positive value of the project, effectively control the risk, especially the reasonable definition and management of acceptable risk, has become an important problem to be solved in engineering practice and research.

2. LITERATURE REVIEW

Engineering value is multi-dimensional, with many scholars emphasizing the role of engineering construction in promoting economic growth and acting as a medium for cultural communication. The realization of engineering value is a complex process involving multiple links such as technological innovation, project management, and stakeholder collaboration. Currently, an increasing number of scholars have recognized the value of engineering projects and conducted research on it.

Guan Yinxian [3] proposed that integrating water conservancy culture into water conservancy project construction has important guiding and practical value for contemporary water conservancy project construction, demonstrating cultural value. Wang Ting [4] et al. studied the public perception of value in major engineering projects based on social media comments and found that the value dimensions of major engineering projects mainly include five categories: service functional value, socioeconomic value, social value, emotional value, and cultural cognitive value. Yang Honglin [5] et al. analyzed world irrigation engineering heritage and proposed that engineering has extremely important practical and humanistic values. Wang Teng [6] et al. proposed in their study of urban roads that viewing engineering from the perspective of engineering value can fully leverage the advantages of preventive maintenance.

Engineering risks stem from a wide range of sources and are characterized by objectivity, uncertainty, complexity, and dynamics. Therefore, engineering risk assessment is the basis of risk control, and effective identification and control of these risks are crucial to project success, which has attracted much research in recent years. For example, Song Yuehao [7] et al. proposed a risk assessment model combining the risk identification matrix method and the analytic hierarchy process (AHP) for risk identification in water conservancy projects. Hu Yuanyuan [8] et al. used the risk matrix and AHP to analyze the influencing factors and their weights of social stability risks in first-class highway toll projects. Zhao Li [9] et al. selected a combination of AHP and fuzzy comprehensive evaluation method to construct a risk assessment model. Liu Na [10] established a multi-level fuzzy risk matrix assessment model, determined risk levels through calculations of this model, and obtained comprehensive risk values by multiplying the risk values of each factor by their weights and summing them up.

In summary, in recent years, with the continuous expansion of engineering scale, increasing technical complexity, and growing attention from all sectors of society to engineering impacts, research on engineering value and its risk identification and control has shown a significant growth trend.

3. ANALYSIS OF ENGINEERING VALUE AND RISKS

3.1. Multiple Values of Engineering

Engineering value is diverse, covering multiple dimensions such as economic, social, environmental, and cultural values.

3.1.1. Economic Value

Engineering construction is an important driver of economic development. Large-scale infrastructure projects represented by highways, railways, and ports can improve regional transportation conditions, reduce logistics costs between regions, promote economic exchanges, and drive the development of related industries. For example, the construction of China's high-speed rail has not only made travel more convenient but also boosted related industries such as steel, machinery manufacturing, and electronic information, bringing huge employment and economic benefits to the nation.

3.1.2. Social Value

Engineering drives social progress. Medical projects enable the public to receive better services and improve their health; educational projects improve school facilities and provide possibilities for educational equity; housing projects solve the problem of housing for the public and enhance their quality of life. Hope Primary School projects provide good learning conditions for children in poor areas, serving as a turning point in many children's lives and a landmark of educational equity and social progress.

3.1.3. Environmental Value

The environmental value of engineering is reflected in multiple aspects, including the protection of the natural environment, rational use of resources, and improvement of ecosystems. Under the concept of sustainable development, an increasing number of engineering designs and operations focus on the application of energy-saving technologies and fully consider impacts on ecosystems. Projects such as sewage treatment and waste classification can reduce pollutant emissions and improve the ecological environment. New energy projects, such as wind and solar power generation, help reduce dependence on traditional fossil fuels, lower carbon emissions, and mitigate global climate change. For instance, Beijing Daxing International Airport defined green construction goals from the outset. In its heating and cooling systems, it adopted a composite scheme of multi-energy complementation, including ground-source heat pumps, centralized gas boilers, boiler waste heat recovery systems, conventional electric refrigeration, and ice storage, successfully creating the largest multi-energy complementation ground-source heat pump project in China. This project can centrally meet the heating needs of nearly 2.5 million square meters of surrounding planned buildings, achieving an annual emission reduction of 18,100 tons of standard coal.

3.1.4. Cultural Value

From the perspective of cultural inheritance, engineering is a vivid witness to historical culture. Ancient buildings, in particular, represent the typical engineering of a dynasty, embodying the architectural craftsmanship, aesthetic consciousness, and social cultural connotations of that period. The Forbidden City continues and inherits the court culture, ritual systems, and historical culture of the Ming and Qing dynasties in the form of architecture. With the development of the times and technological progress, more new materials and technologies have emerged, driving cultural innovation. Many modern engineering buildings incorporate traditional Chinese craftsmanship into modern design concepts. For example, the new Suzhou Museum uses typical elements such as the pink walls and dark tiles of Suzhou in its architectural sculpt, combining the traditional charm of the Jiangnan water town with modern concise lines.

3.2. Types of Risks in Engineering Practices

The types of risks in engineering practices are diverse and complex, with risks faced in different links and fields having their own characteristics. This paper discusses them mainly from four dimensions: technical, management, environmental, and social.

3.2.1. Technical Risks

Technical risks refer to risks based on technology itself, specifically the uncertainty or impossibility caused by immature technical means, as well as risks caused by backward technology or too fast technological updates. For example, in super-high-rise buildings, problems in architectural design, construction technology, or materials can lead to structural safety issues. Deep-sea oil and gas extraction projects face equipment failures and mining accidents due to complex submarine topography and high extraction difficulty. Additionally, new technologies applied in construction projects may be updated and eliminated within a certain period after completion and operation. The new technologies used in engineering may become invalid because they cannot keep up with project development needs or be timely improved in combination with actual projects. For instance, some previously built data centers, if the project itself did not consider sufficient capacity, may need new renovations or upgrades due to excessive data volume or insufficient server Quantity just after commissioning.

3.2.2. Safety Risks

Safety risks are important types of risks in engineering practices, directly related to personnel life safety, engineering quality, and social stability. For example, if safety measures are not taken in a timely manner for problems such as high-altitude falls, blasting, and mechanical operations during construction, accidents causing injuries or deaths are likely to occur. In bridge construction, accidents such as scaffold collapse and lifting equipment failure may occur. Other major safety impacts at construction sites include injuries from falling objects and electric shocks from high-voltage power lines. In addition, attention should be paid to occupational health and safety issues in engineering, mainly referring to physical harm to people caused by the engineering working environment. For example, in underground tunnel excavation and chemical engineering, there are large amounts of dust and toxic and harmful gases. If workers do not take good protection measures while working in such an environment for a long time, they are likely to suffer from occupational diseases such as pneumoconiosis and poisoning, which not only seriously affect workers' physical health but may also bring economic losses such as medical compensation to enterprises and damage their images.

3.2.3. Environmental Risks

Engineering construction and operation may cause damage to the ecological environment. In terms of the natural environment, engineering construction is often affected by natural disasters such as earthquakes, floods, and typhoons. For example, port projects in coastal areas, if hit by strong typhoons during construction, may damage the completed foundation structure, interrupt the construction progress, and cause huge economic losses. Building projects in seismic zones, if the seismic design and construction are not up to standard, are prone to collapse and other serious consequences during earthquakes. Ecological environment risks refer to the damage to ecosystems caused by engineering activities. For example, the construction of water conservancy and hydropower projects may change river ecosystems, affect fish migration, damage wetland environments, and lead to a reduction in biodiversity. If mineral resource mining projects lack effective ecological protection measures, they will cause ecological deterioration such as soil erosion and land desertification, destruction the local ecological balance.

3.2.4. Social Risks

Social risks mainly involve social public opinion, changes in policies and regulations, and conflicts among stakeholders. Therefore, the public's attitude and views on engineering are crucial, as engineering may trigger social contradictions and conflicts. Land acquisition and demolition for large-scale projects may lead to damage to residents' interests and trigger mass incidents. Pollution such as noise and dust during engineering construction may affect the quality of life of surrounding residents, leading to complaints and disputes. Changes in policies and regulations also bring uncertainties to engineering. For example, if the national subsidy policy for the new energy vehicle industry suddenly changes, it may affect the investment plans and production scales of related enterprises, having a significant impact on the economic benefits of engineering. In addition, the interest demands of different stakeholders in engineering practices, such as developers, local residents, and environmental protection organizations, vary. If these interest relationships cannot be effectively coordinated, conflicts are prone to occur, interfering with the normal progress of engineering.

4. STRATEGIES FOR REALIZING POSITIVE ENGINEERING VALUE

4.1. Innovation-Driven and Technical Application

Innovation-driven and technical application are key levers for realizing the goodness of engineering. In addition to improving productivity and reducing costs, their more valuable aspect is to use technology as a gripper to exert greater social, economic, and environmental effects through systematic improvement of engineering technical solutions. It is necessary to encourage engineering innovation, actively adopt new technologies, new materials, and new processes, and continuously improve engineering construction quality and management level. For example, Singapore's "Smart Nation" initiative makes full use of technological forces. After investigating the national household and sensor networks, it identifies the needs of the elderly and prioritizes the deployment of devices to monitor falls, using technology to help all Singaporeans and accelerate the digitalization process.

4.2. Scientific Planning and Design

In the early stage of engineering, detailed scientific planning and design are required, as well as relevant research and demonstration. Engineering planning should be done according to local regional development, resource conditions, environmental capacity, and other factors. For engineering planning and design, a detailed understanding is needed. In this stage, the overall needs, goals, and relevant constraints of the project should be studied. Accurate data support for project decision-making is provided through analyses of market surveys, project scheme economic rationality, technical feasibility, environmental impacts, etc. For example, before the construction of urban rail transit projects, the route alignment, station layout, etc., should be comprehensively planned in combination with the city's population, traffic volume, and future development trends to increase the service efficiency and coverage of rail transit. The Guangzhou Metro Line 18 is a well-planned and convenient transfer line connecting Xiancun Station and Wanqingsha Station. As China's first 160 km/h fully underground suburban high-speed express line, it provides convenience for Mass travel.

4.3. Operation and Continuous Optimization

The operation stage is an important period for continuously generating economic benefits and exerting the full-life-cycle value of engineering. During operation, refinement operation and innovative technology management should be used to ensure the normal operation of all facilities and equipment in the engineering, extend the engineering life, achieve greater social effects, reduce the cost of the entire life cycle, and meet the functional requirements of social engineering. Take the Singapore MRT fault problem as an example: in 2015, the average number of kilometers traveled by each Singapore MRT train before a fault was 1.33 million km, which increased to 1.64 million km in 2020 and 2.68 million km by 2023.

4.4. Multi-Stakeholder Collaboration and Public Participation

Multi-stakeholder collaboration and public participation can not only integrate multiple resources, draw on various professional knowledge, improve decision-making scientificity, and promote engineering development but also involve many aspects in engineering construction, such as owners, design units, construction units, supervision units, research institutes, etc. Each has its own advantages and can conduct analyses and evaluations at different levels. Through coordination, the work of all parties can be matched, conflicts reduced, and the advantages of all parties integrated to form complementary advantages. The public can be encouraged to participate in engineering decision-making, construction, supervision, and other activities through multiple channels to improve their sense of identity and satisfaction. Take waste treatment projects as an example: when determining the location of waste treatment plants, the public can be involved in the decision-making process through holding hearings and soliciting residents' opinions.

5. ENGINEERING RISK CONTROL PATHS

Engineering risk control can be carried out in stages, including the pre-planning stage, design stage, implementation stage, and operation stage.

5.1. Pre-Planning Stage

In the early stage, engineering risk identification and risk assessment should be done well. Common methods for risk identification include expert investigation, brainstorming, checklist method, etc., which are used to comprehensively identify various possible risk factors. For example, in the risk identification of tunnel projects, geological experts, construction experts, etc., can be organized to analyze the geological conditions and construction methods of the tunnel crossing, and potential problems such as collapse and water inrush can be found. In the early planning stage of the Xiong'an New Area underground space development and construction, more than 30 experts were invited to independently assess the risks of underground space development in Xiong'an New Area. There are also many risk assessment technologies, generally using a combination of qualitative and quantitative risk assessment methods, such as risk matrix method, fault tree analysis, Monte Carlo simulation, etc., to assess the identified risks to determine the possibility of risk occurrence and the severity of consequences, providing a basis for risk control. For example, in the analysis of the construction period delay of the Shanghai Tower, the Monte Carlo simulation method was used to simulate through variable analysis, obtain the probability distribution, and calculate the delay days and probability.

5.2. Engineering Design Stage

Risk control in the engineering design stage is very important, related to engineering quality, cost, and progress. In the process of engineering construction, attention should be paid not only to the engineering progress but also to establishing a risk monitoring system, strengthening communication within the team, and real-time tracking of changes in the external engineering environment. Specific risk monitoring objectives should be determined according to the different requirements and characteristics of engineering design, such as whether the design complies with relevant specifications, whether the design can be completed on time, and whether the design cost is controlled within the engineering budget. Information technology should be used to build a communication platform, and regular coordination meetings should be organized for the design team, owners, construction units, etc., to communicate and understand the design progress and solve problems and suggestions put forward by all parties. The design scheme should be timely revised according to changes in national and local regulations, policies, and technical standards. For example, when encountering new environmental protection policies to improve building energy efficiency design, the design team needs to adjust the design of the building envelope, material selection, and equipment selection to make the building energy efficiency design more in place.

5.3. Implementation Stage

During the engineering implementation process, progress monitoring, quality monitoring, safety monitoring, cost monitoring, and environmental monitoring should be carried out well. According to the requirements of the total construction period, prepare a detailed construction progress plan, clarify the start and end time nodes of engineering projects, as well as the completion time of key projects. Check whether the construction party's safety production system is sound, whether the safety management organization is complete, and whether the personnel of the safety department are in place. Determine the engineering quality standards and acceptance requirements, implement the project cost control target value of the engineering construction contract and budget, divide the project cost target value into each sub-project and construction stage according to the sub-projects, and carry out dynamic tracking in combination with the engineering situation, strictly control and limit the expenditure of various costs, and ensure that all costs do not exceed the project's estimated cost. In addition, the environmental pollution problems (such as noise, dust, wastewater discharge) that may be caused by engineering construction to the surrounding area should be considered, and the environmental quality of the construction site should be monitored at fixed points. If environmental problems are found, the construction unit should be actively urged to rectify them to avoid unnecessary contradictions, disputes, or penalties due to environmental protection issues in the later stage.

5.4. Operation Stage

Risk monitoring in the engineering operation stage mainly involves three aspects: equipment and facility risk monitoring, safety risk monitoring, and performance & benefit risk monitoring. Formulate a detailed work plan to complete daily inspections of equipment and facilities. Determine specific inspection contents based on the inspection items, cycles, and standards specified in the equipment manuals, combined with the operational status of the equipment. Develop a practical maintenance plan for equipment and facilities to ensure their stable operation.

Ensure that all safety regulations during the operation stage are effectively implemented, including personnel access control, safe operation procedures, emergency response plans, etc. Establish a hidden danger inspection mechanism to promptly detect new safety hazards. According to the monitoring system, regularly collect Key Performance Indicator (KPI) data, analyze and evaluate whether the actual operation effect of the project meets the expected goals. Conduct user satisfaction surveys in a timely manner, solicit suggestions and opinions from users on project operation services, and check whether users are satisfied with the comfort, safety, and convenience provided by the building. When any abnormal performance indicator is detected, promptly analyze the causes and propose specific improvement measures.

6. ANALYSIS AND MANAGEMENT OF ACCEPTABLE RISKS

6.1. Definition of Acceptable Risks

Acceptable risk refers to the risk limit that a society, organization, or individual can tolerate under given conditions. Influencing factors include cultural background, social values, economic development level, laws and regulations, etc. The standards for acceptable risks vary across different countries, regions, industries, or engineering projects. For example, civil aviation is a high-risk industry requiring strict safety conditions, so its acceptable safety risk is low, while some low-risk small-scale projects may have higher acceptable risks.

6.2. Assessment Methods for Acceptable Risks

6.2.1. Assessment Based on Cost-Benefit Analysis

Cost-benefit analysis is a method to balance how to adopt measures with minimal costs to avoid risks. It quantifies and compares the potential costs of taking measures with the effects that such measures can achieve. If the benefits outweigh the costs, adopting risk response measures is economically feasible, meaning the risk can be accepted. However, if the costs brought by the risk exceed the benefits, careful consideration is needed before deciding whether to adopt the measures, unless there are non-economic reasons necessitating such actions.

6.2.2. Fuzzy Comprehensive Evaluation Method

Using fuzzy mathematics theory, this method converts fuzzy risks into quantitative evaluation results. First, determine the evaluation index system and evaluation set; then establish a fuzzy relation matrix, synthesize the evaluation results of each index, and obtain the fuzzy comprehensive evaluation result of the risk. For example, when evaluating the risks of a certain engineering project, the evaluation indices may include technical difficulty, construction environment, management level, etc.; the evaluation set can be high risk, relatively high risk, medium risk, relatively low risk, and low risk. The fuzzy evaluation method is used to obtain the evaluation results of each index, establish a fuzzy relation matrix, and combine the weights of each index to calculate the comprehensive risk evaluation result of the engineering project, thereby determining whether the project risk falls within the acceptable range. This method can handle fuzzy and uncertain risk information and provide ideal evaluations for non-quantifiable risk factors. However, it requires pre-defining the membership function of the fuzzy relation and determining the weights of each index, which involves subjective judgments and may make the understanding of evaluation results difficult.

6.2.3. Brainstorming Method

Gather industry authorities and project participants to brainstorm, inspire ideas, and comprehensively identify all potential risks. Then evaluate whether the organization can bear these risks. For example, in brainstorming for new product R&D projects, issues such as demand changes, technical challenges, and competitors launching similar products may be discussed to decide whether the project should continue. Everyone can give full play to their subjective initiative, think deeply, and collect rich information to form a series of ideas. However, its disadvantage is that some people may tend to consider problems based on their own experience, leading to a one-sided perspective or confusion due to excessive information. Therefore, the advantages and disadvantages of this method are both evident.

6.2.4. Event Tree Analysis (ETA)

Starting from the occurrence of a certain event, this method analyzes the process step by step, considers the possibility of each event occurring in the process, and quantifies the possibility of each result by combining these possibilities, thereby obtaining the risk (i.e., the possibility of all consequences) brought by the final event. For example, for a fire incident, "fire occurrence" is taken as the initial event, and the results of various situations are analyzed, such as whether the alarm can be normally activated after the fire, whether firefighters can arrive in time, and whether corresponding fire extinguishing measures are taken, including the probability of casualties or property damage. Through this method, it can be determined whether the risk of a fire accident is acceptable.

6.2.5. Assessment Based on Public Participation

Risk assessment is not only a technical task for professionals but also closely related to people's vital interests and social values. Public participation makes risk assessment more comprehensive and objective, closer to the fundamental interests and needs of the public, and the assessment results more persuasive and credible. Risk assessment based on public participation is an evaluation of public opinions, values, and needs. In the assessment process, the role of the public should be fully emphasized. The public can be invited to express their views on issues of concern through questionnaires, public hearings, etc., and incorporate public opinions into the acceptable risk assessment system.

6.3. Dynamic Management of Acceptable Risks

Acceptable risks are not fixed; they will continuously adjust the risk level and corresponding control measures over time due to changes in external and internal factors, such as technological development, social concept updates, and regulatory updates. Regular risk assessments of projects should be conducted, and a monitoring system for risk factor monitoring, periodic evaluation, and information feedback collection should be established to promptly detect risk changes. Adjust corresponding response plans according to actual situations, adopt new methods and technologies, and optimize management processes. Strengthen internal and external collaboration among departments, enhance information transmission between superiors and subordinates, and form good hierarchical relationships and interconnected business exchanges. Set evaluation indicators including risk control effects, costs, benefits, etc., evaluate the current management status through periodic tests, and further optimize the risk management system. The ultimate goal is to achieve dynamic optimized control of acceptable risks, enabling projects or organizations to develop healthily at a certain risk level. For example, as environmental protection receives increasing attention, the public has higher requirements for the environmental impact of engineering construction, so relevant parties may adopt stricter criteria to measure whether such impacts are acceptable.

7. CONCLUSION

Engineering has multiple values such as economic, social, and environmental values, but it is also accompanied by various risks including technical, safety, environmental, and social risks. Realizing positive engineering values requires strategies such as innovation-driven technical application, scientific planning and design, operational continuous optimization, and multi-stakeholder collaboration. Risk control should run through all stages of engineering, including pre-planning, design, implementation, and operation. The reasonable definition and dynamic management of acceptable risks are the key to balancing engineering values and risks. In engineering practice, all factors should be comprehensively considered, the risk management system continuously improved, and sustainable development promoted to create greater value for society. In the future, with the continuous advancement of technology and changes in social needs, research on engineering values and risks will face new challenges and opportunities, requiring continuous in-depth exploration.

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