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Cost Control and Risk Management of Civil Engineering Construction Projects

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Abstract. The civil engineering industry is highly competitive and cost control and risk management are necessary. This paper focuses on the cost control and risk management of civil engineering construction projects. Although numerous cost control techniques and risk management frameworks have been developed, a notable gap remains between theoretical models and practical implementation. Key factors affecting cost control include material procurement, construction period, and personnel turnover. Measures can be taken in these three aspects to control costs. Risk management covers four links: risk identification, assessment, response, and monitoring, and a systematic approach is required to deal with risks. The effective combination of cost control and risk management, such as establishing a risk-driven cost control system, can enhance project benefits. To achieve comprehensive project management, it is necessary to construct a full-life cycle cost control framework and a risk matrix assessment mechanism. The combination of cost control and risk management ensures the success of the project.

Keywords: Cost control, risk management, engineering, construction projects

1. Introduction

Significant advancements have been made in the field of cost control and risk management in civil engineering construction projects. Scholars have proposed a variety of cost control methods such as the target cost method, Value Engineering (VE), and standard cost method, and combined with big data technology to achieve cost prediction and dynamic monitoring. In the domain of risk management, a systematic framework for risk identification, assessment, response and monitoring has been established.

Despite these theoretical advancements, practical application remains limited. This paper focuses on the application of cost control and risk management strategies within real-world civil engineering construction projects. The research addresses three core issues:

1.Strategies for controlling the overall cost of civil engineering projects;

2.Practical methods of risk management applicable to construction environments;

3.The integration of cost control and risk management into a unified approach to achieve comprehensive project management.

The research methods in this article is primarily literature Research. Studying the cost control and risk management of civil engineering construction projects is of great significance. Cost control is

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an essential process to attain project success and enhance its value [1]. It can help enterprises has reasonably funds, reduce unnecessary expenses and enhance economic benefits. Futhermore, it enables the early identification of risks, the formulation of countermeasures and ensures the smooth progress of projects. Finally, it avoids construction delays and quality issues, safeguards the enterprise's reputation, and promotes the healthy development of the civil engineering industry.

2. Cost control

2.1. The factors of cost control

With the development of the world economy, increasing attention has been placed on the duration and cost of projects [2]. Multiple factors influence cost control, including material procurement, construction schedule, and workforce stability.

In terms of material procurement, the material procurement link has a significant impact. If the procurement timing is not properly grasped, for example, materials are purchased during the peak price period, the cost will inevitably increase substantially. If the quality of materials is not strictly controlled, rework and replacement of defective products will incur additional expenses. Furthermore, reliance on unreliable suppliers or lack of bargaining power can drive up procurement prices, ultimately elevating the overall project cost.

Regarding the construction period, firstly, an extended construction period will directly increase direct costs such as labor, machinery leasing, and material storage. The daily average cost usually accounts for 0.3% - 0.5% of the total project cost. Secondly, indirect costs such as management fees, loan interest, and site maintenance fees increase linearly with the construction period. For every 1% increase in the interest rate and every one-month extension of the construction period, the financial cost will rise by approximately 0.2%. Therefore, reasonably shortening the construction period of the critical path and optimizing resource allocation can reduce the total cost by 8% - 12%.

As for the turnover of personnel, it has a significant impact on the cost control of civil engineering construction projects. Personnel recruitment cost is an important issue. High employee tureover triggers this charge [3]. When new employees join, time and resources need to be invested in their training, and the training cost for each person may reach several thousand yuan. Frequent personnel changes are likely to cause poor work handover, leading to project delays. Each day of delay may incur an additional cost ranging from several thousand to tens of thousands of yuan. When skilled workers leave, the overall efficiency of the team decreases, which increases labor costs.

2.2. Methods to control cost

Based on the three factors above that affecting cost control, a guaranteed cost control gain is obtained through a convex optimization problem [4], the methods of controlling cost can be discussed in three aspects.

First, the cost of material procurement accounts for a high proportion of the total project cost, and it is of great significance to control this. Before procurement, it is necessary to conduct a comprehensive market survey and conduct an in-depth analysis of the price trends of materials. At the same time, establishing long-term and stable cooperative relationships with high-quality suppliers can make sure the product quality and the timeliness of supply. Accurately accounting for the quantity of materials is also crucial. With the help of BIM technology, lower inventory costs and material losses can be achieved.

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Second, reasonably controlling the construction period is an important part of cost control. Formulating a scientific and reasonable progress schedule is the foundation. Utilizing network planning technologies allows for the optimization of resource allocation, thereby avoiding issues such as idle labor, rework, and time wastage. In addition, actively adopting advanced construction technologies and equipment can greatly improve construction efficiency and avoid the increase in costs such as labor and machinery leasing caused by backward technologies leading to an extended construction period.

Personnel mobility also has an impact on project costs. Establishing a perfect incentive mechanism and an excellent corporate culture can improve employee satisfaction and reduce the staff turnover rate. During the recruitment process, strict screening should be carried out to ensure that the recruited personnel have the corresponding qualities and stability, and reduce the recruitment and training costs caused by frequent personnel changes. Moreover, conduct efficient training for new employees in order to help them quickly get familiar with work processes and requirements and avoid the increase in costs due to poor work connection and low efficiency.

In conclusion, by taking approaches from material procurement, construction period, and personnel mobility, and implementing cost control measures, civil engineering construction projects can achieve significant improvements in both economic efficiency and overall competitiveness.

3. Risk management

3.1. The concept of risk management

Risk identification, assessment, and mitigation have been widely used for effective risk management in international construction projects. However, contractors sometimes cannot know what risk exists, and even when they identify the risk, they sometimes do not know the impact on project cost or how well it can be mitigated after award [5].

The risk management of engineering construction projects is a dynamic management process that aiming to ensure the achievement of project objectives. It includes the following four key aspects:

The first part of Risk Management is risk identification. Risk identification is the process of systematically searching for potential risks in a project through structured methods. The most common risk division is classified in terms of occurrence frequency and the scope of impact [6]. Common types include natural risks, technical risks, managerial risks, and external risks. The process enables stakeholders to anticipate and prepare for various contingencies. Many of these risks can be mitigated or even avoided with proactive planning. The second part is risk assessment, which is the process of determining the risk level using both qualitative and quantitative methods. Through Probability Analysis, Impact Assessment, Matrix Analysis and Sensitivity Analysis, the risks during the project can be easily assessed. The third part is risk response. It is the process of formulating targeted strategies, following the principle of "prevention first, combination of prevention and control". It can be divided into four parts, Avoidance Strategy, Mitigation Strategy, Transfer Strategy, Acceptance Strategy. These strategies help assess risks during the whole construction project. The last section is risk monitoring. Risk monitoring is the process of implementing dynamic tracking and optimization, including: Process Tracking, Early Warning Management, Change Control, Emergency Response and Post-assessment Mechanism. These methods help monitor the risks after risk identification, risk assessment and risk response, and get ready for dealing the risks.

This system achieves continuous improvement and manage risks. The accuracy of risk prediction is improved through technologies such as big data analysis and artificial intelligence, refined

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development of engineering construction project management and make preparation to deal with the coming risks.

3.2. Methods of dealing with risks

In the construction sector, a systematic risk management method must be used to limit the unfavorable effects of these risks, both collectively and individually, on the building project [7]. Building upon the four stages of risk management discussed above, the following methods offer practical approaches for risk handling and problem resolution.From the perspective of risk identification, a multi-dimensional identification system can be adopted, covering risks such as geological and hydrological conditions, design defects, construction techniques, environmental impacts, and schedule delays. Through expert interviews, historical data review, on-site inspections, and the SWOT analysis method, a risk list is constructed. For example, a bridge project in Harbin discovered the risk of underground obstacles in advance through 3D geological modeling.

From the aspects of risk assessment, it is important to use the LEC method (risk matrix) to quantify the risk levels, and evaluate quantitative indicators. Establish a risk database, and classify and manage more than 200 identified risks. For example, the gas outburst during shield construction is classified as a Grade I risk, and a special emergency plan needs to be formulated. Determine the risk weights through the Analytic Hierarchy Process (AHP) to form a dynamic assessment report.

The third way to deal with risk is to form risk respond strategies. These include avoidance (eliminating the risk), mitigation (reducing the impact), transfer (shifting the risk to a third party, such as through insurance), and acceptance (acknowledging the risk without immediate action, but with contingency plans in place).

As for risk monitoring, it is necessary to build an intelligent monitoring system. During the construction stage, BIM+GIS technology can be used to monitor the deformation of deep foundation pits, and automatically issue an alarm when the settlement rate exceeds 3mm/d. In schedule management, Primavera software can be applied to conduct dynamic schedule compression simulation, and start the rush work plan when the delay of the critical path exceeds 7 days. As for emergency management, establish a three-level response mechanism. For instance, for the risk of low temperatures during winter construction in Harbin, reserve emergency supplies such as electric blanket heating systems.

Through full-life cycle risk management, the project risk occurrence rate can be reduced by more than 40%. For example, a housing project in Harbin achieved zero safety accidents and completed the project 28 days ahead of schedule through risk pre-control. It is recommended to establish a risk knowledge base and regularly update the response measures to achieve continuous improvement in project management.

4. Combine cost control and risk management

In civil engineering construction projects, the effective combination of cost control and risk management is the core to enhance project benefits and ensure the achievement of project objectives. Value at Risk (VaR), a fundamental concept in the financial field, functions as a precise instrument that, under a certain confidence level, estimates the maximum potential loss of a financial asset or investment portfolio within a specific future timeframe [8] The following methods can combine cost control and risk management effectively.

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4.1. Risk-driven cost control system

Establish a dynamic cost model based on risk assessment, and use tools such as Monte Carlo simulation to quantify the impact of risk events on costs. For example, in the deep foundation pit support project, it is necessary to simultaneously consider the risk of changes in the support scheme caused by the uncertainty of geological conditions and the risk of fluctuations in steel prices. Adopt Earned Value Management (EVM) to monitor the Cost Performance Index (CPI) and Schedule Performance Index (SPI) in real time is a good way to solve the problem.

4.2. Whole life cycle cost risk management

This method mainly introduces Value Engineering (VE) and risk matrices in the design stage, and conducts 4D cost risk simulation through Building Information Modeling (BIM) technology. During the construction phase, adopting a cost risk early warning indicator system to transform risk factors such as fluctuations in the prices of main materials and labor disputes into cost control parameters can save cost and reduce the risks.

4.3. Dynamic monitoring and emergency response mechanism

A two-dimensional "cost-risk" monitoring platform should be built to integrate real-time data from Internet of Things (IoT) sensors and visual feeds, allowing for the immediate detection of construction progress and cost deviations. A three-tier emergency response mechanism can then be activated to initiate appropriate cost control plans based on the risk level, improving responsiveness to dynamic changes.

4.4. Contract management and risk sharing mechanism

Optimizing contract terms is critical, especially in Engineering, Procurement, and Construction (EPC) contracts. For instance, in an affordable housing project in Harbin, by setting adjustable price clauses, the risk of steel price fluctuations was shared between the owner and the contractor in a ratio of 7:3. A maximum price limit mechanism was agreed. Additionally, incorporating engineering insurance and guarantee systems can transfer systematic risks, such as those caused by force majeure events, and mitigate the likelihood of cost overruns.By constructing a risk-oriented cost management system, the transformation of cost control from passive correction to active prevention can be realized. Cost and risks highlighting the need for a life-cycle-informed approach to optimal management of infrastructure systems[9]. According to the China Construction Industry Association, for projects implementing the collaboration between cost and risk management, the average cost deviation rate has been reduced to 3.2%, a decrease of 47% compared with the traditional mode.

5. Achieving comprehensive project management

In civil engineering construction projects, the collaborative management of cost control and risk management is the key to achieve comprehensive project benefits. The two form a closed-loop management system through dynamic balance. Higher resource and technology costs are typically associated with shorter project durations [10]. Firstly, a full-life cycle cost control framework needs to be established, and risk prevention costs should be included in the budget preparation. For example, contingency fees should be reserved to deal with potential risks such as changes in

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geological conditions. Secondly, a risk matrix evaluation mechanism should be constructed to identify key risk points. Thirdly, a dynamic monitoring and early warning system should be implemented. Internet of Things devices are used to collect construction data in real time, and big data analysis is combined to predict cost deviations. Finally, a flexible emergency response mechanism should be established. For force majeure events such as extreme weather, risks can be transferred through insurance strategies, and at the same time, the construction organization design should be optimized to reduce the loss of idle work. The methods above help achieving the comprehensive management of the project.

6. Conclusion

This paper concludes that in civil engineering construction projects, cost control is affected by material procurement, construction period, and personnel turnover. Risk management, which comprises four essential components, must be effectively integrated with cost control to optimize project outcomes. To achieve comprehensive management, a full-life cycle cost control framework and a risk matrix assessment mechanism are needed. However, the research has limitations. Most of the cost control and risk management methods lack practical verification. Future research could focus on real - world case studies to test and improve these methods. Additionally, exploring more advanced technologies to enhance the accuracy of risk assessment and cost prediction would be beneficial.

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