Research on Risk Identification and Supervision Intervention Mechanisms in the Construction Phase of Building Projects

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Abstract: Construction stage is the most intensive and high-risk stages of construction projects which included many kinds of risk types and complex influence factors. It affects directly the quality, safety, schedule and cost control of a project. The scientific identification of potential risks and the establishment of effective supervision intervention mechanisms during construction have become key problems in engineering management. This study specifically revolves around the construction phase. It firstly identifies the features and factors of risks on construction, building up a risk identify framework from multiple dimensions of safety, quality, schedule, cost and environment. Secondly, according to the responsibilities and functions of supervision work, it explores key intervention mechanisms in three stages: risk pre-control stage, risk handling stage and post-risk assessment stage), proposing a model linking risk identification with supervision intervention. Finally, three-dimensional pathways for optimization are provided from institutional policy, technical means and organizational safeguards, to provide systematic references for enterprise risk management in the construction phase of building projects. Results show that by establishing an optimized risk identification method and a strict supervision intervention mechanism, the research system not only reduced the occurrence and severity of construction risks but also improved the rigor and scientific attitude of supervision work. It has great significance for promoting the standardization and intelligent management of engineering construction project.

1. Introduction

In recent years, with the rapid growth of China's construction industry and the increasing difficulty of engineering projects, risks in the construction phase are becoming more and more prominent [1]. construction information system construction process As a core implementation stage, this period has been a stage prone to accidents and quality issues. It hinders the economic and social gain of projects as safety incidents, schedule delays, quality defects, and cost overruns occur quite frequently. It has become an important issue that needs to be further researched in construction project management, from scientifically identifying potential risks during construction, and establishing effective supervision intervention mechanism [2].

Construction risk management has received significant attention from scholars around the world both theoretically and practically [3]. International studies, notably in the UK, cultivated a robust and comprehensive approach towards understanding risk across three phases — identification, assessment and control KR; BAH; Parker et al.. However, domestic research has mainly centers on practical engineering application and technology like the safety risk, schedule management or quality control. The existing methods for identifying risks during construction are still limited, and they do not have systematic and dynamic identification approaches [4]. Underutilization of supervision to control construction risks, and imperfect intervention mechanism. The application of information and intelligent technologies in construction risk management still needs to be improved.

This paper analytically provides a systematic risk recognition framework used for determining primary type of risk during the construction process, which may be applied to the construction phase [5]. Merging supervisory tasks with the execution of stable work, it puts forward a three-level intervention mechanism covering risk pre-control, risk management and post-risk evaluation.

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Institutional policies, technical means and organizational safeguards present paths for optimization. The innovations of our article are: firstly, systematic methods to achieve multidimensional risk identification; secondly, the diversion of intervention mechanisms for different phases in the construction process and integration of risk recognition with supervision; thirdly, the use of novel information technology can provide directions for intelligent development in construction process risks [6]. The research has theoretical guiding significance and practical effect on risk identification, and supervision intervention during the construction of building project, promoting improvement of risk ability management and the integrated upgrading of engineering quality security.

2. Risk Identification Framework for Construction-Phase Building Projects

The risk during construction phase has certain characteristics such as high uncertainty, influence scope and multi-factor coupling [7]. The construction process requires large amounts of personnel, materials and machinery, combined with complex and variable environmental conditions leading to a much higher frequency and damaging potential of risk events during this phase than any other. Construction-related risks extend beyond conventional safety concerns to a variety of aspects: quality, schedule, cost, environmental impact and policy. In risk management practice, the comprehensive and systematic identification and classification of construction phase risks is crucial for laying a foundation for subsequent supervision interventions and risk control [8]. The probability of risk occurrence during the construction phase can be expressed as follows:

$$P_i=\frac{n_i}{N}(1)$$

For risk identification methods, classical methods could be used including expert judgment, analytic hierarchy process (AHP), and Delphi method [9]. Moreover, the fuzzy comprehensive evaluation method and grey system analysis can also be applied to quantitatively evaluate complex risk factors scientifically. Dynamic risk identification based on data mining has become a research hotspot in recent years with the development of big data, Internet of Things (IoT), and artificial intelligence (AI) technologies [10]. The real-time monitoring of construction site data such as personnel behavior, equipment operating status, and environmental parameters allows for early warning before potential risks can avoid some risk situations to shift the focus on In-situ Semantic analysis techniques ensure fine-grained accuracy in identifying hazards and risk factors.

In terms of risk classification system, construction stage risks are generally divided into the following five major categories: 1. Safety risks, mainly manifested in accidents such as collapse, falling from high altitude and machinery injury; 2. Quality risk refers to poor material used, non-standard construction methods and concealed works; 3. progress risk including project delay, workflow coordination failure and resource allocation inadequacy; 4. Cost-risk means the cost overruns and budget increase, price fluctuations and contract disputes; The fifth is environmental policy risk includes extreme climate weather, stricter environmental requirements or new policies/decrees issued by regulatory authorities. Scientifically categorizing these risks allows supervisors to take more focused actions at various stages.

Build a “multi-dimensional, multi-tiered” risk identification framework for construction phase. Based on risk signature, leveraging identification approaches as instruments, and backed by a discretized taxonomy, the framework forms an adaptive-risk-based scalable architecture for managing these risks. By using this framework, systematic risk identification during construction phase is realized which could provide theoretical basis and data support for construction supervision interventional mechanism to improve the level of risk management during construction period.

3. Establishing Construction Phase Supervision Intervention Mechanisms

During construction, intervention mechanisms in supervision is a key concern in ensuring the execution of projects and avoiding Risks. They embody of the embedding of supervision at all stages of the risk management process. Specifically, supervisors need to not only establish pre-risk controls and reduce the probability of risk events through construction organization design review of documents, technical briefing sessions, and risk warning systems before the event occurs; But also actively intervene during during risk outbreak process to implement emergency response measures for safety incidents and quality rectification control but also progress control measures to minimize casualties. In addition, supervision should carry out post-event evaluation and feedback, summarize the lessons learned from the event, continuously improve its own risk database, and feed supervision knowledge and risk prevention experience into design and construction management through the closed loop with both dynamic ability to form a closed-loop dynamic management. Following this basis, the supervision intervention mechanism in this paper is based on risk pre-control, risk handling and post-risk assessment and feedback three level tools for classification discussion.

3.1 The Role and Mechanism of Supervision in Risk Pre-control

During the construction phase, a critical step for preventing potential risks from snowballing into actual accidents is to utilize risk pre-control. Supervision is essential in this process both for organizing, supervising and guiding the same. By reviewing construction organization designs, supervision can provide suggestions for optimization to preemptively identify potential safety hazards and technical defects in construction plans and ensure the rationality of construction schemes. Supervision is involved in technical presentation and construction plan discussion, clarifying key control points of what the contractor wants to implement. This facilitates construction staff awareness and reaction concerning potential risks, thus decreasing the probability of accidents at onset. The expected loss is quantified through the following formula:

$$I_i = \sum_{j=1}^{m} w_j \cdot s_{ij} \quad (2)$$

The total risk exposure is calculated by combining multiple risk factors as shown below:

$$RPN_i = P_i \cdot S_i \cdot D_i \quad (3)$$

Supervisors also set up and carry out risk warning systems, monitoring important indicators in the course of construction. Early detection of abnormal conditions can achieve dynamic monitoring of high-risk processes, key structural nodes, critical construction machinery and environmental factors. Contractors receive caution alerts and are expected to take correction actions. This mechanism allows for enhanced proactive supervision and faster response by the contractors, achieving early risk detection and prevention. The distribution of construction risk categories is illustrated in Figure 1:

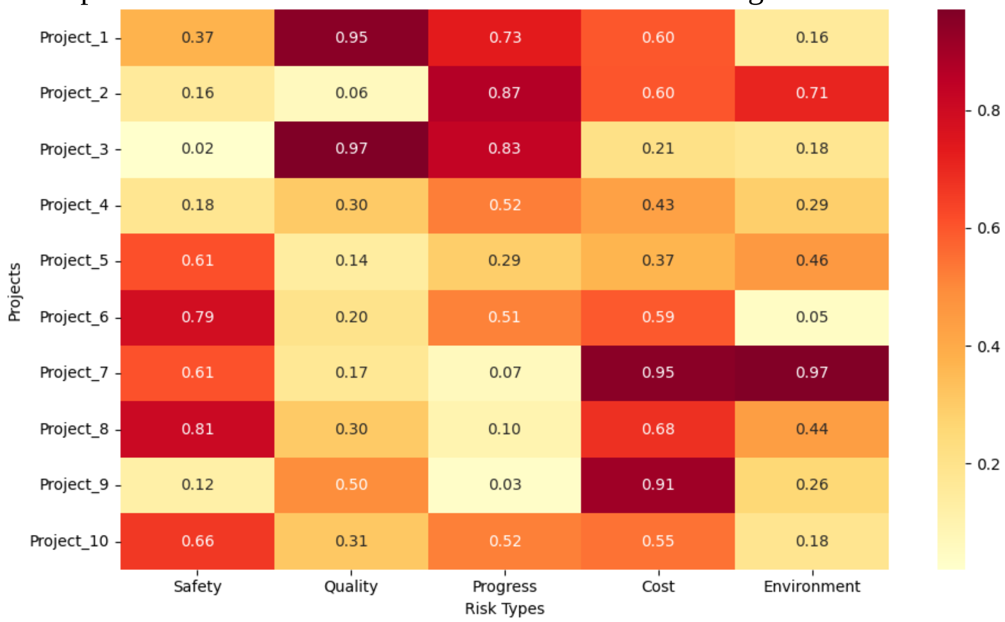

Figure 1 Risk Probability vs Impact Heatmap

At the level of regulatory bodies, risk ledgers and responsibility lists can be implemented to associate different risks with relevant supervisory responsibilities, clarify management requirements and responsible parties in each link. For this reason, in order to achieve a systematic, process-oriented prevention and control of risks, such that the system is low-level construction management for standardized scientific constructing. During the risk prevention and control phase, supervision should go beyond oversight and inspection. By reviewing the scheme, providing technical guidance, and establishing early warning systems, it emphasizes the need for proactive risk management to build a solid foundation for safety, quality, progress and cost management in subsequent construction stages.

3.2 Intervention Measures by Supervision in Risk Management

During the construction phase of a project, timely and effective response measures to risk events are vital in reducing losses and preventing accidents from deteriorating. This process means that you will act as a third-party manager and overseer, which normally entails core responsibilities for organization coordination, implementation directive practice, and implementing supervision. In case of safety incidents, the supervisor should immediately activate emergency plans, conduct a thorough investigation of the scene, direct the construction unit to carry out safety isolation and personnel evacuation and initial response to accidents, and assist relevant units in commencing rescue operations and investigations. It is also to make sure that the incident can contain and avoid secondary damage in a timely manner.

On the quality issue resolution front, supervisors have on-site inspections, testing and remediation tracking to ensure contractors implement effective corrective action for substandard work or construction deviations. They should ensure that they validate the reasonableness and achievability of remediation plans, monitor process and results to assure issues are fully addressed, and capture lessons learned to avoid a recurrence. The efficiency of supervision intervention is represented by the following expression:

$$EL_i=P_i \cdot C_i \quad (4)$$

Supervisors are also key to addressing time delays and cost risks. If construction plans change, with schedule slips or cost overruns, supervisors minimize delays to subsequent tasks by optimizing the sequence of work and managing contractor expenditures according to contract terms. This highlights risk identification and prevention at the project scheduling stage by undertaking full-process tracking by supervisors, thereby facilitating timely construction risk treatment during construction and allowing for smooth project progress. The core function of supervision in risk management is based on three principles: quick response, scientific guidance, and full coverage. It ensures closed-loop regulation from the perspective of integration involving safety, quality, schedule, and cost. But it does give good protections for risk management while construction is ongoing.

3.3 Functions of Supervision in Post-Risk Assessment and Feedback

Post evaluation and feedback in the construction stage is crucial for achieving closed-loop management and for continuous improvement of risk management capabilities after resolution of risk incidents. During this stage, supervision mainly performs information collection and analysis summary functions, as well as experience feed-back. Supervisors should systematically collect all types of risk incidents that occur during construction and do a good job in the implementation of intervention measures, establish a risk database as a reference for subsequent construction projects. By analyzing data on accident causes, handling measures, cost impacts and schedule effects, supervisors can recognize the weaknesses of construction management and risk location. The cost–benefit ratio of monitoring activities can be formulated as follows:

$$E_i=1-\frac{R_{i,\text{after}}}{R_{i,\text{before}}} \quad (5)$$

Supervisors should examine the effectiveness of contractor corrective action and risk resolution results to assess the effectiveness of intervention measures with written assessment reports. The above assessments not only monitor the effectiveness of risk control for this project, but also provide a basis for construction and supervision in similar civil engineering projects to improve the science and standardization level of construction management. The correlation between supervision intervention intensity and risk reduction is shown in Figure 2:

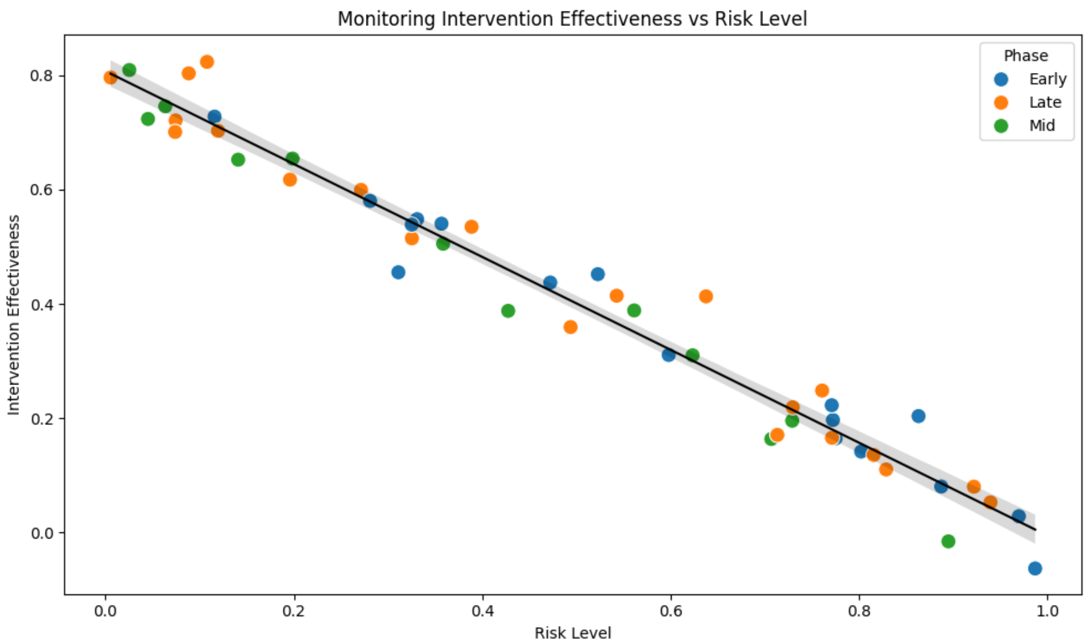

Figure 2 Monitoring Intervention Effectiveness vs Risk Levels

This means that supervisors feed-back and summarize risk experiences and lessons learned in management into design, construction, and supervision systems. It will deliver optimization of construction planning, enhancement of supervision workflows and location of risk prevention approaches which would success transfer knowledge and continue enhancing management. In this closed-loop feedback process, the accumulation of risk identification, intervention and management in construction has been promoted continuously to provide effective guarantee for ensuring safety, quality and efficiency throughout the whole life cycle of construction projects.

4. Optimization Pathways for Construction Phase Risk Management and Supervision Intervention Mechanisms

In addition, risk management and supervision intervention mechanisms during the construction process greatly influence project quality, safety, and economic efficiency. Construction phase risk management is supported by institutional frameworks and policies that constitute its first line of defence. Firstly, relevant regulations and standards for construction risk management need to be further refined to clarify the division of responsibilities and scope of authority with respect to risk prevention and control between contractors and supervision agencies. For example, set operational ground rules for high-risk processes and clarify the supervisory authority's rights to intervene in quality, safety and schedule management. This can be achieved by providing risk management assessment and incentive mechanisms, linking the performance of risk management to the evaluation systems of construction contractors and supervision agencies so that all parties are motivated in carrying out active risk identification and intervention. And at the same time, urge relevant government departments and industry associations to formulate relevant guiding policies for standardized and normalized safety, quality, and environment construction site management as well as ensure that risk management measures are truly implemented on a system level. The optimization of intervention mechanisms is mathematically modeled in the following equation:

$$RI=\sum_{i=1}^{n} w_i \cdot R_i \quad (6)$$

As construction informatization and intelligentization develop, technological tools are playing a more and more important role in the risk management and supervision intervention on the construction site. BIM (Building Information Modeling) technology can manage visualization throughout the construction lifecycle, which is conducive to the early warning of risk in design and construction, and enhance the scientific nature of risk prevention and control. The introduction and implementation of

IoT, sensors, and monitoring systems allow for the real-time tracking of critical indicators at a site (such as staff behavior, equipment operation status, environmental conditions, construction progress), allowing dynamic risk identification and early warning. By using big data and artificial intelligence to analyze historical project risk data, it can provide early warning reminders of potential trends at risk, so as to achieve the purpose of giving guidance decisions for supervision, and intelligently refining the management of risks.

The people and systems that work together are the elementary components of administering risk management. Finally, the personnel must have systematic engineering management knowledge, abundant construction experience, and periodic training on risk management, safety management and new technology applications should be carried out to improve their identification of potential risks and intervention capabilities. The second is to optimize the organizational structure of construction projects, establish a multi-level and clear risk management and supervision system, ensure that there are people responsible for monitoring risks at all stages of construction. In conclusion, establish effective information sharing and collaborative platforms between construction units and supervision units to ensure timely communication of risks and coordinated responses that can significantly enhance risk management efficiency as a whole.

Can indeed develop a dimensional and hierarchical dynamic risk management system for the construction phase, through the combination of institutional policy safeguard, technical support system, personnel organization guarantee measures. By breaking through the traditional supervision mode, this system internalizes risk identification into a scientific and realistic process to improve the proactivity of supervision intervention, which can better guarantee safety, quality and efficiency in construction projects. It has important theoretical significance and practical value.

5. Conclusion

The present paper focuses on risk management in the construction phase of building projects. It provides a structured analysis of the features and root causes of construction-phase risks, enabling a framework for risk identification from the perspectives of ensuring safety, quality, schedule adherence, cost control, and environmental sustainability. It suggests a three-tiered supervision intervention mechanism based on supervision responsibilities and practical work that includes risk pre-control, risk handling, and post-risk assessment. We established a construction phase risk management and supervision intervention system that is systematic, dynamic and operational based on the research of optimization path in institutional dimension, technical dimension and organizational dimension. The findings indicate:

Scientific risk identification methods help in comprehensive identifying potential risks during construction which and provides a reliable basis for supervision intervention; by taking effective supervision intervention mechanism in terms of prevention, mitigation and post-assessment to minimize the probability of occurring and severity of construction risk and ensure overall process safety and project quality. Through institutional guarantee, technical support, personnel optimization all leads to continuous improvement progress compliance level across the board achieves systematic optimization of project safety quality system has been proposed through data mining process model construction tips.

With the continuous development of informatization and intelligentized construction industry, the method can also evolve in terms of digitalization and intelligence for risk management and supervision intervention mechanism during a construction period. The implementation of big data analysis, BI modeling, IOT and artificial intelligence technology will improve the accuracy and timeliness of risk detection and enhance the ability to intervene in advance. Simultaneously, institutional policies should be constantly improved, supervision team building needs to be strengthened, and experience feedback mechanisms need to be established in order to continue optimizing the construction risk management. This ensures a solid basis for the safety, quality and sustainable development of construction projects.

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