Research on Supervision Strategies and Quality Risk Control in Green Building Construction

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Abstract: With the widespread promotion of green building concepts in the construction industry, quality management and risk control during the construction phase have gradually become crucial elements for achieving green objectives. Construction supervision, serving as the key link connecting design, construction, and operation/maintenance, directly impacts the energy-saving and environmental performance as well as the engineering quality of green buildings through its scientific rigor and effectiveness. Based on the characteristics of green building construction, this paper analyzes major quality risks that may arise during the construction process and explores multi-dimensional strategies, including full-process supervision, quality control at critical junctures, and collaborative supervision mechanisms. Furthermore, it proposes establishing a quality risk early-warning system and an information-based management platform to enhance risk response capabilities and quality assurance levels during the green building construction phase. Research indicates that optimizing supervision strategies and refining quality risk control systems not only effectively mitigates construction quality hazards but also promotes the comprehensive achievement of green building objectives, providing valuable insights for the sustainable development of the construction industry.

1. Introduction

In recent years, with the deepening implementation of energy conservation, emission reduction, and sustainable development strategies, green building has become a crucial direction for the transformation and upgrading of China's construction industry[1]. Green building emphasizes not only reducing resource consumption and environmental pollution during design and construction phases but also achieving enhanced energy efficiency and ecological protection throughout the entire lifecycle. In this process, the construction phase, as the critical link for realizing green building objectives, places particular importance on quality control and risk management[2].

The construction process involves multiple stakeholders, complex procedures, novel materials, and high technical requirements[3]. Inadequate management can easily lead to quality hazards and resource wastage, compromising the building's green performance and potentially causing safety incidents and economic losses. How to effectively leverage the supervisory and control functions of construction supervision during green building projects and establish a scientific quality risk prevention mechanism has become a critical issue of widespread concern in the industry[4].

Extensive research on construction supervision and quality control has been conducted both domestically and internationally[5]. Overseas studies often emphasize full-process supervision and the application of information management, focusing on achieving refined oversight of construction phases through digital platforms. Domestic research, meanwhile, concentrates more on establishing supervision systems and implementing tiered risk control, proposing multi-level oversight models. Considering the unique demands of green buildings, existing research still shows gaps in areas such as constructing risk early-warning systems, cross-disciplinary collaborative supervision, and the application of intelligent tools.

This paper combines the characteristics of green building construction to deeply analyze its primary issues in quality and risk. It explores strategies for full-process supervision, key-process control, and

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collaborative supervision mechanisms, proposing pathways for constructing a quality risk control system and optimization recommendations[6]. The research aims to provide theoretical references and methodological support for green building construction supervision practices, further promoting the enhancement of green building quality and the sustainable development of the industry.

2. Characteristics of Green Building Construction and Quality Risk Analysis

Green building construction exhibits significant complexity and distinctiveness compared to traditional construction[7]. Its core objectives extend beyond completing physical structures to embodying green principles in material selection, construction techniques, energy utilization, and environmental protection. Specifically, green construction emphasizes the application of energy-efficient and environmentally friendly materials, the integration of renewable energy sources, and the standardized implementation of green construction techniques[8]. These requirements heighten reliance on new technologies, equipment, and materials during construction, thereby imposing greater demands on construction organization and management. The overall quality risk can be expressed by the following index:

$$QRI=\sum_{i=1}^{n}P_i \times I_i \qquad (1)$$

To evaluate weighted quality performance, the following formula is applied:

$$WQS=\frac{\sum_{i=1}^{n} w_i \cdot q_i}{\sum_{i=1}^{n} w_i} \qquad (2)$$

Quality risks that may arise during green building construction primarily include material risks, process risks, equipment risks, and environmental risks. Regarding materials, green building materials are often innovative but may exhibit uncertainties in quality stability and applicability[9]. In terms of techniques, energy-saving and environmentally friendly construction methods demand high technical proficiency, where even minor operational deviations can lead to quality issues. Concerning equipment, some green construction machinery is still in the early stages of adoption, posing risks of performance instability. Environmentally, construction sites must control dust, noise, and waste emissions; failure to strictly adhere to standards can compromise the achievement of the project's green objectives[10].

Quality risks often stem from multiple factors. First, green buildings impose new demands on materials, processes, and management, yet some construction personnel lack the requisite technical expertise and green awareness, making operational errors more likely. Second, construction supervision mechanisms exhibit certain lagging tendencies, with some stages lacking preemptive controls and dynamic oversight, preventing timely detection and correction of risks. Third, green construction involves cross-disciplinary and multi-process operations. Inadequate coordination can easily cause workflow disruptions or ambiguous responsibilities, increasing the likelihood of risks. As shown in Figure 1, the risk distribution of different construction stages can be visualized through probabilistic analysis:

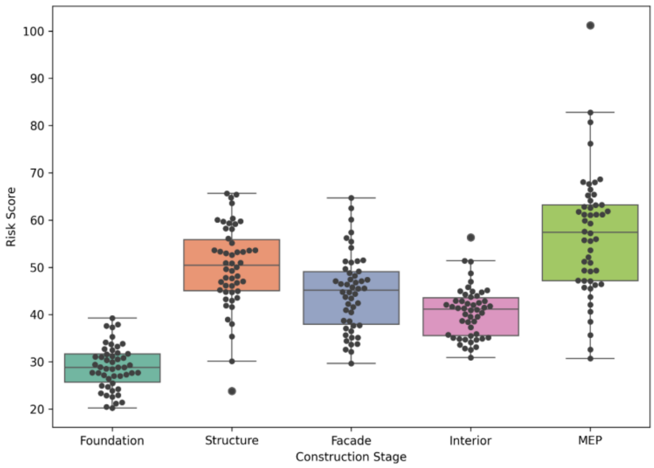

Figure 1 Risk Score Distribution Across Construction Stages

In summary, green building construction plays a vital role in promoting energy conservation, environmental protection, and sustainable development. However, its complexity and technological innovation also introduce new quality risk challenges. These risks stem not only from uncertainties in materials and technologies but are also closely tied to management mechanisms and personnel competence. Without establishing a scientific risk identification and control system during the construction phase, the overall objectives of green buildings become difficult to guarantee. Therefore, conducting systematic research on supervision strategies and quality risk control tailored to the characteristics of green building construction holds significant theoretical value and practical relevance.

3. Research on Supervision Strategies for Green Building Construction

The complexity and multidimensional requirements of green building construction necessitate that supervision work be conducted simultaneously in both breadth and depth. Supervision must not only span the entire construction process to ensure compliance with green standards at each stage but also enforce strict control over critical procedures and core processes to prevent the accumulation and spread of quality risks. Furthermore, the implementation of green buildings involves multi-party collaboration, requiring supervision to facilitate effective cross-disciplinary and cross-entity cooperation through robust organizational and coordination mechanisms. Based on this, green building construction supervision strategies can be developed across three dimensions—full-process supervision, critical-point control, and organizational coordination—to form a systematic framework for quality assurance and risk prevention.

3.1. Full-Process Supervision Strategy

Green building construction differs from traditional projects in that its objectives extend beyond structural safety and functional realization to include energy efficiency, environmental protection, and sustainable development. This necessitates that supervision extends beyond isolated inspections to encompass the entire construction lifecycle, establishing a systematic quality assurance mechanism. Full-process supervision enables proactive risk control through early identification and prevention, coupled with dynamic monitoring and post-event reviews to achieve closed-loop management of quality issues, thereby ensuring the effective implementation of core green building objectives. Risk occurrence is often assumed to follow a normal distribution, as represented by:

$$f(x)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{3}$$

During the pre-construction phase, supervision should focus on pre-control of materials, processes, and construction plans. For green building materials, supervisors must rigorously verify performance metrics and environmental certifications to prevent substandard or non-compliant materials from entering the site. Construction plans should be pre-approved for compliance with green construction codes and energy-saving/environmental standards. Supervisors should also participate in technical briefings and personnel training to enhance workers' green awareness and operational skills, reducing quality risks at the source, Figure 2 illustrates the monitoring effectiveness of sustainable construction measures under varying project conditions:

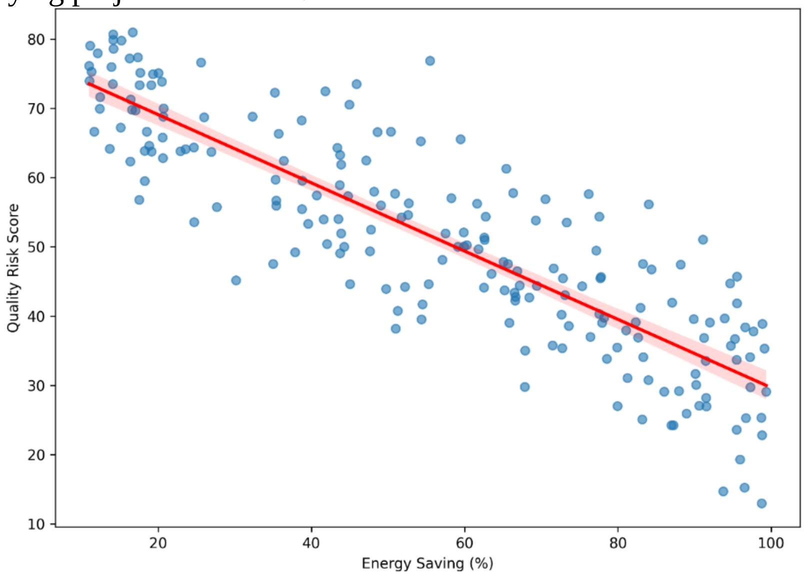

Figure 2 Relationship between Energy Saving and Quality Risk

During construction, supervisors must intensify dynamic oversight of critical processes and key areas. Full-process on-site supervision or spot checks should be conducted for energy-saving component installation, renewable energy equipment commissioning, concealed work construction, and other stages to ensure compliance at every step. Utilizing information technologies (such as BIM and IoT monitoring) for real-time collection and analysis of construction data can significantly enhance supervision efficiency and accuracy. The essence of mid-process supervision lies in identifying issues, correcting deviations, and preventing minor hazards from escalating into systemic quality failures.

Supervision does not conclude upon project completion. Instead, post-construction summaries should facilitate knowledge accumulation and continuous improvement. Supervision units should systematically analyze quality issues, risk points, and their resolution outcomes during construction, compiling case studies and improvement recommendations to inform future green building projects. Supervisors must also participate in final acceptance inspections and performance evaluations to verify whether the project meets established green building objectives. Through this closed-loop mechanism, full-process supervision not only ensures the quality and safety of the current project but also provides a sustainable improvement pathway for industry development.

3.2 Quality Control Methods for Critical Stages

The construction outcomes of green buildings largely depend on the quality of green building materials and energy-efficient equipment. The material delivery stage serves as the primary checkpoint for quality control. Supervisors must rigorously review the environmental performance, certification labels, and technical specifications of building materials to prevent non-compliant or substandard materials from entering the construction site. Simultaneously, functional testing and trials must be conducted on energy-saving equipment such as photovoltaic systems, ventilation systems, and water circulation devices to ensure their performance aligns with design specifications. Effective control at this stage lays a solid foundation for subsequent construction phases.

Green building construction often involves the integration of multiple disciplines and processes, such as the coordination between structural work and energy-saving insulation layers, or the combination of MEP installations with building energy systems. Inadequate handover between processes can easily lead to rework or functional defects. Supervisors must implement dynamic oversight during this phase, conducting on-site supervision or node acceptance for critical processes to ensure handover points comply with construction technical specifications and green standards. Contractors are required to maintain detailed handover records to facilitate quality traceability and accountability.

In green building construction, concealed works—such as insulation layer installation, waterproofing system construction, and pipeline laying—significantly impact overall building performance yet are often difficult to inspect directly after completion. Supervisors must conduct rigorous process inspections and item-by-item acceptance during concealed work phases to ensure construction quality meets design requirements. Random sampling and documentation must be performed for parameters like insulation layer thickness and waterproofing layer continuity. Subsequent processes may only proceed after supervisor approval to prevent latent defects from being concealed and escalating into major quality issues. The sustainability performance index can be defined as a linear combination of environmental, quality, and social factors:

$$SPI=\alpha E+\beta Q+\gamma S \quad (4)$$

The ultimate success of green building projects manifests in achieving energy consumption control, environmental protection, and sustainability objectives. Construction supervision should implement full-process monitoring of energy-saving and environmental protection indicators, including recording and analyzing construction energy consumption, sorting and recycling construction waste, and controlling dust and noise. Utilize information-based monitoring tools to dynamically collect and compare energy efficiency data, promptly identifying deviations and proposing improvement measures. By strengthening the implementation of energy-saving and environmental protection indicators, supervision not only ensures the green performance of the building itself but also promotes the enhancement of green management levels among construction enterprises.

3.3 Supervision Organization and Coordination Mechanisms

Green building construction involves multidisciplinary integration and complex processes, making traditional single-discipline supervision models inadequate. Establishing a robust supervision organizational structure is crucial. Supervision units should assemble multidisciplinary teams tailored to project characteristics, incorporating professionals from architecture, structural engineering, MEP, energy conservation, and environmental protection to achieve complementary expertise. Through rational division of labor and clear role definitions, supervision coverage across the entire construction process and critical stages is ensured, enhancing both professionalism and effectiveness. The effectiveness of risk control measures is calculated using:

$$RCE=\frac{R_{before}-R_{after}}{R_{before}}\times 100\% \quad (5)$$

Green building construction supervision extends beyond the scope of supervision units alone, requiring effective collaboration among multiple stakeholders including the construction entity, design firm, contractor, and material suppliers. A cross-stakeholder coordination mechanism should be established, such as holding regular coordination meetings, setting up joint working groups, and implementing information sharing systems. Strengthening communication and shared responsibility can prevent quality issues caused by information gaps or ambiguous accountability, thereby achieving consistency and synergy in construction objectives.

With the widespread application of technologies like BIM, big data, and IoT, the coordination mechanism for green building construction supervision is gradually transitioning toward informatization and intelligence. Through information-sharing platforms, supervisors can access real-time data on construction progress, material quality, and energy consumption metrics while enabling instant communication and feedback with all parties. Simultaneously, intelligent tools assist supervisors in risk prediction and decision optimization, significantly enhancing collaborative efficiency and the scientific approach to problem resolution. This not only increases transparency in supervision but also promotes active participation and accountability among all stakeholders.

The effective operation of collaborative mechanisms relies on institutional safeguards and standards. During organizational coordination, supervisors must strictly adhere to national and industry-issued green building standards and construction specifications, ensuring all parties operate under unified criteria. Additionally, incentive-penalty mechanisms and accountability tracing systems should be established to institutionalize responsibility awareness. Through standardized and institutionalized oversight, collaborative mechanisms can develop sustainable operational models, providing systemic assurance for comprehensive improvements in green building construction quality.

4. Quality Risk Control System and Optimization Recommendations

Risks in green building construction are often concealed and cumulative. Failure to identify and address them promptly can severely impact project quality and green objectives. Through risk identification, tiered management, and dynamic monitoring, risks can be anticipated and intervened upon before they materialize. To address potential performance instability in novel green materials, establish specialized monitoring and sampling inspection systems to ensure early detection and resolution of risks, thereby reducing accident probabilities. The cost–benefit ratio of green construction projects can be expressed as:

$$CBR=\frac{B_{green}-C_{green}}{C_{green}} \tag{6}$$

Green building construction quality extends beyond structural safety and craftsmanship to encompass energy efficiency, environmental performance, operational functionality, and economic benefits. Therefore, a multidimensional evaluation system covering technical, environmental, economic, and social benefits must be developed. Quantifying metrics such as construction energy consumption, carbon emissions, and waste utilization rates provides a more comprehensive reflection of construction quality. Simultaneously, evaluation outcomes should be integrated into project performance assessments and accountability mechanisms, incentivizing contractors and supervisors to continuously enhance quality management standards.

With the advancement of digitalization and intelligent technologies, information technologies like big data, IoT, and blockchain hold vast potential for application in construction supervision and risk control. BIM platforms enable visual management of construction progress, material performance, and energy efficiency metrics; IoT sensors can monitor real-time environmental parameters and energy consumption levels on-site; blockchain technology ensures data authenticity and traceability. These information tools not only enhance risk identification accuracy but also improve decision-making scientific rigor and transparency.

To comprehensively elevate green construction quality and risk control, efforts should focus on three dimensions: institutional, technological, and personnel. First, refine legal frameworks and standards for green construction to promote industry standardization; Second, promote intelligent supervision platforms and advanced construction techniques to achieve refined and intelligent management of the construction process; Third, strengthen training and assessment for construction and supervision personnel to enhance their green awareness and professional capabilities. Through multidimensional optimization measures, a scientific, systematic, and sustainable quality risk control system can be established, providing robust support for the promotion of green buildings and the industry's high-quality development.

5. Conclusion

Supervision and quality risk control during the construction phase of green buildings are critical to ensuring the successful achievement of energy-saving and environmental protection goals. This paper examines the characteristics of green building construction and associated quality risks, analyzes potential risk types and their causes during the construction process, and proposes multi-dimensional supervision strategies including full-process supervision, key-point control, and collaborative supervision organization. Based on this, it explores pathways for establishing a quality risk control system and optimization recommendations. Research indicates that only by integrating full-process supervision with risk early-warning mechanisms, enhancing information technology applications, and refining collaborative mechanisms and standard systems can quality hazards during construction be effectively mitigated, thereby safeguarding the sustainability and comprehensive benefits of green buildings.

Green building will increasingly emphasize the deep integration of smart construction and information-based supervision. As emerging technologies like BIM, big data, and IoT mature, construction supervision will gradually shift from experience-driven to data-driven approaches, making risk identification and control more scientific and precise. Concurrently, the refinement of industry standards and legal frameworks will provide stronger institutional safeguards for green building quality management. It is foreseeable that green building supervision will play an increasingly vital role in driving the construction industry's green transformation and high-quality development.

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