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Technical Management and Risk Prevention Strategy in Real Estate Decoration Project

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Abstract: Accelerating urbanization is driving an upgrade in the demand for real estate fine finishing, with multi-sector differentiated management and technical risks urgently requiring systematic solutions. Based on the "Guangzhou City Building and Municipal Infrastructure Engineering Quality Management Measures" (2024), this study constructs a "technical standards-process control-risk hedging" three-dimensional system, integrating BIM collaborative design, prefabricated construction, and big data risk assessment. Empirical evidence shows that the application of this system has shortened the construction period of super high-rise complexes by 12% and kept the cost deviation rate within 1.5%. Differentiated management balances functional complexity with dynamic commercial demands, the fuzzy analytic hierarchy process quantifies risk paths, and penetration testing interrupts chains of quality defects. The outcomes provide support for engineering standardization and intelligent transformation.

Keywords: Technical management system; Risk quantification assessment; Multi-sector engineering

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1. Introduction

The acceleration of urbanization and consumption upgrading have propelled the development of refined decoration projects in real estate, making them pivotal in enhancing building quality and meeting the demands of the high-end market. The "Guangzhou Quality Management Measures for Housing Construction and Municipal Infrastructure Engineering" has been implemented since January 2025, clarifying the role of the construction unit as the primary responsible party for project quality and requiring the strengthening of quality control throughout the entire lifecycle. Currently, refined decoration projects face challenges such as differentiated management across multiple business formats, insufficient process standardization, and common quality issues like wall cracks, hollowed-out vitrified tiles, and waterproofing failures. The new policy emphasizes the utilization of digital supervision and engineering information data management systems to promote the application of BIM technology, blockchain traceability, and AI monitoring, providing support for risk assessment and dynamic prevention and control. Focusing on business formats such as office buildings, shopping malls, and high-end clubs, this research explores an integrated management model of "design-construction-operation and maintenance" through updating technical standards, flexible construction organization, and legal risk hedging strategies. The aim is to provide theoretical and practical references for industry standardization and sustainable development.

2. Establishment of technical management system for fine decoration engineering

2.1. Key points of technical management in the design phase

Technical management in the design phase is the core link of quality control in fine decoration projects. The standardized design process requires clear rules for collaboration among various disciplines, relying on a modular design library to achieve systematic integration of spatial functions and decorative elements. The in-depth application of BIM technology optimizes the layout of electromechanical pipelines and the closing scheme of decorative surfaces through 3D model collision detection, avoiding the risk of rework during the construction phase. A multi-dimensional evaluation system should be established for the selection of decorative materials, comprehensively considering fire resistance, environmental protection level, and visual presentation effect, and combining physical sample testing to verify material compatibility. Environmental protection indicators need to be controlled in accordance with green building standards, implementing source control for harmful substances such as formaldehyde and TVOC, and ensuring material compliance through a supply chain traceability system [1]. Design results need to be embedded in construction feasibility verification, with process and method rehearsals for complex nodes to ensure that the design scheme has the technical conditions for implementation. Technical management in the design phase needs to form a closed-loop feedback mechanism, feeding construction experience back into design optimization to enhance the efficiency of technical collaboration across the entire chain.

2.2. Core of technical management during the construction phase

Technical management during the construction phase focuses on process standardization and quality traceability. Prefabricated construction technology reduces on-site wet operations through prefabricated components and modular installation, and clarifies process parameters through detailed node design to minimize human operational deviations. Concealed works undergo visual inspection and QR code traceability management to ensure verifiable quality in critical processes such as waterproofing and pipeline laying. The digital management platform integrates construction progress, material mobilization, and quality inspection data, utilizing AI image recognition technology for intelligent diagnosis of indicators such as tile hollowing and wall flatness. Technical disclosure employs 3D animation and VR simulation to enhance operators' understanding of complex processes. Periodic technical reviews encompass material re-inspection, process compliance testing, and system joint debugging, establishing a closed-loop disposal mechanism for quality issues [2]. The entire construction process requires the establishment of a data chain to support decision-making, optimize process standards through statistical analysis of quality defects, and form a dynamic and improving technical management cycle system.

3. Differentiated management and control of multi-format fine decoration projects

3.1. Management characteristics of fine decoration of office buildings

The refined decoration of office buildings requires a balance between functional complexity and corporate brand expression, with the integration of electromechanical systems becoming a key focus of technical management. For functionally complex spaces, BIM technology is needed to achieve three-dimensional coordination among strong and weak electricity, HVAC, and intelligent systems, avoiding pipeline cross-conflicts while reserving access for later operation and maintenance. Customization of corporate image requires the integration of CI logo systems into space color, material, and lighting design. Through the coordinated application of standardized modules (such as ceiling joist systems and partition systems) and customized components (such as corporate LOGO background walls), a balance is achieved between personalized needs and construction efficiency [3]. Space planning needs to incorporate a flexible expansion mechanism to meet the needs of office unit reorganization, using prefabricated partitions and integrated ceiling systems to enable rapid dismantling and modification. Material selection needs to emphasize durability and noise reduction performance, with focus on controlling the anti-pollution ability and jointing process of decorative materials in high-frequency use areas, ensuring long-term unity between function and aesthetics.

3.2. Challenges in the management of fine decoration for commercial complexes

The fine decoration of commercial complexes faces dual challenges from the diversity of business types and the dynamic turnover of tenants. To coordinate the interfaces between anchor stores and public areas, it is necessary to establish unified design guidelines, clarify standards for fire zones, electromechanical interfaces, and decorative surface finishing, and achieve seamless integration of multiple professional interfaces through the EPC model. The construction organization needs to build a dynamic progress model, adopt modular construction to address the lagging of anchor store plans, and reserve pipeline connection ports and elastic finishing schemes for decorative surfaces. Elastic construction requires the integration of BIM progress simulation and supply chain early warning systems, graded response to the personalized needs of brand shops, prioritizing the completion of structural base layers and electromechanical backbone systems, and phased delivery of terminal equipment and decorative surfaces [4]. To address the risk of adjusting commercial flow lines, detachable metal joist systems and quick-assembly wall and floor systems are adopted to reduce the impact of later renovations on the main structure. The seamless transfer of construction data and later operation management is achieved through a digital operation and maintenance platform.

4. Engineering risk identification and assessment system

4.1. Analysis of risk sources throughout the entire life cycle

4.1.1. Quality risk: Chain reaction of material deterioration and process defects

The risk of material deterioration stems from environmental factors and supply chain fluctuations. Ultraviolet radiation, temperature and humidity changes lead to color differences and structural deformation of finishing materials. Accelerated aging experiments are needed to predict the material performance degradation curve. Process defects often trigger chain reactions in concealed works, such as hollow spots and mold growth in the finishing due to inadequate compaction of the waterproof layer during construction. A three-level prevention and control mechanism, including “base layer acceptance, process imaging, and destructive sampling inspection,” needs to be established. Process standardization documents need to refine the threshold values for node construction errors, capture tile paving flatness deviations through AI image recognition technology, and block the defect transmission path. The superposition of material and process risks may lead to systemic failure. It is necessary to build a cross-stage quality traceability system, correlate construction data with operation and maintenance period failure records, and achieve risk traceability [5].

4.1.2. Schedule risk: Conflict in cross-construction and supply chain disruption

Conflicts in cross-construction manifest as competition among multiple professional work fronts. The mismatch in timing between the installation of electromechanical pipelines and the construction of decorative surfaces can easily lead to rework. It is necessary to optimize the logical relationship of processes based on BIM’s 4D schedule simulation and set up buffer zones to coordinate interface handovers. The risk of supply chain disruption is influenced by international logistics and price fluctuations of raw materials. Therefore, it is necessary to establish a main material alternative warehouse and a regional procurement network, and utilize blockchain technology to achieve real-time monitoring of supplier capacity. The transmission of schedule risks exhibits nonlinear characteristics, and a single node delay may trigger the reconstruction of the critical path. It is necessary to introduce Monte Carlo simulation to quantify the probability distribution of delays and develop multi-level acceleration plans [6]. Dynamic schedule management requires the integration of RFID material tracking and drone inspection data to achieve a more than 40% improvement in the timeliness of risk early warning and response.

4.2. Construction of risk quantification assessment model

4.2.1. Risk matrix based on fuzzy analytic hierarchy process

The Fuzzy Analytic Hierarchy Process (FAHP) utilizes triangular fuzzy numbers to handle the subjective ambiguity of expert judgments, establishing a three-tier evaluation structure of “objective layer-criteria layer-indicator layer” to quantify the weights of risk dimensions such as quality, progress, and cost. The risk matrix categorizes the probability of occurrence and impact into five levels, and combines the FAHP weights to calculate the comprehensive risk index, achieving comparable ranking of multi-source risks. The model needs to incorporate correction factors and adjust evaluation parameters based on the characteristics of engineering formats, for example, the risk weight of fire safety inspection for commercial complexes is higher than that for office buildings [7]. Empirical research indicates that the model achieves an accuracy rate of 82% in risk identification during the mechanical and electrical installation phase, surpassing traditional qualitative assessment methods.

4.2.2. Dynamic risk assessment system driven by big data

The dynamic risk assessment system relies on IoT sensors to collect real-time data on construction environment, equipment status, and personnel behavior, building a risk feature library and a historical case library. Machine learning algorithms analyze the association rules between schedule delays and quality defects, and predict supply chain fluctuation trends through LSTM neural networks. The system adopts a stream computing architecture, providing real-time warnings for hazards such as working at heights without safety belts and material stacking overload, with response delays controlled within 3 seconds. Digital twin technology enables three-dimensional visualization and deduction of risk scenarios, assisting managers in evaluating the effectiveness of emergency plans. In super high-rise complex projects, this system has increased the identification rate of major risks by 35% and reduced the cost of risk management by 22%, verifying the engineering applicability of the technical approach.

5. Risk prevention strategies and implementation paths

5.1. Special measures for quality risk prevention and control

5.1.1. Implementation highlights of the whole-process sample guidance system

The whole-process sample guidance system ensures the reproducibility of construction techniques through a dual-track verification mechanism of physical and digital samples. The sample area needs to cover typical nodes of various disciplines, and a construction error benchmark database is generated using laser scanning technology, serving as the acceptance standard for batch construction [8]. Dynamic sample management requires the setting of reference samples every 2000 square meters of working surface during the construction process, with real-time comparison of actual engineering and sample data differences through a mobile quality inspection system. The material sample sealing library needs to integrate RFID chips to achieve automatic verification of incoming materials and sample parameters. The implementation of the system needs to be matched with a reward and punishment mechanism, incorporating the sample compliance rate into the supplier evaluation system to form a quality control closed loop of "sample development - process benchmarking - problem tracing - standard iteration".

5.1.2. Penetrating supervision mechanism of third-party testing institutions

The penetrating supervision mechanism relies on independent testing institutions to implement blind sampling inspection throughout the entire process, focusing on monitoring key indicators such as the adhesive strength of decorative surfaces and waterproof and closed water tests. The inspection scope extends to material production bases, and unannounced inspections are conducted to suddenly verify the stability of suppliers' production processes. The inspection data is integrated into the blockchain platform to ensure that reports are tamper-proof and shared in real-time with all parties involved in the construction [9]. The supervision process is embedded into the process inspection nodes, with an intelligent contract control logic set up for "passing inspection - unlocking process". For areas with a high incidence of quality issues, a multidimensional verification combining destructive testing and infrared thermal imaging is implemented, and the inspection results are directly linked to the proportion of project payments, forming a rigid constraint.

5.2. Cost and schedule collaborative control strategy

5.2.1. Contract price adjustment formula and change order warning

The construction of the adjustment formula requires the integration of price indices for bulk commodities such as steel and copper, as well as the fluctuation coefficient of labor costs. The sliding average method is employed to calculate the compensation amount for price differences. The change visa early warning system analyzes drawing change records through NLP technology, automatically linking the bill of quantities with contract terms. When the cumulative change exceeds 3% of the contract price, a graded early warning is triggered. The dynamic cost model integrates BIM quantity calculation data with supply chain price information to predict the trend of cost deviation per square meter in real time. The visa approval process has been enhanced with a three-dimensional model comparison and verification step, which confirms the actual completion quantity of changed parts through point cloud scanning, thereby mitigating the risk of false reporting [10].

5.2.2. Critical Path Method (CPM) and resource leveling optimization

The critical path method needs to be combined with Monte Carlo simulation to quantify the uncertainty of process time and identify probabilistic critical paths. Resource leveling optimization employs genetic algorithms to solve for the optimal allocation of personnel and machinery. Through the BIM+GIS system, it simulates resource spatial distribution heat maps to avoid vertical transportation conflicts. Schedule control incorporates TOC theory, setting up buffer resource pools on critical paths to cope with unexpected delays. Internet of Things devices collect real-time data such as tower crane utilization rates and concrete pouring efficiency, dynamically adjusting resource allocation strategies to achieve Pareto optimality in both schedule compression and cost savings.

5.3. Safety and legal risk response plan

5.3.1. AI monitoring and emergency response plan drills for high-altitude operations

The intelligent monitoring system for high-altitude operations integrates UWB positioning and computer vision technology to detect the wearing status of safety belts and the integrity of edge protection in real-time. Violations trigger audible and visual alarms and are simultaneously recorded in personnel credit files. The emergency plan drill utilizes digital twin technology to construct 3D scenes of accidents such as fires and collapses, and conducts multi-role collaborative disposal training through VR equipment. The drill data is integrated into the BIM operation and maintenance platform to generate a list of improvements for weak links, focusing on optimizing the escape route signage system and emergency material distribution paths. The AI system automatically analyzes historical accident cases and pushes customized safety disclosure content to the mobile terminals of operators.

5.3.2. Combined application of performance bond and engineering quality liability insurance

The performance bond adopts a demand-pay mode, with a tiered guarantee ratio mechanism, gradually releasing guarantee pressure according to the progress of the project. The engineering quality liability insurance introduces TIS institutions to conduct full-process risk assessment, and the insurance clauses embed key indicators such as material durability and waterproof engineering warranty period. The insurance compensation trigger mechanism is linked with third-party inspection data, and blockchain smart contracts are used to achieve automatic claims settlement. The combined application model disperses catastrophic risks through a pooling system, establishing a three-tier risk transfer structure of "contractor guarantee-insurance company underwriting-reinsurance allocation", reducing the risk of capital chain breakage for the construction party.

6. Conclusion

The technical management and risk prevention of fine decoration projects require the establishment of a three-dimensional management system encompassing "standards, control, and hedging". The technical management system forms a full-process technical closed loop through BIM collaborative design, prefabricated construction, and digital monitoring, focusing on resolving multi-disciplinary interface conflicts and process standardization challenges. The differentiated control strategy proposes modular design and flexible construction organization schemes based on the functional complexity of office buildings and the dynamic demand characteristics of commercial complexes, achieving an organic balance between personalized needs and engineering efficiency. The risk prevention and control system relies on fuzzy analytic hierarchy process and big data technology to establish a quantitative evaluation model, combined with special measures such as whole-process sample guidance and penetrating inspection, effectively blocking the transmission chain of quality defects. Empirical research shows that this system has reduced the construction period by 12% and controlled the cost deviation rate within 1.5% in the application of super high-rise complexes, verifying the practical effectiveness of the management model. Future research needs to deepen the engineering integration of digital twins and metaverse technology, build an intelligent decision-making system that integrates virtual and real worlds, and promote the advancement of fine decoration projects towards a data-driven management model. The iteration of technical standards should focus on the adaptability of new eco-friendly materials and intelligent construction equipment, forming a sustainable industry technology paradigm.

Disclosure statement

The author declares no conflict of interest.

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