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Research on Project Lifecycle Management in Housing and Municipal Engineering Supervision: With Quality Safety and Cost Control as the Core

Yifeng Wang*

Shenzhen Jianli Construction Supervision Co., Ltd., Shenzhen 518107, Guangdong, China

**Author to whom correspondence should be addressed.*

Abstract: Housing construction and municipal engineering have full lifecycle characteristics, involving multiple stages. Emphasizing the coherence and systematicity of each stage, the supervisor should establish a three-dimensional management system. Establishing quantitative evaluation models and visual monitoring schemes to ensure quality and safety, as well as introducing cost control methods and innovative collaborative management mechanisms, ultimately forming a supervision-led paradigm and proposing directions for the application of digital twin technology.

Keywords: Housing construction; Municipal engineering; Full lifecycle management; Supervisor

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1. Introduction

The full life cycle management of building and municipal engineering encompasses multiple stages, such as project initiation and decision-making, design preparation, construction implementation, and operation and maintenance. These stages are closely connected and form a highly complex system. In recent years, relevant policies in the engineering construction field have been continuously improved. For example, the "Opinions on Promoting the High-Quality Development of the Engineering Supervision Industry" released in 2022 has emphasized the importance of supervision in engineering management. Against this backdrop, the study of the full life cycle management model for building and municipal engineering supervision has become particularly significant. From the construction of a three-dimensional management system for supervision units to the establishment of quality and safety evaluation indicators and systems, and from the application of cost-control methods to the innovation of multi-party collaboration mechanisms, all these aspects must focus on full life cycle management. This is aimed at achieving collaborative optimization of quality, safety, and cost. By doing so, it can enhance the management level and efficiency of engineering projects, ensuring that the engineering supervision plays a key role in each stage of the project's full life cycle. Ultimately, this will promote the high-quality development of the engineering supervision industry.

2. Construction of theoretical framework for project lifecycle management

2.1. Analysis of the full life cycle characteristics of housing construction and municipal engineering

Building and municipal engineering projects have unique full life cycle characteristics. In the project initiation and decision-making stage, it is necessary to comprehensively consider various factors such as social demand, economic feasibility, and environmental impact, and conduct a comprehensive project feasibility study [1]. In the design preparation stage, emphasis should be placed on accurately grasping the project's functional requirements to ensure that the design plan meets the project objectives and relevant standards. The construction implementation stage involves the collaborative work of many participants, including construction units and supervision units, with quality, safety, and cost control being of vital importance. The operation and maintenance stage emphasizes the long-term management of engineering facilities to ensure their normal operation and meet functional requirements. Compared with traditional engineering management models, full life cycle project management places greater emphasis on the coherence and systematicness of each stage, focusing on optimizing resource allocation from an overall perspective to improve the project's comprehensive benefits.

2.2. Innovation of supervision-led management mechanism

Supervision units should build a three-pillar management system covering decision-making support, process monitoring, and performance evaluation. This system strengthens the supervision units' core role in the full life cycle management of projects and enables dual control over quality and safety as well as cost. In the decision-making support area, supervision units must offer professional advice for project decisions by considering project features and relevant standards. This ensures the scientific and rational nature of decisions [2]. Process monitoring should span all project stages, with real-time tracking of key indicators related to quality, safety, and cost. Problems identified during this process should be resolved promptly. Performance evaluation involves a thorough assessment of the entire project and each individual stage. It summarizes the lessons learned to provide valuable references for future projects. Through this innovative management mechanism, supervision units can better fulfill their duties and enhance project management standards and benefits.

3. Research on quality and safety control system

3.1. Quality and safety assessment inspection standard system

To provide a scientific basis for quality and safety assessment, a quantified assessment model has been established. This model consists of 12 core indicators, which include material testing, process compliance, and structural safety. The material testing indicator ensures that all materials used in the project meet the required quality standards, effectively controlling quality from the source. The process compliance indicator monitors whether the construction process adheres to standard procedures, which helps to guarantee the stability of construction quality [3]. The structural safety indicator focuses on the key structural components of the building, ensuring they can withstand the expected loads. In addition, a mobile-end quality inspection system has been developed. This system allows supervisors to record and upload inspection data in real-time, improving the efficiency and accuracy of inspections. It also enables the timely identification and resolution of quality and safety issues.

3.2. Dynamic supervision mechanism for quality and safety

A visual monitoring plan based on BIM technology has been designed to build a dynamic supervision mechanism for quality and safety. Through BIM models, real-time monitoring of building and municipal engineering projects is conducted, with warning thresholds set. When the monitoring data exceeds the threshold, a warning is promptly issued [4]. At the same time, a management process that includes a closed-loop rectification has been established to address warning issues in a timely manner and ensure that corrective measures are effectively implemented, forming an effective feedback mechanism. On this basis, a responsibility-tracing system has been established to clarify the responsibilities of all participants in quality and safety management. This enables accurate identification of the responsible party when problems arise, thereby increasing the emphasis placed by all participants on quality and safety management and ensuring the quality and safety of building and municipal engineering projects.

4. Methodology of engineering cost control

4.1. Full cycle cost control strategy

4.1.1. Application of value engineering in the design stage

Implementing value engineering during the design stage is vital for optimizing construction planning, and it is a crucial part of the cost control process. Through functional cost analysis, value engineering can identify those design elements that are either excessively costly or over-designed. By examining the cost-to-function ratios and making targeted adjustments to the design, it is possible to achieve a more optimal balance between cost and functionality [5]. Furthermore, establishing a constructability review mechanism is essential for controlling design changes. This review process can detect potential construction-related issues in the design phase, such as overly complex construction techniques or impractical construction methods, and provide feedback to the design team. This early detection and subsequent optimization can help avoid costly design changes during construction, which often result in increased engineering costs, including the need to re-procure materials and additional expenses due to project delays.

4.1.2. Dynamic cost monitoring during the construction phase

When it comes to cost control in the construction phase, integrating Earned Value Management (EVM) with BIM5D to establish a cost early-warning system holds great significance [6]. This system enables real-time matching of work-in-process with payment progress, allowing for precise tracking of the project's financial status. By utilizing the three basic parameters of EVM, Planned Value (PV), Earned Value (EV), and Actual Cost (AC), as well as four evaluation indicators such as Schedule Variance (SV) and Cost Variance (CV), the system provides a comprehensive analysis of project cost and schedule. Meanwhile, BIM5D technology creates an integrated environment that combines a three-dimensional model, time-related data, and cost-related information. This powerful integration not only facilitates the timely detection of cost and schedule variances but also enables the prediction of cost-related trends, offering strong support for cost control during the construction phase and helping ensure the project stays within budget.

4.2. Optimization of approval and construction cost

4.2.1. Administrative approval process reengineering

To improve the efficiency of administrative approval, the development of parallel approval operation guidelines is imperative. These guidelines should clarify the order of each approval stage, the required documentation, and the responsibilities of the respective approval departments. This approach can reduce the time-consuming and communication-intensive process of dealing with different departments for companies seeking approval [7]. Moreover, creating a permit processing progress tracking matrix is essential. This matrix should include detailed records of the start time, expected completion time, actual completion time, and any issues encountered in each stage. By doing so, companies can stay informed about the progress of the permitting and approval process and take timely measures to address potential delays, thereby ensuring the smooth progress of the entire process and effectively controlling costs.

4.2.2. Compliance cost control

Creating a policy and regulation database and establishing a compliance-review checklist that covers seven major areas, including environmental protection and fire safety, is a vital initiative for controlling compliance-related costs. By maintaining a comprehensive database, it is possible to obtain up - to - date and accurate policy and regulation information, which provides a solid basis for cost control in construction projects [8]. During the permitting and approval process, the checklist can be used to conduct a thorough review of each stage to ensure that the project meets all compliance requirements. This helps avoid additional costs that may arise from violations, such as fines and expenses related to rectification. It is equally important to keep the checklist updated and refined to adapt to the ever-changing policy and regulatory environment. This ensures effective compliance-related cost control and guarantees that the cost-control methodology plays a positive role in optimizing the permitting and approval cost.

5. Innovation of collaborative management mechanism

5.1. Multi-party collaborative organizational structure

5.1.1. Strengthen the core role of the supervisory unit

Strengthening the core role of supervision units is crucial in the supervision of housing construction and municipal engineering. It is necessary to establish a scientifically reasonable multi-party collaborative organizational structure, in which the supervisory unit should be in a key position. By designing a supervision authorization system that includes 28 rights and responsibilities clauses, the scope of power and responsibility of the supervision unit in the project is clarified, enabling it to better fulfill its duties [9]. At the same time, establish rules of procedure for engineering meetings, standardize the behavior and decision-making process of all parties in the meeting, ensure effective transmission of information and timely resolution of problems. The supervisory unit, relying on its professional knowledge and experience, plays a coordinating, supervising, and guiding role in multi-party collaboration to ensure the achievement of quality, safety, and cost control objectives in the project's entire lifecycle management.

5.1.2. Construction of responsibility matrix for participating parties

Innovative collaborative management mechanisms are crucial in the full lifecycle management of construction and municipal engineering supervision projects. The construction of the responsibility matrix for participating parties under the multi-party collaborative organizational structure is a key step. By compiling the RACI responsibility allocation matrix, the specific responsibilities of design, construction, and other parties in quality and safety control can be clearly defined [10]. This helps to avoid the phenomenon of shirking responsibilities caused by unclear responsibilities, and improves the efficiency and execution of quality and safety management by all parties involved. After clarifying the responsibilities of all parties, each participating party can better carry out their work within their own scope of responsibility, ensure the achievement of engineering quality and safety goals, and lay a good foundation for cost control, promoting the effective implementation of project lifecycle management.

5.2. Information management platform

5.2.1. Construction of engineering data platform

The construction of the engineering data platform is crucial for the full lifecycle management of housing and municipal engineering supervision projects. Develop a data cockpit system by integrating key elements such as quality inspection data, cost ledger, and schedule plan. The system is capable of real-time collection, integration, and analysis of various types of data, providing comprehensive and accurate information support for project management. The integration of quality inspection data helps to promptly identify quality issues and take measures to solve them, ensuring that the engineering quality meets standards. The inclusion of cost ledger can achieve precise control and analysis of costs, avoiding cost overruns. The integration of schedule plans can enable managers to have a clear understanding of project progress, adjust strategies in a timely manner, and ensure that the project progresses according to plan. The data cockpit system presents these data in an intuitive way, improving decision-making efficiency and scientificity, and promoting the smooth implementation of the project.

5.2.2. Development of mobile collaborative applications

The engineering collaboration app plays an important role in the full lifecycle management of construction and municipal engineering supervision projects. This app covers 12 functional modules, including problem rectification and visa processing. In the problem rectification module, problems can be uploaded in real time, and the rectification process can be tracked to ensure the quality and safety of the project. The visa processing module facilitates the recording and approval of various types of visas, effectively controlling costs. Through these functional modules, all parties involved in the project can communicate and collaborate in real-time. For example, if construction personnel discover quality problems, they can immediately provide feedback on the APP, and the supervisory personnel will respond quickly and provide rectification suggestions. All parties will work together to promote rectification. At the same time, the integration and analysis of various information by the APP also provides strong support for project decision-making, improves management efficiency and decision-making scientificity, and achieves effective control of quality, safety, and cost.

5.3. Risk warning mechanism

5.3.1. Quality and safety risk map

It is crucial to construct a quality and safety risk map to address the quality and safety risks in housing construction and municipal engineering supervision. Establish a warning indicator system with 8 major risk sources, including foundation pit collapse and formwork support, as the core. By conducting in-depth analysis of these risk sources, identify key indicators and their thresholds. For example, for the risk of foundation pit collapse, monitoring indicators such as changes in groundwater level and displacement of slope soil. When the indicator exceeds the set threshold, issue a warning signal in a timely manner. Utilizing advanced monitoring technology and equipment to collect real-time data and provide accurate basis for risk assessment. At the same time, by combining historical data and engineering experience, continuously optimizing the risk map and warning indicator system, improving the accuracy and timeliness of risk warning, and effectively ensuring the quality and safety of housing construction and municipal engineering.

5.3.2. Cost overrun warning model

Developing a cost prediction system based on machine learning algorithms that can accurately predict the costs of construction and municipal engineering supervision projects. The system learns and analyzes a large amount of historical data to uncover the patterns and influencing factors of cost changes. On this basis, a three-level warning mechanism of red, yellow, and blue will be established. When the predicted cost approaches or reaches the yellow warning line, remind relevant personnel to pay attention to cost dynamics and strengthen cost monitoring measures; When the red warning line is reached, it indicates that the risk of cost overruns is extremely high, and targeted measures need to be taken immediately for adjustment, such as optimizing construction plans, controlling material waste, etc. The blue warning line serves as a preliminary reminder of potential cost trends, in order to prepare in advance and effectively achieve full lifecycle management and control of project costs.

6. Conclusion

In the supervision of housing construction and municipal engineering, project lifecycle management is crucial. Through research, a supervision-led full lifecycle management paradigm has been formed, which emphasizes the key role of supervision in various stages of the project. At the same time, the synergistic optimization effect of quality and safety, and cost control was verified, clarifying the close relationship between quality, safety, and cost, as well as the advantages of collaborative management. On this basis, further development directions for engineering management cloud platforms based on digital twin technology are proposed. Digital twin technology is expected to bring more efficient and accurate monitoring and decision support to engineering management, enabling engineering supervisors to better cope with complex project environments, achieve more effective control over quality, safety, and cost, and thus improve the management level and efficiency of the entire housing and municipal engineering.

Disclosure statement

The author declares no conflict of interest.

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