Research on the application and innovation of construction project supervision in the whole life cycle management of engineering projects

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Abstract: The traditional supervision mode is limited to the construction stage, facing problems such as stage separation, technical lag and role limitation. The concept of whole life cycle management (WLC) promotes the reform of engineering management mode, emphasizing the value optimization of the whole process from decision-making, design and construction to operation and maintenance and demolition. This paper analyzes the connotation and function evolution of construction project supervision, and points out that it is transforming from supervision during construction to integrated management covering the whole cycle. Subsequently, the article elaborated the application of construction engineering supervision in five stages, such as decision-making, design, construction, operation and demolition, and combined with BIM, Internet of Things and other technologies, discussed how to realize intelligent and integrated development of supervision services. Finally, the paper puts forward the innovation path of construction engineering supervision, including technical innovation (digital technology, intelligent algorithm and big data), mode innovation (WLC supervision, multi-agent collaborative service) and management innovation (process standardization and agility, organizational structure and incentive mechanism reform, and compound training of supervision talents' ability). Through technological innovation, mode innovation and management innovation, construction engineering supervision will realize the role change from passive control to active value-added, and provide systematic solutions for the high-quality development of the construction industry.

1. Introduction

The traditional supervision mode is limited to the quality, schedule and cost control in the construction stage, and it faces three bottlenecks: the service fails to extend to the design decision, the management relies on manual and paper-based management, which leads to insufficient risk warning, and the collaborative mechanism is missing and the rights and responsibilities are unclear under EPC (General Project Contracting) mode [1]. The concept of whole life cycle management (WLC) promotes the reform of engineering management mode, emphasizes the whole process value optimization from decision-making, design and construction to operation and maintenance and demolition, and relies on data integration and dynamic decision-making to improve efficiency. The supervision function needs to be transformed from supervision during construction to integrated management covering the whole cycle, which has become the inevitable direction of industry development.

2. Connotation and function evolution of construction project supervision

Construction engineering supervision refers to the management service activities of qualified supervision enterprises entrusted by the construction unit to carry out professional supervision on construction quality, progress and cost according to laws, regulations, contracts and technical standards. Its core function is to ensure that construction projects are carried out in accordance with laws and regulations, design requirements, construction specifications and related standards, and to ensure project quality, safety and progress [2-3]. Supervision runs through the whole process of the project, from decision-making, design, construction to completion and acceptance, aiming at ensuring the safety, quality and timely delivery of the project.

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China's construction engineering supervision system has undergone five stages of evolution since 1988. From the initial pilot in some cities and systems, it has been steadily promoted nationwide since 1993, and the number of supervision units and employees has increased rapidly; After the promulgation of the Building Law in 1998, it entered the stage of comprehensive promotion, and the industry ushered in rapid development; From 2006 to 2016, the standardization was improved through a series of laws and regulations, and the professionalism and efficiency of services were significantly enhanced; Since 2017, the supervision industry has entered a new stage of transformation and upgrading, and gradually expanded to the whole process of engineering consulting services, committed to providing comprehensive and efficient services covering the project WLC, and promoted the in-depth reform of the engineering construction management model.

3. Application of construction engineering supervision in WLC

Construction engineering supervision runs through the project WLC, and realizes the role change from passive control to active value-added through technical innovation and system improvement (Figure 1). With the deep application of BIM, Internet of Things and other technologies, supervision services are developing towards intelligence and integration, becoming the core link connecting all participants and providing systematic solutions for the high-quality development of the construction industry [4].

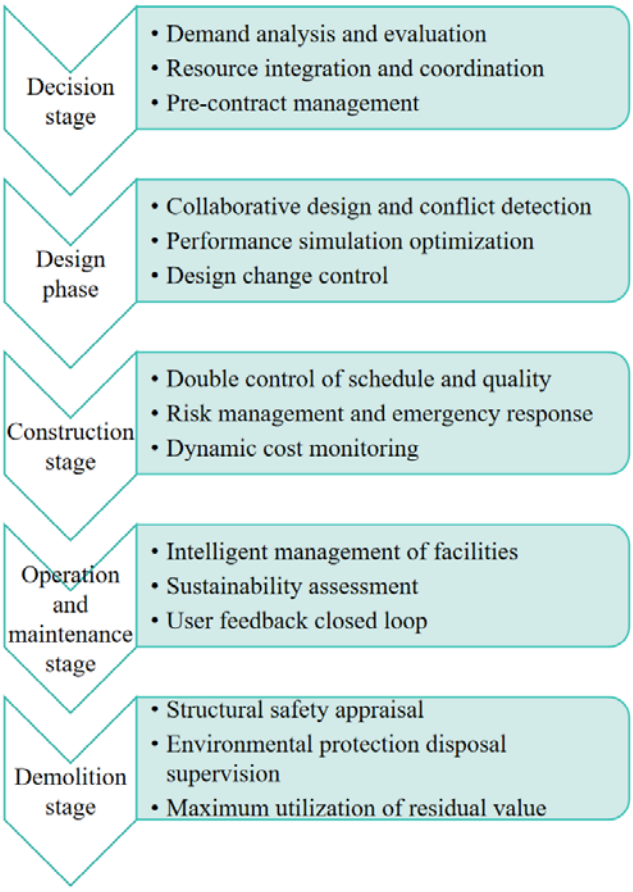

Figure 1 Application framework of construction engineering supervision in WLC

3.1 Decision stage

In the decision-making stage of the project, the supervision function has been moved from the traditional construction supervision to the pre-planning stage, and deeply involved in demand analysis and evaluation. By investigating market trends and policies and regulations, it helps the owner to clarify the functional orientation, performance indicators and budget framework of the project, enhance the scientificity of feasibility study and reduce the decision-making risk [5].

Supervision plays a bridge role in resource integration and coordination, promotes multi-disciplinary and multi-stakeholder argumentation, optimizes design scheme to match investment objectives, and through pre-contract management, reviews bidding documents and contract terms, prevents legal risks, and ensures the compliance start of the project.

3.2 Design phase

In the design stage, the supervisor realizes collaborative design and conflict detection with the help of digital tools such as BIM, integrates professional models such as architecture, structure and electromechanical, identifies and solves collision problems in drawings in advance, and reduces rework in the construction stage [6]. Through the performance simulation of energy consumption, lighting and structural safety, it supports the green, low-carbon and spatial optimization design, establishes a dynamic control mechanism for design changes, and makes technical and economic comparison and selection for major modifications, so as to ensure that the scheme meets the functional and aesthetic requirements while taking into account the cost and feasibility, and comprehensively improves the design quality and project benefits.

3.3 Construction stage

In the construction stage, the supervisor realizes the coordinated control of progress and quality through digital means, tracks the construction progress in real time by relying on monitoring platform, three-dimensional laser scanning and other technologies, accurately identifies quality problems and improves the detection efficiency. At the same time, strengthen risk pre-control and emergency response, develop a visual operation guidance system for new technologies such as prefabricated buildings, reduce construction risks and improve the first-time excellent rate, and dynamically compare the engineering quantity and cost data through BIM model to timely warn of cost overruns and realize refined cost control [7].

3.4 Operation and maintenance stage

In the operation and maintenance stage, the supervision function extends to the intelligent and sustainable management of facilities, transforming the completed BIM model into an operation and maintenance database, integrating equipment information, supporting AR inspection and fault prediction, and improving the property response efficiency and service quality [8]. Through regular evaluation of building performance, suggestions on energy-saving optimization and transformation are put forward, and a closed-loop mechanism of user feedback is established to collect experience data, which provides data support for the value improvement of building WLC and future project optimization, and promotes the transformation of engineering construction to long-term operational benefit orientation.

3.5 Demolition stage

In the demolition stage, the supervisor appraised the structural safety of existing buildings through nondestructive testing technology, scientifically formulated a step-by-step dismantling plan, and gave priority to promoting the recycling of reusable materials [9]; At the same time, supervise the classification and environmental protection disposal of waste to ensure compliance with relevant laws and regulations and minimize the impact on the surrounding environment; With the help of reverse logistics system, the recycling of old components is promoted, the efficiency of resource utilization is improved, and the goal of maximizing building residual value and sustainable development is realized.

4. Research on innovation path of construction project supervision

With the transformation of the construction industry to digitalization, greening and industrialization, and the deepening of the concept of project WLC management (covering the whole process of planning, design, construction, operation and maintenance until demolition), the traditional construction project supervision mode gradually exposes problems such as lagging

technical means, insufficient coordination efficiency and weak risk pre-control ability. In this context, the innovation and upgrading of supervision services has become a key link to promote the high-quality development of the industry.

4.1 Technical innovation

Technical innovation is the core driving force for upgrading supervision service. It mainly solves the pain points of "information asymmetry, difficult process traceability and slow risk response" in traditional supervision through the application of digital and intelligent tools, and realizes the dynamic perception and precise control of engineering WLC data.

4.1.1 Deep application of digital technology

By integrating the BIM model in the design, construction and operation and maintenance stages into the supervision platform, the supervisor can view the three-dimensional visual progress plan, concealed engineering node parameters and material specification information in real time, conduct collision detection and construction simulation before construction, and avoid design defects in advance; During the construction, the actual progress and planned deviation are compared by the model, and the supervision focus is dynamically adjusted by combining with 4D-BIM (time dimension). Intelligent sensors are deployed in the construction site to collect real-time data of engineering entities, environmental parameters and equipment status, and automatically warn the risk of exceeding the limit through edge calculation and cloud analysis.

4.1.2 Intelligent algorithm and big data-driven decision-making

The machine learning algorithm is used to train historical engineering data, and a risk prediction model is established to assist the supervisor to formulate targeted control strategies in advance. By analyzing the concrete pouring data, a correlation model of "pouring time-ambient temperature-crack probability" can be constructed for residential projects, which can guide the on-site adjustment of maintenance scheme and reduce the later maintenance cost.

4.2 Mode innovation

Mode innovation focuses on breaking the limitation of traditional supervision "single construction stage supervision", extending to WLC and the whole industry chain collaborative service, and enhancing the comprehensive value of supervision through role transformation and multi-party collaborative mechanism reconstruction.

4.2.1 Exploration of WLC supervision mode

Traditional supervision mostly focuses on the construction stage, while WLC management requires supervision services to extend forward to the project planning and design stage and backward to cover the operation and maintenance stage. For example, the green building project can be introduced into the "planning-design-construction-operation and maintenance" integrated supervision team, and the optimization scheme of curtain wall shading system can be put forward in the design stage to reduce the energy consumption in the later operation; In the operation and maintenance stage, BIM model is used to quickly locate the fault point of equipment and shorten the maintenance time.

4.2.2 Multi-agent collaborative service model

The supervisor cooperates with professional institutions such as cost consultation and legal consultation to provide the owner with one-stop service of "technical supervision+cost control+compliance review". In the EPC project, the supervision team participates in the contract clause review (defines the responsibility interface of all parties) synchronously to avoid disputes caused by fuzzy interface [10]. Through the government-enterprise data sharing platform, the supervisor synchronizes the on-site inspection data to the supervision department in real time, and receives policy guidance, forming a double guarantee mechanism of "enterprise self-discipline+government supervision".

4.3 Management innovation

Management innovation is the guarantee of technological innovation and mode innovation, and the core lies in building an agile, efficient and professional supervision management system through process reengineering, organizational change and talent ability improvement.

4.3.1 Combination of process standardization and agility

Formulate supervision operation standards covering WLC, such as "BIM Supervision Operation Rules" and "Internet of Things Monitoring Data Management Regulations", and define key control points at each stage; At the same time, in view of sudden risks, an "emergency supervision response process" is established to enhance the flexibility of management.

4.3.2 Reform of organizational structure and incentive mechanism

Traditional supervision enterprises often adopt "hierarchical" management, which easily leads to the lag of information transmission. In the practice of innovation, some enterprises carry out "project matrix management", divide BIM group, testing group and coordination group according to specialty, directly meet the project requirements, and support the "performance-oriented" incentive system, incorporate technological innovation achievements and risk pre-control effects into the assessment, link them with bonuses and promotion, and stimulate the initiative and creativity of the team.

4.3.3 Compound training of supervision talents' ability

WLC supervision requires supervisors to have the ability of engineering technology, digital tool application, project management and cross-disciplinary collaboration. Enterprises cultivate compound talents through the dual-track system of "internal training+external introduction". Regularly carry out skills training such as BIM software operation and big data analysis; Introduce professionals with information background and green building certification from outside to form an echelon structure of "technical experts+management experts".

5. Conclusion

In the decision-making stage, the supervisor helps the owner to define the functional orientation and budget framework of the project by participating in demand analysis and evaluation, so as to reduce the decision-making risk. In the design stage, digital tools such as BIM are used for collaborative design and conflict detection to optimize the design scheme. In the construction stage, the coordinated control of progress and quality is realized by digital means, and the risk pre-control and emergency response are strengthened. In the operation and maintenance stage, the completed BIM model is transformed into an operation and maintenance database to support intelligent and sustainable management. In the demolition stage, nondestructive testing technology is used for structural safety appraisal, and the dismantling scheme is scientifically formulated to promote the recycling of resources. In terms of technological innovation, the application of digital and intelligent tools has solved the pain points such as information asymmetry, difficult process traceability and slow risk response, and realized the dynamic perception and accurate control of engineering WLC data. In terms of mode innovation, the WLC supervision mode and multi-agent collaborative service mode are explored, which enhances the comprehensive value of supervision. In terms of management innovation, an agile, efficient and professional supervision management system has been constructed through the combination of process standardization and agility, the reform of organizational structure and incentive mechanism, and the compound training of supervision talents' abilities. The application and innovation of construction project supervision in WLC management not only improves the quality and efficiency of the project, but also promotes the deep reform of the management mode of the project construction, and provides a systematic solution for realizing the high-quality development of the construction industry.

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