Research on supervision process reengineering and efficiency improvement in high-performance building construction

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Abstract: The rapid development of high-performance buildings puts forward higher requirements for engineering supervision, and the traditional supervision mode has shortcomings in technical adaptation, management cycle and responsibility traceability. This paper discusses the optimization scheme of high-performance building construction supervision process based on process reengineering theory, aiming at improving supervision efficiency and ensuring project quality, safety and progress. Firstly, the paper analyzes the application of the theory of process reengineering in engineering management, and puts forward the framework of supervision process reengineering, covering organizational structure optimization, process reengineering, information platform construction and personnel capacity improvement. Secondly, the paper focuses on the key technologies to improve efficiency, including intelligent decision support system, resource optimization allocation algorithm and efficiency evaluation index system. Finally, the paper puts forward the continuous improvement mechanism of supervision management based on PDCA cycle, and emphasizes the importance of scientific index system to promote the standardization and upgrading of supervision mode. This study provides theoretical guidance and practical path for high-performance building construction supervision process reengineering, which is helpful to improve the overall level of supervision industry and promote the high-quality development of construction industry.

1. Introduction

Driven by the goal of "double carbon" and building industrialization, high-performance buildings have developed rapidly. However, the traditional engineering supervision mode is difficult to meet its needs in terms of technical adaptation, management cycle and responsibility traceability: in the face of new technologies such as BIM and intelligent construction, it is difficult for traditional manual supervision to realize real-time monitoring of key performance; Supervision work is mostly concentrated in the construction stage, which cannot cover the whole life cycle collaboration between design and operation and maintenance [1]; Moreover, the scattered recording method makes it difficult to trace the quality of materials and processes. The traditional supervision mode can't meet the fine requirements of high-performance buildings because of the lag of information transmission, mismatch of resources and backward technical tools, which leads to frequent problems such as rework and time delay [2]; Driven by the policy and market demand, the supervision industry is accelerating the digital transformation. The "14th Five-Year Plan" and other documents clearly require the development of intelligent supervision system, and the market also expects the supervision to shift from compliance supervision to providing value-added services such as carbon emission optimization and cost control.

2. Application of process reengineering theory in engineering management

The theory of process reengineering emphasizes customer-centered, focusing on core value activities by simplifying processes and eliminating redundant links; At the same time, it advocates breaking departmental barriers, promoting cross-functional collaboration and information sharing, and making full use of information technology to drive process optimization to improve overall

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efficiency and responsiveness [3].

In engineering management, the theory of process reengineering is widely used in project schedule, quality, cost, safety and contract management. Through the use of ERP and other systems to optimize the schedule and real-time monitoring, strengthen the quality standard formulation and inspection procedures to improve the quality of the project, achieve cost control with the help of accurate budget and cost difference tracking, formulate safety plans and carry out training to strengthen safety management, and at the same time ensure the implementation of terms through strict contract review and execution monitoring, thus promoting the systematic optimization and efficiency improvement of the project management process as a whole.

3. Supervision process reengineering framework

The goal of process reengineering in engineering supervision is to ensure the quality, safety and progress of the project, realize the efficiency, standardization and intelligence of supervision work by optimizing the process, improve the overall management level of the project, and ensure that all technical indicators of high-performance buildings meet the standards smoothly [4]. In order to achieve this goal, it is necessary to follow the basic principles of standardization, standardization, informationization and co-assimilation, that is, unify work norms, clarify post responsibilities, rely on information technology to empower, and promote multi-agent linkage to build a scientific and systematic modern supervision system. In terms of organizational structure, we should establish a clear supervision team, define the division of responsibilities of the chief supervision engineer, professional supervision engineer and auxiliary personnel, and set up full-time posts according to modules such as quality control, schedule management and safety supervision to avoid overlapping or absence of functions and improve the efficiency of professional management. At the same time, it is necessary to establish an inter-departmental collaboration mechanism, with the help of a digital collaboration platform, to realize real-time communication and information sharing between the supervisor and the owner, design, construction and other parties, and to improve decision-making efficiency and execution synergy.

The core module of process reengineering runs through the whole cycle of engineering construction (Figure 1). In the preliminary preparation stage, BIM technology is used to strengthen design review, find design conflicts in advance, and pre-control risks in combination with big data analysis to formulate dynamic response strategies; In the construction process, the Internet of Things, unmanned aerial vehicles and intelligent inspection system are deployed to realize real-time monitoring and automatic quality evaluation of key parameters, establish a closed loop of electronic change management, and use AR/VR technology to carry out digital acceptance of concealed works to ensure the traceability of the process [5-6]; In the stage of acceptance and evaluation, the standardized acceptance of sub-projects is carried out, and the detection accuracy is improved with the help of intelligent instruments. At the same time, a performance feedback mechanism is established based on supervision data, and a multi-dimensional evaluation report is generated to continuously optimize management efficiency.

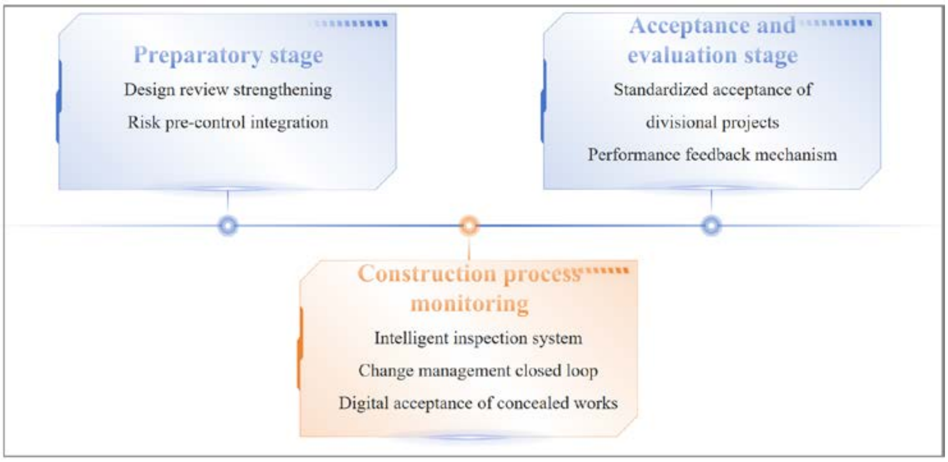

Figure 1 Core module of process reengineering

In order to support the digital transformation of supervision process, it is necessary to build a perfect information platform. By building a cloud data hub, integrating BIM model, schedule and detection data, one-stop query and cross-terminal collaboration of multi-source information are realized, and the data are connected with the construction party system by API interface to ensure real-time synchronization of data; AI technology is applied to assist decision-making, machine learning is used to predict risks, optimize resource allocation, and supervision document abstracts are automatically extracted and generated through natural language processing to improve information processing efficiency. Supporting the development of lightweight mobile applications, supporting the uploading of photos, marking feedback and instant communication of on-site problems, significantly shortening the instruction transmission chain and improving the response speed [7]. At the same time of technology upgrading, it is also necessary to establish a supporting personnel capacity improvement system: design a modular training matrix covering the application of new technologies, interpretation of laws and regulations and communication skills, and carry out on-the-job learning by combining online and offline; Carry out the incentive mechanism linking vocational qualification certification with performance, smooth the promotion channel and enhance the motivation of talent development [8]; And through the establishment of enterprise knowledge base and expert think tank, organize experience exchange regularly, promote the explicit precipitation and sharing of hidden experience, and comprehensively improve the professionalism and collaborative ability of the supervision team.

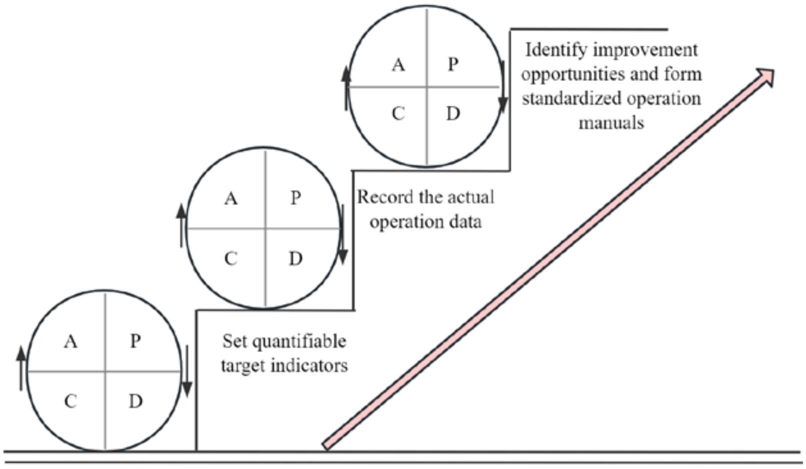

Figure 2 PDCA cycle

Continuous improvement of supervision management is realized through PDCA cycle, as shown in Figure 2. In the "planning" stage, according to the characteristics of the project, formulate the supervision plan and set quantitative goals; In the "execution" stage, monitor and record the operation data according to the optimized process [9]; In the "inspection" stage, compare and analyze the deviation between the plan and the actual situation, and identify improvement opportunities; In the "treatment" stage, the optimization strategy is adjusted, and the effective practices are solidified into standardized operation manuals to promote the continuous iterative upgrading of the supervision system.

4. Key technology of efficiency improvement

4.1 Intelligent decision support system

Traditional supervision decision-making is mostly based on the engineer's experience judgment. In the face of multi-disciplinary cross-operation, sudden risks or design changes in high-performance buildings, decision-making efficiency is often low due to information fragmentation and response lag. Intelligent decision support system provides real-time and accurate decision-making basis for supervision by integrating multi-source data and AI algorithm, which is the key entrance to improve process efficiency. The system integrates BIM model, sensor data of Internet of Things, on-site images, progress reports of contractors, etc., and builds a full-dimensional data pool covering "man-machine-material-method-environment". In the construction of deep foundation pit, the system can simultaneously obtain the monitoring value of supporting structure displacement, the change of groundwater level and the data of historical similar engineering case base. Based on machine learning, the historical supervision problem base and real-time data are trained to realize automatic risk classification and probability prediction; Combined with simulation technology, the effects of different disposal schemes are previewed to assist supervision to quickly choose the optimal path. The system automatically generates standardized supervision instructions including specific problem description, specification basis, rectification time limit and responsible subject, and synchronizes them to construction units, design units and other related parties through mobile APP to reduce communication loss. Intelligent decision support system transforms supervision from "data collector" to "intelligent analyst", and the decision-making time in typical scenarios can be shortened from traditional hours to minutes, at the same time, it reduces the risk of misjudgment caused by human experience deviation and supports the pre-positioning and precision of supervision process.

4.2 Resource optimal allocation algorithm

High-performance building construction involves the dynamic deployment of a large number of heterogeneous resources (manpower, equipment and materials). Traditional supervision relies on manual experience to coordinate resources, which is prone to insufficient resources or redundant waste in key links. Through mathematical modeling and intelligent scheduling, the resource optimal allocation algorithm realizes "on-demand allocation" and "dynamic balance" of supervision resources, which is the core driving force to improve process efficiency.

Aiming at the multi-objective conflict in high-performance buildings, with the constraint of "critical path method+quality risk weight", the supervision priority of each construction process is calculated by linear programming model. Allocate more inspection resources for steel structure welding, and appropriately reduce the inspection frequency for non-load-bearing partition masonry. Combining real-time data with historical laws, genetic algorithm or ant colony algorithm is used to optimize the space-time distribution of supervisors and testing equipment. In the core tube construction stage of super high-rise building, the algorithm automatically adjusts the supervision and inspection period of vertical transportation equipment according to the daily formwork climbing progress to avoid conflict with the concrete pouring peak period. The supervision team is divided into several "agents", and the cooperative strategy of each agent is strengthened to realize the linkage configuration of cross-disciplinary resources. When the safety team finds the hidden danger of scaffolding in a certain area, the system automatically triggers the quality team to check the association of formwork support in this area, thus reducing repeated work. The optimal allocation algorithm of resources makes the investment of supervision resources accurately match the construction risks and schedule requirements. In typical projects, the investment of supervision manpower can be reduced by 15%-20%, and the supervision coverage of key processes can be increased to over 95%, while avoiding the delay of construction period caused by resource mismatch [10].

4.3 Efficiency evaluation index system

The lack of a unified efficiency evaluation standard is the pain point that it is difficult to continuously improve the traditional supervision process-the "hidden value" of supervision work is often ignored, while the "explicit action" may become a mere formality. The efficiency evaluation index system is a closed-loop management tool to drive the continuous optimization of the process by quantifying the key links of the supervision process and clarifying the "direction of efficiency improvement" and "yardstick of improvement effect". The supervision efficiency evaluation system covers three dimensions: core efficiency, collaborative efficiency and technical empowerment:

(1) Core efficiency index. Focus on the direct output of the supervision process, including ① the problem response time (the average time from risk discovery to instruction issuance), ② the

supervision coverage rate of key processes, ③ the rework rate (the proportion of follow-up rectification works caused by missed inspection by supervisors), and ④ the process cycle compression ratio (compared with the total supervision time in the traditional mode).

(2) Synergistic efficiency index. Measure the cooperation efficiency between the supervisor and the contractor, including ① information transmission delay, ② multi-party meeting efficiency (the number of problems solved by a single coordination meeting) and ③ resource sharing rate.

(3) Technical empowerment indicators. Reflect the application effect of intelligent technology, including ① the adoption rate of intelligent decision-making (the proportion of system recommendation scheme actually implemented by the supervisor), ② the proportion of data-driven decision-making (the proportion of decision-making based on real-time data to total decision-making) and ③ the contribution of algorithm optimization (the manpower/time cost saved by resource scheduling algorithm).

By collecting index data regularly and combining with PDCA cycle, the benchmark analysis is carried out: if a link index fails to meet the standard, it will be traced back to the rule setting of intelligent decision-making system or the parameter deviation of resource allocation algorithm, and the model logic or resource allocation strategy will be adjusted accordingly, forming a spiral of "evaluation-improvement-re-evaluation". The scientific index system transforms the supervision efficiency from "fuzzy perception" to "measurable, comparable and optimizable", which not only provides a basis for the process improvement of a single project, but also forms a benchmark reference through the accumulation of industry data, and promotes the standardization and upgrading of the supervision mode of the whole industry.

5. Conclusion

The introduction of advanced technologies such as BIM, Internet of Things and intelligent decision support system can realize the standardization, intelligence and co-assimilation of supervision work, and effectively solve the problems of lagging information transmission, mismatched resources and backward technical tools in the traditional mode. The scheme can significantly improve the problem response time, reduce the rework rate, improve the supervision coverage of key processes, and realize the accurate allocation of supervision resources through the resource optimization allocation algorithm, thus reducing the labor input and improving the supervision coverage of key processes. In addition, the established efficiency evaluation index system provides a quantitative basis for the continuous improvement of supervision process and promotes the overall improvement of supervision efficiency. This study not only provides a new methodology for the practice of high-performance building construction supervision, but also lays a theoretical foundation for the digital transformation and standardization upgrade of the supervision industry, which is of great significance to promoting the high-quality development of the construction industry.

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