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Research on the Quality Management Method Based on Dynamic Response throughout the Entire Process of Complex Projects

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ABSTRACT
Complex projects are characterized by multiple links, high uncertainty, and involvement of numerous stakeholders. Traditional quality control methods cannot meet the demand for dynamic changes throughout their entire process. Therefore, this paper takes the whole-process quality management of complex projects as the core of research, and constructs a dynamic response quality management system from three stages, namely preliminary preparation, core implementation, and post-implementation guarantee. Firstly, it clarifies the prerequisites for quality management by anchoring the alignment between quality objectives and the full project cycle, establishing a foundation for multi-stakeholder collaboration, and setting a benchmark based on customer needs. Then it advances the implementation of quality management through the rapid disposal of quality anomalies at each stage, the dynamic cross-link information transmission, and the real-time optimization of control plans. Finally, it optimizes the guarantee for quality management by means of full-dimensional effectiveness review, experience accumulation and reuse, and iterative improvement of a long-term mechanism. Through the construction of this complete path system, the aim is to solve the problems of dynamic quality management of complex projects, improve the stability and adaptability of project quality, and provide practical reference for quality management of similar projects.

KEYWORDS
Complex project; Entire process; Dynamic response; Quality management

1 Introduction

With the upgrading of industries and the increasing complexity of projects, many dynamic factors emerge during the project implementation process, and the difficulty and uncertainty of quality control are also increasing. As a result, traditional static quality management methods can no longer meet the requirements of dynamic response throughout the entire process. Quality is one of the core objectives of a project, and the effectiveness of quality management directly affects the success and long-term value of a project. Therefore, developing a full-process dynamic response quality management method that adapts to the characteristics of complex projects has become an important topic in current industry practice and theoretical research. Based on the full-process control logic of complex projects, this paper explores an engineering quality management model that is suitable for the dynamic changes of complex projects, thereby improving the comprehensiveness, pertinence, and effectiveness of the quality control system for complex projects, and promoting the continuous improvement of their quality.

2 Preparatory Paths for Full-Process Dynamic Quality Response

2.1 Anchor the Alignment between Quality Objectives with the Full Project Cycle

Quality management of complex projects is a key and difficult issue in engineering construction [1]. Among them, the alignment of quality objectives with the full project cycle is the primary link to ensure the dynamic quality response of complex projects. It means that the quality objectives are not static and one-time determined indicators. Instead, they need to be continuously adjusted and refined in accordance with the characteristics of each project stage, resource input, technical difficulty, and changes in external environment. At the initial stage of a project, according to the overall project plan, the overall quality objectives should be decomposed into phased quality objectives for each stage such as design, procurement, project, testing, and handover. The decomposition should not only run vertically through the time axis, but also cover various professional fields and technical interfaces horizontally, forming a matrix-based objective network. At the project execution stage, based on the objective review mechanism, forward-looking adjustments should be made to quality objectives for subsequent stages, in order to ensure the coordination between the feasibility and challenge of objectives, keep quality requirements consistent with the actual situation of projects, and provide clear and operable guidance for the whole-process quality control.

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2.2 Construct a Foundation for Quality Management among Multiple Stakeholders

The successful implementation of complex projects requires the joint efforts of users, research contractors and supporting units. Therefore, establishing an effective multi-stakeholder quality collaboration mechanism is critical to achieving the full-process dynamic quality response. The core of foundation building is to clarify the quality responsibilities and authority boundaries of each participant, and to construct a cooperation framework with information transparency, clear responsibilities, benefit sharing and risk sharing through formal contracts and agreements, as well as informal communication channels. At the same time, it can utilize digital collaboration platforms to achieve real-time sharing and traceability of information such as process records, inspection data, and problem reports, thereby breaking down organizational barriers and information silos. In addition, it should hold regular quality coordination meetings, joint inspections, experience exchanges to cultivate a sense of collaboration and trust among all stakeholders, and form a quality management community with consistent goals and coordinated actions, thereby providing strong organizational support for addressing uncertainties and sudden quality problems in a project.

2.3 Establish Quality Benchmarks Based on Customer Needs

The ultimate goal of any quality management is to meet customer expectations. In complex projects, taking customer needs as the starting point for quality standards is a crucial prerequisite for ensuring the realization of project value and the achievement of dynamic quality response. It requires that at the beginning of a project, customer needs, especially the important quality characteristics related to functionality, performance, reliability, safety, user experience and other aspects, should be comprehensively and accurately identified and defined through sufficient communication, investigation, and analysis. These demands should be translated into quantifiable and verifiable quality technical standards and acceptance criteria to form a benchmark document for project quality requirements. More importantly, it is necessary to recognize that customer needs will evolve as the project progresses, market environment changes, or understanding deepens. Therefore, it is essential to build a continuous consumer communication and feedback mechanism to evaluate the impact of consumer needs on the project scope, cost, schedule, and quality benchmark, and make adjustments through a standardized change management process. Only by regarding customer needs as the evaluation criteria for quality management can the full-process dynamic response truly serve value creation.

3 Core Implementation Paths for Full-Process Dynamic Quality Response

3.1 Rapid Identification and Disposition of Quality Anomalies at Each Stage

Project management is one of the most important link in enterprise management, and its effectiveness directly affects the development of a company [2]. It is crucial to quickly identify and promptly address quality anomalies at each stage, which constitutes a vital link in ensuring project quality. Accordingly, it should establish a comprehensive quality inspection system, set up quality checkpoints and key indicators at each stage of projects, and utilize regular inspections, sampling tests, and real-time data monitoring to timely identify quality issues. Once an anomaly is detected, an emergency response procedure should be initiated immediately to organize relevant personnel to analyze the cause of the anomaly. Based on the analysis results, corresponding treatment measures should be formulated. Issues that can be resolved immediately shall be rectified in a timely manner, while issue requiring a certain amount of time and resources to address shall be subject to detailed rectification plans with responsible persons assigned. At the same time, the disposition process should be tracked and supervised to ensure that the issue are thoroughly resolved and to prevent the escalation or recurrence of quality anomalies, thus maintaining stable and controllable quality at each stage of a project.

3.2 Dynamic Transmission and Collaboration of Cross-stage Quality Information

Complex projects consist of multiple stages, and the quality information of each stage is interrelated and mutually influential. Therefore, it is of great important to achieve the dynamic transmission and collaboration of quality information across stages. Enterprises need to build a unified information management platform. By integrating the full-chain quality information such as design parameters, procurement quality inspection reports, real-time production data, and test defect records, the platform can eliminate information barriers between various stages, achieve the visual representation and one-click retrieval of data from each stage, and ensure the real-time and accurate transmission of quality information across all stages. Meanwhile, enterprises should establish an information feedback mechanism, and promptly process and feed back the information in the information-receiving phase to form an information loop. Additionally, enterprises should build a cross-department quality collaboration working group. The online collaboration module of the platform should be utilized to conduct real-time communication, jointly analyze and judge cross-stage quality issues, and

formulate collaborative disposition plans. Furthermore, the functions of layout control and operation traceability can be leveraged to ensure that the execution path of the plans can be traced. On this basis, multi-dimensional analysis should be regularly conducted using the linked data accumulated on the platform to identify patterns of quality influence among stages. Based on these findings, information transmission paths and collaboration mechanisms should be improved, so as to enhance the response speed and collaborative efficiency of cross-stage quality control.

3.3 Real-Time Optimization and Adjustment of Quality Management Plans

For enterprises, implementing comprehensive quality management holds positive significance for enhancing their overall competitiveness, enabling them to maintain an advantageous position in the fierce market competition [3]. In turn, the real-time optimization and adjustment of the quality control plans serves as a key fulcrum a comprehensive quality management system to maintain its flexibility and effectiveness. Enterprises should rely on a data-driven dynamic feedback system, and leverage technologies such as IoT sensors and quality data collection systems to capture real-time quality indicator data at each project stage. Based on these multi-dimensional data, by using big data analysis and machine learning algorithms to build a quality anomaly prediction model, enterprises can identify potential risk points in advance and adjust the control strategies accordingly. In addition, enterprises should also establish a cross-departmental collaborative scheme iteration mechanism, involving personnel from production, R&D, supply chain, and other departments, to jointly improve the management process based on real-time quality feedback, ensuring that the scheme adjustments are compatible with project progress and resource allocation. Such real-time optimization capability can not only significantly reduce the cost of quality problem remediation, and shorten the problem response time, but also enable enterprises to quickly adjust quality standards and management measures in the face of changing market demands or supply chain fluctuations, and continuously deliver stable and reliable products or services, thereby forming an irreplicable quality advantage in competition.

4 Post-guarantee Paths for Full-Process Dynamic Quality Response

4.1 Full-Dimensional Review and Evaluation of Quality Effectiveness

For engineering enterprises, project quality management is an essential means to sustain and extend their life, and a key to winning in competition [4]. The full-dimensional review and assessment of quality effectiveness, in turn, represents a systematic review and in-depth analysis of quality performance across all stages of the full project] cycle. Its core lies in breaking through the limitations of traditional single result-oriented evaluation, integrating data from various aspects such as the compliance of design schemes, the precision of project processes, the reliability of materials and equipment, the project cycle fulfillment rate, the degree of cost control deviation, and customer satisfaction, and adopting a combination of quantitative analysis and qualitative interviews to identify the main driving factors of quality compliance or deviation. During the review, it is necessary to sort out the completion status of quality objective, the implementation effect of dynamic response measures, and the resolution speed and impact scope of various quality issues during project execution. Moreover, it also needs to identify the weak links in quality management comprehensively based on the feedback from all project stakeholders. During the evaluation process, it should collect relevant data such as progress, cost, and compliance, and analyze the causes of deviations by comparing with preset quality standards, so as to provide clear and feasible basis for subsequent quality improvement and offer reference for determining quality objectives in future projects. As a result, the review and evaluation can effectively contribute to the improvement of quality management capabilities.

4.2 Accumulation and Reuse of Quality Improvement Experience

The core of accumulating and reusing quality improvement experience is to transform effective quality control methods and dynamic response techniques formed throughout the entire project process into replicable resources. At the project conclusion stage, quality problem-solving cases, emergency response plans, and process optimization schemes should be organized. Some parts that are highly project-specific and not reusable should be removed, and main universal experience should be extracted. It also need to establish a standardized carrier for experience accumulation, with clear definitions of experience classification, recording methods, and storage paths, to ensure that relevant personnel can conveniently search for and use them. At the same time, it should establish a promotion mechanism for experience sharing. It can regularly hold quality experience exchange meetings and case discussions to share accumulated effective experience with various project teams, thereby motivating all stakeholders to take the initiative in applying it. In addition, a dynamic update mechanism for the experience database should be established. Every quarter, it can review accumulated experience, supplement the database with new problems and new solutions from the practical

experience of new projects, and revise and improve existing experience content based on reuse feedback, thus truly achieving the cyclic iteration and value maximization of quality improvement experience throughout the entire process.

4.3 Iterative Improvement of a Long-Term Quality Response Mechanism

The iterative improvement of a long-term quality response mechanism should rely on the results of review and evaluation, as well as accumulated experience, and integrate industrial development trends and project management requirements to continuously optimize the mechanism's process and operation modes. Mechanism loopholes identified in the review, such as complex response processes, unclear responsibilities, and untimely resource allocation, should be are improved sequentially. And responsible persons, response times, and collaboration methods for each process should be defined to ensure the smooth operation of the mechanism. At the same time, accumulated experience should be incorporated into the mechanism, and quality control standards, emergency response plans, and risk warning indicators should be updated, in order to make the mechanism meet the needs of project management. Besides, it is necessary to establish a tracking and feedback channel for the operational effectiveness of the mechanism to promptly obtain feedback on the use of the mechanism during project execution, and conduct regular evaluations of the applicability of the mechanism to form a closed-loop iterative approach of "evaluation-optimization-implementation-re-evaluation", ensuring that it can sustainably provide stable support for the dynamic quality response throughout the entire project process and continuously improve the systematicness and scientificity of quality control.

5 Conclusion

Based on the dynamic response quality management method for the entire process of complex projects, a closed-loop system consisting of pre-preparation, core execution and post-guarantee should be established. This system transforms quality management from static control to dynamic empowerment, shifts local optimization to system collaboration, and changes post-correction to full-process prevention. It not only enhances the predictability, response speed and continuous improvement ability of project quality control, but also solves the issues of dynamism, collaboration and long-term effectiveness in quality management under complex project environments, thus providing important reference value for advancing the development of project management theory and practice.

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