Journal of Civil Engineering and Urban Planning (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/jceup.2025.070309
ISSN 2616-3969 Vol. 7 Num. 3

Research on Dynamic Cost Management and Cost Optimization Control of Residential Building Projects

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Keywords: Construction Project Cost; Dynamic Management; Cost Optimization; Whole Life Cycle; BIM Technology

Abstract: This paper systematically studies the theoretical framework and practical paths of dynamic cost management and cost optimization control in residential building projects. Addressing the shortcomings of traditional static management models in dealing with market fluctuations and project complexity, it proposes a dynamic management system based on the whole life cycle theory. The research realizes data connectivity by constructing a BIM collaboration platform, establishes a closed-loop control mechanism of "monitoring-early warning-decision-correction," and optimizes resource allocation by applying value engineering methods. The results show that dynamic management, through the deep integration of technical tools, management methods, and organizational systems, realizes a paradigm shift from passive accounting to active value creation, significantly improving the accuracy of cost control and the comprehensive benefits of the project. This system provides a theoretical basis and practical guidance for construction enterprises to improve their cost control level.

1. Introduction

Currently, China's construction industry continues to consolidate its pillar position in the national economy. However, with the intensification of market competition and the increasing volatility of raw material prices, the traditional static and fragmented project cost management model is struggling to cope with the complexity of the entire project lifecycle[1]. As a major sector related to the national economy and people's livelihoods, residential building construction's cost control accuracy directly affects corporate profitability and market competitiveness. In this context, dynamic project cost management, as a systematic method that runs through the entire lifecycle of project decision-making, design, construction, and settlement, can effectively respond to market changes and engineering changes through real-time monitoring, feedback, and adjustment mechanisms, thereby achieving precise cost pre-control and optimization[2]. Promoting the development of dynamic management theory and practice is of significant practical and strategic value for improving project investment benefits, guiding the digital transformation of the construction industry, and practicing the concept of green and low-carbon development[3].

This study aims to systematically construct a theoretical framework for dynamic cost management of residential building construction projects and propose operable cost optimization and control strategies. The research focuses on three aspects: in-depth analysis of the theoretical basis and core principles of dynamic management, clarifying its essential differences from traditional static management; accurate identification of the key problems and constraints existing in the current cost management of residential building construction projects, especially the pain points such as information asymmetry, mechanism deficiencies, and technological lag; and, combining information technology and advanced management concepts, proposing an integrated control strategy covering full lifecycle collaboration, dynamic response, value engineering, and compliance management to provide theoretical basis and methodological support for construction enterprises to improve their cost control level.

2. Theoretical Foundation

2.1 Concept and Characteristics of Dynamic Management

Dynamic cost management for residential building projects is a management model that involves continuous monitoring, predictive adjustment, and optimized control of project costs throughout the entire project lifecycle, based on real-time data collection and analysis. Its essence lies in establishing a closed-loop control system of "plan-do-check-act" to achieve proactive and forward-looking cost management. Compared to traditional static management, dynamic management has three significant characteristics: real-time capability, enabling timely capture of influencing factors such as market price fluctuations and design changes; systematic approach, organically integrating cost management with elements such as progress, quality, and safety; and forward-looking perspective, achieving proactive control of cost risks through data prediction and analysis[4]. This management model transforms project cost management from passive accounting to active value creation, adapting to the complex and ever-changing management needs of modern construction projects.

2.2 Theoretical Support for Dynamic Management

Cybernetics provides the methodological foundation for dynamic management. By establishing a feedback regulation mechanism, the deviation between actual cost and target cost is used as a control signal to promptly adjust management actions and maintain system stability. Systems theory emphasizes treating project cost management as an organic whole composed of subsystems such as decision-making, design, construction, and settlement, where the synergy between subsystems determines the overall management effectiveness. Value engineering theory plays a crucial role in project selection and optimization by seeking the best cost-performance ratio through function-cost ratio analysis. The whole life cycle cost theory broadens the management perspective, requiring consideration of cost-effectiveness throughout the entire usage cycle of the project, avoiding shortsighted behavior where short-term cost savings lead to increased long-term operating costs. These theories collectively constitute the multi-dimensional theoretical system of dynamic management.

2.3 Comparative Analysis of Dynamic Management and Static Management

Dynamic management differs fundamentally from traditional static management in terms of management philosophy, methods, and results. Regarding the scope of management, static management is limited to cost accounting at specific stages, with management at each stage disconnected from the others. Dynamic management, however, covers the entire project lifecycle, forming a continuous management loop. In terms of risk response, static management lacks an early warning mechanism for external factors such as market fluctuations and policy adjustments, often responding passively after the fact[5]. Dynamic management proactively prevents and controls risks by establishing risk early warning models and contingency plans. Regarding synergy effectiveness, static management isolates the goals of each department, easily leading to goal conflicts. Dynamic management achieves coordinated optimization of cost, schedule, and quality through an information-sharing platform. These differences determine that dynamic management has significant advantages in complex project environments.

2.4 Basic Principles of Dynamic Management

The full lifecycle collaboration principle requires breaking down departmental barriers and establishing information-sharing mechanisms for design, construction, cost, and other departments to ensure consistency in cost control objectives across all stages. The dynamic response principle emphasizes the establishment of a sensitive monitoring and early warning system to respond quickly to uncertain factors such as engineering quantity changes and material price fluctuations. The value-oriented principle pursues the maximization of full lifecycle value by eliminating ineffective costs through value engineering analysis and optimizing resource allocation while ensuring functional quality. The compliance principle requires that management activities strictly adhere to laws, regulations, and industry standards, establishing standardized contract management and auditing processes. These principles are mutually supportive and collectively constitute the code of conduct and evaluation criteria for dynamic management.

3. Current Status and Problem Analysis

3.1 Severe Information Asymmetry and Data Silo Phenomenon

A primary challenge currently facing cost management in residential building projects is a severely impaired information flow mechanism. Significant information barriers exist among project participants, including construction companies, design institutes, construction contractors, and material suppliers. Design institutes often base their cost estimates on idealized conditions, failing to fully consider the actual constraints of the construction site. Construction contractors, unable to obtain complete design intentions and cost composition information in a timely manner, face significant uncertainty in bid pricing and construction organization design. This information fragmentation directly leads to cost estimates deviating from actual conditions and makes it difficult to effectively trace and define responsibilities during project implementation[6]. A deeper problem lies in the fact that cost data generated in each stage of the project is stored in the independent systems of different participants, lacking a unified coding system and exchange standard, forming a large number of "data silos." This makes it impossible to achieve coherent analysis and in-depth mining of full life cycle cost data, greatly weakening the ability to perform cost prediction and control decisions based on historical data.

3.2 Lack of Dynamic Response Mechanism and Delayed Cost Deviation Correction

The cost management systems of most construction companies remain at the level of periodic report aggregation, far from achieving dynamic monitoring and real-time response. The collection of cost data relies heavily on manual filling and ex-post collation, resulting in a significant delay in information updates. Cost overruns are typically discovered only after they have already occurred. Price adjustment clauses in contracts are often rigidly designed, failing to fully consider the risk of drastic market price fluctuations and lacking flexible mechanisms such as index-based pricing or formula-based pricing. When encountering sudden increases in raw material prices, policy adjustments, or force majeure events, project management teams lack a pre-established plan library and rapid decision-making authorization system, making it difficult to make timely and effective responses, and they can only passively accept a situation of cost overruns. This lack of a response mechanism means that engineering cost management is essentially still in a backward mode of "static control" or "ex-post remedy."

3.3 Lagging Management Techniques and Weak Data Analysis Capabilities

The industry exhibits a clear lack of depth and breadth in the application of information technology to cost management. While some companies have introduced cost engineering software, its functionality is mostly limited to quantity takeoff and budget preparation, failing to achieve deep integration with BIM models, schedule management, supply chain management, and other systems. Data analysis methods are generally rudimentary, primarily involving simple comparative analysis, lacking in-depth mining techniques such as big data-based trend prediction and correlation analysis. Due to the absence of unified data standards and interfaces, multi-source data from IoT devices, on-site inspections, and supplier systems cannot be effectively integrated, making it difficult to build comprehensive cost early warning models. At the team collaboration level, design, construction, and cost departments still rely on traditional communication methods, such as meetings and file transfers, resulting in low information collaboration efficiency. Cost risks in design schemes are often exposed only during the construction phase, leading to significant rework and cost waste.

3.4 Value-Oriented Execution Deviations and Lack of Life Cycle Cost Awareness

In practice, many companies fall into the trap of one-sidedly pursuing the lowest short-term costs, violating the principle of optimal value. To drive down bid prices or meet short-term budget targets, they adopt overly simplified schemes, reduce material grades, or compress reasonable processes in design or construction, such as lowering waterproofing grades or using substandard pipes. Although these actions reduce construction costs on paper, they create serious quality risks, leading to increased maintenance frequency, increased energy consumption, and decreased user satisfaction after building delivery[7]. From a life cycle perspective, the total cost increases significantly. At the same time, companies generally lack sufficient consideration of costs in the operation and maintenance phase. They rarely conduct life cycle cost (LCC) analysis in design decisions, failing to incorporate later operational energy consumption and maintenance and renewal costs into the early investment decision-making framework, resulting in a short-sighted phenomenon of "emphasizing construction and neglecting operation."

3.5 Weak Compliance Management and Intensified External Environmental Challenges

Non-standard contract management is one of the main causes of cost disputes. Some contract clauses contain ambiguities in the description of the project scope, change procedures, price adjustment mechanisms, and risk sharing, laying the groundwork for subsequent claims and disputes. The change order management process is chaotic, with unclear approval authority and procedures, often leading to uncontrolled change costs. Facing increasingly stringent environmental policies and the "dual carbon" goals, many projects are still in a state of passive compliance with green building and energy-saving and carbon-reduction requirements, failing to systematically and economically integrate green technology into project design, often resorting to post-remediation measures, which significantly increases compliance costs. In addition, external macro risks such as international commodity price fluctuations, trade policy changes, and financial environment changes have a huge impact on the cost of residential projects involving imported materials or equipment, and the traditional cost management system clearly lacks the ability to resist such systemic risks.

4. Dynamic Cost Management and Cost Optimization Control Strategies

4.1 Building a Full Life Cycle Collaborative Management Platform

Establishing a collaborative management platform based on BIM technology is the core foundation for realizing dynamic cost management. This platform should run through the entire life cycle of project decision-making, design, construction, and operation and maintenance, integrating multi-dimensional data such as design models, quantity data, cost information, and schedule plans. The platform architecture needs to adopt uniform data standards and open interfaces to ensure seamless data docking between all parties. During the design phase, the BIM model's automatic quantity calculation function enables real-time linkage of design changes and cost data, so any design modification can be immediately reflected in cost changes. During the construction phase, the platform integrates a schedule management module to compare actual progress with planned progress, and combines cost execution to achieve joint control of progress and cost. During the operation and maintenance phase, the platform transfers a complete asset and cost database to provide data support for subsequent operation and maintenance. To achieve effective collaboration, it is necessary to develop a "Full Life Cycle Cost Management Implementation Rules" to clarify the data delivery standards, cost responsibility interfaces, and collaborative work processes of the owner, design, construction, supervision and other parties.

4.2 Strengthening Dynamic Response Capability Construction

Building a closed-loop dynamic response mechanism of "monitoring-early warning-decision-making-correction" is the key to coping with market fluctuations. At the monitoring level, the IoT sensors should be deployed to collect on-site data such as material arrival volume, mechanical working hours, and labor consumption. At the early warning level, a multi-level early warning indicator system should be established. When the price fluctuation of major materials exceeds ±5%, or the cost deviation rate of a single item exceeds ±3%, the system automatically triggers an early warning. At the decision-making level, a cost prediction model based on machine learning algorithms can be developed to simulate the impact of different market scenarios on costs, providing data support for management decisions. At the correction level, a standardized emergency response plan library can be established to clearly define the handling procedures, responsible departments, and response measures for various risk events. In terms of contracts, a price adjustment formula is introduced to establish a linkage mechanism between the prices of materials such as steel and commercial concrete and the official price index, achieving risk sharing[8].

4.3 Deepen Value-Oriented Management Thinking

Systematically integrate value engineering principles into the entire project lifecycle, establishing a management system centered on maximizing functional value. During the design scheme selection stage, a quantitative model of "value coefficient = functional importance / cost proportion" can be adopted. The schemes with higher value coefficients should be given priority.

During the construction stage, multi-disciplinary collision detection should be carried out using BIM technology to reduce design changes and rework losses. After the project is delivered, a cost post-evaluation mechanism can be established to analyze the differences between actual operating costs and the design expectations, and provide feedback for optimizing the design standards of subsequent projects.

4.4 Fortify the Compliance Management Defense Line

It is of importance to establish a comprehensive compliance management system covering the entire project life cycle. In terms of contract management, developers should adopt standardized contract templates, precisely defining core terms such as project scope, pricing model, change approval process, and price adjustment mechanism. At the same time, a contract risk database should be established, collecting typical dispute cases and judicial judgment viewpoints to provide decision support for contract negotiations and risk prevention. In terms of change management, a four-level approval system of "application - review - approval - execution" should be implemented to ensure that all change matters are traceable and in accordance with the established procedures. To meet the requirements of green buildings, carbon emission indicators should be incorporated into the design scheme evaluation system, and the life cycle evaluation method should be used to quantify the long-term environmental benefits and cost impacts of each scheme. Additionally, a "legal + cost" dual review mechanism should be established to jointly review major contract changes and claim matters, effectively preventing potential legal risks. And regular compliance training should be conducted to enhance the compliance awareness of all employees and integrate compliance requirements deeply into various business processes.

5. Conclusion

This study systematically constructs a theoretical framework and practical pathways for dynamic cost management and cost optimization in residential building projects. The research confirms that the core value of dynamic management lies in achieving a paradigm shift from passive accounting to proactive value creation through full-cycle, multi-dimensional, and real-time cost control mechanisms. The BIM-based collaborative management platform effectively addresses the information silo challenge, providing a technical foundation for the connection and sharing of cost data. The "monitoring-early warning-decision-making-correction" closed-loop response mechanism significantly enhances the project's risk resistance and market adaptability. The in-depth application of value engineering promotes cost management from "lowest price" to "optimal whole life cycle value." Furthermore, the systematic compliance management and data governance system provides institutional guarantees for the standardization and scientific nature of management activities. The effective implementation of dynamic management is essentially a systematic reconstruction of project management organization, processes, and technology. Its success depends on the deep integration of management concepts, technological tools, and institutional systems, ultimately achieving a coordinated improvement in cost control accuracy, resource allocation efficiency, and overall project benefits.

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