Research on the Transformation of Engineering Cost Management Driven by Information Technology

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Abstract: *Against the backdrop of increasingly large and complex modern construction engineering systems, engineering cost management directly affects the economic benefits of investment entities and the efficiency of socialized resource allocation. For a long time, domestic engineering cost management has largely relied on manual quantity calculation, empirical estimation, and decentralized spreadsheet processing. This traditional model is not only time-consuming and labor-intensive but also highly susceptible to subjective human interference, leading to poor information flow and severe data silos, making it difficult to meet the high standards of dynamic cost control required by modern engineering projects. However, with the rise of a new round of technological revolution, the rapid development of information technologies represented by big data, artificial intelligence, Building Information Modeling (BIM), and cloud computing has provided new tools to address the persistent challenges in cost management. By introducing digital methods, real-time collection, in-depth mining, and interactive sharing of cost data can be achieved, thereby significantly improving management efficiency and decision-making quality. Therefore, exploring the deep integration mechanism between information technology and engineering cost management, and analyzing its current application status, existing bottlenecks, and corresponding strategies, holds profound practical significance for promoting the transformation and upgrading of the industry. This represents not merely an update of technical tools but a fundamental shift in management thinking and operational paradigms, marking the engineering cost industry's transition from a "labor-intensive" model to a "technology-intensive" and "intelligence-driven decision-making" one.*

Keywords: *digital technology, engineering cost control, transformation challenges, implementation paths, deep integration*

Introduction

In the context of an increasingly large and complex modern construction engineering system, engineering cost management directly affects the economic benefits of investment entities and the efficiency of socialized resource allocation. For a long time, domestic engineering cost management has largely relied on manual quantity calculation, empirical estimation, and decentralized spreadsheet processing. This traditional model is not only time-consuming and labor-intensive but also highly susceptible to subjective human interference, leading to poor information flow and severe data silos, making it difficult to meet the high standards of dynamic cost control required by modern engineering projects. However, with the rise of a new round of technological revolution, the rapid development of information technologies represented by big data and artificial intelligence has provided new tools to address the persistent challenges in cost management. By introducing digital methods, real-time collection, in-depth mining, and interactive sharing of cost data can be achieved, thereby significantly improving management efficiency and decision-making quality. Therefore, exploring the deep integration mechanism between information technology and engineering cost management and analyzing its application status and existing bottlenecks hold profound practical significance for promoting the transformation and upgrading of the industry. This represents not merely an update of technical tools but a fundamental shift in management thinking and operational paradigms.

1. Core Application Scenarios of Information Technology in Cost Control

The introduction of information technology is not merely a simple stacking of tools but rather a deep restructuring of the entire process of engineering cost management. The following will elaborate on its core application scenarios in intelligent cost management from four dimensions: big data, artificial intelligence, Building Information Modeling (BIM) technology, and cloud computing.

1.1 Big Data Empowers Data Integration and Prediction

Engineering cost management involves massive amounts of heterogeneous data, covering historical project archives, market dynamics, and supply chain information. Big data technology utilizes ETL tools for data cleaning and standardization and employs distributed storage solutions such as HDFS to achieve secure archiving.

1.1.1 Data Warehouse Construction

Big data technology utilizes ETL (Extract, Transform, Load) tools to perform standardized cleaning and integration of data from diverse sources, including internal historical project archives from enterprises, external market material price information, policy and regulation databases, supply chain data, and macroeconomic indicators. By constructing distributed storage systems (such as HDFS), enterprises can securely and efficiently archive massive amounts of data. On this basis, the construction of an enterprise-level cost data warehouse breaks down information barriers between departments and across projects. Managers can employ data mining techniques to conduct in-depth analysis of implicit correlations within the data. For example, by analyzing the cost per unit area indicators of projects in different regions and of various structural types, a multi-dimensional cost indicator library can be established. This approach not only facilitates the rapid preparation of highly accurate investment estimates but also enables real-time tracking of the dynamic impact of market price fluctuations and policy changes on costs, thereby driving a complete shift in decision-making from the past "experience-driven" model to a "data-driven" one.

1.1.2 Application of Predictive Models

Based on machine learning algorithms, various cost prediction models can be constructed. Through cluster analysis and regression analysis of data such as material consumption, labor hours, and machinery shifts from similar past projects, the system can provide a scientific reference range for resource planning in new projects. For example, in the material procurement phase, the system can predict future price trends based on historical data and market trends and recommend the optimal purchasing timing, thereby reducing inventory backlogs and capital occupation while improving capital turnover efficiency. In addition, big data can also be used for sensitivity analysis to simulate the impact of different variables (such as a 10% increase in raw material prices or a one-month delay in the project schedule) on the total project cost, helping management formulate more resilient cost control strategies.

1.2 Artificial intelligence technology excels at processing unstructured data and automating workflows, significantly reducing human errors, enhancing response speed, and liberating cost management personnel from tedious, repetitive tasks.

1.2.1 Intelligent Quantity Takeoff and Pricing

Intelligent quantity takeoff software employs image recognition technology to automatically extract component information from drawings, enabling rapid completion of engineering quantity calculations. The intelligent pricing system then matches the appropriate quota library based on project characteristics, facilitating fast quotation and substantially shortening the preparation cycle.

1.2.2 Risk Early Warning Mechanism

AI can also construct risk assessment models. By learning from historical risk data, it automatically reviews the compliance of cost documents and identifies potential cost overruns or schedule risks. In practice, AI systems can monitor abnormal cost fluctuations around the clock. Once any expenditure is detected to deviate from the preset threshold, it immediately triggers an alert, transforming risk management from post-hoc remediation to preventive measures.

1.3 BIM Technology Enables Full Lifecycle Collaboration

Building Information Modeling (BIM) technology breaks down information barriers across project stages by constructing three-dimensional digital models that incorporate both geometric and physical information, thereby achieving information integration and seamless flow.

1.3.1 Design and Construction Collaboration

During the decision-making and design stages, BIM supports multi-disciplinary collaborative modeling and utilizes clash detection functions to identify design conflicts in advance, avoiding cost waste caused by rework during construction.

1.3.2 Dynamic Monitoring and Settlement

During the construction phase, a 5D model is formed by integrating schedule and cost information, enabling dynamic monitoring of project costs. At the completion stage, the BIM model serves as a data carrier, providing a comprehensive basis for settlement review and ensuring the traceability and transparency of cost data throughout the entire lifecycle. This allows cost management personnel to visually correlate each cost item with its corresponding physical component, greatly enhancing the visualization level of cost control.

1.4 Cloud Computing Promotes Platform-Based Collaboration

Cloud computing addresses the issues of limited local storage and collaboration difficulties, providing technical support for cross-regional management.

1.4.1 Real-Time Data Sharing

Through cloud service platforms, all participating parties can access cloud data anytime and anywhere, enabling real-time sharing of tender documents, bills of quantities, and schedule information, thereby breaking the constraints of time and space.

1.4.2 SaaS-Based Software

The trend toward software as a service (SaaS) in cost management software allows users to utilize the latest features without the need for local deployment. It supports multi-user online collaborative work, significantly improving team communication efficiency and data security while reducing enterprise IT operation and maintenance costs. Particularly in large-scale cross-regional projects, cloud platforms enable headquarters to monitor the cost status of projects in various locations in real time, achieving centralized group-wide control.

2. Current Challenges and Countermeasures

2.1 The Contradiction Between Technological Iteration and Cost Pressure, and Its Resolution

The short cycle of information technology updates requires enterprises to continuously invest funds in upgrading software and hardware. For small and medium-sized cost consulting firms, the high costs of technology introduction and maintenance pose a significant burden, which may lead to a lag in technology adoption and hinder their ability to benefit from digitalization, thereby exacerbating the Matthew effect within the industry. Many enterprises often find themselves trapped in a dilemma of "falling behind if they do not adopt, and finding adoption useless," lacking a scientific assessment of technology suitability.

Countermeasures: Enterprises should establish an informatization development strategy, set up dedicated research and development funds, or collaborate with technology companies to develop customized solutions. Governments can encourage enterprises to upgrade their technological equipment through tax incentives or subsidy policies, lowering the threshold for digital transformation and stimulating market vitality. Internally, enterprises should establish a technology trial-and-error mechanism, allowing for the exploration of new technology application boundaries within a certain scope, thereby avoiding blind following of trends.

2.2 Insufficient Data Standardization and System Construction

The industry lacks unified data exchange standards, and the poor compatibility of data formats between different software programs leads to difficulties in data sharing. Inconsistencies in basic standards such as engineering quantity calculation rules and material coding systems limit the effectiveness of big data analysis and cross-project comparisons, creating new "digital silos." The uneven quality of data also severely affects the reliability of analysis results: garbage in, garbage out.

Countermeasures: Industry associations should take the lead in establishing unified data coding, exchange formats, and storage specifications to break down information silos. A data quality monitoring mechanism should be established to ensure the accuracy and consistency of source data, laying a solid foundation for big data analysis and promoting the value circulation of data elements. Standard setting should possess a certain degree of foresight to adapt to future technological evolution, ensuring the vitality of these standards.

2.3 Regulatory Policies Lagging Behind Technological Development and Their Improvement

Existing engineering cost regulations are mostly formulated based on traditional models, and they lack comprehensive provisions regarding the legal validity and regulatory requirements for new forms such as electronic bidding and cloud-based data storage. Enterprises face compliance risks when applying new technologies and, in some cases, hesitate to experiment boldly due to the absence of legal clarity. For instance, the legal validity of electronic signatures remains disputed in certain specific scenarios, which hinders the widespread adoption of cloud-based settlement.

Countermeasures: Government departments need to accelerate the revision of relevant pricing standards and bidding regulations, clarify the legal validity of electronic data, and fill regulatory gaps. At the same time, they should strengthen policy dissemination, guide enterprises in the compliant use of information technology, foster a healthy digital ecosystem, and ensure the orderly development of the industry. Regulatory methods should also be digitized, leveraging big data technologies to enhance market behavior monitoring and improve regulatory efficiency.

2.4 Shortage of Versatile Talent and Talent Development

Digital cost management requires practitioners to possess both engineering expertise and information technology skills. Currently, the industry faces a significant shortage of such versatile talent, with traditional practitioners struggling to transition and a training system that remains underdeveloped. This situation constrains the in-depth application of technology and the realization of its innovative potential. Senior cost engineers possess extensive experience but are often less proficient in software operation, while young employees excel in technical skills but lack on-site experience. This structural contradiction is difficult to resolve in the short term.

Countermeasures: Enterprises should establish regular training mechanisms to enhance employees' software operation and data analysis capabilities. Universities should optimize their curriculum offerings and strengthen industry-university-research collaboration to cultivate versatile talent proficient in both technology and management. By improving salary incentives, enterprises can attract and retain core talent, providing intellectual support for the long-term development of the industry. Encouraging mentorship programs within enterprises can facilitate the integration and transmission of experience and technical skills, alleviating the issue of talent gaps.

3. Current Major Challenges and Bottlenecks

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4. Strategies for Promoting Deep Integration

4.1 Increasing Technology Research and Development and Financial Investment

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4.3 Improving Laws, Regulations, and Supervision Mechanisms

Government departments need to accelerate the revision of relevant pricing standards and bidding regulations, clarify the legal validity of electronic data, and fill regulatory gaps. At the same time, they should strengthen policy dissemination, guide enterprises in the compliant use of information technology, foster a healthy digital ecosystem, and ensure the orderly development of the industry. Regulatory methods should also be digitized, leveraging big data technologies to enhance market behavior monitoring.

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Enterprises should establish regular training mechanisms to enhance employees’ software operation and data analysis capabilities. Universities should optimize their curriculum offerings and strengthen industry-university-research collaboration to cultivate versatile talent proficient in both technology and management. By improving salary incentives, enterprises can attract and retain core talent, providing intellectual support for the long-term development of the industry. Encouraging mentorship programs within enterprises can facilitate the integration and transmission of experience and technical skills.

Conclusion

The introduction of information technology has brought about a paradigm shift in engineering cost management, significantly enhancing the industry's level of refinement and operational efficiency. Although challenges still exist in areas such as technical standards, supporting regulations, and talent development, the joint efforts of multiple parties to build a sound digital ecosystem will undoubtedly lead to the deep integration of technology and management. In the future, with the continuous evolution of technology, engineering cost management will become more intelligent and transparent, injecting strong momentum into the sustainable development of the construction industry and ultimately achieving a dual enhancement of both economic and social benefits. This process will not be accomplished overnight; it requires professionals in the industry to maintain strategic resolve, continue exploring and practicing, and collectively propel engineering cost management to new heights.

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