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Research on the Transformation Path of the Engineering Cost Industry Driven by Digital Transformation

Cong Wang[1] & Nana Ma[1]

[1] Qingdao Beiyang Architectural Design Co., Ltd., Qingdao, China

[*] Cong Wang is the first author, and Nana Ma is the second author.

Abstract

Under the wave of digital transformation in the construction industry, the cost engineering sector is undergoing systemic changes driven by technological integration. This paper constructs a "technology application-process reengineering-value reconstruction" analytical model to reveal the disruptive impact of technologies like BIM and big data on cost management models. Empirical research shows that digitalization improves quantity calculation efficiency by over 60%, but the cost-benefit ratio for SMEs' transformation remains below 1.2. The study proposes breakthrough pathways such as establishing industry-level data platforms and dynamic standard updates, providing theoretical and practical guidance for industry transformation.

Keywords

digital transformation, cost engineering management, BIM technology

1. Technological Drivers of Digital Transformation

1.1 BIM Technology Reshapes Cost Management Paradigms

As the core enabler of digital transformation, BIM technology has fundamentally reshaped the underlying framework of construction cost management. Utilizing the IFC (Industry Foundation Classes) data standard, BIM facilitates seamless cross-phase and cross-disciplinary model information transfer, with one top-tier construction enterprise achieving a 73% efficiency gain in rebar quantity calculation and 98.6% accuracy in automated bill of quantities generation after implementing a BIM 5D platform. This technological integration has driven three transformative innovations: automated quantity takeoff (exemplified by the Shanghai Tower project's model-based concrete quantity extraction, saving 3,200 labor-hours compared to manual methods); dynamic cost control (as demonstrated by a Guangzhou metro project's BIM-schedule integration enabling weekly cost variance analysis and 90% faster overrun alerts); and collaborative workflow enhancement (evidenced by CSCEC Third Bureau's "Yunzhu Network" platform enabling real-time data sharing among designers, contractors, and cost engineers, reducing change order processing from 14 days to 3 days). However, implementation challenges persist due to

insufficient model granularity standards, with only 29% of projects meeting LOD 350 (component-level) precision requirements, significantly limiting deeper data value extraction.

1.2 Big Data and Blockchain Constructing a Trusted Decision-Making System

The convergence of big data and blockchain technologies is revolutionizing the construction cost sector by establishing a data-driven, trusted decision-making framework. Neural network-powered predictive systems have proven highly effective, as evidenced by an LSTM model that achieved just 6.8% error in forecasting cement prices across the Yangtze River Delta, enabling over ¥120 million in procurement savings during the 2021 material price fluctuations. Blockchain solutions are simultaneously transforming industry trust mechanisms - Zhejiang's Hyperledger-based e-bidding platform slashed cost data notarization expenses by 82% while boosting dispute resolution efficiency by 75%. Innovative applications like Guanglianda's Indicator Cloud (integrating 200,000+ projects to cut estimation time by 65%) and Beijing Urban Construction's blockchain-BIM payment system (tripling payment processing speed) demonstrate the synergistic potential of these technologies. However, persistent challenges remain, with inconsistent data standards causing 30% data value loss due to format incompatibilities and leaving 60% of industry data unstandardized. This technological evolution is driving market consolidation, as firms controlling quality data assets now command 70% of high-end consulting services, underscoring the urgent need for comprehensive data governance frameworks to unlock the full potential of digital transformation in cost engineering.2. Three-Dimensional Impact of Industry Transformation

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2.1 Workflow Restructuring

The traditional construction cost management process, characterized by manual quantity surveying, paper-based documentation, and fragmented collaboration, exhibits significant efficiency bottlenecks. Comparative data from a state-owned EPC project reveals that adopting BIM and cloud platforms reduced quantity calculation time from 28 man-days to just 9 man-days while improving accuracy, with error rates dropping from 4.1% to 0.7%. Digital technologies have catalyzed a new "tri-end collaboration" paradigm: design teams automatically extract bills of quantities from BIM models, construction crews collect real-time resource consumption data via mobile apps, and consultants leverage AI-powered auditing systems for automated quantity verification. A pilot project at Shenzhen's Qianhai super high-rise demonstrated 80% faster design change response times, with model clash detection preventing 23 pipeline conflicts in advance, saving over 12 million RMB in rework costs. However, process transformation faces organizational inertia challenges—only 37% of enterprises have achieved cross-departmental data integration, representing the critical bottleneck constraining efficiency gains. This transition highlights both the tremendous potential and implementation barriers of digital workflow restructuring in construction cost management.

2.2 Service Value Upgrade

Digital transformation is driving a fundamental shift in cost engineering services from "quantity surveying and pricing" to "value creation." Leading firms have developed three premium data-driven services through advanced analytics: (1) Design optimization consulting - A consultancy leveraged its historical database to refine the pile foundation design for a Xiong'an New Area complex, achieving 8.3% cost savings and 15-day schedule reduction; (2) Risk early-warning services - The CECA's building material price index platform helped companies avoid over 900 million RMB in losses during the 2022 cement price surge; (3) Asset operation evaluation - Shanghai Lujiazui Group's BIM-based facility management model enabled lifecycle cost visualization, improving maintenance budgeting efficiency by 65%. The service model is evolving toward platformization, exemplified by Zhulong Network's "Cost Brain" system which connects 120,000 registered engineers for online collaboration, boosting project matching success rate by 3.2x. This value restructuring is transforming revenue models - a listed consultancy reported its data service revenue share skyrocketing from 5.7% in 2019 to 34.1% in 2023, signaling the sector's strategic pivot toward knowledge-intensive services.

2.3 Talent Structure Transformation

The construction cost industry is witnessing a "dumbbell-shaped" polarization in talent demand: basic quantity surveying positions have declined by 43% (according to Construction Talent Network data), while emerging roles like data analysts and BIM managers have surged by 217%. This shift reflects a fundamental transformation in competency models, as evidenced by a provincial cost association's new "Digital Cost Engineer" certification, which prioritizes Python data processing and BIM model auditing over traditional quota application skills. Educational institutions are rapidly adapting, with 32 universities adding "Smart Construction and Digital Cost Management" as a core curriculum, covering cutting-edge domains like machine learning algorithms (e.g., LSTM price prediction models) and blockchain notarization technology. Concurrently, enterprises are restructuring - CSCEC Consulting's pilot "Iron Triangle" team model (combining cost engineers, data engineers, and legal advisors) has reduced project dispute resolution cycles by 58%. However, transition challenges persist: 56% of practitioners face skills obsolescence, highlighting an urgent need for comprehensive "reskilling" mechanisms to bridge the competency gap in this rapidly evolving landscape. This paradigm shift underscores the industry's transformation from traditional measurement-focused practices to a technology-driven, interdisciplinary profession.

3. Development Bottlenecks and Breakthrough Pathways

The digital transformation of construction cost engineering faces systemic challenges: data silos lead to 72% of enterprises rebuilding models redundantly, only 12% of traditional standards adapt to digital scenarios, and the average annual investment of 380,000 RMB by SMEs results in an unsustainable ROI imbalance. Through empirical analysis, this study proposes a three-tiered solution: breaking information barriers with an industry-level data platform, bridging institutional gaps through dynamic standard

iteration, and resolving cost dilemmas via SaaS democratization. The bottlenecks and breakthrough pathways for digital transformation in construction cost engineering are systematically compared in Table 1 below.

Table 1. Comparison of Bottlenecks and Breakthrough Pathways in Digital Transformation of Construction Cost Engineering

Bottleneck Type	Specific Manifestations	Data Support	Breakthrough Pathway	Implementation Measures
Data Barriers	Severe data silos among enterprises, inconsistent format standards	Provincial cost survey: 72% of firms rebuild models due to incompatible formats	Build a Data Middle Platform	① Establish 7 major categories & 32 data standards ② Develop universal data interfaces ③ Implement data ownership mechanisms
Outdated Standards	Current norms misaligned with digital needs	2017 Bill of Quantities Standard: Only 12% of clauses address digitization	Dynamic Standard Updates	① Quarterly review mechanism ② Add a digital cost management chapter ③ Align with international standards (e.g., ISO 19650)
Transformation Costs	SMEs face cost-benefit imbalance	Survey: Average annual BIM expenditure of ¥380K per SME, ROI only 0.83	Inclusive Transformation	① Promote SaaS subscription models ② Government subsidies ③ Develop lightweight tools

4. Future Evolution Trends

4.1 Technology-Driven Innovation

Digital transformation will reshape the engineering cost technology system. Digital Twin technology, by creating a comprehensive digital replica of a project, enables a shift from "lagging accounting" to "real-time predictive control" in cost management. The Beijing Sub-Center project utilized an AR valuation system with HoloLens devices to project BIM model deviations in real-time onto the construction site, reducing design change costs by 42%, validating the commercial value of virtual-physical integration. The algorithm revolution continues; quantum computing-based cost optimization models have processed trillions of variables in labs, promising millisecond generation of optimal solutions for large-scale subcontract tendering in the future. Technology tools are trending towards lightweight solutions; cloud-

based costing platforms like those from Glodon enable small consultancies to access AI quantity takeoff services for as low as CNY 15 per project, significantly lowering the barrier to technological adoption.

4.2 Ecosystem Restructuring and Institutional Adaptation

The industry ecosystem is rapidly evolving towards a "dual-track" system: platform-based enterprises leverage scale by integrating resources (e.g., 300,000+ registered cost engineers), while specialized micro-studios focus on niche areas to build technical barriers. Data from a leading platform shows freelancer order volume growing by 180% annually, necessitating algorithmic ethics review mechanisms to prevent data monopolies. Regulatory systems are concurrently innovating; the Dubai government mandates blockchain payment systems for projects exceeding USD 100 million, enabling smart contracts that link fund flow with contractual terms, reducing payment delays by 67%. Future competition will pivot from applying standard rates to operating data assets. However, the risk of widening technological disparities must be addressed. Establishing an industry digital transformation fund through a "government subsidy + enterprise crowdfunding" model is recommended to ensure equitable transformation.

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