Engineering Change from the Perspective of Big Data - Cost Risk Control Analysis of Supply Chain Collaboration

Miao Li [1, *], Zhilin Liu [2], Shuyan Ren [3]

[1] School of Computer Engineering, Guangzhou City University of Technology, Guangzhou, China

[2] School of Architectural Engineering, Guangdong Technology College, Zhaoqing, China

[3] School of Accounting, Hubei Business College, Wuhan, China

* Corresponding Author Email: limiao1@stu.gcu.edu.cn

Abstract. In response to the frequent supply chain disruptions and the cost control issues caused by construction project changes, this article uses big data technology as a support to construct a collaborative control framework for engineering changes and supply chains. The study systematically investigates the transmission mechanism of cost risks in material supply, logistics distribution, supplier performance, inventory management, and other links under the change scenarios. Through multi-source data fusion, machine learning risk identification, dynamic evaluation models, and real-time warning systems, achieve collaborative control of the entire change supply chain cost chain. Research has shown that big data-driven collaborative models can significantly reduce additional costs caused by material shortages, expedited logistics, inventory waste, and price fluctuations, and improve change response efficiency and cost control accuracy. The control system proposed in this article can provide theoretical and practical references for achieving cost reduction, efficiency improvement, and risk control in large-scale construction projects.

Keywords: Big data, engineering changes, supply chain collaboration, cost risk control, construction supply chain.

1. Introduction

Construction project scales and environmental complexity make engineering changes inevitable. Frequent changes disrupt the supply chain, causing delays, inventory issues, and price fluctuations. Uncontrolled risks lead to cost overruns. Traditional cost management relies on post-accounting and lacks supply chain visibility, making it hard to respond to change-driven risks. Firms that use big-data coordination gain competitiveness.

Existing research lacks focus on cost risk from engineering changes. Most controls are project-bound, disconnecting changes from supply chain effects and delaying information. Traditional methods depend on historical data and expert judgment, without big-data mining capabilities for risk quantification. Firms also ignore how changes transmit cost risk through the supply chain (e.g., bullwhip effect), leaving them reactive and without early warning systems.

Big data offers a way forward. Data fusion and machine learning enable mining of historical records, market data, and supply chain status. This breaks down silos between design, procurement, construction, and cost management, supporting a full-chain control system. With big-data risk models, managers can predict change impacts, quantify risk paths, and set up early warnings.

This study proposes a big-data paradigm for cost-risk management in engineering change and supply chain coordination. It examines how cost risks spread through material supply, logistics, and inventory under changing scenarios.

2. Analysis of the Cost Risk Transmission Mechanism of Engineering Changes

2.1. Design Changes and Cost Deviations

Design changes are one of the core causes of cost deviations in engineering construction. When engineering projects change due to changes in requirements or other necessary reasons, it will inevitably lead to price fluctuations. The transmission mechanism and risk control of cost deviation caused by changes are reflected in multiple aspects. One of them is the triggering and transmission mechanism of cost deviation. Cost deviation caused by design changes usually leads to changes in "quantity" and "quality". The increase or decrease in quantity does not change the quality standards. The original price settlement standard has not undergone substantial changes, and the deviation mainly comes from the increase or decrease in engineering quantity. The adjustment of quality standards will have a substantial impact on the price, leading to more complex cost deviations. On the other hand, deviations caused by changes in design can lead to multidimensional risk impacts, and cost deviations caused by design changes can also have a chain reaction. Serious project cost deviations can reduce investment returns and even exceed budgets and timelines, while uncontrollable cost deviations can disrupt a company's cash planning and other expectations[1]

2.2. Procurement Changes and Supply Chain Risks

Procurement changes, as a necessary means of responding to market demand fluctuations or unexpected situations, can easily become a trigger for supply chain risks if not effectively controlled [2]. Procurement changes are usually triggered by internal demand adjustments or external environmental factors. When changes occur, risks will be transmitted through multiple paths in the supply chain. Changes will result in additional costs due to the loss of control over direct costs. Changes also mean that production needs to be suspended to wait for new documents or materials, and the changes require revalidation or small-scale trial production. This process can easily lead to delays in the originally promised delivery date and disrupt the original plan. Any change is a challenge to the existing stable state. Under the condition of rushing progress, it may compress some seemingly insignificant processes, which can easily lead to potential defects flowing into the market. At the same time, frequent changes disrupt all original plans and rhythms, leading to a decrease in coordination between each other. If a company heavily relies on a single supplier and has no alternative solutions, the change process can easily lead to supply chain disruptions.

2.3. Construction Changes and Loss of Control of On-site Costs

There is a close causal relationship between construction changes and uncontrolled on-site costs in engineering construction[3]. Construction changes are often seen as a necessary means of responding to unexpected situations on site and optimizing design. But in practical operation, it is easy to evolve into project cost control and schedule delay. Many projects have resulted in settlement prices far exceeding budgets due to the loss of effective constraints on construction changes and the resulting on-site confirmations. There are many situations where construction changes lead to loss of control over on-site costs, first reflected in the absence of pre-accident contract constraints and the ineffective approval process during the process. Many of the later disputes stem from the ambiguity of the earlier contracts. Moreover, there are many violations of the principle of "construction before approval" carried out on-site. Some projects bypass the formal change process to meet deadlines or avoid regulatory oversight. This lack of management leads to arbitrariness that not only makes on-site costs easily out of control, but also leads to fraudulent behavior that exploits loopholes. To break the vicious cycle of cost control caused by construction changes, it is necessary to build a full cycle firewall from the source to settlement. Prior control should be achieved, with clear pricing and adjustment principles in the contract, detailed risk sharing mechanisms, and supplementary principles agreed upon in advance for possible engineering omissions.

3. Case Analysis

This chapter uses Shaanxi Construction Engineering Holding Group Co., Ltd. (hereinafter referred to as Shaanxi Construction) as a case study to analyze the practical impact of big data collection on controlling change procurement costs.

The research is carried out from three dimensions: the transformation background, the effectiveness of material cost control, and the improvement of platform sourcing efficiency, and analyzes the specific role of big data technology in reducing procurement costs, simplifying transaction processes, and reducing supply chain transaction costs. Finally, it provides a practical basis for big data, enabling risk control of engineering change and optimizing the construction supply chain system.

3.1. Shaanxi Construction Digital Top-level Planning and Traditional Procurement Pain Points

Shaanxi Province issued the "168" digital transformation strategy at the beginning of the "14th Five-Year Plan" to provide top-level support for supply chain digitization and change cost control: one core goal, six top-level architectures, and eight digital implementation project groups. Centralized supply chain procurement digitization is the core component of construction. The group established the professional operation entity of Shaanxi Construction Digital Technology Co., Ltd., and jointly established the industrial digital ecology with Guanglianda, to get through the data change of the whole link of design, cost, procurement, and construction, and to solve the problems of supply and demand imbalance and cost out of control caused by the change by relying on "data+connection+algorithm" [4]

Before the implementation of the big data centralized procurement system, the subsidiaries and project departments of Shaanxi Construction Corporation implemented the decentralized procurement mode. Under the superposition of frequent engineering changes, the cost risk is continuously transmitted and amplified along the supply chain. Similar risk transmission phenomena have been studied in the construction supply chain [5]. The circulation of traditional building materials is divided into multi-layer distribution channels, with dealers at all levels increasing prices. In case of temporary changes, such as specification adjustment and on-site visa, small purchases will generate an urgent premium of 10%~40%. The change demand of each project is reported independently, lacking a unified collection channel of the group, and the demand fluctuation is amplified along the supply chain, resulting in double losses of material supply interruption and inventory backlog, which is consistent with the judgment that design changes will cause supply chain risks in existing studies [6]. At the same time, the change account, price data, and supplier information are separated from each other, and it is impossible to predict the price trend with the help of historical change data. The whole process of change depends on offline manual circulation, and the approval cycle is up to 7 days. Therefore, secondary cost losses such as construction delay and acceleration claims are very easy to occur.

3.2. Trinity Centralized Purchase Collaboration System Architecture and Operation Mechanism

In view of the above difficulties, Shaanxi Construction has built a big data centralized purchase system consisting of three platforms, namely, Shaanxi Construction Cloud Mining, Bulk Material Performance Platform, and Huashan Cloud Commerce, forming a closed-loop chain of "change demand Collection - Intelligent Matching - Logistics Planning - cross-project inventory scheduling - dynamic cost accounting".

At the bottom of the system, a multi-source fusion database is built to collect multiple types of data such as BIM models, change visa, supplier capacity, real-time building material price, and warehouse inventory. After the change approval is completed, the system automatically disassembles the list of material additions and deletions, and the platform has more than 87000 suppliers [4]. The

algorithm engine distinguishes demand scenarios according to the type of change: long-term batch changes are included in the annual centralized bidding, and sudden and sporadic changes are given priority to matching idle inventory or direct supply sources of origin to avoid middlemen's price increases. Among the three platforms, Shaanjian Yuncai is responsible for large-scale bidding for changes in main materials. The bulk material performance platform is dedicated to structural main materials such as steel and square timber. Huashan Yunshang, which was launched in 2020, is for sporadic changes in materials such as decoration, mechanical, and electrical equipment. Supporting the "four centralized" control mechanism (centralized summary of demand, unified pricing, centralized distribution, and unified accounting), hedging the risk of price rise caused by changes through large-scale procurement.

3.3. Quantitative Effect of Change Cost Control Under the Mode of Big Data Centralized Purchase

This part uses the vertical data comparison before and after the digital transformation of Shaanxi construction, and all cost and transaction data are from the annual report of the group's operations and the industry research data of Guanglianda [4]. Compared with the decentralized procurement mode before the transformation, under the centralized procurement and direct supply mode, the cost of various commonly used main materials for change has been significantly reduced: the purchase price of square timber has been reduced by 35%, the aluminum formwork has been reduced by 25%, the price of wires and cables has been reduced by more than 20%, and the paint and coating has been reduced by 50%. In 2019, the group intensively purchased 1.65 million tons of steel, which directly saved the purchase cost of 300million yuan, and can quickly respond to sudden changes in foundation and structure. The logistics and inventory costs were significantly optimized; the change expedited transportation costs were reduced by 90%, the cross-project allocation reduced the idle loss of materials by 60%, and the additional material costs caused by engineering changes were reduced by 15%~30% on average. The emergency project of the Xi'an public health center is a typical practical case. The sudden large-scale design changes of the project rely on the resource integration ability of the whole industrial chain of large-scale centralized procurement. The first batch of steel distribution is completed in 3 hours, and all construction materials are allocated in 9 days to avoid high construction period claims. This case shows the potential of the big data supply chain to ensure supply and control price in response to sudden changes.

3.4. Huashan Cloud Business Platform Optimization, Change Collaborative Operation Efficiency

It takes a week for traditional change procurement to go through the whole process. Huashan cloud commerce has opened up the channels of design, cost, and procurement data to realize the automatic disassembly of change requirements, online price comparison, and paperless approval. The process efficiency has been greatly improved, which is in line with the conclusion of existing Research on reconstructing the change approval process by digital means and improving collaboration efficiency [7]. The platform has a built-in supplier and price database to automatically compare prices among multiple merchants, reducing the labor cost of offline communication by 70%. Online documents are marked throughout the process, and the approval cycle is reduced to 1 day. The group's large digital screen shows the change of material supply and demand and warehouse stock of each project in real time, weakening the bullwhip effect of the supply chain from the source [5]. The transaction scale of the platform can prove the collaborative value. In 2022, the single-day transaction volume of "June 18" was 5.32 billion yuan, and the total amount of online transactions exceeded 380billion yuan. Researchers continue to rely on the scale effect to reduce the comprehensive transaction cost of changing scattered procurement.

3.5. Existing Shortcomings and Practical Constraints of the Current Centralized Purchase Mode

Although the Shaanxi construction big data centralized procurement system has achieved remarkable results, there are still multiple limitations in the implementation process. The digital supporting facilities for small-scale projects at the county level are not perfect, the Bim and change account system are not fully covered, and scattered changes cannot be accessed to the group's centralized purchase channels, and there is still a purchase premium; Electromechanical and decorative non-standard components lack batch centralized purchase conditions, and the adaptability of big data intelligent matching algorithm is insufficient; The investment threshold of software and hardware for the whole digital platform and smart construction site is high, and it is difficult for small and medium-sized construction enterprises to follow suit; Most of the existing early warning indicators are macro price and arrival rate indicators, and there is a lack of special prediction models for subdivisional scenarios such as geological changes and decoration changes. The degree of refinement of risk prediction is insufficient.

4. Analysis of Supply Chain Collaborative Risk Control Strategies

4.1. Risk Mitigation: Pre-change Forecasting and Plan Optimization

The construction unit should utilize big data mining capabilities to advance risk management to the pre-construction stage. By importing historical project records into the engineering change database and applying association rule algorithms, high-frequency change factors such as design omissions and sudden geological conditions can be identified during the design phase, providing a basis for change prediction. By combining BIM tools with supply chain resource simulation solutions [8], collision detection and full process virtual drills can be completed before construction, reducing changes caused by design conflicts or resource mismatches from the source.

4.2. Risk Mitigation: Dynamic Procurement and Inventory Scheduling

The construction unit needs to coordinate with contractors, supervisors, and major suppliers to improve supply chain response speed and suppress bullwhip effects through real-time data exchange. Previous studies have shown that uncontrolled changes during construction are the main cause of cost overruns and project delays [9], and rapid response is crucial.

After the change order is issued, the information system automatically recalculates the material requirements and matches them with the supplier's real-time production capacity to achieve precise replenishment and avoid inventory backlog or downtime waiting for materials. A cross-project data sharing platform can break down information barriers between projects. When changes lead to material shortages, the system can quickly allocate idle inventory from neighboring projects or central warehouses to smooth supply fluctuations.

4.3. Collaborative Management Mechanism: Synchronization of Design, Cost, Procurement, Supplier, and Construction Information

The full chain information sharing platform aims to overcome the inherent delay of linear management. By breaking down the data barriers between change orders, cost estimates, procurement records, and schedules, this platform can achieve "one change, multiple synchronized responses".

Based on this interconnection, parallel workflows have become possible: when the design party initiates changes, the cost and procurement departments synchronously obtain updated data, and evaluation and procurement preparation can be initiated without waiting, greatly shortening the change response cycle. This digital collaborative approach runs through the entire change process, reducing cost fluctuations and helping to ensure on-time delivery.

4.4. Real-time Monitoring and Warning System for Big Data

Dynamic monitoring is a prerequisite for ensuring the implementation of strategies. Firstly, set key performance indicators (KPIs), including cost deviation rate, change frequency, on-time delivery rate, and supplier fulfillment rate, to quantitatively evaluate the status of the supply chain. Secondly, based on the distribution of historical data, dynamic safety thresholds are set for each indicator. When the monitoring value exceeds the threshold (such as a sudden increase in material prices), the system automatically triggers a graded warning.

Establish a closed-loop mechanism of "monitoring → warning → disposal → review", regularly evaluate the warning effect, and continuously optimize the warning model and control strategy using machine learning to enable the system to have adaptive evolution capability [10].

5. Conclusion

This study, supported by big data technology, systematically explores the impact mechanism of engineering changes on construction supply chain collaboration and cost risk, and proposes a data-driven collaborative control strategy. The main conclusions drawn are as follows: Firstly, there is a significant risk conduction mechanism between engineering changes and supply chain collaboration. Research indicates that the conduction effects of design changes and cost deviations, procurement changes and supply chain risks, and construction changes and on-site cost out-of-control are not linearly superimposed, but are mutually amplified and constrained among various nodes in the supply chain, ultimately forming systematic collaborative risks. Secondly, big data-driven multi-source data fusion and machine learning algorithms significantly enhance the objectivity, timeliness, and scientific nature of risk identification.

Although this study has made some progress in theoretical construction and methodological application, there are still the following limitations: firstly, the challenges of data acquisition and quality control objectively exist. Multi-source data fusion relies on the integrity and consistency of various business systems, but in practical engineering environments, data silos are still common. Secondly, the breadth and depth of case verification need to be expanded. Due to limitations in research resources and data availability, the selected case projects in this study mainly focus on the field of construction engineering and are mainly large-scale public projects, which limits the representativeness of the sample. Thirdly, the threshold and cost issues of technological application are worth paying attention to. Although big data-driven collaborative management has significant advantages in theory, it places high demands on the technological reserves, capital investment, and talent allocation of small and medium-sized enterprises. How to achieve universality of technical solutions under controllable costs is a key challenge in applying theoretical research to industrial engineering practice.

Future research can explore in depth from the following directions: firstly, deepen interdisciplinary research and construct more refined risk transmission models. In the future, interdisciplinary methods can be introduced to dynamically simulate the transmission path of engineering changes in the supply chain network. Secondly, expand the dimensions of data and technological means to enhance the intelligence level of risk identification. With the maturity of technologies such as the Internet of Things, blockchain, and digital twins, a more comprehensive data perception system can be built in the future. Thirdly, conduct multiple case comparative studies and long-term follow-up evaluations to enhance the universality and reliability of the conclusions. Future research can expand the sample range to cover construction projects of different types, regions, and scales. Establish a long-term tracking mechanism to record performance changes after the implementation of control strategies.

Authors Contribution

All the authors contributed equally and their names were determined by mutual agreement.

References

[1] Jing J, Wu Y H, Meng L Z, et al. Research on cost adjustment mechanism and dispute rsolution paths under the impact of engineering changes. China Enterprise Operation Management Knowledge Repository, 2025, 23(4): 58-62.

[2] Wu Y H. Procurement change management of electromechanical equipment. International Engineering & Labor Services, 2016, (10): 71-72.

[3] Meng L Z. Discussion on engineering cost management and cost control of construction enterprises. Management & Technology of Small and Medium-sized Enterprises (Early Monthly Issue), 2020, (5): 7-8.

[4] Glodon Company Limited. The road to digital transformation of construction enterprises. Beijing: China Architecture & Building Press, 2022: 25-37.

[5] Wang H C, Zhou Z X, & Guo X F. Research on risk transmission mechanism of prefabricated building precast component supply chain under uncertain demand. Journal of Beijing University of Civil Engineering and Architecture, 2023, 39(4): 98-105.

[6] Shi J. Supply chain risk assessment and management for product design changes. China University of Mining and Technology, 2024.

[7] Luo H B, et al. Optimization of design change management process for subway engineering based on BIM. Journal of Civil Engineering and Management, 2023, 40(1): 1-7.

[8] Zhuang B. Research and application of pipeline comprehensive design and construction technology of hotel installation engineering based on BIM technology. Guangdong Civil Engineering and Architecture, 2022, 29(5): 11-14.

[9] Yang X L. Discussion on risk control and management of engineering changes in construction projects. China International Finance (English & Chinese), 2018, (2): 223-224.

[10] Zhao P, Liu G C, Zhou T T, et al. Intelligent matching method of engineering cost control strategy under big data environment. Journal of Wuhan University (Engineering Science), 2023, 56(9): 1073-1080.