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Optimization of Construction Engineering Projects by Lean Management

Ze Tong

Department of Civil and Architectural Engineering, Zhejiang University of Science and Technology, Hangzhou, China
tongze1166@uok.edu.gr

Abstract. With the rapid development of the economy and technology, the construction industry needs to provide more advanced and high-quality solutions for larger-scale and more technically challenging projects. Traditional construction management models can no longer meet the demands of the modern era. Lean management, which focuses on reducing waste and optimizing processes, offers innovative approaches to cost control, resource coordination, and quality management in engineering. This article explores the specific applications of lean management in the entire project lifecycle, including the construction of a cost control system, the optimization of value and business flows, and the implementation of full-process quality traceability. It demonstrates the significant benefits of lean management in reducing labor costs, improving construction efficiency, and ensuring project quality. Research indicates that through systematic optimization, lean management breaks through traditional management bottlenecks in terms of cost, quality, and schedule, effectively enhancing corporate economic benefits and market competitiveness. In the future, when integrated with digital technologies, it can further drive the construction industry towards more efficient and sustainable development.

Keywords: Lean management, Construction engineering, Cost control, Resource coordination

1. Introduction

In the era of rapid technological and economic development, the engineering construction sector is facing significant challenges. As projects are implemented, higher demands are placed on project management. Traditional management models, which are outdated, struggle to manage more complex technologies, diverse investment methods, and larger-scale projects, often leading to resource wastage, redundant processes, and coordination conflicts. When dealing with even larger projects, these models fail to meet the evolving needs of the times. Lean management, however, offers significant advantages in process monitoring and cost control for engineering construction. The focus has always been on promoting more scientific construction practices. The ZHOU system systematically analyzes the importance of cost control in the construction process for achieving economic benefits [1]. By optimizing and monitoring costs throughout the project, it enhances the company's economic efficiency and ensures sustained competitiveness [2]. Applying lean

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management to engineering is the development trend of the engineering construction industry in the new era. Beyond cost control, it extends to optimizing resource coordination mechanisms—such as integrating value streams and business flows to streamline human, material, and financial resource allocation—and establishing full-process quality traceability systems. For example, cases like Nanjing D Group's prefabricated component base and the Suzhou factory project have demonstrated how lean principles eliminate waste, enhance collaboration, and boost efficiency. In the future, when combined with Building Information Modeling (BIM) and the Internet of Things (IoT) and other new technologies, it can effectively realize the quality control and cost optimization of engineering, greatly reduce the loss of resources, and improve the economic benefits of engineering projects. This integration will further break through traditional management bottlenecks, driving the industry toward precision, sustainability, and intelligence.

2. Overview and advantages of lean management

Lean management was introduced by the Japanese automobile company Toyota in the 1950s. This management approach, centered on lean production, aims to reduce resource waste, optimize project processes, and enhance production efficiency and quality, thereby achieving high returns with minimal costs. The concept of lean management also holds significant potential and value in the construction industry. For instance, at H Construction Company, lean management can effectively manage project costs and ensure quality control. By optimizing the coordination mechanisms of engineering projects, it reduces resource consumption, addressing the issues of outdated coordination mechanisms and excessive resource loss common in traditional management models, thus promoting more efficient and higher-quality completion of construction projects [3, 4].

3. Lean management for project cost control

3.1 Cost saving of the project

Lean management aims to establish a comprehensive cost control system for engineering projects, covering aspects such as cost budgeting, cost control, and cost accounting. Currently, construction projects often face issues of high costs, low efficiency, and significant resource waste. By applying lean management strategies to the cost estimation of building decoration projects, it is possible to enhance construction efficiency and reduce losses from rework and waste. For instance, Company H used lean management to meticulously break down target costs, reasonably allocate costs at each stage during project implementation, and conduct comprehensive monitoring and adjustments of cost formation and operations. This approach helps predict costs more accurately, calculate and eliminate unnecessary costs before the project starts, minimize potential financial risks, ensure the company's sustained competitiveness, increase the return on investment, and ensure that construction projects proceed steadily and safely [3, 5].

3.2 Typical case analysis

The Nanjing D Group's R&D and production base for prefabricated components has adopted a lean construction approach. This approach transforms the production process from batch manufacturing to rhythm response. By introducing Lean Value Stream Mapping (VSM), the 12 core processes in the prefabrication workshop have been broken down, eliminating the fragmented state of idle molds and rush work and inventory buildup. This has ended the resource waste of producing for inventory, transforming prefabrication from passive supply to active adaptation. The lean system is deeply

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integrated with BIM models and production data, turning the rigid conflict of design changes leading to component scrapping into flexible adjustments through collaborative optimization, thus shortening the design iteration cycle. On the construction side, the assembly progress at the construction site is fed back to the prefabrication component factory, enabling dynamic supply-demand matching. This has evolved prefabrication supply into an elastic response, fundamentally restructuring the resource scheduling logic of construction projects. In terms of production cycle control, value stream analysis eliminates hidden time wastage such as idle curing kilns and redundant mold debugging. Rather than simply shortening construction project times, this approach adapts the rhythm of prefabrication to the elasticity of construction, optimizing capacity release during rush work and allowing for flexible adjustments when construction is delayed, thus avoiding idle resources. Lean management upgrades prefabrication from an isolated link to the rhythm engine of construction projects, replacing the fragmented segment with a flow logic, enabling true just-in-time collaboration in prefabricated buildings. This provides a breakthrough sample for the management dimension of the construction industry's transition from coarse construction to precision manufacturing.

In 2024, Masa Noguchi provided a detailed analysis of the future prospects of prefabricated buildings for sustainable and large-scale customization. He believes that these buildings will see broader application and promotion in the construction industry, aiming to maximize customer value and minimize factory waste, continuously meeting the needs of both customers and factories [6, 7].

4. Lean management optimizes the resource coordination mechanism of engineering projects

4.1 Value flow and business flow collaborative optimization

Based on lean management, the production and business links are reconstructed through standardized processes, and a physical asset collaborative inventory mechanism is established to realize the deep integration of value flow and business flow. This mechanism improves the efficiency of resource allocation and reduces operating costs by eliminating process breakpoints and reducing redundant operations [4].

In terms of human resources, the lean management system is used to optimize the allocation of personnel, accurately arrange human resources, clarify the functions of different positions, avoid problems such as unclear responsibilities, establish a multi-channel communication platform, and ensure the speed of information circulation and collaboration.

In terms of material resources, the project implements lean management for the required materials, accurately tracking inventory and demand. This approach optimizes resource allocation and streamlines the production and supply chains, aiming to maximize the economic benefits of the project. By integrating value and business flows, it minimizes unnecessary resource waste, enhances the utilization rate of construction equipment, improves the mobility of various resources within the project, ensures the quality and speed of material supply, and fosters long-term stable cooperation among all parties [8].

In terms of financial resources, detailed and accurate budget statistics should be carried out before the start of the project, and a perfect monitoring mechanism for capital flow should be established to implement safety monitoring and real-time early warning of the funds of the engineering project, so as to timely find and adjust the crisis caused by deviations in the construction process.

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4.2 Verification of practical engineering cases

Taking the 2020 Suzhou factory construction project, which adopted lean construction methods, as an example, this project is one of the first successful cases of lean construction in China [9]. The project covers a total construction area of 50,000 square meters, including a factory building, a warehouse, and an office building. In terms of cost control, the Last Planner System (LPS) was used to plan construction costs, and the Kanban system was employed to manage material and economic flows, reducing resource waste and unnecessary expenses, improving the accuracy of cost forecasting, and achieving precise cost management. For progress monitoring, the LPS dynamically adjusted the construction schedule, ensuring efficient coordination among various processes, shortening the project duration, and maintaining controllable construction progress while achieving efficient progress connections. Regarding resource utilization and optimization, a comprehensive quality and safety management mechanism was introduced, and the Just-In-Time (JIT) production system was applied to precisely control equipment and materials, strictly controlling from material selection to process execution, reducing the incidence of engineering accidents, minimizing on-site losses through prefabricated construction, completing standardized production ahead of schedule, enhancing overall construction efficiency, ensuring building quality, and integrating IoT technology for full-process monitoring. IOT sensors were used to track material storage and equipment operation in real time, forming a visual resource scheduling platform, preventing process stagnation due to delayed resource allocation, and achieving dual improvements in quality and safety. The digital control model integrated with IoT enabled a virtuous cycle in the production process, continuously improving engineering links, optimizing coordination mechanisms, and positively impacting project performance in terms of cost, progress, quality, and safety [10].

5. Application of lean management in engineering quality management

5.1 Whole process quality control system

By establishing a comprehensive quality control system throughout the construction process, the lean management philosophy is integrated into every stage of construction, from pre-construction material and equipment inspection to dynamic supervision during construction and quality acceptance after completion. Through the establishment of standardized work processes and a quality traceability mechanism, strict control is applied to critical procedures and key areas. By analyzing construction data and equipment operation parameters, the system can predict potential quality issues and respond swiftly.

5.2 Evolution of industry application

In recent years, lean management has been applied to the field of power engineering. The implementation of lean management in State Grid projects provides valuable references for power engineering construction under new circumstances [7]. Additionally, lean management can strictly control key stages and critical areas of the project, thereby improving work efficiency, enhancing project quality, and identifying potential quality issues and risks during construction [11].

In the context of national power grid projects, the application of lean management highlights unique value distinct from conventional construction practices. Its core objective is to address the industry's challenges in the power grid system, which include high safety standards, stringent time constraints, and complex network coordination. For instance, in a provincial power grid renovation

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project, traditional management methods have led to several issues: long equipment maintenance cycles (with an average single outage maintenance lasting 48 hours), redundant material inventory (with a turnover rate of transformers and other key equipment at only 2.1 times per year), and low inter-departmental collaboration efficiency (information transmission delays exceeding 2 hours between dispatching, maintenance, and operation). Lean management has overcome these challenges through three innovative mechanisms.

First, by establishing a comprehensive risk management system for power grid projects, a closed loop of status monitoring-early warning-response is created, integrating lean principles throughout the maintenance cycle. Using intelligent sensors to monitor 128 key parameters, including transmission line temperatures and substation equipment loads in real time, fault tree analysis (FTA) is employed to predict potential equipment defects in advance.

Second, the reconstruction of value streams based on the power grid topology. Considering the network characteristics of the power grid, which is characterized by a ring network structure and radial power supply, value stream mapping (VSM) is used to optimize the logic of maintenance procedures. Under the traditional model, transmission line maintenance requires power outages for a step-by-step inspection. After the lean transformation, live detection + drone inspection is conducted as a preliminary step, complemented by a three-pronged approach of maintenance, debugging, and acceptance. This has increased the efficiency of maintaining a single 220kV line by 200%, significantly reducing downtime and greatly enhancing maintenance efficiency.

The third approach is to implement a specialized collaborative mechanism for the power industry. This involves establishing a real-time collaboration platform among dispatchers, maintenance personnel, and users. By adopting the Quick Model for Equipment Replacement (SMED) concept in lean management, the process of power outages is optimized. The traditional practice of submitting maintenance requests 72 hours in advance has been replaced by a dynamic approval mechanism based on load forecasting. This mechanism, combined with mobile operation terminals, ensures that on-site data is synchronized to the dispatch center within 5 minutes. The emphasis is placed on real-time data-driven risk warnings and a collaborative response mechanism, which promotes the rational use of energy and enhances project quality, providing innovative ideas for the development of engineering projects.

6. Conclusion

Lean management, as a revolutionary approach to overcoming traditional management bottlenecks in the construction industry, systematically addresses core issues such as resource waste, low collaboration efficiency, and lagging quality control by reshaping the entire value stream. By focusing on eliminating waste, it upgrades cost control, resource scheduling, and quality management from a coarse model to dynamic optimization, precise coordination, and full-process traceability. This approach enhances project execution efficiency and shifts management thinking towards data-driven practices, providing a significant path to improve efficiency and competitiveness in the construction industry, especially in the context of technological complexity and project scale.

From practical applications, cases like Nanjing D Group's prefabricated components base and the 2020 Suzhou factory project have proven its effectiveness: it reduces rework and waste, shortens construction cycles, and improves resource utilization. In power engineering, it solves problems such as long maintenance cycles and low collaboration efficiency, enhancing overall project performance.

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In the future, lean management needs to further integrate with digital technologies, using tools like IoT, BIM, and big data to build an intelligent control system. This will address the current challenges of insufficient flexibility in progress plans and limited industry adaptability, promoting a shift from partial optimization to full industrial chain collaboration. The construction industry will accelerate its move towards efficiency and intelligence, and through the synergy of management innovation and technological revolution, it will provide robust support for the industry's response to future technological changes and sustainable development needs, truly achieving a significant leap from traditional construction to lean construction.

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