Research on Optimization of Construction Management Process of Construction Project

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Abstract. With the steady growth of China's economy these years, the construction industry has experienced rapid development while also facing a series of management challenges. This research aims to optimize construction management process by analyzing the application of lean construction principles and the “Define, Measure, Analyze, Improve, Control” (DMAIC) methodology. Firstly, the study introduces the basic concepts and implementation strategies of lean construction, it focuses on reducing waste and maximizing value. Then the study discusses the practical application of lean construction combined with building information modeling (BIM) technology, emphasizing how BIM can enhance project coordination and reduce errors. In the next part, the research analyzes the five stages of DMAIC theory. The Define Stage determines project objectives and customer needs, and the Measure Stage collects data to understand current performance. Then the Analyze Stage identifies the cause of the problem, and after that is the Improve Stage in which solutions are developed and implemented. Finally, the Control Stage, which ensures that improvement measures can be maintained in the long term. The results show that both lean construction and DMAIC methodologies can significantly enhance construction efficiency and quality, reduce costs and risks, and improve customer satisfaction. These findings emphasize the importance of adopting modern management techniques in the construction industry to achieve efficient and sustainable development.

Keywords: Project management; process optimization; lean construction; BIM; DMAIC.

1. Introduction

With the continuous growth of China's economy and the acceleration of urbanization, the construction industry has ushered in opportunities of rapid development. However, at the same time, it faces a series of management challenges. The scale of construction projects continues to expand, the types of projects tend to be diversified, and the pressure of quality, safety, and schedule and cost control in construction management is growing day by day. In this condition, the traditional construction management method has been unable to cope with various problems brought by complex projects, such as project schedule lag, cost out of control, waste of resources and poor information communication and other phenomena are becoming increasingly prominent, and it is urgent to optimize through more modern and efficient management methods [1].

Construction management of construction projects, as a complex system engineering, involves design, procurement, construction, acceptance and other links, which are interlinked and each link needs to coordinate a large number of personnel and resources. In the actual construction process, information asymmetry, work flow is not smooth, unreasonable allocation of resources and other problems often affect the smooth progress of the project, resulting in time delay, frequent quality problems, cost overruns and other serious consequences. Therefore, how to improve the efficiency and quality of construction management has become the core issue that needs to be solved in the current construction industry.

In recent years, with the continuous innovation of information technology and management concept, the new construction management method has gradually entered the field of construction, and the effect of optimization is remarkable. The exploration and application of modern management methods can provide more efficient, accurate and sustainable construction management solutions for the construction industry. Among them, lean construction draws on the concept of lean production to streamline the process, eliminate waste, optimize resource allocation, and promote the efficiency of

the construction process [2]. In addition, as a systematic process optimization tool, DMAIC can effectively identify and solve bottleneck problems in construction project management, and improve the quality and efficiency of project execution through five stages: Define, Measure, Analyze, Improve and Control [3].

This paper mainly studies the application of the lean construction concept and DMAIC theory on construction project management process optimization. On this basis, then discusses how lean construction and DMAIC play a role in the actual project, so as to improve the overall efficiency of construction project management.

2. Lean Construction

2.1. Concepts and Methods

Lean construction is a management method derived from the lean production concept of the manufacturing industry, with the core objective of maximizing value creation and minimizing waste. In the construction industry, this means more efficient workflows, less material waste, and more optimized project time management. Lean construction emphasizes the collaboration of the entire project team to enhance the overall performance of the project through continuous improvement and process optimization. Its implementation requires thinking from the very beginning of the project about how to improve efficiency by reducing unnecessary work and material use [2]. Its key methods include four points: process optimization, pull system, continuous improvement, and waste identification. Process optimization is identification of non-value-added activities through Value Stream Mapping and elimination or simplification steps. Pull systems means using Pull Planning to ensure that construction activities are only carried out when needed, reducing inventory and waiting times. Continuous improvement is the implementation of the "plan, do, check, act" (PDCA) cycle, constantly seeking improvement opportunities. Waste identification is to identify and eliminate waste, including overproduction, waiting time, unnecessary transportation, process defects, excessive processing, unnecessary inventory, unnecessary movement, talent waste [4].

2.2. Application

2.2.1. Combination of lean construction and BIM technology

The combination of lean construction and BIM technology provides a brand-new project management method, which realizes the innovation of project management by integrating the accurate data and visualization capabilities of BIM with the process optimization concept of lean construction. BIM technology provides practical project data, including design parameters, bill of materials, construction progress, etc. By integrating various data provided by BIM and its own 3D visualization management ability, it can be used to enhance the efficiency and effect of lean construction. BIM allows the project team to virtually construct the building before construction, thereby identifying and resolving potential design conflicts and construction problems before the actual construction is carried out. This ability of pre-planning and simulation coincides with the goal of eliminating waste and optimizing process in lean construction, making project management more accurate and efficient [5].

At the same time, since all project participants can access the latest project information and use shared models through BIM technique, the project team can achieve a higher level of collaboration [6]. This process transparency reduces misunderstandings and rework in the process of project construction management, and ensures that each member can clearly understand the project objectives and progress [7]. Besides, BIM can be used to simulate the construction process and optimize resource distribution to reduce waste and delay. For example, BIM can help predict material demand and construction schedule, so the team could timely arrange material procurement and labor allocation, thus reducing excess production and waiting time [8].

Besides, the application of BIM tech can be further extended to the field of quality control and safety management of construction projects. By taking construction specifications and safety standards in the model, BIM can help project teams monitor construction quality, predict potential safety risks, and reduce defects as well as unnecessary movements. This method can not only improve the construction efficiency, but also improve the final quality of the building and ensure the safety.

The combination of lean construction and BIM technology provides a new perspective for construction project management. Through precise data-driven decision making, enhanced team collaboration and visual simulation of the construction process, resource conservation and optimization of the construction process are realized, thus giving the construction industry greater efficiency.

2.2.2. Application Case

This paper cites the case study of Li and Bai [5]. This case focused on a new super high-rise integrated office building project in China, which has a total floor area of 62,721.64 square meters, including 35 floors above ground and 3 floors below ground, and a total building height of 177.85 meters [5]. The project adopts BIM technology to help lean construction, covering many aspects such as finite element analysis of mass concrete placement, deepening design of steel structure joints, and optimizing layout of comprehensive pipelines. Through these applications, the project aims to realize the efficient connection of each link, improve construction quality and efficiency, and reduce construction costs [5].

In this project, the combination of BIM technology and lean construction is present in many aspects and runs through the entire construction management process. Through the BIM collaborative management platform, the project team managed the site in an all-round way, reasonably assigned the job responsibilities of all parts of the team, worked out the BIM planning and implementation plan, and formulated a reasonable implementation schedule to ensure the orderly development of the work, thus improving the general contracting management ability of the project. The technology is also applied to the optimization of drawings, so that the design and the site construction can be connected in time. At the same time, before the implementation of the construction plan, the node method is optimized and the construction simulation is carried out through BIM, which reduces the potential errors in the construction and improves the construction efficiency. In addition, BIM technology makes the fine deployment of the construction site possible, makes full use of the limited space, and realizes the maximum utilization of space. In terms of drawing joint review and collision inspection, it improves the communication efficiency, discovers and solves drawing problems in time through the creation of three-dimensional models and collision detection functions. Subsequently, combined with BIM technology and finite element analysis software, the project team analyzed the hydration heat generated in the process of mass concrete pouring, and proposed measures to prevent concrete from cracking. In the deepening design of steel structure, the combination of BIM and lean construction improves the project quality, while the problems in design and construction are dealt with in the optimization of electromechanical integrated pipeline, the visual management of pipeline installation is realized, the pre-control ability in the construction process is strengthened, and the on-site construction is effectively guided. These comprehensive applications show the strong potential of BIM technology in improving construction quality, efficiency and cost savings, and provide strong support for the optimization of construction project management process.

In order to further improve the application effect of BIM technology in construction project management, it is suggested that the project team continue to carry out BIM technology-related training and education, so as to improve the team members' proficiency and application ability of BIM tools, and ensure that all professionals can effectively use BIM technology to communicate and collaborate. At the same time, it is suggested to strengthen the cooperation between the cross-professional teams, realize information sharing through the BIM platform, optimize the project management process, and improve the decision-making efficiency. In addition, the project team should attach importance to the late maintenance and update of the BIM model, ensure the accuracy and timeliness of the model information, and provide reliable data support for the late operation and

maintenance of the project, so as to realize the efficient management of the whole life cycle of the project

3. DMAIC Theory

3.1. Concepts and Methods

DMAIC theory is the core component of six sigma management strategy, which represents five stages: Define, Measure, Analyze, Improve and Control [9]. It aims to improve business processes, improve quality and efficiency, and reduce waste and variation through a series of continuous steps [10]. The implementation of DMAIC methodology requires not only a deeper analysis of current processes, but also strict measurement and analysis of data to ensure the effectiveness and sustainability of the method [11].

In the construction project, the application of DMAIC theory can help enterprises identify and eliminate potential limits in the construction process through systematic process optimization [10]. Specifically, the application of DMAIC can be divided into following five stages:

The first stage is the Define Stage, during this period, the project team need to clarify the project objectives and customer needs, and determine the scope and objectives of the improvement project. In construction projects, it usually involves a clear definition of what the project needs to achieve, as well as setting standard for the success of the project.

The second stage is the Measure Stage, during which the team should evaluate the performance of the current process in a quantitative way in order to determine the efficiency and effectiveness of the process, including the measurement of key performance indicators, such as construction period, cost, quality control, etc.

The third stage is the Analyze Stage, which analyzes the data collected in the measurement stage and identifies the sources of variation and key influencing factors in the process. In-depth analysis of construction methods, material use efficiency, human resource allocation and other aspects will be included.

The fourth stage is the Improve Stage, the improvement plan will be designed based on the results of the Analyze Stage, including the application of new construction techniques, process reorganization or optimization and some other measures to improve the efficiency and quality of construction.

The final stage is the Control Stage, the project team will ensure the continuity and stability of improvement measures, and develop control strategies and monitoring systems to maintain the results of improvements. This stage may involve measures such as setting new work standards, training employees and conducting long-term quality monitoring [11].

3.2. Application

3.2.1. Application in the field of construction project management process optimization

The DMAIC methodology is usually a multidimensional application in the optimization of the construction project management process, which focuses on a systematic approach to improve the efficiency of the management process, reduce costs and risks, and improve project quality and customer satisfaction. This methodology lays the basic part of the project by precisely defining the project objectives and customer requirements [12]. In the Measure Stage, the project team is able to accurately know the efficiency and effectiveness of the entire process through the collection and analysis of project data, providing solid data support for subsequent analysis. In the Analyze Stage, the team needs to identify in-depth the sources of variation in the management process as well as some significant factors in order to develop effective improvement measures. And in the Improve Stage, construction efficiency and quality can be significantly improved by introducing new construction techniques and reorganizing processes [11]. Subsequently, the project team needs to set up control strategies and monitoring systems to ensure the stability of the improvement results [3].

The application of DMAIC methodology can also significantly reduce the cost and risk of construction projects. Enterprises can reduce the waste of resources, optimize the allocation of resources, and effectively reduce project costs. At the same time, by enhancing the transparency and control ability of the process, the project construction can more effectively identify and manage project risks, and reduce the potential of project delays and unqualified quality [13].

In addition, this approach can improve construction quality and customer satisfaction. By continuously improving the construction process, the project team was able to improve construction quality and reduce rework and defects, thereby increasing customer satisfaction. Since DMAIC method emphasizes the importance of customer participation, the project team can better understand customer needs through close communication and feedback with customers and provide products and services that better meet customer expectations [11].

On the basis of the above aspects, through the cyclic application of DMAIC methodology, the project team can constantly identify new improvement opportunities, implement improvement measures, and monitor the improvement effects, so that the continuous improvement and optimization of the management process does not stop at this part of the construction, but extends to the whole project process [3]. In the international research field, the theory of process improvement in Six Sigma management methodology has been relatively mature, which can help enterprises to carry out process reengineering and optimization, so as to achieve the goal of product quality requirements and customer demand [14]. The application of DMAIC method can help enterprises eliminate process defects and ineffective operations in production and management, so as to ensure quality, cost and time control and improve the competitiveness of enterprise management. After years of practice and development, Six Sigma management has evolved from a tool specifically used to improve quality at the beginning to an effective method for enterprises to improve business performance and formulate strategic plans [15].

To sum up, the application of DMAIC methodology in the optimization of construction project management process not only improves project management efficiency, reduces costs and risks, but also improves construction quality and customer satisfaction, and achieves continuous improvement of the project. The realization of these application results, thanks to the systematic and data-driven characteristics of DMAIC methodology, which enables construction projects to maintain competitiveness in a rapidly changing market environment.

3.2.2. Application cases

This paper cites the research cases of scholars such as Piotr Nowotarski to demonstrate the application of DMAIC method in real construction projects [9]. The case study is based on a residential construction project in Kolo, Poland, which was delayed due to design errors and required a redesign and building permit. Therefore, the project team optimized the foundation engineering process through the DMAIC method to improve the quality and efficiency of construction. In the specific operation process, the project team implements DMAIC method to optimize the process according to the process of definition, measurement, analysis, improvement and control, as shown in Fig. 1.

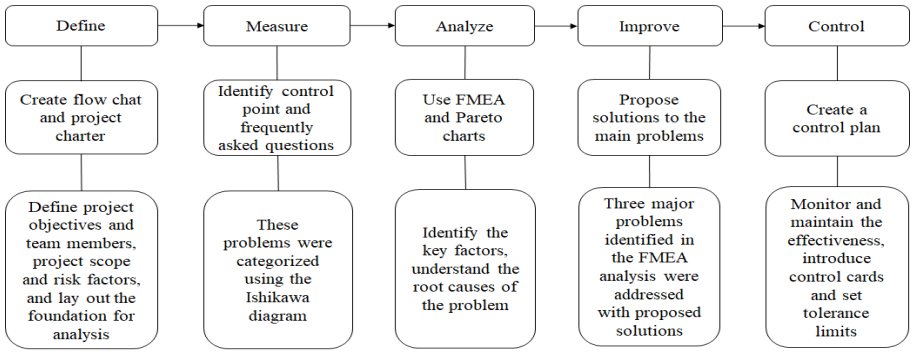

Fig 1. The Case of DMAIC Optimization Process in Construction Projects.
(Picture credit: Original)

The application of the DMAIC method significantly improved the quality of the foundation engineering process in the construction project and reduced the occurrence of potential problems by around 40%, decreasing losses and avoiding possible errors. The increased acceptance of DMAIC method by the project team can reflect the positive impact of DMAIC method on the construction side's awareness of improving construction quality and the team's problem-solving ability.

Despite the positive results of the DMAIC approach in this case, further research is needed to confirm the estimated problem-solving rate. It is recommended that more practice case studies be performed on similar construction sites to validate and optimize how DMAIC is applied. In addition, according to different cases, the project team needs to adjust and customize the DMAIC method to adapt to the actual needs of different building construction projects.

4. Conclusion

This paper mainly discusses the application of lean construction concept and DMAIC theory in the construction project management process optimization, and complements their application effect in actual projects.

(1) Lean construction concept significantly improves the efficiency and quality of construction projects through process optimization, pull system, continuous improvement and waste identification methods. In particular, the combination of lean construction and BIM technology provides data-driven decision support for project management, enhances team collaboration, and realizes resource saving and process optimization through visual simulation of the construction process.

(2) DMAIC theory provides a systematic process optimization tool for construction project management through its five stages of Define, Measure, Analyze, Improve and Control. The projects that applying DMAIC theory have achieved positive results in improving project quality and efficiency, reducing cost and risk, and enhancing customer satisfaction, and realize continuous improvement of project management process.

(3) Although Lean construction and DMAIC theory show potential in building construction project management, there are still shortcomings in the research field. Future research needs to explore the combination of these management concepts with emerging technologies, such as artificial intelligence and the Internet of Things, to achieve a higher level of project management optimization. At the same time, more practical cases are needed to verify the effects of these theories, and adjust and optimize them referring to the actual situation of different projects. In addition, interdisciplinary integration will be an important direction for future research to achieve more comprehensive and in-depth optimization effects of project management processes.

References

[1] Du Lipeng. Research on process optimization of construction project management based on BIM. Hebei University of Engineering, 2018.

[2] Tan Lei. Integration of BIM Technology and Lean Construction: Improving Efficiency and Reducing Waste of Urban Construction Projects. Guangxi Network Security and Informatization Federation. Proceedings of the 1st Academic Exchange Conference on Engineering Technology Management and Digital Transformation. Yubei Branch of Zhonglian Luhai Group Co., LTD., 2024, 3: 45-47.

[3] Guo Xuexi. X Construction Enterprise Construction Project Business Process Optimization Research. Ningbo University, 2022.

[4] Zhang Qin, Xian Haijun, Wen Xiang, et al. The Application and Practice of BIM Technology in Construction stage under Lean Construction, Digital Construction, and Green Low Carbon Model, China Graphic Society.2024 Collection of Award-winning Engineering applications of the 13th "Longtu Cup" National BIM Competition. China Construction Fourth Engineering Bureau Co., LTD., 2024: 58-72.

[5] Li Zhibiao, Bai Haoxing. BIM technology power a new high-rise project lean construction. Journal of Sichuan Cement, 2024, 8: 64-66.

[6] Lin Zhisong, Yin Xunbin, Zhu Jin, et al. BIM+CIM helps Lean Construction in the Construction stage of Zhongshan Seventh Institute, China Graphic Society.2024 Collection of Award-winning engineering applications of the 13th "Longtu Cup" National BIM Competition. China Construction First Bureau (Group) Co., LTD, 2024, 12: 130-141.

[7] Jin Weiqiang, Cao Junjie. Discussion on Construction of Assembly Lean Collaborative Design Based on BIM. Journal of Intelligent Building and Intelligent City, 2022, 6: 102-104.

[8] Zhang Haibin, Wang Xinglong, Zhang Xiaona, et al. Exploration and application of data-driven project management platform based on BIM and lean construction. Information Technology in Civil Engineering and Construction, 2021, 13 (02): 125-131.

[9] Nowotarski P, Szymanski P, Rzepecka P. DMAIC Method of Quality Improvement of Ground Works Processes: Case Study. IOP Conference Series Earth and Environmental Science, 2019, 221 (1): 012002.

[10] Wang Jianzhong. Application of Six Sigma Theory in Construction enterprises, Editorial Board of Environmental Engineering, Industrial Building Magazine Co., LTD. Proceedings of the 2019 National Academic Annual Meeting of Environmental Engineering (Volume 2). MCC General Institute of Construction Research Co., LTD., 2019, 5: 1075-1079.

[11] Liu Jinhua. The study of process optimization method in building construction enterprise based on DMAIC theory. Chengdu University of Technology, 2012.

[12] Mariana Bravo, Camila Augusto Euphrosino, Patricia Stella Pucharelli Fontanini. DMAIC Manual for an Integrated Management System: Application in a Construction Company, Proc. 28th Annual Conference of the International Group for Lean Construction (IGLC28), Berkeley, California, USA, 2020.

[13] Xiong Jin. Quality Control of DMAIC Process in the Construction of Composite Panels in Prefabricated Buildings —A Case Study of the L Project in Caijia Cluster. Engineering Construction and Design, 2024, 8: 209-211.

[14] Abdelhamid T.S. Six Sigma in lean construction systems: opportunities and challenges. In Proceedings of the 11th Annual Conference for Lean Construction, 2003: 22, 24.

[15] Harry M.J. Six Sigma: a breakthrough strategy for profitability. Quality Progress, 1998, 31: 60-64.