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Research on the Application of Bim in Civil Engineering Project Management

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Abstract: In modern society, civil engineering is an essential element in construction, which has a great influence on project quality. The increasing demands and complexities, along with the trend of international collaboration, pose significant challenges. Building Information Modeling (BIM) has emerged as a powerful tool to enhance the quality and efficiency of civil engineering projects. This study examines the application of BIM in civil engineering project management, focusing on risk management, quality management, and cost and process management. The research spotlights the obstacles and implementation strategies regarding BIM adoption, including the lack of technicians conforming to unified standards, the need for changes in the management model and process, and the defective information - sharing and collaboration mechanisms. To address these challenges, the paper proposes several optimization strategies, which include developing high-quality technical talent through multi-level training systems, fostering a cohesive team with effective incentives, promoting management model and process innovation, and improving information sharing and collaboration mechanisms. Establishing a unified data exchange platform and enhancing BIM software interoperability are also recommended to facilitate better collaboration and promote healthy industry development.

Keywords: Building Information Modeling (BIM), risk management, quality management, civil engineering

1. Introduction

In the modern society, civil engineering is considered a crucial part of construction. Moreover, it has a direct impact on the quality of the entire projects [1]. However, due to the ever-increasing demands and labors, the larger scale of buildings and more complex equipment come into being. Additionally, the growing trends of Earth integration involve an increase in the number of international projects and cooperation with partners from a materially and technically more advanced and economically stable environment [2].

Moreover, civil engineering through information project management such as BIM (Building Information Modeling) can improve the quality of engineering construction. Several developed countries have developed productive implementation systems, for instance, formulating national and global BIM guidelines, managing risk issues by legal conventions, establishing the validation, development and skills of BIM and the business case for BIM implementation [3]. In China, civil engineering construction and management informatization mainly represent that various information technology (notably BIM) is applied in the construction and management to improve the construction

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level of civil engineering, for example, by strengthening the cooperation of information technology and computer simulation technology. Meanwhile, improving the quality of surveying and mapping in civil engineering projects, so that the level of civil engineering construction and management can be effectively improved [1]. This essay is going to argue about the application of BIM in the management of civil engineering projects, highlighting the barriers as well as the implementation of risk management, quality management and progress - cost management.

2. The feasibility and importance of project management in civil engineering research

2.1. Definition and characteristics

Engineering project is a work or task, which must be completed within a limited time, and managed and controlled according to the budget and quality standards. The project has three characteristics: single project, clear project objectives and project integrity as the management object [4].

2.2. Process

A project needs to follow certain steps and procedures: firstly, through the general assumption of the project, determine the proprieties, characteristics, and objectives; next, choose the appropriate scheme and plan, organize the implementation to control progress, cost, and quality; finally, check and analyze the completed project to determine the effect and summarize. The processes within a project are closely inter - related and cannot be completed by a single department or unit alone. Consequently, unified command and coordination are essential. Project management encompasses the entire process of planning, organizing, controlling, and coordinating to ensure project success. In order to achieve the project objective, it is necessary to exercise control over the project. The key to effective project control is to measure the actual process regularly and compare it with the planned process and corrective measures should be taken immediately if needed [1].

2.3. Module design

The project management module design is divided into five components: (1) the project management module, which includes engineering progress, accounting information, and consumables statistics; staff can log in to manage project progress, perform daily and monthly accounting, and track the quantity, cost, and specifications of materials. (2) The equipment management module, which covers equipment warehousing, damage reporting, outbound, and statistics; staff can manage equipment warehousing, report damages, and handle outbound information, including detailed data on material categories, names, and numbers. (3) The financial management module, which primarily handles financial information. (4) The supplier management module, which manages contract and supplier information, including basic details of contracts between the construction party and suppliers. (5) The system management module, which provides user information, authority, and system data management, including user permissions, data backup, and recovery [1].

3. BIM

3.1. Overview of BIM

BIM (Building Information Modeling), as the three-dimensional mathematical model of civil engineering projects, consolidates information on buildings, structures, and equipment into a unified framework in a visually intuitive format [5]. BIM technology not only provides simulation and optimization of the construction process but also facilitates subsequent design, construction, cost estimation, operation and maintenance management [6].

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3.2. Application

3.2.1. Risk management

Risk and uncertainty typify situations in which outcomes could deviate negatively from the projected ones. In civil engineering projects, this may cause price overruns, construction deadline overruns, and a lack of quality in project progress and final completion. Qualitative and quantitative analyses play an important role in the risk management process [2]. Hence, integrating BIM technology with intelligent construction techniques and other advanced technologies facilitates the rapid acquisition, processing, and exchange of engineering information. This provides sophisticated management tools for all phases of engineering construction. Consequently, this approach not only mitigates risks but also facilitates swift surveys and real-time monitoring of project sites, thereby enhancing surveying and monitoring efficiency, shortening construction duration, reducing project management costs, and ultimately improving the overall effectiveness of project management [5].

3.2.2. Quality management

Quality is an important content of civil engineering construction project management, which is also an important basic task during the specific application of project management. During the construction of civil engineering, BIM technology combined with sensing technology and big data analysis technology can monitor all kinds of information existing in the process of engineering construction in real time, and detect and deal with existing problems in time, so as to improve the accuracy and quality of engineering construction [5]. In construction projects, sensor technology can be utilized to achieve real - time monitoring of structural safety, environmental changes, and equipment working conditions. By deeply analyzing the monitoring data, problems can be detected and appropriately addressed. BIM can avoid the accumulation of construction adversely quality problems and safety hazards in subsequent construction operations, which contributes to the development of civil construction engineering construction operations, as well as improve the overall quality of construction projects [6].

3.2.3. Cost and process management

In the management of cost and time planning, when costs are exceeded and deadlines are missed, it not only impacts the civil engineering industry but also the general overall economy and development of countries. Therefore, using BIM models and platforms to monitor the costs of materials, labor, and other expenses, can generate budget versus actual reports which promote managers to supervise cost overruns and ensure budget control. In addition, managers can also use BIM technology to create construction schedules for all steps as well as the start and end times of each task. This helps in arranging tasks, improving efficiency, and reducing construction time, and also makes information exchange between on - site managers easier and project progress smoother [6].

4. BIM technology issues in civil engineering project management

4.1. Lack of unified technical talent

Olugboyega claimed that the barriers to BIM adoption are social science. BIM technology and other advanced technologies need professionals with interdisciplinary skills, such as BIM engineers and data analysts [3]. There is a serious shortage of such talent and high demands for interdisciplinary skills, making the talent shortage problem more prominent [5]. In engineering practice, the lack of high-quality engineering technicians directly affects project implementation and results. This is especially true in cross-regional collaboration and project management. There is no doubt that the

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organization's operational costs will rise in the short term due to BIM implementations, as such implementations require training the staff who are not familiar with BIM [7]. A shortage of BIM technicians and data analysts, an unwillingness to share information, legal, cost, and security issues, together with limited big - data application, severely restrict the automation and intelligence levels in the construction industry [3].

4.2. Need for management model and process change

Combining BIM technology with other advanced technologies requires redesigning and adjusting engineering management methods and processes. In practice, some managers may be conservative on new work methods and management needs. Some construction organizations may suspect the need to chang existing methods, and worry about the risks and uncertainties that new technologies might bring [5]. They are considered reluctant to spend money on such issues, particularly when they do not perceive the return on investment in the short or long term [7]. Lack of senior management support, BIM software cost and training problems, coupled with cultural issues, management obstacles (such as responsibility-based information), lack of BIM assistance and lack of collaboration among colleagues have all affected the adoption of BIM.

4.3. Poor information sharing and collaboration contracts

The lack of communication among the construction project team also results in a delay in the project. Different regions and industries have different data formats and interface standards which make information share and exchange very difficult. For instance, in Chinese construction project management, information silos and poor information flow are common which lead to low collaboration efficiency and high communication cost [5]. Moreover, inefficient contracts and lack of trust among project participants, leading to the information barriers as well as low cooperation efficiency. Traditional contracts cannot accommodate BIM adoption. Current contract conditions are inappropriate and counterproductive in a BIM-enabled project environment. Contractual issues such as BIM model ownership, intellectual property rights, model development level, model management, risk allocation, and delivery of results schedule have not been included as clauses in standard forms of contract. Legal implications of BIM adoption pose a contractual risk to project delivery. The lack of practical contract conditions make multidisciplinary collaboration and information integration in BIM illegal in project delivery [3].

5. Optimization strategies for BIM technology and advanced technology in civil engineering project management

5.1. Develop technical talent and team building

BIM and advanced technology applications need high-quality engineering talent. By allocating training resources reasonably and increasing investment in BIM technology and related professional knowledge training, managers must strengthen skill training and establish a multi-level, multi-channel training system to skilled personnel with both theoretical and practical abilities can be developed [5]. For instance, when actors say there are no 3D representation conventions like those in 2D, they do not use concepts that replace 2D conventions in 3D, such as LOI (level of information) and LOD (level of detail). These concepts are crucial for agreeing on the content of a digital mock-up used as a deliverable [8]. Collaboration with universities and research institutes can also help integrate theory and practice, jointly cultivating high-quality technical talent [5].

In addition to excellent technicians, a good team is essential. Companies should organize team training, technical exchanges, and project collaboration to improve communication and cooperation

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among team members [5]. For example, effective incentive mechanisms should provide reasonable salaries and career advancement opportunities, motivating employees to actively engage in BIM technology and new technology research and application.

5.2. Promote management model and process innovation

Evans claimed that top management provides support and a collaborative work environment [9], contributing to enhancing BIM benefits in construction practice. Soft total quality management (TQM) and its impact on firm performance show that human resources, quality culture, motivational leadership, and relationship management are important. These factors contribute to TQM validity [10]. A flexible and efficient engineering management system should be built, leveraging data-based decision support to move towards intelligent and precise management. Through data analysis and prediction, managers can better understand project progress and risks, making informed decisions to improve management efficiency and quality. Efforts should also be made to promote advanced management concepts and methods through lectures, training, and case studies [5]. This will enhance employees' understanding and acceptance, facilitating the implementation of new management tools and methods.

5.3. Improve information sharing and collaboration mechanisms

Interoperability or incompatibility of major BIM software is still a significant barrier in the global civil engineering industry. Encouraging more collaborations among these software vendors and construction firms will ensure a higher level of compatibility and reduce the incidence of data loss during data migration between software [11]. Full migration to cloud BIM by firms and developers could minimize this issue. A unified data exchange and collaboration platform should be established to enable effective information exchange and cooperation among all parties. This platform should support data storage, file sharing, and real-time communication, facilitating information exchange and collaboration among project team members. Regulations and guidelines for information sharing and collaboration should be strengthened, promoting an "open sharing" mindset. Encouraging resource and experience sharing among participants can achieve mutual benefits. For external partners, industry alliances and chambers of commerce can enhance information exchange and collaboration, promoting healthy industry development [12].

6. Conclusion

This paper outlines the application, challenges and implements of BIM in modern civil engineering, where the problems mainly manifest in three areas. Firstly, there are three applications of project management in civil engineering: risk management, quality management and cost and process management. Next, some barriers cause issues of BIM of project management in civil engineering:(1) there is a shortage of interdisciplinary technical talent; (2)traditional engineering management models and processes often resist change;(3) not only poor information sharing and collaboration, but also inefficient contracts and a lack of practical contract conditions, exacerbate these issues, making BIM integration into project delivery challenging. Last but not least, Effective BIM and advanced technology applications require high-quality engineering talent. Managers should invest in multi-level training systems to develop skilled personnel with both theoretical and practical competencies, such as LOI and LOD. Collaboration with universities and research institutes can further enhance this. A cohesive team is also essential, supported by effective incentives and training. Management model and process innovation, including data-based decision support, can improve efficiency and quality. Enhancing BIM software interoperability and establishing a unified data

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exchange platform will facilitate better information sharing and collaboration, promoting healthy industry development.

This study has several limitations that warrant acknowledgment. This research did not employ empirical methods, which could have provided more robust and data-driven insights. Additionally, the number of literature sources used in this study is limited, potentially restricting the comprehensiveness of the findings. For future research, it is recommended to incorporate empirical studies to validate the proposed strategies and their impact on BIM and advanced technology applications. Furthermore, a broader review of existing literature and the inclusion of more case studies can provide a more comprehensive understanding and enhance the generalizability of the findings. This will help in developing more effective and practical recommendations for the development of technical talent, team building, management innovation, and information sharing mechanisms in the construction industry.

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