The BIM Based Hospital Safety Engineering Management During the Construction Phase

Qiongzhen Tang[1,*], Zhongjie Liu[1,2], Liuhui Wang[3], Beibei Chen[4]
[1]Xiangsihu College of Guangxi Minzu University, Nanning, Guangxi, China
[2]Guangxi Guiji Hongye Engineering Co., Ltd., Nanning, Guangxi, China
[3]Liuzhou Municipal Facilities Maintenance and Management Office, Liuzhou, Guangxi, China
[4]Guangxi Tag Digital Architecture Technology Co., Ltd., Liuzhou, Guangxi, China
**Corresponding Author*

Abstract: As the scale of construction projects continues to expand, construction safety management has encountered great challenges. Traditional safety management methods mainly rely on manual inspection and post-processing, which is difficult to meet the complex needs of modern construction projects. The Building Information Modeling (BIM) technology, as an emerging information tool, has gradually been applied to various stages of construction by relying on its visualization, integration and collaboration characteristics, showing great potential in safety management. This paper takes the Building Project of Pingxiang People's Hospital in Guangxi as an example to analyze the application of BIM technology in safety management during the construction stage of construction projects. This study presents the application advantages of BIM technology in construction safety management and provides practical guidance for subsequent construction project safety management.

Keywords: BIM; Safety Engineering; Construction Phase; Safety Management

1. Introduction

In recent years, with the rapid development of China's economy, the construction industry has gradually become one of the indispensable pillar industries in the national economy. The rapid expansion and technological innovation in this field have put forward higher requirements for construction safety management. However, traditional construction safety management methods generally rely on manual operation, which is characterized by a strong dependence on the experience of managers and workers, a relatively single management method and mainly based on post-error correction, making it difficult to achieve dynamic control and forward-looking early warning of the entire construction process. This management method is obviously unable to meet the increasingly complex and efficient needs of modern engineering construction today.

Against this background, Building Information Modeling (BIM), as an emerging digital technology concept, has gradually penetrated into the construction industry and begun to lead the transformation of construction management methods. BIM technology integrates various relevant information data of construction projects to construct a visual three-dimensional model, and realizes multi-party collaboration through dynamic data updates. It greatly improves the work efficiency of engineering construction, optimizes resource allocation, and effectively reduces communication costs, providing a strong technical guarantee for the implementation of complex projects.

In practice, the application of BIM technology has shown significant advantages. Salzano A. et al. [1] improved workplace safety by transitioning from a traditional passive approach to an active, comprehensive framework that integrates BIM into the design and execution phases, enabling dynamic assessment and mitigation of risks. Through the implementation of two case studies - the Search for Hidden Particles (SHiP) experiment at the European Organization for Nuclear Research (CERN) and the maintenance of the facade of the Santa Croce Church in Florence, they demonstrated the significant impact of BIM on reducing accidents, ensuring compliance with safety protocols, and

streamlining project execution. Fargnoli M. and Lombardi M [2] explored the research trends of BIM technology in design safety improvement, dynamic visualization, cross-domain application, and risk analysis. They also emphasized the potential of BIM technology, believing that it can improve the communication efficiency and risk early warning capabilities of the construction process, and suggested that more practical BIM applications should be developed in the future to address the current research gaps and promote the transformation of construction safety management from passive management to active management. Akram R et al. [3] proposed an automated hazard identification and safety improvement strategy, which was integrated into different stages of the project. The research focused on how to identify and control safety hazards in the construction process through visualization, real-time monitoring, rule checking and data integration of BIM technology, thereby improving safety management efficiency and reducing the accident rate. These reveal that BIM has great potential in accident prevention, risk management, site monitoring, etc.

Moreover, Zhang Yi [4] by summarizing and analyzing the main scenarios, unique advantages and existing problems of BIM technology in construction safety management, targeted solutions and countermeasures were produced, and countermeasures were proposed to strengthen equipment investment, improve personnel quality, improve process specifications and ensure data security, so as to promote the in-depth application and development of BIM technology in construction safety management. Yuan Wenting [5] studied the application methods of BIM technology in building safety management are discussed, including reasonable identification of hazard factors, pre-simulation of construction plans, verification of three-dimensional collisions and combination with PDCA cycle. The application of BIM technology in the safety management of scaffolding in this building is proposed, including the main structure information model, scaffolding scheme design, scaffolding engineering quantity and safety information in the scaffolding 3D model. And the results indicate that BIM technology is of great significance in the safety management of building construction projects and can improve construction safety and efficiency. Wang Xinrui [6] proposed that BIM technology, with its visualization, dynamic simulation and coordination characteristics, provides strong support for the optimization of construction site layout, dynamic simulation of construction process, conflict management of construction space, information management of construction safety and information presentation of construction safety education, timely detection of potential risks and formulation of targeted measures, thereby improving the level of construction safety and reducing the possibility of accidents. Xu Dongmei [7] used specific project cases to deeply analyze the application of BIM technology in construction safety management, demonstrating its significant role in improving construction efficiency, optimizing resource allocation, strengthening safety management and reducing safety hazards. Xin Zhongqi [8] pointed out that with the increase in the complexity and scale of construction projects, traditional safety management methods can no longer meet the needs, and BIM technology has significantly improved the efficiency and effectiveness of construction safety management through three-dimensional visualization, information integration and simulation prediction. In addition, with the help of BIM technology, safety management during the construction phase can achieve early warning, analysis and control of safety risks through virtualization and information technology, reduce human operation errors and improve the level of on-site safety management [9,10].

In conclusion, in terms of establishing safety indicators, the three-dimensional model can be used to intuitively display the functions and physical information of the project, analyze and eliminate safety hazards. Moreover, in terms of identifying hazard sources, various factors on the construction site, such as geology, environment, etc. can be simulated to predict and solve safety problems in construction, optimize collision problems, improve safety inspection efficiency, and reduce accidents. Furthermore, in terms of construction safety, the process is optimized based on the actual conditions of the construction site, the construction progress is coordinated, efficiency is improved, data is

updated in real time, multi-department collaboration and information sharing are supported, errors in the design process are reduced, and the transparency of construction information and collaboration efficiency are improved.

Thus, from a theoretical perspective, this study provides comprehensive information support and technical guarantees for solving the safety management problems caused by the scale and complexity of the Pingxiang People's Hospital, reducing safety hazards caused by errors, improving scientific management, breaking through the limitations of traditional two-dimensional drawings and single manual management, and establishing a scientific, efficient and safe management system. Moreover, from a practical application perspective, BIM technology ensures construction safety through refined management, such as risk analysis and real-time data updates. It helps improve the efficiency of construction safety management and provides technical support for subsequent operation management.

2. Application Framework of BIM Technology in Safety Management during the Construction Phase

2.1 Application Model of BIM in Safety Management

As a digital building information management tool, BIM technology involves multiple stages such as design, construction and operation of construction projects. During the construction phase, BIM technology can integrate the three-dimensional spatial information, time schedule and cost control of the construction project to provide data support and decision-making basis for safety management.

According to Figure 1, in the BIM application model of safety management, the construction work can be started from the following aspects:

In terms of safety risk identification and assessment model, with the help of BIM model and combined with the three-dimensional data of the construction site, potential safety risks in the construction process can be identified and assessed. Thus, the use of BIM technology can achieve dynamic monitoring of factors such as equipment, personnel flow and construction sequence, and timely detect safety hazards.

In terms of the construction site safety monitoring and management model, the BIM model is combined with the Internet of Things technology to monitor the safety status of the construction site in real time, including the entry and exit of personnel, the operating status of construction machinery, and the storage of materials, and timely feedback on safety issues that occur on site.

In terms of the safety training and emergency management model, a virtual construction site is created based on BIM technology, and by simulating real work scenes and emergency situations, safety training and emergency drills are provided to construction personnel to enhance their safety awareness and emergency response capabilities.

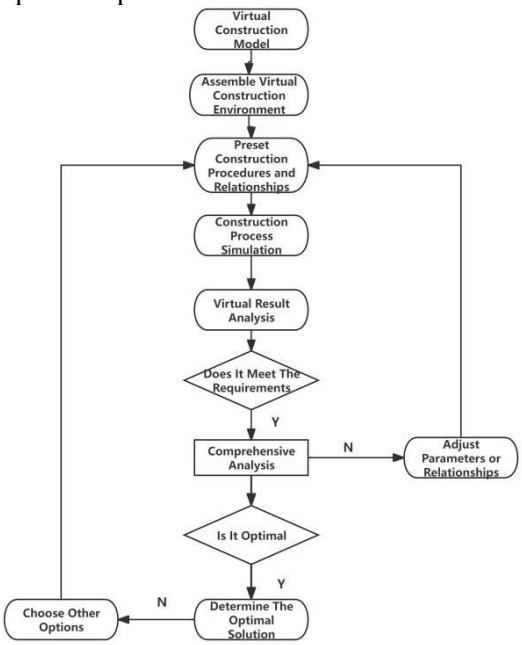


Figure 1. BIM Model Construction Flow Chart

2.2 BIM Technology Application on Safety Engineering Management

Identification and analysis of safety risks in the construction stage steps are illustrated in Figure 2. According to the flow chart, the steps can be elaborated as follows:

(1) combined with the project's construction process, construction sequence and the actual situation of the construction site;

(2) use BIM technology to identify and analyze possible safety hazards. For instance, use collision detection tools to check the interference between structural components and equipment to avoid conflicts during construction;

(3) use construction simulation to predict

possible safety hazards of high-altitude operations and reduce the risk rate;

(4) use BIM and Internet of Things (IoT) technology to conduct real-time monitoring of the construction site, including personnel safety, equipment operation, material management, etc.

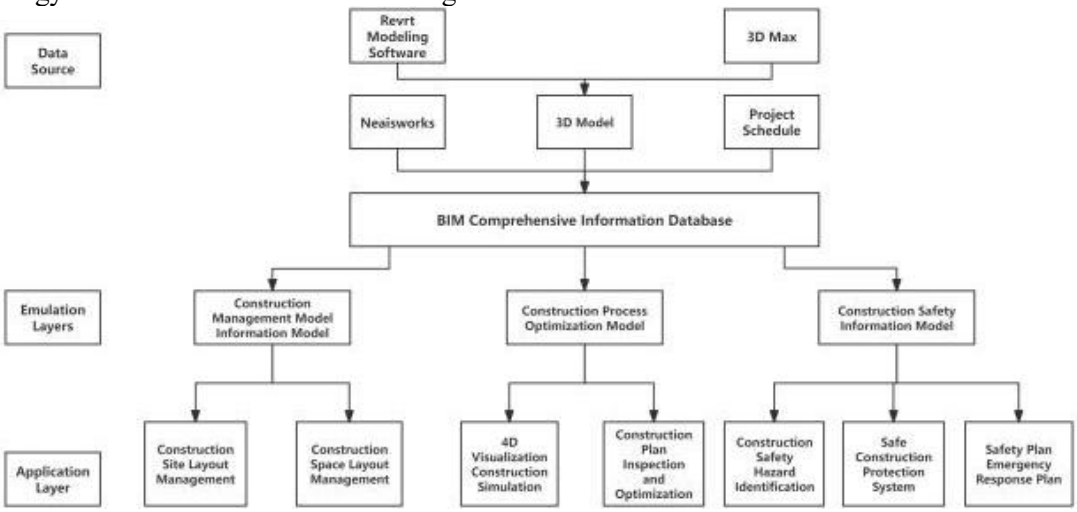


Figure 2. Construction Safety Management Model Based on BIM

During the construction process, the safety management data collected by the BIM platform is analyzed, the effectiveness of safety management measures is evaluated, and optimization and adjustment are made according to the actual situation to ensure the continuous improvement of safety management during the construction stage. With the help of sensors, the data of the construction site is captured in real time, and then the information will be transmitted to the BIM system to provide dynamic reference for safety management decision makers.

3. Case Analysis of The Construction of the Pingxiang People's Hospital

3.1 Project Overview

The Pingxiang People's Hospital in Guangxi belongs to the key construction project of Pingxiang People's Hospital. This project is located in the urban area of Pingxiang. Its significance lies in improving the level of medical facilities in the hospital and providing more efficient medical services to local residents. The project has a large construction scale, including many functional areas such as inpatient buildings, outpatient buildings, and comprehensive service buildings, with a construction area of approximately 8180.76 square meters. The project planning construction period is 1 year, divided into multiple construction phases, including civil construction, installation construction, decoration construction, etc., as shown in Figure 3.

The key issues of the project require it to be strictly implemented in accordance with relevant safety management regulations during the construction phase, so as to ensure that the safety risks in the construction process can be effectively controlled and managed, prevent safety accidents, and ensure the safety of construction personnel and the public.

Figure 3. The Pingxiang People's Hospital

3.2 Main Application Process of Safety Management Based on BIM Technology

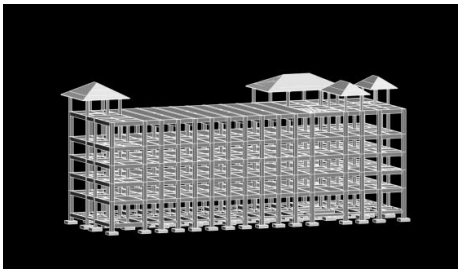
In the construction process of the Pingxiang People's Hospital, BIM technology has shown certain effectiveness in the link of construction safety control. Its key role is mainly reflected in some core application practices, and these practices have improved the construction safety engineering management.

Firstly, a detailed three-dimensional building

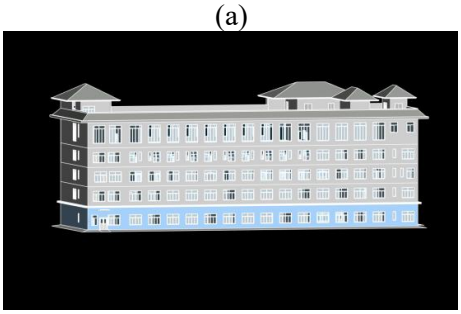
model was created through BIM technology, as shown in Figure 4 (a)-(c). All kinds of project data (such as design drawings, construction progress, equipment information, etc.) are integrated on one platform. Through the BIM model, the construction team can identify potential safety hazards, predict and avoid safety risks such as high-altitude operations and mechanical injuries in advance. Especially in the construction process, using the collision detection function of BIM, conflicts between construction design and site layout can be discovered early to avoid safety accidents. For example, tower crane construction simulation avoids tower crane collision and realizes intuitive analysis and optimization of on-site tower crane installation. The work of displaying tower crane site layout and selection is shown in Figure 4 (d).

With the integration of the Internet of Things (IoT), BIM technology has achieved dynamic monitoring of the safety status of the construction site. After various sensors and monitoring devices are arranged on the construction site, information such as environmental dynamics, personnel flow, and the working status of mechanical equipment can be uploaded to the BIM system in a timely manner to ensure the timeliness and accuracy of the data. After the BIM model is used to identify the hazard source, the guardrail is automatically generated, as shown in Figure 5 visualizing the safety management situation. Safety managers can discover safety hazards in a timely manner and take necessary safety measures. This dynamic monitoring capability makes safety management during the construction process more accurate and efficient.

Moreover, by using BIM models as a database for digital safety training can effectively optimize the level of safety education and teaching efficiency, and can also reduce safety hazards on the construction site. Most of the time, new workers do not know much about the working environment, and BIM technology has the characteristics of intuitive visualization, which can help them quickly adapt to and understand the on-site conditions and provide support for safety technology briefings. Safety training that combines BIM with virtual reality technology has more advantages. With the help of BIM to build virtual construction scenes, construction workers can immersively identify potential dangers and improve safety perception. Combined with safety management explanations to ensure understanding of key links and safety measures, BIM can also be used for emergency plan simulation to improve emergency response capabilities, as shown in Figure 6.



(a)



(b)

(c)

(d)

Figure 4. The Building Information Model of Pingxiang People's Hospital

Figure 5. Safety Management Visualization

Figure 6. Construction Simulation Training

Therefore, BIM technology ensures the safety of the construction process by efficiently identifying potential safety hazards, implementing real-time monitoring, and realizing dynamic adjustments. It has great potential in project management. With the advantages of data integration, visualization, and multi-party collaboration, BIM technology helps to identify potential safety risks in a timely manner and respond to them, reducing the probability of safety accidents and contributing valuable practical experience for reference for similar construction projects. The use of this technology has improved the safety management efficiency of the construction site, and also improved the information transparency and collaboration during the construction process, providing innovative solutions for the safety management of future construction projects.

4. Evaluation of BIM technology in the construction phase

4.1 Construction of evaluation index system

The comparison of BIM technology and traditional methods from the three dimensions of accident rate, hidden danger identification rate and efficiency improvement in construction is shown in Table 1.

Table 1. The Evaluation Index System

	Index	Database
Accident Prevention	Accident Occurrence Rate (cases per 10,000 man-hours)	Enterprise Accident Statistical Report
Hidden hazard Management	Hazard identification Rate (%)	Safety Inspection Records Rectification Ledger
Process Efficiency	Safety plan formulation time (days) | Emergency drill duration (hours)	Project Management Plan Meeting Minutes

4.2 Comparison of Hazard Identification Efficiency

The BIM model integrates RFID sensors to monitor the edge protection status in real time, and the speed of hidden danger discovery is increased by 40%. The BIM algorithm is used to analyze historical data, predict high-risk areas, and accurately locate hidden dangers as shown in Table 2.

Table 2. Hazard Identification Efficiency

Indicator	Traditional Management model	BIM Technology Application Phase	Improvement Margin
Hazard Identification Rate (%)	72%	95%	23%
Evaluation of Hazard Rectification Time (days)	5.2	2.1	59.6%

4.3 Improved Safety Management Efficiency

BIM generates three-dimensional safety briefing animations, replacing traditional two-dimensional drawings, and significantly reduces the error rate of workers' understanding. Safety drills and training based on BIM have significantly reduced the emergency response time of accidents. The safety management efficiency of BIM technology before and after the project construction phase is shown in Table 3.

Table 3. Safety Management Efficiency

Process link	Traditional management is time-consuming	BIM technology can be time-intensive	Efficiency improvement
Security Plan Editing	14 days	6 days	57%
Safety briefing training	3 hours/time	1.5 hours/time	50%
Emergency plan drill	8 hours	3hours	62.5%

In summary, compared with traditional safety management, BIM technology has significantly improved the effectiveness of safety management during the construction phase, especially in terms of accident prevention, hidden danger identification and management efficiency. By introducing BIM technology, construction management has changed from traditional passive response to

active prediction and intervention, effectively reducing the risk of safety accidents and providing valuable experience and practical guidance for similar projects in the future.

5. Conclusion

This paper discusses the application of BIM technology in the safety engineering management of the construction phase through a case study of the Pingxiang People's Hospital in Guangxi. The study shows that BIM technology has greatly improved the efficiency and effectiveness of construction safety management through its powerful data integration, visualization and collaborative work functions. During the implementation of the project, BIM technology not only helped to timely identify and prevent potential safety hazards, but also ensured the safety of construction through real-time monitoring and dynamic adjustment measures.

The main contribution of this study is that through the application of BIM technology, the traditional safety engineering management model has been optimized and the transparency and collaboration efficiency of construction site information have been improved. In the specific application process, BIM technology has shown significant advantages in safety risk identification, construction site monitoring, emergency drills, etc., and has effectively reduced safety accidents during the construction process. After the introduction of BIM technology, construction management has shifted from the traditional passive response to active prediction and intervention, which has improved the safety and management level of the entire construction process. Although BIM technology has achieved certain results in the safety management of construction, it still encounters many challenges in its actual application, such as the degree of technology popularization, data standardization and high investment costs. In the future, during the promotion of BIM technology, it is necessary to strengthen technical support, formulate unified standards and enhance the acceptance of technology by industry personnel.

As technology continues to develop, BIM will play an increasingly critical role in construction safety management and promote the construction industry to develop in the direction of intelligence and digitalization, which provides innovative solutions for safety management in the construction stage and also provides valuable experience and reference for the implementation of similar projects in the future.

Acknowledgments

Author Qiongzhen Tang and co-author Beibei Chen highly appreciate the research funding supported by Digital Architecture Technology Research Fund (No. TDHKRI202401).

References

[1] Salzano A, Cascone S, Zitiello E P, et al. Construction Safety and Efficiency: Integrating Building Information Modeling into Risk Management and Project Execution. Sustainability, 2024, 16(10): 4094.

[2] Fargnoli M, Lombardi M. Building information modelling (BIM) to enhance occupational safety in construction activities: Research trends emerging from one decade of studies. Buildings, 2020, 10(6): 98.

[3] Akram R, Thaheem M J, Khan S, et al. Exploring the role of BIM in construction safety in develo countries: Toward automated hazard analysis. Sustainability, 2022, 14(19): 12905.

[4] Zhang Yi. A brief discussion on the application of BIM technology in construction safety management. State-owned Enterprise Management, 2024, (08): 1 15-116.

[5] Yuan Wenting. Application of BIM technology in construction safety management of building projects. Building Materials Development Guide, 2024, 22(14): 97-100.

[6] Wang Xinrui. Research on the application of BIM technology in construction safety management. China Building Decoration and Renovation, 2024, (11): 86-88.

[7] Xu Dongmei. Research on construction safety management of building projects based on building information modeling technology. Construction and Budget, 2024, (04): 73-75.

[8] Xin Zhongqi. Application and discussion of construction safety management based on BIM technology. Value Engineering, 2024, 43(29): 166-168.

[9] Lin Rongfa. Application of BIM

technology in construction safety management. Juye, 2021, (02): 125-126.
[10]Qiao Shoujiang, Wu Rui. Analysis on the application of BIM technology in construction safety management. Intelligent Building and Smart City, 2023, (09): 112-114.

