Scholar Publishing Group
International Journal of Engineering Technology and Construction
https://doi.org/10.38007/IJETC.2024.050105
ISSN 2789-7176 Vol. 5, Issue 1: 42-50

BIM-based Security Management of Underground Buildings

Wenqiang Zhou*

Research Office, Jiangsu Urban and Rural Construction Vocational College, Changzhou 213147, Jiangsu, China
zhouwenqiang11@126.com
**Corresponding Author*

Keywords: BIM Technology, Underground Buildings, Security Management, Risk Assessment

Abstract: The security management of underground buildings has become increasingly important. This study aims to explore an underground building security management method based on Building Information Modeling (BIM), and propose an innovative security management strategy by integrating BIM technology with security management practices. The methods section described the process of collecting security accident data, including the organization and analysis of historical accident data, as well as the construction of a BIM security management model. By collecting historical data on construction security accidents in underground buildings, statistical methods were used to classify and trend analyze the accident data, in order to identify high-risk construction stages and common types of accidents. In addition, this study also investigated the application cases of BIM technology in underground building security management, and collected practical application data of BIM technology in risk assessment, security planning, construction monitoring, and accident prevention. The research results indicated that BIM technology exhibited significant advantages in risk assessment and monitoring. Through BIM technology, the accuracy of risk identification has significantly improved, reaching a maximum of 98.2%. In addition, as the application of BIM deepened, the emergency response time continued to decrease, with a minimum of 27 minutes. These results validate the potential of BIM technology in improving the efficiency of underground building security management.

1. Introduction

With the acceleration of urbanization, the development and utilization of underground space are becoming increasingly frequent. How to efficiently utilize underground space while ensuring construction security has become an urgent problem to be solved. This article proposes a BIM-based underground building security management method, which achieves functions such as risk assessment, construction monitoring, emergency response, and information sharing through an integrated BIM model. Through empirical research, this article demonstrates the significant effects of BIM technology in improving risk identification accuracy and shortening emergency response time, providing a new solution for underground building security management.

The introduction section of the article introduces the background and significance of the research, as well as the main contributions and structural arrangement of this article. Secondly, the relevant work section reviews the current situation of underground building security management and the application of BIM technology in security management, providing a theoretical and practical basis for this study. The methods section describes the process of collecting security accident data and constructing a BIM security management model. The results and discussion section showcases the advantages and application effects of BIM technology in security management, and further validates the effectiveness of BIM technology. Finally, the conclusion section summarizes the main findings of this study and provides suggestions for future research directions in underground building security management.

2. Related Work

In the field of construction engineering, security has always been the primary task of project management. Zhang Shi mainly analyzed the security of underground engineering construction, used expert investigation method to identify risks, obtained risk factors that affect production, and took corresponding measures. Through the research on construction security management of the underground engineering of the Zhoushi Town Nursing Home project in Kunshan City, the project construction security was ensured in engineering practice, and good benefits were achieved, providing reference for similar engineering construction [1]. In order to ensure the internal security of buildings, Li Juan applied intelligent systems into building security management, mainly researching security management systems based on intelligent buildings, and analyzing and exploring their functions [2]. Xiong Huiling studied the risk control and security management of subway construction passing through existing buildings. Taking the construction of the entrance and exit section of a certain subway project in Guangzhou as an example, the main risks during the construction process were analyzed. Targeted risk control measures were proposed for invading piles and non invading but affected pile foundations, and countermeasures were proposed to prevent building tilting after completion of construction [3]. Wang Hua effectively strengthened the supervision and management of the safe use and maintenance of existing building glass curtain walls through "three-level" curtain wall security management (owner self inspection, district level inspection, and city level supervision), using targeted methods such as "regular inspection" or "security appraisal", effectively preventing security hazards in use, improving the overall protection level and risk resistance ability of the city, and ensuring the safe operation of the city [4]. Zhao Xin took the perspective of systems theory and used scientific methods to plan and make decisions, organize and command, control and regulate various elements and activities of construction [5]. Babalola A aimed to conduct bibliometric analysis of global BIM research progress, providing an evaluation of the latest development trends related to the construction, engineering, and construction industries [6]. Ma L examined the differences and similarities in the adoption of BIM between New Zealand and China. A questionnaire survey was conducted in these two countries to investigate the obstacles and strategies for implementing BIM [7]. Sameer H introduced the extension of BIM through the development of sustainable resource applications, which can be used to determine the material, water, and climate footprint of buildings during the design phase [8]. Baldauf J P proposed a method of using BIM to manage customer requirements. The proposed method supported healthcare design by adopting a process based customer demand management approach, with the aim of improving value generation [9]. Evans M aimed to investigate the key obstacles encountered by major building stakeholders in integrating BIM and lean construction in large-scale construction projects [10]. In the above research, the application of BIM technology in underground building security management has not been fully explored. This study aims to explore in depth the security management of underground buildings based on BIM, and propose an innovative security management method by integrating BIM technology with security management practices. This study analyzed the potential application of BIM technology in underground building security management and explored its specific implementation strategies in risk assessment, construction monitoring, emergency response, and other aspects. Through this study, it is expected to provide more efficient and intelligent solutions for the security management of underground buildings, further improving the security and efficiency of construction.

3. Methods

3.1 Collection of Security Accident Data

In the research on BIM based security management of underground buildings, this study collects historical data on construction security accidents of underground buildings, including the time, location, causes, impacts, and consequences of accidents [11-12]. By analyzing accident reports, key security risk factors such as collapse, fire, and gas leakage during construction are extracted, and statistical methods are used to classify and trend analyze accident data to identify high-risk construction stages and common types of accidents. The collected data is shown in Table 1:

Table 1. Historical data of underground building accidents

ID	Incident Date	Location ID	Incident Type	Injured	Fatalities	Direct Economic Loss (10,000 USD)	Construction Phase
1	Mar-15-2021	L101	Collapse	2	0	5	Early Stage
2	May-21-2021	S202	Fire	0	0	8	Middle Stage
3	Jul-03-2021	N303	Gas Leak	0	0	0	Late Stage
4	Sep-10-2021	L104	Equipment Failure	0	0	0	Maintenance Stage
5	Nov-05-2021	S105	Collapse	1	1	10	Early Stage
6	Jan-20-2022	N205	Fire	0	0	12	Middle Stage

Table 1 presents the historical records of construction security accidents in underground buildings in a data-driven manner, and each data item is of great significance for BIM-based security management research [13-14]. These detailed data collection and analysis work have a positive effect on identifying security risks during the construction process, taking preventive measures, and reducing accident rates, helping to optimize security management strategies and improve construction security.

Secondly, this study investigates the application cases of existing BIM technology in underground building security management, including the creation, use, and management of BIM models, and collects practical application data of BIM technology in risk assessment, security planning, construction monitoring, and accident prevention. By interviewing industry experts, construction management personnel, and security officials, first-hand information on the application of BIM technology in security management is obtained. An analysis is conducted on how BIM technology improves the security management workflow of underground buildings, including real-time monitoring and accident response during security review and construction during the design phase.

In the process of data collection, this article adopts multiple data sources for cross validation to ensure the accuracy and reliability of the data, and strictly screens and preprocesses the collected data to provide high-quality data support for subsequent research and analysis. At the same time, data collection follows relevant privacy protection and data security regulations to ensure that all sensitive information is properly processed.

3.2 Construction of BIM Security Management Model

The establishment and refinement of BIM security management models first involve creating three-dimensional geometric BIM models of underground buildings and defining their physical and functional characteristics [15-16]. Subsequently, detailed architectural elements are added, including structural components, pipes, cables, ventilation systems, etc., and corresponding attribute information is assigned to them. Then, collision detection tools in BIM software are used to identify and resolve potential conflicts in the design, optimize the construction plan; the integration of security management functions includes integrating key security functions such as risk assessment, security planning, accident simulation, and emergency response plans into the BIM model. The BIM model is used for risk assessment, simulating different construction scenarios, identifying potential security risk points, such as insufficient support structures, fire hazards, etc., and developing corresponding preventive measures and procedures to ensure compliance with security regulations and standards. The risk assessment considering the probability of accident occurrence $P(A_i)$ and the severity of accident $S(A_i)$ can use the following formula:

$$Risk = \sum_{i=1}^{n} P(A_i) \times S(A_i) \quad (1)$$

A_i is the i-th possible accident that may occur; n is the number of all possible accidents that may occur; $Risk$ refers to the overall risk assessment value.

The accident simulation function allows managers to simulate specific security events, evaluate their impact on construction personnel and projects, and develop emergency response plans based on simulation results to ensure that actions can be taken quickly and effectively in the event of real events, reducing losses. Accident simulation loss assessment:

$$L = C + D + M \quad (2)$$

L refers to the total loss of the accident; C refers to direct economic losses; D refers to indirect economic losses; M refers to the losses caused by personal injury and death.

The formula for emergency response efficiency is:

$$E = \frac{T}{T_{max}} \quad (3)$$

E refers to the efficiency of emergency response; T is the actual response time; T_{max} is the maximum acceptable response time.

The BIM security management model provides comprehensive security assurance for underground building construction, helping managers predict and respond to potential security issues in advance, improve construction security, and reduce the probability of accidents. The real-time updates and collaboration capabilities of the BIM model enable all project participants to access the latest security information, enhancing the security awareness and emergency preparedness capabilities of the entire project team [17-18].

3.3 BIM Security Management Strategy

The core of BIM security management strategy lies in utilizing BIM technology for risk assessment and prevention measures, as well as emergency response and accident handling [19-20]. By using BIM models, the construction and operation process of underground buildings are simulated to identify potential security risk points, such as structural instability, construction equipment failures, and material defects. Based on these risk assessment results, preventive measures are developed and implemented to optimize construction plans, and the safest construction methods and technologies are selected to ensure that construction personnel comply with security regulations. In addition, BIM models are also used to plan emergency evacuation routes, security assembly points and rescue channels, develop emergency response plans, and provide real-time data support in the event of accidents, assisting decision-makers in quickly and accurately evaluating the impact of accidents, allocating resources, and organizing rescue operations. The implementation of these strategies significantly improves the security management level of underground buildings during the planning, construction, and operation stages, reduces the occurrence of security accidents, and ensures effective emergency response and accident handling in the event of accidents.

4. Results and Discussion

4.1 Advantages of BIM Technology in Security Management

BIM technology greatly enhances the efficiency and effectiveness of underground building security management by providing building information models. Firstly, the high-precision 3D visualization capability of BIM models enables project teams to intuitively identify potential security risks, such as defects in structural design, potential conflicts and collisions during construction, and improper use of equipment and materials. As shown in Figure 1, the efficiency of visualizing BIM technology in different security management tasks is shown:

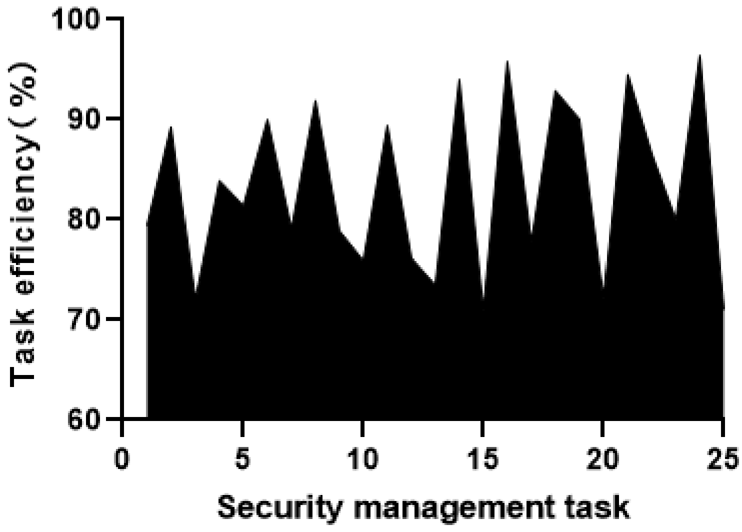

Figure 1. Efficiency of security management tasks

Figure 1 shows that the efficiency of BIM technology in different security management tasks is at an excellent level, ranging from 71% to 96.4%. These data further confirm that BIM technology is particularly effective in improving risk management, optimizing construction plans, strengthening team communication, and enhancing emergency response capabilities. The high efficiency of BIM technology not only means that security issues can be identified and resolved faster, but also means that resources can be more effectively utilized, reducing time and cost waste.

Secondly, the large amount of building information integrated in the BIM model, including material properties, component dimensions, security standards, etc., provides data support for risk assessment. These pieces of information help project managers develop more precise and effective preventive measures, such as setting safe distances, strength requirements for support systems, and planning emergency escape routes. The time dimension feature of BIM technology allows project teams to dynamically manage and optimize security plans during the construction process. By simulating the construction progress, the construction process and schedule that may cause security issues are predicted and adjusted.

By simulating emergency situations, BIM models can help plan evacuation routes, determine safe assembly points, and evaluate the allocation of rescue resources. In real emergency situations, BIM models can provide critical building information to assist in rapid decision-making and effective rescue operations.

4.2 BIM Application Results for Risk Assessment and Monitoring

The comprehensiveness of BIM technology in risk assessment and monitoring lies in the integration of a large amount of building information in BIM models, including geometric data, material properties, structural performance, etc. This provides data support for the comprehensive identification of potential risks during the construction and operation of underground buildings, and the accuracy is reflected in the combination of BIM technology with 3D visualization and data analysis, making risk assessment more accurate. The accuracy of risk identification before and after using BIM technology is shown in Figure 2:

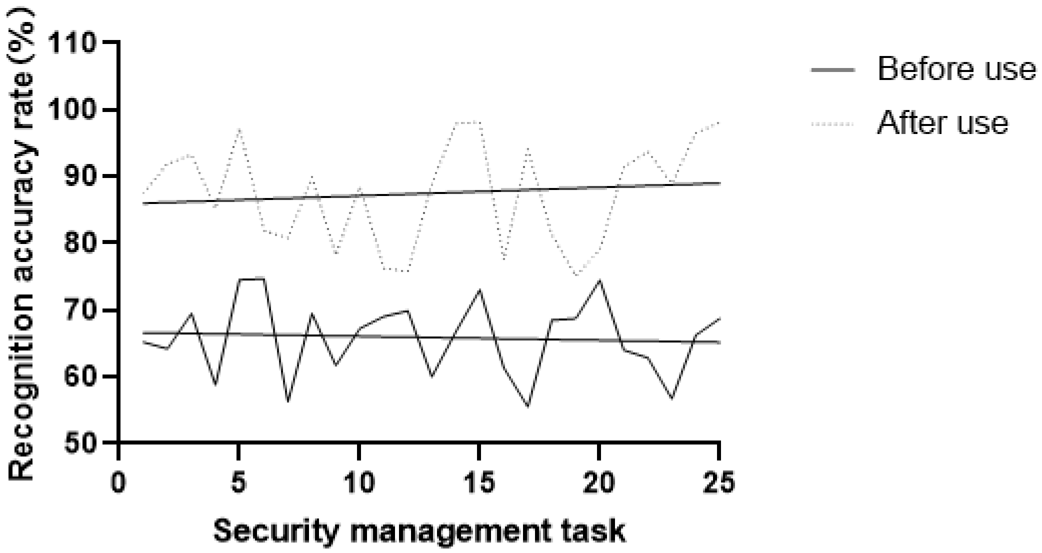

Figure 2. Risk identification accuracy

Figure 2 shows the significant advantage of BIM technology in risk identification in security management tasks. After using BIM technology, the accuracy of risk identification has significantly improved, reaching a maximum of 98.2%, which verifies the potential of BIM technology in improving the efficiency of underground building security management. BIM technology, combined with real-time data and historical performance records, provides project teams with a comprehensive and in-depth perspective to identify and analyze potential security risks, thus significantly improving the accuracy of risk identification.

Real-time monitoring and dynamic management are achieved through the integration of BIM models with sensors and monitoring equipment on the construction site, allowing project teams to promptly identify and respond to potential security issues and optimize risk mitigation measures. The detailed information in the BIM model can be used in emergency situations to quickly develop rescue plans, determine evacuation routes and security exits, and identify critical rescue resources and equipment locations. Continuous risk monitoring is achieved through regular updates of BIM models, tracking the usage and wear of buildings, and predicting and preventing potential operational risks. In terms of information sharing and collaboration, the BIM model, as a shared information platform, promotes communication and collaboration among project team members, and all stakeholders participate in the risk management process together.

4.3 Discussion on Security Management Strategies Based on BIM

The application of BIM technology in underground building security management has brought innovation to traditional security management methods. BIM not only provides an integrated and multidimensional information model, but also enables more precise and comprehensive management of security risks throughout the entire lifecycle of underground buildings through this model. The relationship between the application level of BIM technology and emergency response time is shown in Figure 3:

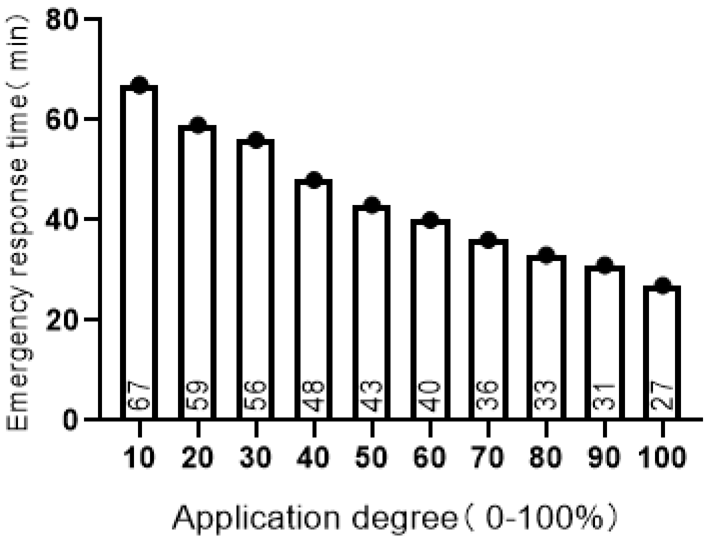

Figure 3. Emergency response time

Analyzing the data in Figure 3, it can be seen that as the application of BIM deepens, the emergency response time continues to decrease, with a minimum of 27 minutes. This indicates that BIM can quickly provide critical building information in emergency situations, such as structural layout, security exit locations, evacuation routes, etc., to help make response measures.

The high-precision 3D visualization of BIM enables project teams to identify potential security hazards during the design phase and prevent them through design optimization. This early intervention risk management strategy effectively reduces security risks in later construction and operation. The integrated data of material properties, construction plans, equipment performance, etc., in the BIM model provides rich information for risk assessment. The integration of sensor technology and BIM technology can realize the continuous monitoring of construction security. By installing sensors on construction sites, real-time data such as environmental parameters and equipment working status can be obtained, and can be combined with BIM to achieve dynamic management of construction security; in the event of an emergency, BIM can provide detailed building information, and help rescue personnel to quickly understand building structure and develop rescue plans, thereby speeding up rescue efficiency; the information-sharing platform of BIM promotes communication and cooperation among project teams, and the relevant personnel of all parties involved in the construction can access the BIM model to acquire the latest safety information in time and ensure security management measures are unified.

5. Conclusion

The results obtained in this study have practical significance, because they help to understand more clearly the role of BIM technology in improving the efficiency and effectiveness of underground building security management. From the perspective of empirical research, this paper proves that the application of BIM technology can not only improve the accuracy of risk point identification, but also effectively save the time of dealing with emergencies. These developments show that BIM technology has great potential and value in the security management of underground buildings. It is necessary to attach great importance to the important role of BIM technology in the application process, and continue to carry out targeted demonstrations in the subsequent development, so as to integrate the evaluation of major risk points, the optimization of construction plans, the real-time communication between construction units and field personnel, and the improvement of emergency response mechanisms. At the same time, the combination of sensor network and BIM to build real-time dynamic security management support has broad application prospects. With the continuous development and innovation of technology, BIM technology can have a far-reaching impact on the security management of underground buildings and provide a new direction for the development of building security management.

Funding

This work was supported by Jiangsu Construction System Science and Technology Project (Guidance Category) (2018ZD134).

References

[1]Zhang Shi, Shi Chunhui, Ding Jiancheng, Jiang Fengchang, Zhou Guixiang, Zhang Yonghao. Research on Safety Management of Underground Construction of Nursing Home in Zhoushi Town, Kunshan City [J]. Urban Architecture, 2021,18 (24): 195-198

[2] Li Juan. Research on Safety Management Based on Building Intelligence [J]. Fire Protection Industry (Electronic Version), 2023,9 (11): 10-12

[3] Xiong Huiling, Gao Liying. Risk control and safety management of shield tunneling through existing buildings. Building Safety, 2022, 37 (5): 46-49

[4] Wang Hua. Safety management of existing glass curtain wall buildings in Shanghai [J]. Building Technology, 2022, 6 (6): 99-100

[5] Zhao Xin. Construction management of adjacent buildings in shield tunneling [J]. Building Technology, 2022, 53 (9): 1236-1238

[6]Babalola A, Musa S, Akinlolu M T, et al. A bibliometric review of advances in building information modeling (BIM) research[J]. Journal of Engineering, Design and Technology, 2023, 21(3): 690-710.
[7]Ma L, Lovreglio R, Yi W, et al. Barriers and strategies for building information modelling implementation: a comparative study between New Zealand and China[J]. International Journal of Construction Management, 2023, 23(12): 2067-2076.
[8]Sameer H, Bringezu S. Building information modelling application of material, water, and climate footprint analysis[J]. Building Research & Information, 2021, 49(6): 593-612.
[9]Baldauf J P, Formoso C T, Tzortzopoulos P. Method for managing requirements in healthcare projects using building information modelling[J]. Engineering, construction and architectural management, 2021, 28(8): 2090-2118.
[10]Evans M, Farrell P. Barriers to integrating building information modelling (BIM) and lean construction practices on construction mega-projects: a Delphi study[J]. Benchmarking: An International Journal, 2021, 28(2): 652-669.
[11]Zhang Z, Zou Y. Research hotspots and trends in heritage building information modeling: A review based on CiteSpace analysis[J]. Humanities and Social Sciences Communications, 2022, 9(1): 1-22.
[12]Acheng P O, Kibwami N, Mukasa T J, et al. Building information modelling adoption in Uganda's construction industry[J]. International Journal of Construction Management, 2023, 23(13): 2185-2208.
[13]Kwon T H, Park S H, Park S I, et al. Building information modeling-based bridge health monitoring for anomaly detection under complex loading conditions using artificial neural networks[J]. Journal of Civil Structural Health Monitoring, 2021, 11(5): 1301-1319.
[14]Costin A, Hu H, Medlock R. Building information modeling for bridges and structures: Outcomes and lessons learned from the steel bridge industry[J]. Transportation Research Record, 2021, 2675(11): 576-586.
[15]Musella C, Serra M, Menna C, et al. Building information modeling and artificial intelligence: Advanced technologies for the digitalisation of seismic damage in existing buildings[J]. Structural Concrete, 2021, 22(5): 2761-2774.
[16]Olawumi T O, Chan D W M. Green-building information modelling (Green-BIM) assessment framework for evaluating sustainability performance of building projects: a case of Nigeria[J]. Architectural Engineering and Design Management, 2021, 17(5-6): 458-477.
[17]Olatunji O A, Lee J J S, Chong H Y, et al. Building information modelling (BIM) penetration in quantity surveying (QS) practice[J]. Built Environment Project and Asset Management, 2021, 11(5): 888-902.
[18]Malagnino A, Corallo A, Lazoi M, et al. The digital transformation in fire safety engineering over the past decade through building information modelling: A review[J]. Fire Technology, 2022, 58(6): 3317-3351.
[19]Pogorelskiy S, Kocsis I. Automation for structured cabling system in data centers using Building Information Modelling[J]. International Review of Applied Sciences and Engineering, 2022, 13(3): 335-345.
[20]Meisaroh M, Husin A E, Susetyo B. Analysis of key success factors using rii method on the implementation building information modeling (bim)-based quantity take-off to improve cost performance hospital structure[J]. Solid State Technology, 2021, 64(2): 3179-3188.