Intelligent Engineering Management of Prefabricated Building Based on BIM Technology

Jing Feng1, Zhiying Zhang[1*], Yuequn Xu[1], Aiju Zhang[1]
[1]Architecture Department, Shijiazhuang Institute of Railway Technology, Shijiazhuang, Hebei Province, 050041, China
Emails: jingfeng59@126.com, zhangzhiying67@163.com, yuequnxu7@163.com, aijuzhang@126.com

Keywords: Prefabricated building; Construction management; BIM; Fine management

Received: February 24, 2022

This article solves the problem of China's construction industry adopted by the traditional extensive construction mode for a long time. The traditional methods was falling behind as they have the largest number of accidents among various types of safety accidents in the construction industry. This paper puts forward a new mode of fine construction management based on BIM. This article depicts the experimental analysis considering 277 accidents of falling from height, accounting for 54% of the total. There were 72 collapse accidents, ranking second among all types of safety accidents in the construction industry. It further discusses the application measures and benefits of BIM Technology in fine management from four aspects of quality management, schedule control, cost management and safety management. It is demonstrated from experimentation that BIM Technology has brought good economic and social effects to aid fine management.

Povzetek: S strojnim učenjem in pomočjo BIM tehnologije so bile analizirane nesreče v kitajskem gradbeništvu.

1 Introduction

China's construction industry has adopted the more traditional extensive construction mode from a very long time. With the improvement of the construction market, prefabricated buildings have gradually attracted extensive attention [1]. As the main difference between prefabricated buildings and traditional buildings, the construction site of prefabricated buildings is not only in the assembly site, but also in the manufacturing plant. It is precisely because of the extension of the construction site that the construction management becomes more and more complex, from the traditional single management of the construction site to the current project management of both manufacturing plant and construction site. In addition, the construction mode is changed from wet operation to dry operation, and from cast-in-situ to assembly, which also changes the whole construction management system [2].

At the same time, due to the development of the construction technology of prefabricated buildings, the traditional problems existing in prefabricated buildings, such as the connection quality of components and fittings and the production and manufacturing of large components and fittings, have been solved, thus promoting the rapid popularization of prefabricated buildings to a certain extent. However, in the process of popularization, with the extension of the management chain and the increase of the management process, new problems continue to emerge. In order to coordinate the construction process of prefabricated buildings at the management level, improve the construction management efficiency of prefabricated buildings. It further promotes the development of prefabricated buildings from the management level has become a major problem to be solved [3]. The major applications of BIM technology in building designing are depicted in Figure 1.

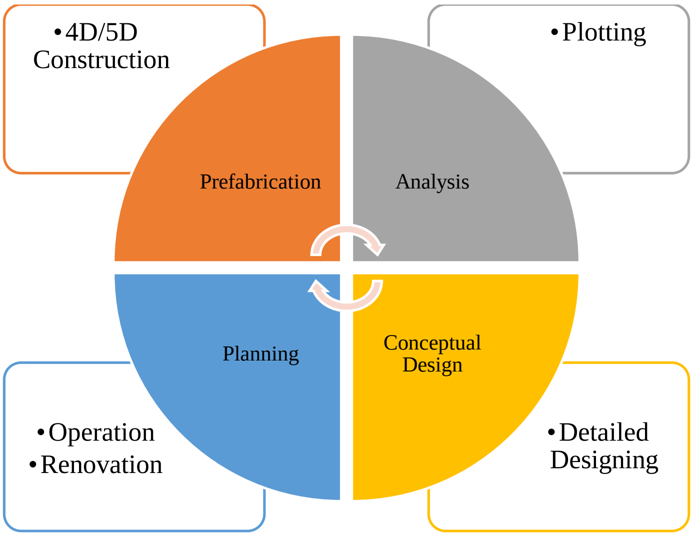

Figure 1: The major applications of BIM technology in building designing

The research gap lies in the view of the complex management problems of prefabricated buildings. This paper contributes in introducing BIM Technology into the construction process of prefabricated buildings, in order to find an appropriate construction application management mode of prefabricated buildings based on BM technology. With the help of the built BM model platform, it can effectively coordinate the management of manufacturing plant and assembly site. The proposed methodology can eliminate the information island effect in the management process, and integrate a series of management processes such as production and manufacturing, logistics and transportation. It further addresses the temporary storage and on-site assembly of components and parts, so as to provide some reference for the application of BIM Technology in the management of assembly building construction.

Further, this article is organized as: section 2 presents the literature review followed by discussion of methods in section 3. Research results of experimentation are depicted in section 4 followed by conclusion in section 5.

2 Related work

With the rapid development of society and the advancement of urbanization, the requirements for the construction industry are higher and higher. Fabricated building components are made in factories, with fast construction speed, good precision and quality. They can meet the green building design and construction requirements of "four sections and one environmental protection" to the greatest extent. They are in line with the development of modern construction industry and have received strong support from China [4]. The development of BIM Technology in China is relatively late. At present, it is mainly concentrated in the design stage, and its application in prefabricated building construction project management is relatively small. Guo and Wei combined with the characteristics of prefabricated buildings and BIM Technology, analyzed the application value of BIM Technology in the whole life cycle of prefabricated buildings, and established a collaborative platform of prefabricated buildings based on BIM Technology [5]. Li *et al.* used Revit API and c# high-level programming language technology to establish the data statistical analysis process of light assembly construction process [6]. Szelag discussed the application of BIM Technology in the design and construction of prefabricated buildings from four aspects: model creation, collision detection, progress simulation and real-time roaming [7]. Zhang constructed the ISM model of restrictive factors and believed that the fundamental reason restricting the development of prefabricated buildings in China is the lack of professionals [8]. Wesz *et al.* constructed the assembly building integration system based on BIM platform, which promoted the application of BIM Technology in assembly building [9]. Qianqian put forward the assembled building management mode with BIM Technology as the information means and lean construction as the guiding ideology [10].

Abey and Anand established the maturity evaluation model of BIM Technology in the construction stage of prefabricated buildings [11]. Ngo *et al.* constructed a BIM application capability evaluation model of prefabricated buildings based on grey clustering, and proposed a new construction management and quality control method of prefabricated system based on BIM Technology and laser scanning [12]. Wang and Srinivasan established a quality management system for assembly component production by combining the core values of BIM Technology and RFID technology [13]. Serrano analyzed the role of BIM Technology in pre-construction planning, component management and control, construction schedule management, site dynamic layout and cost management of prefabricated buildings [14]. However, the construction process of prefabricated buildings is different from ordinary cast-in-situ buildings. Its construction site is not only a construction site, but also a factory.

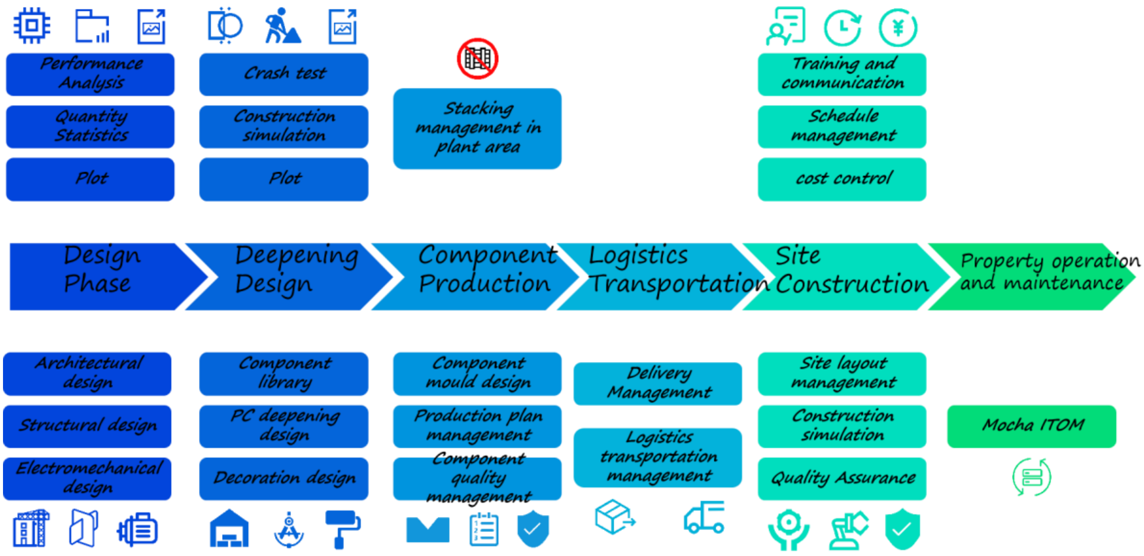

Figure 2: Development trend of prefabricated building construction

The cost management, quality management, safety management and schedule management in these two aspects can be better and faster realized under the coordination of BIM Technology, as shown in Figure 2. Therefore, it is of great theoretical and practical significance to analyze the role of fine management in the process of prefabricated building construction from BIM Technology.

3 Research method

Fine construction management is to control the details of the construction process accurately and standard, so as to save resources and reduce costs to the greatest extent [15]. BIM Technology is the integration and circulation of various information of buildings, which can provide complete and accurate information for fine construction and improve the efficiency of fine construction management. In previous engineering projects, BIM and fine construction management were not used at the same time, but from the perspective of theoretical research, it is feasible to apply BIM concept and fine construction management to engineering projects.

3.1 BIM Technology and fine construction management have common goals

Fine construction management is to formulate a specific and clear responsibility system from the perspective of management, implement the responsibility requirements of each participant, minimize the resources consumed in the construction process, achieve accurate control of the construction process, reduce material waste and reduce construction cost [16]. BIM Technology is to accurately divide the tasks by stages through information, visualization and other means, simulate the construction process, find a weak link in the process, and correct the construction scheme in time, so as to reduce the construction cost and improve the project benefit. It can be seen that the objectives of the two are the same, and ultimately to reduce the construction cost.

3.2 Both refined construction management and BIM require the participation of all units

BIM is an information sharing technology in the whole life cycle of buildings, which involves many participants and each stage of construction, and requires the cooperation and exchange of each participant such as the owner, the design unit and the government [17]. Refined construction management is a comprehensive management method, which penetrates into every link of the work. Each activity participant needs to form refined ideas and earnestly implement the refined system. Form a corporate culture with the fine concept as the core, which is an important guarantee for fine construction management. Both have a common mass base and are consistent in terms of participants.

3.3 Fine construction management can make up for the deficiency of BIM from the management level

At present, most of the research and application of BIM in China are focused on the technical aspects of drawing deepening design, site dynamic layout, construction progress simulation, construction process simulation, BIM calculation, pipeline comprehensive optimization and so on, lacking the research on the management mode based on BIM Technology. To really use BIM well, we not only need advanced software and single node technology application, but also need advanced management scheme to match it, so as to give full play to the role of BIM, grasp the construction objectives as a whole, reduce resource waste and ensure the completion of construction objectives. Through fine construction management, the deficiencies in BIM management are made up, and the obstacles to the development of BIM Technology are eliminated from the root [18].

3.4 BIM Technology in turn promotes the development of fine construction management

BIM Technology injects "information" elements into fine construction management, which in turn promotes the development of fine construction management [19]. The core of BIM is to realize the transmission and sharing of information. BIM model stores all kinds of building information. This building information model can be used as the basis of the project, provide accurate and real data for the construction of various disciplines, optimize the construction scheme, and reasonably allocate the use of personnel and materials, so as to promote the development of fine construction management.

3.5 The refined construction management integrated with BIM Technology is more operable

The application of BIM in fine construction management provides accurate and real data support for fine management, so that the work is refined and the assessment quantification is based on, rather than based on experience. So that the fine management is no longer an empty rules and regulations, but carried out with good reasons, which enhances the operability of the fine management.

The construction fine management mode based on BIM includes fine management objectives, management contents, management elements and management system. BIM based construction fine management mode is based on fine management and BIM Technology as the core. It decomposes and refines the construction process accurately and in detail, implements the responsibilities of each step, and clarifies, concretizes and quantifies the responsibilities, with the main goal of minimizing the resources occupied by management and reducing management costs. Figure 3 depicts the construction fine management mode based on BIM [20].

Under the traditional mode, the quality control of engineering projects is mainly in the design and construction stages, and mainly carried out by the construction unit, the construction unit and the supervision unit. Generally, the quality of the project is inspected and accepted by relevant units or personnel organized by the supervising engineer (or the project leader of the construction unit) on the basis of the self-inspection and evaluation of the construction unit according to the qualified quality standard [21-23]. The whole process of project quality control under the traditional mode is shown in Figure 4.

Under the traditional mode, the construction unit generally enters the project from the bidding stage of the project, and rarely or basically does not participate in the design of the project. Therefore, the quality control in the design stage of the project is mainly responsible by the design unit and the construction unit. The work content of quality control in the design stage mainly includes two aspects: the control of quality standards adopted by the project and the control of design work quality itself [24,25].

In recent years, with the maturity of the construction market, Chinese construction enterprises have gradually established a quality-oriented business philosophy, which has steadily improved the quality level of construction projects. However, the extensive construction management mode cannot be completely changed in the short term. The construction quality control system under the old mode is still adopted by most projects, and there are still many problems in construction quality:

i. In the traditional working mode, there are a large number of CAD drawings in the construction stage, and the drawings of various disciplines are independent of each other, resulting in the disharmony between a large number of drawings, which brings hidden dangers to the construction. At the same time, for buildings with strange shapes and complex structures, two-dimensional drawings are difficult to express and workers are difficult to understand, making technical disclosure difficult, which may cause construction quality problems.

ii. The project lacks construction quality control scheme. At this stage, the project quality control mainly depends on supervision, self inspection and spot check. It is too late to check the construction problems, and the hidden dangers cannot be eliminated before they occur.

iii. The key parts of quality control are not included in the construction scheme. The quality inspectors are not clear about the location, testing time and requirements of quality inspection objects, resulting in non-standard inspection in the construction process, untimely quality inspection and evaluation, and the project management personnel do not understand the quality of the construction process. The construction quality will not be evaluated as a whole until the project is completed.

iv. The construction of engineering project is a systematic and complex process, which requires mutual coordination and cooperation between different disciplines and types of work. However, in engineering practice, due to different majors or different affiliated units, it is difficult to coordinate and communicate among various types of work in advance. This leads to the poor coordination of various professional types of work in the actual construction, resulting in the discontinuous progress of the project, or the need for frequent rework, as well as the collision, even mutual destruction and interference between various types of work, which seriously affects the quality of the project. For example, the work sequence arrangement of other professional teams such as water and electricity and the main construction team is unreasonable, resulting in the arbitrary gouging and opening of bearing walls, plates, columns and beams during the construction of hydropower, which destroys the main structure and affects the quality problem of structural safety.

v. China has strict regulations and division on the quality of building materials, and individual enterprises also have their own quality standards for the use of materials. However, in the actual construction process, the management of building material quality is often not paid enough attention. In order to pursue additional benefits, individual construction units will intentionally or unintentionally use some non-standard engineering materials in the construction process of engineering projects, resulting in problems in the final quality of engineering projects. In the traditional two-dimensional design, the disciplines and drawings are independent and not related to each other, so it is inevitable that there will be some problems of disharmony between the drawings. In BIM model, each individual building component is represented only once, such as shape, attribute and position in the model. All drawings, reports and analysis information sets obtained in the same version of BIM model are interrelated, and they are changed and updated everywhere. This function can solve the problem of disharmony among drawings. And in the process of establishing the three-dimensional model, we can have an intuitive and comprehensive understanding of the project, so as to find the errors and defects in the design before the project construction, improve the engineering design quality and eliminate the engineering quality problems from the source. The speed and accuracy of establishing BIM model are very key. The speed and accuracy of modeling directly affect the effect of later engineering application. Autodesk Autodesk Revit 2015 software is selected for the initial modeling of the project. Revit has the powerful functions of architectural design, structural design and electromechanical design modeling, and can accurately and flexibly represent the geometric and physical characteristics of components. In the Revit model, all drawings, plan views, 3D views and schedules are established in the same database of the building information model. There is a close correlation between the 3D model and the drawings, so one modification will be automatically modified everywhere else, saving a lot of manpower and time to adjust the drawings and ensure the coordination between the drawings. At the same time, you can accumulate and create your own parametric family library, and create the current model by adjusting the parameters of the original component family when creating the model, which can greatly improve the modeling speed [26-28]. Complete the establishment of BIM model within the specified working days, record the errors found in the drawings during the creation process, and submit them to the designer in writing for modification opinions. See drawing joint review record Table 1 for some parts.

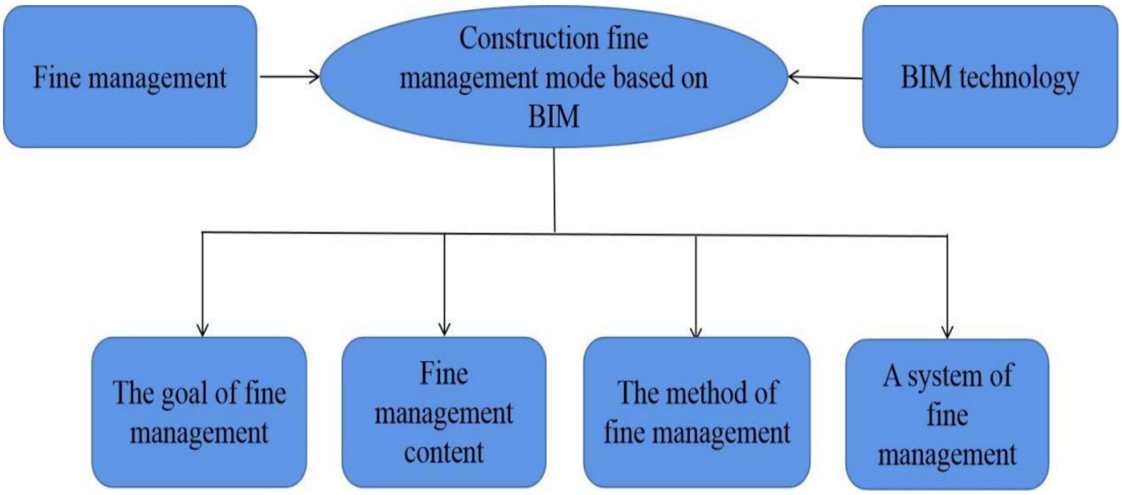

Figure 3: Construction fine management mode based on BIM

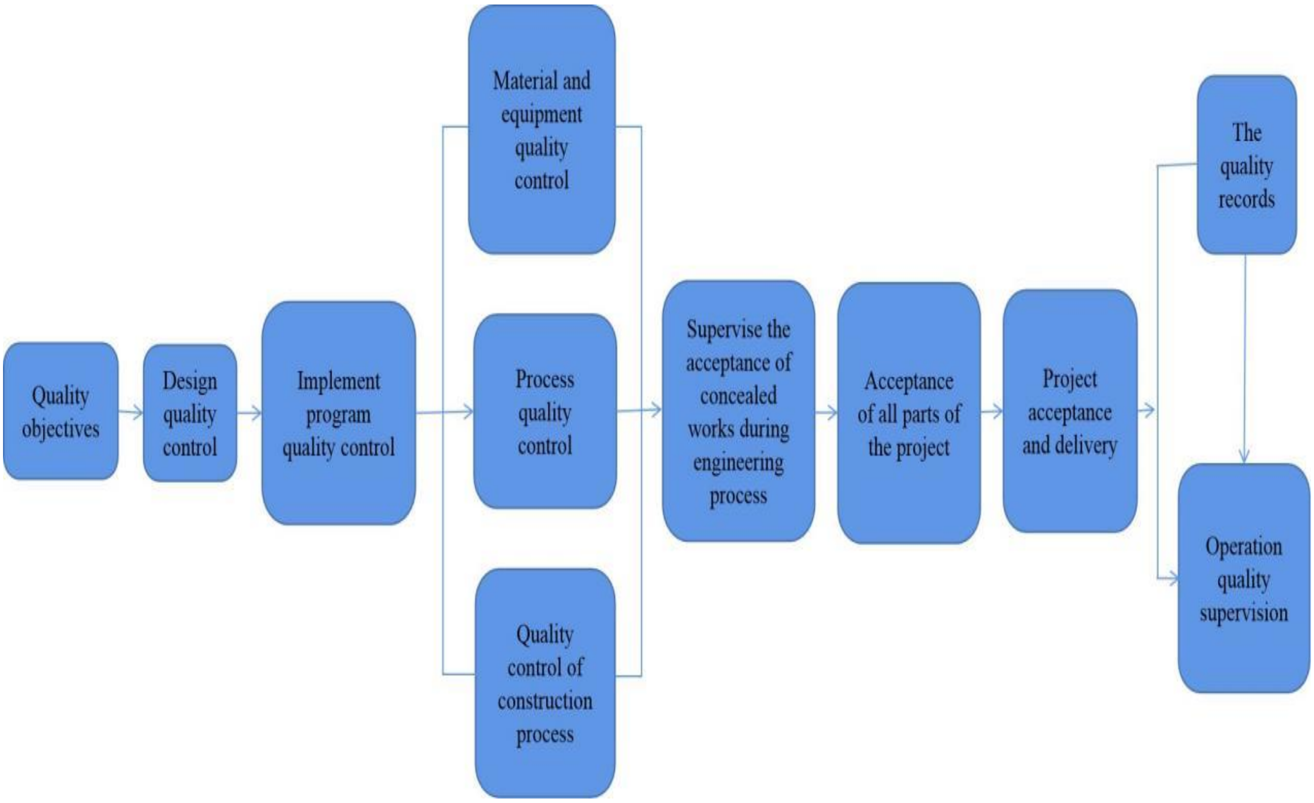

Figure 4: Quality control process of engineering project under traditional mode

Project name	**Phase II (C10 plot) project of resettlement housing in a large residential community**		**Major**	**Civil engineering**
Joint examination place	Project meeting room		Date	
Serial number	Drawing No	Questions about drawings	Reply comments	
1	Building construction-01 and construction-03	The distance between axis m and axis L between axes 15-17 is inconsistent with the two drawings	Subject to building construction-01	
2	Structural construction-04	On the 11m floor of axis L and axis A, the beam position is inconsistent with the elevation. In the architectural drawing, the roof beam is aligned with the lower part.	Change the beam position to align with the lower part	
3	Structural construction-01	In the first point of 3.10, in the strength grade of concrete components, the rest floors of the frame beam of the main building are (soil above 0.000) C30, and the rest floors of the main floor slab are (soil above 0.000) C25. The	The strength grade of slab concrete shall be changed to that of frame beam of the same floor	

		concrete strength of the beam slab is different. Can the concrete strength grade of the beam slab be changed to the same strength grade? Is it feasible?	
4	Structural construction-05	There is no dimension for the opening beam at the junction of axis D and axis 6 of the second floor beam	According to the size of opening beam on the first floor
5	Structural construction-08	The beam between axis F and axis G on axis 7 is not marked	The beam is kl16
6	Structural construction-08	There is no kz-15 method in the column table	To the top of the third floor, the reinforcement shall be kzi5 on the first floor

Table 1: Drawing joint review record

4 Results and Analysis

Due to the characteristics of the construction industry and low safety investment, the labor environment and safety situation of construction workers are not optimistic. According to the accident statistics of the project quality and safety supervision department of the Ministry of housing and urban rural development. The statistics of safety accidents in China's construction industry are shown in Figure 5, and the statistics of accident deaths are shown in Figure 5. It can be seen that the number of safety accidents and deaths maintain a downward trend, and the safety production situation tends to be stable on the whole, but it is still at a high level, and the decline is not obvious.

The complete comparison of accident number with corresponding accident fatalities is depicted in Figure 7. The types of production safety accidents in China's construction industry are shown in Figure 8. The types of construction safety accidents in China mainly include falling accidents, collapse accidents, object strike accidents, etc. It can be seen that falling from height has the largest number of accidents among various types of safety accidents in the construction industry. It is revealed that 277 accidents, accounting for 54% of the total while collapse accidents ranked second among all types of safety accidents in the construction industry, with 72, accounting for 15%. The third type of safety accidents in the construction industry is object strike accidents, 66, accounting for 15%. Lifting injury accidents, machine injury accidents and electric shock accidents account for 10%, 5% and 2% of the total safety accidents respectively, ranking 4th-6th respectively.

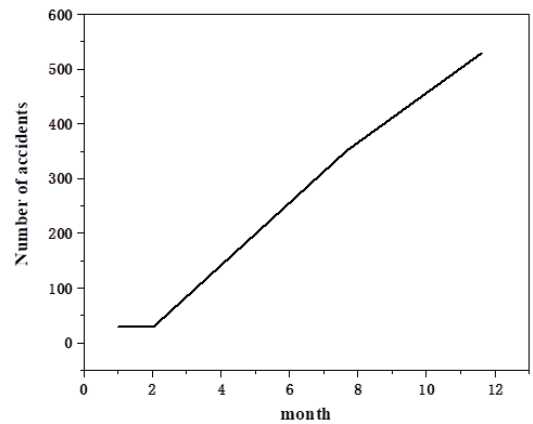

Figure 5: Number of accidents

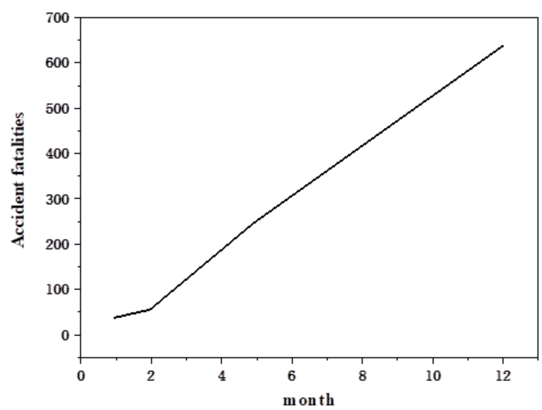

Figure 6: Accident fatalities

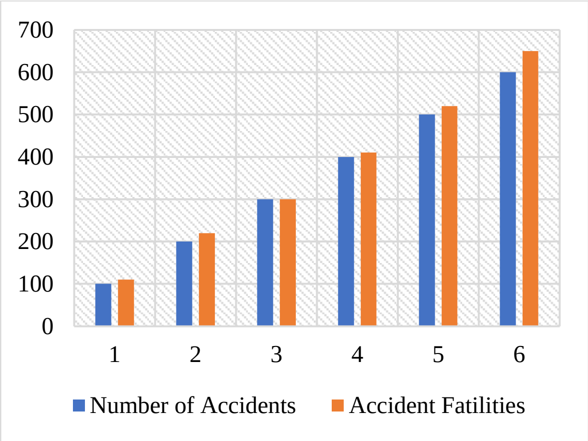

Figure 7: Comparison of accident number with corresponding accident fatalities

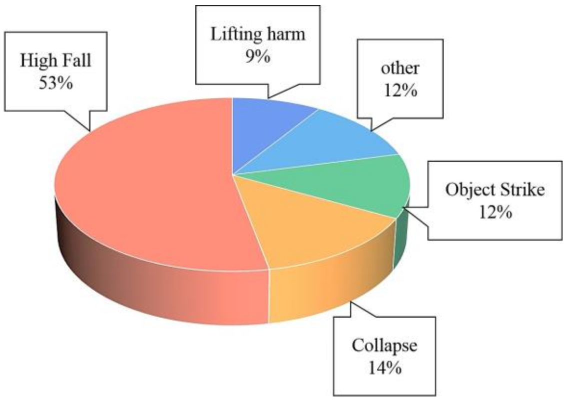

Figure 8: Accident types in the year 2020

Based on the above safety statistics of China's construction industry, it can be seen that the current safety production situation of China's construction industry is still not optimistic, safety accidents are still not effectively controlled, causing huge economic losses, casualties and unnecessary losses every year. Falling from height, collapse and object strike are the most frequent types of accidents. The cumulative number of the above three types of safety accidents accounted for about 80% of the total number of accidents in 2020, and the mortality rate is also the highest among all kinds of accidents.

The main causes of safety accidents include non-standard construction market behavior, imperfect safety management system, ineffective preventive measures, incomplete elimination and treatment of hidden dangers in safety production, backward safety management level and technology, weak safety awareness of construction workers, taking chances and not strictly abiding by professional norms. The understanding of the construction process is not thorough enough, and there are potential safety hazards in the construction process or site layout. The difficulty of fall prevention management of large-scale construction projects is that it is difficult to find all edges and openings that need protection [29,30]. The traditional management method is mainly based on the two-dimensional drawings and the environmental inspection and supervision management of the construction site to find the four openings that need protection: staircase, elevator, entrance and exit and reserved opening.

Five temporary edges: the periphery of balustraded balcony, the periphery of roof without external frame protection, the periphery of frame engineering floor, both sides of stair ramp and the outer side of unloading platform. With heavy workload and low efficiency, it is difficult to find all potential falling safety hazards of the project and formulate corresponding safety protection measures in time. For the safety measures of openings, the safety protection measures taken for openings of different sizes are different, as shown in Table 2.

Opening size	Safety measures
Greater than 150 cm	Guardrail protection and safety flat net protection shall be added around the opening
50-150 cm	A layer of grid grid formed by fastening steel pipes must be set and covered with scaffold board
25-50 cm	For openings during the installation of prefabricated components and openings formed temporarily due to lack of components, bamboo and wood can be used as cover plates to cover the openings
2.5-25 cm	Use solid cover plate to cover the opening for protection
Less than 2.5cm	Considering the size of the hole and the reduced possibility of falling objects, it is ignored

Table 2: Safety protection measures for portal

Using BIM modeling, 4D virtual construction technology and visualization characteristics, we can find out the potential falling safety hazards in different construction stages and parts in the process of 3D model and 4D virtual construction. Then the fall protection model is established and imported into the structural model for detection to ensure that there are no security vulnerabilities in the fall protection system.
The state-of-the-art comparison of the proposed method with the other techniques depicted in the literature is presented in Figure 9. This figure reveals the state-of-the-art comparison of accident prediction accuracy for various methods reported in the literature survey.

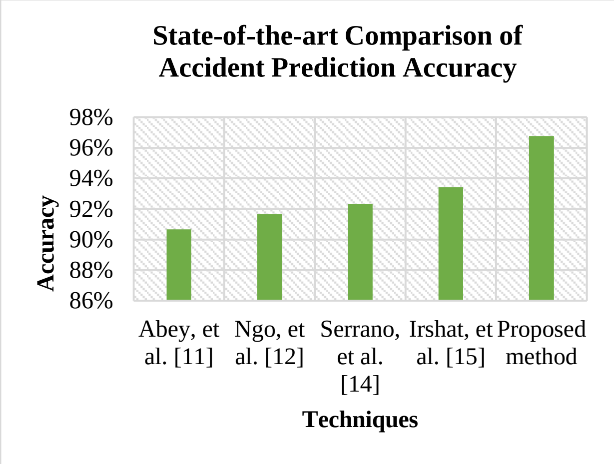

Figure 9: State-of-the-art Comparison Accident Prediction Accuracy

The study of this model reveals that it is easy to find out all the edges and openings with potential fall safety hazards in the whole project. Then place the built edge and opening fall protection model in the structural model to form a fall protection system, provide a visual management platform for managers, and strengthen the communication effect of safety plan. Before the actual construction, the simulated construction environment can be observed to identify and analyze the hazard sources. Optimize the construction scheme and site layout, or formulate emergency measures to control safety risks and avoid safety accidents. In large and complex projects, many workers often carry out construction in different parts, but it is difficult for us to grasp the overall situation on site. In the virtual construction model, we can clearly see the potential risk factors in different parts.

5 Conclusions

China accounted for 80% of the total number of accidents in 2020, and the mortality rate was also the highest among all kinds of accidents. The main causes of safety accidents include irregular behavior in the construction market. In order to solve these problems, this paper puts forward the specific application of BIM Technology in engineering construction safety management, and discusses the advantages and application effects of BIM technology in construction safety management. BIM based safety management can enable project managers to discover in advance, the risks that may affect the project construction progress or lead to safety accidents during project implementation. This article further formulates the corresponding control measures, strengthen the communication of safety plan and emergency plan between project management personnel and construction personnel. It maintains the integration and sharing of information and reduces the occurrence of accidents. Thus, facilitating the implementation of safety plan and the control of safety risks, further promoting the refinement and digitization of construction safety management.

References

[1] Wang, R., Dong, X., Wang, K., Sun, X., Fan, Z., & Duan, W. (2019). Two-step approach to improving the quality of laser micro-hole drilling on thermal barrier coated nickel base alloys. *Optics and Lasers in Engineering*, *121*, 406-415. https://doi.org/10.1016/j.optlaseng.2019.05.002

[2] Wang, Q., Zhang, B., Yu, S., Xiong, J., Yao, Z., Hu, B., & Yan, J. (2020). Waste-printed circuit board recycling: Focusing on preparing polymer composites and geopolymers. *ACS omega*, *5*(29), 17850-17856. https://doi.org/10.1021/acsomega.0c01884

[3] Hardin, M. (2019). Design-Build for Discovery: Applied Research on the Construction Site. *Building Technology Educator's Society*, *2019*(1), 9. https://doi.org/10.7275/642c-vp30

[4] Akinade, O. O., Oyedele, L. O., Ajayi, S. O., Bilal, M., Alaka, H. A., Owolabi, H. A., & Arawomo, O. O. (2018). Designing out construction waste using BIM technology: Stakeholders' expectations for industry deployment. *Journal of cleaner production*, *180*, 375-385. https://doi.org/10.1016/j.jclepro.2018.01.022

[5] Guo, S. J., & Wei, T. (2016). Cost-effective energy saving measures based on BIM technology: Case study at National Taiwan University. *Energy and Buildings*, *127*, 433-441. https://doi.org/10.1016/j.enbuild.2016.06.015

[6] Li, X., Xu, J., & Zhang, Q. (2017). Research on construction schedule management based on BIM technology. *Procedia engineering*, *174*, 657-667. https://doi.org/10.1016/j.proeng.2017.01.214

[7] Szeląg, R. (2017). The use of BIM technology in the process of analyzing the increased effort of structural elements. *Procedia Engineering*, *172*, 1073-1076. https://doi.org/10.1016/j.proeng.2017.02.165

[8] Zhang, Y. (2022). Application of BIM Technology in Project Construction Schedule Management. In *2021 International Conference on Big Data Analytics for Cyber-Physical System in Smart City* (pp. 77-85). Springer, Singapore. https://doi.org/10.1007/978-981-16-7469-3_8

[9] Wesz, J. G. B., Formoso, C. T., & Tzortzopoulos, P. (2018). Planning and controlling design in engineered-to-order prefabricated building systems. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-02-2016-0045

[10] Qianqian, S. U. N. (2018). Design of Prefabricated Old-age Building Based on Modularization: A Case Study of Institutional Elderly Houses Design in Taigou Village, Xi'an City. *Journal of Landscape*

Research, *10*(5).
10.16785/j.issn 1943-989x.2018.5.016

[11] Abey, S. T., & Anand, K. B. (2019). Embodied energy comparison of prefabricated and conventional building construction. *Journal of The Institution of Engineers (India): Series A*, *100*(4), 777-790.
https://doi.org/10.1007/s40030-019-00394-8

[12] Ngo, T. D., Nguyen, Q. T., & Tran, P. (2016, October). Heat release and flame propagation in prefabricated modular unit with GFRP composite facades. In *Building Simulation* (Vol. 9, No. 5, pp. 607-616). Springer Berlin Heidelberg.
https://doi.org/10.1007/s12273-016-0294-3

[13] Wang, Z., & Srinivasan, R. S. (2017). A review of artificial intelligence based building energy use prediction: Contrasting the capabilities of single and ensemble prediction models. *Renewable and Sustainable Energy Reviews*, *75*, 796-808.
https://doi.org/10.1016/j.rser.2016.10.079

[14] Serrano, W. (2019, September). iBuilding: artificial intelligence in intelligent buildings. In *UK Workshop on Computational Intelligence* (pp. 395-408). Springer, Cham.
https://doi.org/10.1007/978-3-030-29933-0_33

[15] Irshat, K., Petr, R., & Irina, R. (2018, October). The selecting of artificial intelligence technology for control of mobile robots. In *2018 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon)* (pp. 1-4). IEEE.
10.1109/FarEastCon.2018.8602796

[16] Brooks, R. A. (1991). Intelligence without representation. *Artificial intelligence*, *47*(1-3), 139-159.
https://doi.org/10.1016/0004-3702(91)90053-M

[17] Winfield, A. F., & Jirotka, M. (2018). Ethical governance is essential to building trust in robotics and artificial intelligence systems. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, *376*(2133), 20180085.
https://doi.org/10.1098/rsta.2018.0085

[18] Vaidyanathan, P. K., Sidduraj, M., & Woods, G. (2016). *U.S. Patent No. 9,405,531*. Washington, DC: U.S. Patent and Trademark Office.

[19] Tian, B. (2018). Building Artificial Intelligence for Dermatological Practice. *Open Access Library Journal*, *5*(04), 1.
10.4236/oalib.1104541

[20] Chiba, D., Akiyama, M., Yagi, T., Hato, K., Mori, T., & Goto, S. (2018). DomainChroma: Building actionable threat intelligence from malicious domain names. *computers & security*, *77*, 138-161.
https://doi.org/10.1016/j.cose.2018.03.013

[21] Gadakari, T., Hadjri, K., & Mushatat, S. (2016, August). Relationship between building intelligence and sustainability. In *Proceedings of the Institution of Civil Engineers-Engineering Sustainability* (Vol. 170, No. 6, pp. 294-307). Thomas Telford Ltd. ,
https://doi.org/10.1680/jensu.16.00028

[22] Ko, C.H., & Li, S. C. (2014). Enhancing submittal review and construction inspection in public projects. Automation in construction, 44, 33-46.

[23] Liu, J., & Shi, G. (2017). Quality control of a complex lean construction project based on KanBIM technology. EURASIA Journal of mathematics, science and technology education, 13(8), 5905-5919.

[24] Sharma, D., Kaur, R., Sandhir, M., & Sharma, H. (2021). Finite element method for stress and strain analysis of FGM hollow cylinder under effect of temperature profiles and inhomogeneity parameter. *Nonlinear Engineering*, *10*(1), 477-487.
https://doi.org/10.1515/nleng-2021-0039

[25] Ting, L., Khan, M., Sharma, A., & Ansari, M. D. (2022). A secure framework for IoT-based smart climate agriculture system: Toward blockchain and edge computing. *Journal of Intelligent Systems*, *31*(1), 221-236.
https://doi.org/10.1515/jisys-2022-0012

[26] Froufe, M. M., Chinelli, C. K., Guedes, A. L. A., Haddad, A. N., Hammad, A. W., & Soares, C. A. P. (2020). Smart buildings: Systems and drivers. *Buildings*, *10*(9), 153.
https://doi.org/10.3390/buildings10090153

[27] Kumbinarasaiah, S., & Raghunatha, K. R. (2021). A novel approach on micropolar fluid flow in a porous channel with high mass transfer via wavelet frames. *Nonlinear Engineering*, *10*(1), 39-45.
https://doi.org/10.1515/nleng-2021-0004

[28] Gruszczak, A. (2016). *Intelligence security in the European Union: Building a strategic intelligence community*. Springer.
https://doi.org/10.1057/978-1-137-45512-3

[29] Horowitz, M. C., Kahn, L., & Mahoney, C. (2020). The Future of Military Applications of Artificial Intelligence: A Role for Confidence-Building Measures?. *Orbis*, *64*(4), 528-543.
https://doi.org/10.1016/j.orbis.2020.08.003

[30] Huang, Z., Lin, K. J., Tsai, B. L., Yan, S., & Shih, C. S. (2018). Building edge intelligence for online activity recognition in service-oriented IoT systems. *Future Generation Computer Systems*, *87*, 557-567.
https://doi.org/10.1016/j.future.2018.03.003