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Application of safety management system in building construction based on BIM and PDCA theory

Jiahui Men

School of Civil Engineering, Northeast Forestry University, Harbin, 150040, China

Abstract: *Nowadays, the construction industry vigorously promotes intelligent construction and new building industrialisation, promotes the application and development of BIM technology, and gradually increases the application rate of BIM Technology in construction engineering. Therefore, this paper provides a broader application idea for BIM technology by integrating BIM technology with PDCA cycle theory. At the same time, it makes an extension for the PDCA cycle theory, with a view to proposing a more perfect implementation plan for building construction safety management. Firstly, this paper analyses six types of construction accidents consisting of falling, object striking, lifting injury, collapsing accident, mechanical injury and other accidents, and analyses the causes of accidents from four aspects: human factors, environmental factors, government supervision and equipment loss and failure. Then, through online research, field research and other methods, based on BIM Technology and PDCA cycle theory, this paper makes a comprehensive analysis of construction safety management from four aspects: safety plan formulation, risk management and control, potential safety hazard inspection, summary and optimisation. The feasibility and efficiency of the BIM-based technology and PDCA cycle theory system in building construction safety management is analysed in terms of the whole construction process. The system can make the safety management more in-depth, scientific and efficient, ensure the safety of construction personnel and improve work efficiency as much as possible.*

Keywords: *BIM; PDCA; Construction Safety; Construction project*

1. Introduction

With the rapid development of the construction industry, engineering projects tend to be complex and diversified, which is a tremendous challenge to construction technology and construction management [1]. Construction safety management has always been an essential part of the construction process. In recent years, with the popularisation and development of BIM Technology (building information modelling), the construction management mode gradually tends to exemplary management [2]. BIM Technology can establish an accurate model of buildings through digital technology, which records the building engineering data and shows the whole life informatisation delicate management process of the construction process [3]. The introduction of PDCA Cycle Theory (plan execution inspection treatment) into the construction safety management system makes the information management mode more systematic and efficient [4]. PDCA cycle theory is based on the four-step cycle of planning, execution, inspection and treatment to realise the excellent management of the whole life cycle of construction projects. Relying on the BIM information management platform and the advantages of PDCA cycle theory and safety management theory, establish a safety management system, realise careful, continuous and visual safety management of construction projects, and improve the accuracy and effectiveness of safety management [5]. It has vital practical significance for the smooth construction of construction projects and the safety of life and property of construction personnel [6]. In recent years, many scholars have studied the application of BIM technology and the PDCA cycle principle in building construction safety management. Yang et al [7] argue that in building construction, the use of BIM technology can effectively reduce the probability of site safety risks. Wei [8] managed construction hazards in engineering projects through technologies based on BIM, big data and Internet of Things. Pu [9] applied the PDCA cycle model to construction safety management and conducted a practical analysis, with significant benefits in the end. Lv et al [10] integrated the PDCA cycle principle with BIM technology to provide new ideas for construction safety management. Therefore, this paper integrates the PDCA cycle management theory and the construction quality and progress management of BIM Technology Application with the PDCA planning, execution, inspection and processing cycle management process [11].

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2. Construction safety management

Construction safety is related to all aspects of employee safety, construction progress and business efficiency. Construction safety management therefore begins with the elimination of potential hazards in terms of the types of safety incidents and their causes. The types of safety accidents and their causes are listed below.

2.1. Type of construction accident

The construction industry is accident-prone. Construction has the characteristics of a long cycle, considerable personnel mobility, complex construction site environment, many open-air and high-altitude operations, and many construction machineries, making the construction itself have huge potential safety hazards [12]. Although the safety plan will be specified before construction, safety accidents may occur due to the weak safety awareness of construction personnel, non-standard construction operation, insufficient safety training, incomplete technical disclosure and other reasons, resulting in casualties and property losses. According to the types of production safety accidents of housing and municipal engineering, the Ministry of Housing and urban-rural development divides them into six categories: falling from a height, object strike, lifting injury, collapse accident, mechanical damage and other accidents [13]. The unsafe points in each accident are shown in Fig.1.

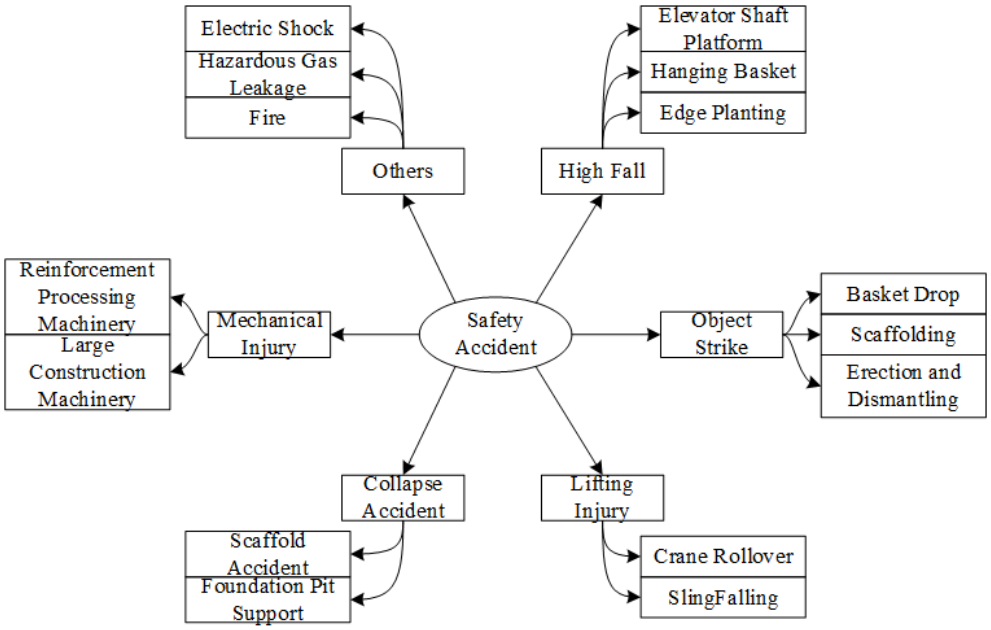

Figure 1: Unsafe points in safety accidents

2.2. Accident cause analysis

2.2.1. Human factor

The turnover rate of construction enterprises is high, there is a shortage of construction personnel, the interval between the check-in and participation in the construction of new employees is short, and the training of new construction personnel by safety officers is not timely, which can easily lead to safety accidents. For example, failure to wear safety helmets and failure to fasten safety ropes for edge operations will leave potential safety hazards and threaten the life safety of construction personnel. February 20, 2002, a power plant in Shenzhen, NO. 5, NO. 6 unit construction project, operating personnel did not fasten the safety belt and the site did not set up a safety net. Three workers were killed when they fell from the roof onto the turbine platform. In addition, there is much large-scale mechanical equipment on the construction site, and there is a blind area of vision. It is also easy to cause accidents if you rush through the mechanical equipment construction area. Construction generally lasts for a long time. With the familiarity of the construction personnel with the workplace, the awareness of safety protection will be weak, and there will be a fluke mentality. On the contrary, accidents are easy to occur at this time.

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2.2.2. Environmental factor

With the accelerating modernisation process and the continuous need for urban construction, China has a vast territory, and the complex and changeable geographical environment is easy to cause safety accidents. In addition, extreme weather is also easy to cause significant safety accidents, such as typhoons, rainstorms, etc. Construction safety accidents caused by strong winds and floods have occurred in Jiangsu, Anhui, Xinjiang and other places in China. Construction in severe weather can not ensure the regular operation of safety equipment. At the same time, extreme weather has solid destructive force, and the materials and mechanical tools placed on the construction site may also become potential safety hazards.

2.2.3. Insufficient government supervision

The orderly construction is inseparable from the control and management of relevant functional departments of the government. The qualification examination of the bid winning enterprise safety inspection during building and construction quality inspection all need the strict control of government departments. At the same time, the shortage of professional and technical personnel and the lack of safety awareness of construction personnel also need the leadership and rectification of government departments to reduce the potential safety hazards during and after construction.

2.2.4. Equipment loss and failure

The construction equipment cannot avoid wear and damage in the long-term use process. For example, the mechanical equipment is not connected with PE protective wire, the anti rope skipping device of steel wire rope is damaged, and the counterweight of the tower crane is reduced, which will lead to safety accidents and severe loss of life and property [14]. In 2016, a mechanical overturning accident occurred in a project in Leiyang. The distributor fixed leg and telescopic leg joint surface welding fixed, so that the lower cover produced heat affected zone and welding defects, resulting in a serious concentration of stress. Under the action of alternating load, fatigue failure occurred on the lower surface of the telescopic leg with the smallest section at the variable section position after welding, and fracture upturned, resulting in the overturning of the whole machine.

3. Establishment and analysis of security management system based on BIM and PDCA

PDCA cycle, also known as a quality loop, is widely used in management. The four letters of the PDCA cycle principle respectively represent the four steps of P (plan), D (do), C (check) and an (action), which continuously cycle. This is the PDCA cycle. P is the planning stage, including determining management objectives and formulating relevant work plans [14]. D is the implementation stage, mainly to organise staff to implement specific strategies according to the developed methods. C is the inspection stage, which is primarily to check whether there is deviation by comparing the implementation of the work plan with the common situation of the project. A is the decision-making stage, mainly to prevent the implementation effect, then include the successful ones into the standard, leave the unsuccessful ones to be solved in the next cycle, and continue the next PDCA cycle. Combining the advantages of BIM Technology, PDCA cycle theory and safety management theory, a safety management system based on BIM and PDCA is established to realise careful, continuous and visual safety management of construction projects, as shown in Fig.2 [15]. This can improve the accuracy and effectiveness of safety management and ensure the life and property safety of front-line construction personnel to the greatest extent [16].

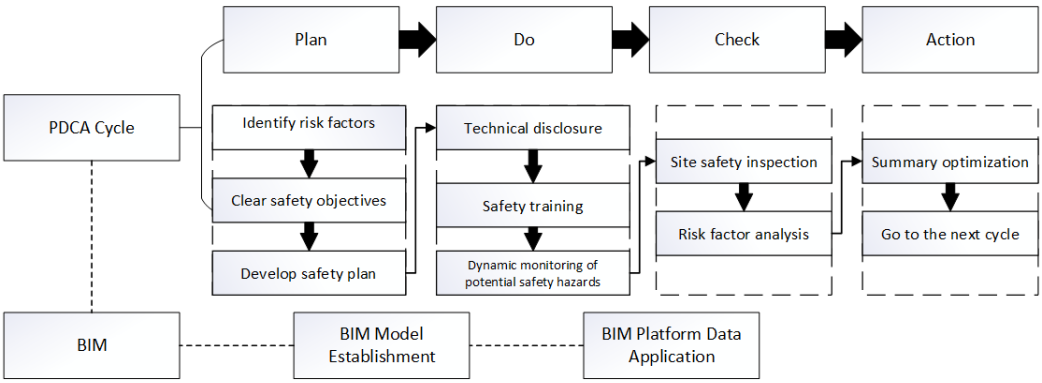

Figure 2: Security management flow chart based on BIM and PDCA

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3.1. Safety planning

The construction site is complex, and there are many potential safety hazards in the construction process, which requires timely identification of safety risk factors in the whole construction process. Based on the 3D model function of BIM, simulate the site conditions and the distribution of construction personnel in different construction stages, identify the risk factors in construction, assign the 3D model with time parameters, and associate the prepared schedule based on the 3D model containing geometric information to form a 4D model[17]. Based on the 4D virtual construction technology of BIM, the possible problems in the construction process are found in advance. The design is optimised through the construction simulation and collision detection of the BIM platform, the corresponding safety plan and protective measures are formulated. The risk factors are eliminated in time [18].

3.2. Risk control

The implementation stage of the safety plan is to effectively control the identified risk factors according to the previously formulated safety plan and protective measures. The combination of safety training, technical disclosure, and BIM platform make the construction personnel more intuitively aware of the risks that may occur in the construction process to improve the safety awareness of personnel and reduce the occurrence of construction accidents [19].

3.2.1. Technical disclosure

The purpose of technical disclosure is to make technicians and construction workers familiar with and understand the project's technical requirements, construction process, and precautions. Timely and effective technical disclosure can make the construction orderly and improve the construction quality. BIM information platform can comprehensively display the construction plan, technical requirements, construction technology and other information of the project to relevant personnel, intuitively show the overall picture and critical parts of the construction process, more intuitively display which construction parts and construction stages may have potential safety hazards, and remind construction personnel to take protective measures, Avoid safety accidents.

3.2.2. Safety training

Carry out information security training through BIM platform, let the construction personnel watch the training videos of safe construction and emergency handling, and use the construction site and the whole construction process displayed by the information platform to let the construction personnel understand the places where there may be potential safety hazards in the area. With the help of virtual reality technology, the construction personnel can experience the construction process in the virtual environment, see the location of potential safety hazards more clearly, simulate the scene when the danger occurs, and bring them more profound experience to improve their safety awareness and reduce the occurrence of accidents.

3.2.3. Dynamic monitoring of potential safety hazards

Dynamic detection of potential safety hazards is crucial in risk control. Build a monitoring platform with real-time connection with the construction site data based on BIM Technology, upload the collected data information to the monitoring platform in real-time with the help of offline data acquisition carriers such as cameras, sensors and WiFi probes, and then grasp the safety production trends in a timely and efficient manner through comparative analysis with BIM model. When dangerous behaviours of construction personnel are found, such as people staying around large machinery during construction, the system will issue a warning and notify the on-site management personnel to eliminate potential safety hazards in time and avoid safety accidents.

3.3. Safety hazard inspection

Safety inspection and acceptance play an essential role in supervising and improving the safety management work. The on-site safety management personnel can take photos and upload the potential safety hazards detected in the construction process through portable equipment and mark the types of risks and solutions. Different colours represent the risk level in the BIM model, detecting potential safety hazards and implementing the rectification in time. The safety inspection process can be standardised by BIM technology, and the potential safety hazards can be removed more efficiently [18].

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3.4. Summary optimisation

Considering the safety management in the construction process from the whole project and the whole process, summarise and reflect on the construction safety management based on the formulation of a safety plan, technical disclosure, safety training, safety inspection and acceptance, strengthen the safety management, improve the awareness of safe construction, and transfer the unsolved and undiscovered problems to the next PDCA cycle. In a continuous cycle, safety measures are optimised and safety plans are improved [20].

4. Conclusion

Based on BIM Technology and PDCA cycle theory, this paper applies it to construction safety management and studies the characteristics of the combination of safety plan formulation, risk management and control, dynamic monitoring of potential safety hazards, safety inspection, summary and optimisation. The following conclusions can be drawn:

(1) The management model established by the safety management system based on BIM and PDCA can more intuitively grasp the safety information of construction projects, making the safety management more efficient.

(2) The construction safety management mode based on BIM and PDCA is based on the safety management theory. The PDCA cycle theory is introduced into BIM Technology to make the safety management more in-depth and the management process more smooth.

(3) The implementation of PDCA cycle theory has realized the continuous and meticulous management of construction project management. The accuracy and effectiveness of safety management are improved by constantly discovering and solving problems.

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