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Research on the Influence of Intelligent Construction Technology on Project Safety Performance

Ling Li[1*], Guangying Song, & Jie Hu

[1] Chengdu College of Arts and Science, Chengdu, Sichuan, 610401, China

[*] Corresponding author, Ling Li, Chengdu College of Arts and Science, Chengdu, Sichuan, 610401, China

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Abstract

Although the quality of construction workers is constantly improving, considering the natural characteristics of the construction industry, such as large scale, long cycle, complex technology, as well as the high mobility of employees, lack of safety awareness, the lag of industry management and technology level, these have not yet reached the essential improvement, which leads to the frequent occurrence of construction safety accidents. In addition, in recent years, construction projects are developing towards a higher and more complex direction, which leads to the increase of construction difficulty. Even though a lot of technical equipment, management resources and information methods have been invested to improve the safety environment of the construction site, the accident rate and casualty rate are still high. Under the background of the current era, the construction industry has become the industry with the largest total number of accidents. Mining the application effect of intelligent construction technology in construction projects, exploring the relationship between intelligent construction technology in practice and the safety performance of construction projects, is conducive to the fuller and more perfect use of intelligent construction technology in safety management practice, and improving the management mode according to the different groups and differentiated management needs involved in intelligent construction technology so as to eliminate the negative concept of construction enterprises in the safety management work, reduce the occurrence of accidents in construction projects, and achieve the purpose of improving the safety performance of construction projects.

Keywords

intelligent construction, safety performance, optimization of safety management

1. Introduction

The construction industry has always been a high-risk industry, and the occurrence of safety accidents will not only cause serious threats to the life and health of workers, but also bring huge economic losses and adverse social impacts to enterprises. In recent years, the rise of smart construction technologies has provided new opportunities to improve the safety performance of construction projects. By combining information technology, advanced manufacturing technologies with engineering management methods, smart construction technologies are expected to enable more efficient, precise, and safer management and operations at all stages of construction projects.

This paper aims to deeply study the impact of smart construction technology on project safety performance. Firstly, the connotation and main components of intelligent construction technology are expounded, including Internet of Things, Building Information Modeling (BIM), artificial intelligence and big data, robot technology etc. Then, the positive impact on safety performance is analyzed in detail from the aspects of risk identification and early warning ability improvement, safety management decision optimization, and worker safety guarantee enhancement. At the same time, it discusses the challenges faced in the application process, such as technology integration and compatibility, data security and privacy protection, personnel quality and acceptance, and puts forward corresponding countermeasures. Finally, it is concluded that although intelligent construction technology faces challenges, it has a significant positive impact on project safety performance, and promoting its effective application will help to improve the safety level of the construction industry.

2. Overview of Smart Construction Technology

Intelligent construction technology is a comprehensive technological system. With information technology as its core, it integrates emerging technologies such as artificial intelligence, big data, the Internet of Things, and cloud computing, and combines advanced engineering construction technologies and management concepts, aiming to achieve intelligent decision-making, automated operations, refined management, and safe and efficient goals throughout the life cycle of construction projects.

The emergence of the term “intelligent construction” is inseparable from the concept of intelligent manufacturing. In 2013, the German government was the first to put forward the concept of Industry 4.0 and became the first country to lead the manufacturing industry into the Industry 4.0 revolution. Industry 4.0 aims to promote the transformation of the manufacturing industry towards intelligence through emerging technological means such as information technology and digital technology. On this basis, the concept of Construction 4.0 was proposed. The core of this concept is to empower the entire construction process with new information technologies and digital technologies, achieving the development goal of transforming from traditional construction methods to intelligent construction methods.

Intelligent construction runs through the management process of the entire life cycle of engineering projects. Each stage has its own core technological support, but all are inseparable from the application of information technology and intelligent technology. For example, Building Information Modeling (BIM) technology has been introduced and developed in China for many years, and data resources can be shared and transferred throughout the entire life cycle of survey, mapping, design, construction, operation and maintenance; the Internet of Things and sensors enable comprehensive perception of people and objects, and play an important role in personnel management, equipment safety, project monitoring and inspection; Big data and cloud computing can complete the analysis and processing of vast amounts of engineering data, strengthening process supervision and prediction.

1) BIM technology

Building Information Modeling (BIM) was first proposed by Eastman in the mid-20th century. It is an engineering data model that integrates various related information of construction projects based on building attributes and 3D digital technology with the help of information technology. After the concept of BIM was put forward, it has been gradually applied to the civil engineering industry after years of development. At present, BIM technology is widely used in project design, construction and operation and maintenance stages.

Building design adopts forward BIM design method to carry out structural model design, which can complete collision inspection through BIM technology to find unreasonable places in time to realize design optimization and reduce engineering changes. BIM technology can simulate and analyze various design schemes, and draw 3D models directly on the platform, which is intuitive and quick to improve the accuracy. BIM model can coordinate various systems of construction projects to eliminate conflicts, shorten design time and reduce design errors and loopholes. BIM platform can strengthen the communication between the designer and the construction party, so that the construction party can participate in the early design stage, and increase the feasibility of the later construction.

BIM technology provides construction simulation technology, which can improve the problem of poor communication and poor cooperation ability of all parties involved in the project, and reduce the waste of human, material and financial resources. The 3D visual model is established through BIM technology, and the data information of building components is imported into the model to guide the construction, so as to reduce rework and rectification. The construction simulation technology of BIM combined with VR (virtual reality) and other information technology improves the operability of construction simulation.

In the operation and maintenance stage, through BIM technology, the information of construction and operation and maintenance stage can be automatically transmitted, so that the whole life cycle of the building can be informatized. Combined with VR and AR technology to realize real scene simulation and real-time data docking, it can reduce the security risk of operation and maintenance management. BIM platform enables real-time information sharing and improves O&M management energy efficiency.

At present, the application of BIM technology in the whole life cycle of the project is expanding, and in the next step, BIM technology will play a greater role through the combination of Internet of Things, cloud computing, mobile communication and other information technologies.

2) Internet of things technology

The concept of the Internet of Things was first proposed in 1999 by the Auto-ID Labs established at the Massachusetts Institute of Technology (MIT) in the United States. It was used to describe a standard system composed of network Radio Frequency Identification (RFID) and other information sensing devices. In 2005, the International Telecommunication Union (ITU) extended the Internet of Things from the early core of RFID and sensors to the dimension of the Internet, enabling people, machines and things to achieve interconnection at any time and place.

Internet of Things technology is the general term for a series of technologies such as RFID technology, sensor technology, intelligent technology and nanotechnology. At present, the application of Internet of Things technology in the domestic construction industry mainly focuses on areas such as sensors, RFID, cloud computing and intelligence. Through the arrangement of sensors, RFID, and two-dimensional codesfor perception and identification, the network is used to realize information transmission and sharing, and with the help of cloud computing, a large amount of perception information is stored, calculated and processed, so as to realize all-round real-time monitoring of people, machines, materials, methods and environment in the engineering construction process.

3) Digital twin technology

Under the background of the rapid development of modern information technology, Digital Twin has become a technology and means that can help intelligent manufacturing, industrial internet, Industry 4.0, smart city, intelligent construction and other contemporary advanced concepts.

With the deepening of research and application, in the face of new trends and problems of technology development, the research team of digital twin technology of Beihang Digital twin proposed a five-dimensional model of digital twin Physical Entity (PE), Virtual Entity (VE), Service (Ss), Twin Data (DD) and Connection (CN), which enabled the integration of digital twin technology with Internet of Things, big data, artificial intelligence and other new technologies merge.

Intelligent construction involves the whole life cycle of the construction process. Data transmission is carried out with the help of the Internet and the Internet of Things, and big data mining and processing are realized through cloud computing and cloud platform. Each stage of the construction process and the construction parties are no longer independent of each other, but connected in series into a system through information technology, which is inseparable from the integration of information and physics in the construction process, and digital twin technology is precisely realized effective means of integration and fusion of various technologies and information.

4) Big data technology

With the advent of the mobile cloud era, the Internet of Things and cloud computing technology develop rapidly, and the speed of data generation is getting bigger and faster. In 2011, the concept of big data was first put forward at the annual word conference. Liu Zhihui et al. (2014) proposed that big data is generated by scientific research, application of the Internet of Things and massive network information, and has the characteristics of Volume (large capacity), Variety (many kinds), Velocity (fast speed) and most important Value (low value density).

Intelligent construction process generates massive data information involving drawings, schedule, cost, labor, management, production, monitoring and other categories. Data collection and processing need the support of big data technology. With the help of hundreds or even more data processors and computers to collect and process big data, it can be summarized into the information that can be obtained by all participants with the help of the platform in a short time, helping managers to control and make decisions on construction projects, and helping professional engineers to carry out and control the follow-up work of projects on the basis of the obtained information processing and decision results.

5) Cloud computing technology

According to NIST (National Institute of Standards and Technology), cloud computing is a pool model that provides convenient on-demand access to shared computing resources (such as networks, servers, storage etc.), which can achieve rapid resource supply and release with minimal management cost or interaction. Cloud computing has the characteristics of dynamic resource allocation, resource pooling, broadband network call, measurability and so on.

The intelligent construction mode of construction industry applies the information architecture of cloud computing to replace the traditional enterprise server information mode, which reduces the information cost and excavates the potential of cloud computing in the management and monitoring of engineering construction process. In the construction process, cloud computing provides services such as information coordination, data processing and resource sharing for big data and Internet of Things. The traditional mode based on enterprise server deployment is replaced by cloud-based information architecture, simplifying the Internet application at the construction site. With the popularization of intelligent terminals, especially some mobile applications that provide public clouds, managers and technicians only need to use mobile terminals such as mobile apps to obtain a large number of information resources in the construction process, which is convenient for daily management and monitoring.

3. Overview of Safety Performance

In the construction industry with high safety risks, “safety first” has become the consensus of every employee. Safety performance, as an important indicator to measure the level of enterprise safety production, has always been a hot topic for research scholars. However, different scholars have different research perspectives and application scenarios on safety performance, so there are many different definitions of safety performance at the present stage. In earlier studies, safety performance mainly included two categories: safety outcomes and safety behaviors. Some scholars define safety performance in terms of safety results, arguing that safety results provide historical information of the bottom line indicators of safety performance, which is defined by measuring the severity of safety production accidents after they occur. In addition to defining safety performance from safety results, safety performance is also described as the actual safety behavior shown by individuals at work, that is, individual safety behavior, and is divided into safety compliance and safety participation. Safety compliance describes the safety-related behaviors that an organization requires individuals to perform to keep the workplace safe; Safety engagement describes voluntary safety-related behaviors that may not directly affect individual safety but contribute to the development of an organizational environment that supports safety.

4. Positive Impact of Smart Construction Technology on Project Safety Performance

4.1 Risk Identification and Improvement of Early Warning Capabilities

(1) Real-time monitoring and data acquisition

The wide application of IOT sensor networks in construction sites makes it possible to monitor projects in real time. For example, in the construction of high formwork, by installing strain sensors and displacement sensors on the formwork support, the force and deformation of the support can be monitored in real time. Once the data detected by the sensor exceeds the preset safety threshold, the system will immediately issue an early warning signal to remind the construction personnel to take timely measures to avoid the occurrence of bracket collapse accidents.

In the safety management of tower crane, the lifting weight, lifting height, amplitude, wind speed and other parameters of the crane can be monitored in real time through the sensor installed on the crane. At the same time, GPS technology can be used to accurately locate the position of the crane to prevent collision accidents between the cranes.

(2) Risk prediction based on BIM and big data

BIM model combined with big data analysis can predict the security risks of the whole project life cycle. For example, by analyzing the historical data of similar projects and the BIM model information of this project (such as building structure form, construction technology etc.), possible safety risks can be identified in advance. For example, in the construction of high-rise buildings, according to the layout and lifting path of tower cranes in the BIM model, combined with the accident type and probability of tower cranes in the historical data, it can predict the collision risk and overturning risk of tower cranes in different construction stages, and prevent them in advance in the construction stage with higher risk.

In the construction of deep foundation pit, the stability of foundation pit can be predicted by using BIM model and big data analysis. By analyzing geological survey data, underground hydrological data, surrounding environment data and monitoring data during construction, a foundation pit stability prediction model is established to give early warning of possible foundation pit collapse risk.

4.2 Optimization of Safety Management Decisions

1) Data-driven decision support

Artificial intelligence and big data analysis provide a scientific basis for safety management decisions. Through the analysis of a large number of safety-related data (including safety inspection results, accident reports, worker training records etc.), project managers can understand the weak links of safety management work and formulate more targeted safety management systems and measures. For example, if data analysis finds that workers in a particular type of work have a high incidence of safety accidents, managers can strengthen training content, optimize training methods, or adjust work processes for that type of work.

In terms of construction schedule arrangement, the relationship between safety risks and schedule in different construction stages can be found by analyzing the schedule data and safety accident data of historical projects. Therefore, when making the progress plan of the project, the construction sequence and construction period should be reasonably arranged to avoid the occurrence of safety accidents caused by rush work.

2) BIM assisted solution optimization

BIM technology can simulate and analyze different construction schemes and evaluate the advantages and disadvantages of each scheme from the perspective of safety. For example, in the construction of formwork engineering, BIM model can be used to simulate the construction process and stress situation of different formwork support systems (such as fastener type steel tube formwork support system and bowl buckle type steel tube formwork support system), so as to intuitively compare the safety performance of the two schemes in terms of stability and bearing capacity, and select a safer and more reasonable construction scheme.

In terms of building fire prevention design, BIM model can be used to simulate smoke diffusion path and personnel evacuation route when fire occurs. Through the simulation analysis of different fire design schemes, the design of fire separation and evacuation passage can be optimized to improve the fire safety performance of buildings.

4.3 Enhanced Worker Safety

(1) Substitution of hazardous operations

Construction robots can replace workers in some hazardous environments. For example, in the demolition and blasting project, the use of robots to carry out partial demolition operations can avoid the exposure of workers to the risk of explosion and building collapse. In construction operations under harsh environments such as high temperature and high dust, the application of robots can also effectively protect the health and safety of workers.

In the aspect of aerial work, such as exterior wall cleaning, curtain wall installation etc., aerial work robots can be used to replace manual operation. These robots have good stability and accuracy, which can reduce the risk of workers falling from height while ensuring the quality of work.

(2) Worker training and behavior correction

Virtual Reality (VR) and Augmented Reality (AR) technologies can be used for safety training of workers. By creating realistic virtual construction scenarios, workers can experience the consequences of safety accidents personally and improve their safety awareness. For example, in the VR training scenario, workers can simulate the escape process at the scene of a fire and learn the correct escape methods and skills.

AR technology is used in the construction site to remind workers to pay attention to safety matters in real time and correct unsafe behaviors. For example, when a worker approaches an adjacent area, the AR device can display warning information and provide correct operation guidance. At the same time, wearable devices (such as smart hard hats and smart wristband.) can be used to monitor the physical status of workers (such as fatigue degree and heart rate). When workers are found to be in poor physical condition, they can be reminded to rest in time to avoid safety accidents caused by fatigue operation.

5. Challenges and Countermeasures

5.1 Technology Integration and Compatibility Issues

(1) Challenges

Intelligent construction technology involves a number of different technical fields, and the integration between these technologies is difficult. For example, to accurately transmit the data collected by IOT devices to the BIM model for analysis and connect with artificial intelligence algorithms, it is necessary to solve the compatibility problems of data formats, communication protocols and other aspects. Sensors and devices produced by different manufacturers may adopt different standards, which brings great obstacles to technology integration.

At the construction site, the collaborative work of multiple intelligent construction technologies also faces challenges. For example, the combination of robotics and IOT technology needs to ensure that robots can receive environmental information collected by IOT sensors in real time and make accurate action decisions based on this information.

(2) Countermeasures

It should establish a unified intelligent construction technical standard system, standardize data format, communication protocol and other technical requirements. It should encourage enterprises to cooperate with each other to jointly develop intelligent construction technology products with strong compatibility. For example, industry associations can organize relevant enterprises and scientific research institutions to formulate standard specifications for the interaction between IOT devices and BIM model data.

Government departments and industry associations should play a guiding and coordinating role in promoting the development of research projects related to technology integration. The key problems in the integration of intelligent construction technology are solved by setting up special scientific research funds and organizing technical breakthroughs.

5.2 Data Security and Privacy Protection

(1) Challenges

In the process of intelligent construction, a large amount of construction site data (including personnel information, equipment operation data, enterprise core technology data etc.) is collected and transmitted. If data security measures are not in place, it may lead to risks such as data leakage and tampering, which will not only affect the security management of the project, but also violate the privacy of workers or the trade secrets of enterprises.

With the application of cloud computing and big data technologies, the centralization of data storage and processing also increases the risk of data security. For example, project data stored in the cloud may be subject to cyber attacks, resulting in data loss or damage.

(2) Countermeasures

Advanced data encryption technology is used to encrypt the collected data to ensure the security of data in the process of transmission and storage. For example, a combination of symmetric and asymmetric encryption is used to encrypt the data collected by IOT sensors and then transmit it to the data center.

It should establish a strict data access authority management system, clarify the access authority of different personnel to data, and prevent data from being illegally obtained. At the same time, it should strengthen data security awareness training for employees to improve their awareness of protecting data security and privacy.

5.3 Personnel Quality and Acceptance

(1) Challenges

The application of intelligent construction technology requires project managers and workers to have corresponding technical knowledge and operational ability. However, at present, most personnel in the construction industry are not familiar with these new technologies, and there is a certain resistance. For example, some older workers may not adapt to new training methods such as VR and AR, and some managers also lack the ability to use big data analysis to make safety management decisions.

In construction enterprises, there is a lack of introduction and training mechanism for intelligent construction technical talents. Because intelligent construction technology involves multiple disciplines, it is difficult for enterprises to recruit compound talents who understand both construction engineering and information technology.

(2) Countermeasures

It will strengthen intelligent construction technology training for personnel in the construction industry, including technical management training for managers and operation skills training for workers. Special training courses can be set up through cooperation with universities and training institutions. For example, colleges and universities can set up professional courses related to intelligent construction to cultivate professionals for the construction industry.

It should promote the application of intelligent construction technology in the project, so that personnel are gradually familiar with and accept these new technologies in practice, and improve the enthusiasm of personnel to learn new technologies through incentive mechanism (such as reward for those who master new technologies etc.).

6. Conclusion

Intelligent construction technology has many positive effects on project safety performance. Intelligent construction technology can effectively reduce the safety risks of construction projects by improving risk identification and early warning capabilities, optimizing safety management decisions and enhancing worker safety. However, there are also challenges in technology integration, data security and personnel quality in the process of promotion and application. Through the establishment of a unified technical standard system, strengthening data security management and carrying out personnel training, the effective application of intelligent construction technology in construction projects can be promoted, so as to continuously improve the safety performance of projects and promote the development of the construction industry to the direction of intelligence and safety. In the future research and practice, it is necessary to further explore the deep integration of intelligent construction technology and project safety management, and constantly improve the relevant technology and management system to adapt to the continuous development of the construction industry.

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