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Research on a Preventative Management System for Construction Accidents Based on Technological Empowerment

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Abstract. The frequent occurrence of construction accidents is a severe challenge faced by the construction industry. Traditional management methods can no longer meet the safety requirements of modern engineering construction. This study is centered on technology empowerment. It has established an accident prevention management system that covers pre-event prevention, in-process monitoring, and post-event emergency response. A comprehensive safety management solution has been formed by integrating advanced technologies such as Building Information Modeling (BIM), big data and machine learning, intelligent personnel training systems, multi-sensor integration systems, unmanned aerial vehicles (UAVs) paired with smart camera, AI behavior recognition, and the interaction between the Internet of Things (IoT) and command platforms. This technical system is expected to lower the accident rate and increase the effectiveness and precision of construction safety management. This system provides strong support for the safe and stable development of the construction industry, and also offers references for safety management in other fields.

Keywords: Prevention of construction accidents, Technology empowerment, BIM, Big data and machine learning.

1. Introduction

As the urbanization process accelerates, construction projects are present everywhere and the issue of engineering safety has become increasingly prominent [1]. Construction is the industry that is most at risk of occupational injuries, with a significant number of individuals suffering injuries and even death in construction accidents every year [2]. These accidents bring immense suffering and loss to the families of the victims.

In the face of the severe situation of frequent construction accidents, traditional engineering management methods are increasingly being replaced because of low regulatory efficiency and high labor costs [3]. The application of technological means in engineering management has become the key to accident prevention and handling. Advanced technologies enable rapid identification of potential hazards in construction projects through online monitoring and data analytics, thereby

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achieving more comprehensive, precise, and timely site supervision and management of construction sites [4].

This study focuses on how to prevent and manage construction accidents through technological empowerment from three stages: pre-construction, during-construction and post-construction, to establish a comprehensive construction accident prevention and management system. By systematically studying and integrating various advanced technologies, the study provides a feasible safety management solution for the construction industry and enhances the overall level of construction safety management.

2. Establishment of construction accident prevention technology system

2.1. Pre-event prevention technology

2.1.1. Construction risk simulation and analysis based on Building Information Modeling (BIM)

In the system that prevents and manages construction accidents, construction risk simulation and analysis based on BIM is a key component of pre-event prevention technology. It integrates and processes various types of information in construction projects through specialized software so that it can build a precise construction model [5]. With this model, complex scenarios at different construction stages can be simulated to conduct a comprehensive inspection of potential risks in the process of constructing [6].

The use of technology that is based on BIM also demonstrates significant dynamic adaptability [7]. As the construction project progresses, there is a possibility of encountering unexpected situations such as design changes and alterations in the construction environment. This technology can respond swiftly by updating model parameters in real-time [8], and reinitiates risk simulation and analysis. This process effectively ensures the precision and timeliness of risk analysis results and provides robust technical support for the smooth advancement of construction projects. It ensures that project management decisions are scientifically made based on the latest and most accurate risk assessment information. In this way, construction teams can formulate scientific and rational risk response strategies in advance. This enables the effective elimination or reduction of potential risks before construction, thereby enhancing work quality and efficiency [9]. This provides a strong foundation for the safety of construction projects and prevents accidents from occurring at the source.

2.1.2. Application of big data and machine learning in accident hazard prediction

The deep integration of big data and machine learning has brought about a new transformation in the prediction of accident hazards in construction projects. Big data can collect a vast amount of data related to construction projects, which cover various types of information during the construction process, such as construction progress, equipment operating status, personnel operation records, and environmental parameters. Machine learning algorithms can conduct in-depth analysis of these data, mine potential patterns and regularities within the data, and accurately identify key factors related to accident hazards [10]. They can model complex data relationships and predict potential accident hazards based on the characteristics of different construction scenarios [11].

As construction projects advance, machine learning models can also be updated in real-time based on new data, continuously optimizing their predictive capabilities. This ensures a high degree

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of sensitivity to accident hazards and enables the timely issuance of early warning signals. Through the close integration of big data and machine learning, construction teams can take effective preventive measures to prevent accidents, significantly reduce the incidence of construction accidents and provide strong support for the smooth progress of construction projects.

2.1.3. Enhancing construction workers' safety awareness and skills through intelligent training systems

In the field of construction engineering, the safety awareness and skill level of construction workers are among the key factors in ensuring construction safety. Intelligent training systems leverage cutting-edge technologies such as VR and AR. They break through the monotony and spatial-temporal limitations of traditional training methods and offer construction workers an immersive and personalized training experience [12]. By simulating real construction scenarios, workers can repeatedly practice operational skills in a virtual environment, become familiar with various safety procedures, and more accurately master the correct construction techniques. Moreover, intelligent training systems can tailor courses based on each trainee’s learning progress and proficiency, ensuring the maximization of training effectiveness. This intelligent training approach not only enhances the safety awareness and skill level of construction workers but also significantly improves the efficiency and quality of training. It is an essential component of the construction accident prevention and management system.

2.2. In-process monitoring technology

2.2.1. Multi-sensor integration systems: monitoring of temperature and humidity, dust, noise, and harmful gases

The multi-sensor integration system is crucial in monitoring environmental conditions at construction sites. Multidimensional environmental data could be collected by this system from the construction site in real time through collaborative operation, including temperature and humidity, dust concentration, noise levels, and the content of harmful gases. Consequently, it constructs a comprehensive and precise environmental monitoring network system [13].

Temperature and humidity monitoring ensure the working conditions of construction personnel and the performance of materials. Dust and noise monitoring provides the basis for dust reduction and noise control, protecting personnel health and surrounding living quality. Harmful gas monitoring can trigger alarms, identify pollution sources, and prevent poisoning accidents. The integration of these sensors not only enhances the efficiency and accuracy of construction site environmental monitoring but also provides strong data support for construction safety management, which contributes to the creation of a safer and more efficient construction site environment.

2.2.2. Environmental dynamic inspection system integrating Unmanned Aerial Vehicles (UAVs) and smart cameras

In the realm of construction engineering, the environmental dynamic inspection system that integrates UAVs and intelligent cameras plays a crucial role. This system artfully combines the high maneuverability of UAVs with the high-resolution imaging capabilities of intelligent cameras to achieve comprehensive and real-time dynamic monitoring of construction sites. UAVs can easily navigate complex terrains and high-altitude environments with their exceptional mobility, reaching areas that are difficult for traditional monitoring methods to access [14], such as around tall

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structures, deep excavations, and remote construction sites. Through UAV inspections, a wealth of detailed environmental data can be collected, including the topography of the construction site, construction progress, material storage conditions and potential safety hazards. Intelligent cameras leverage their high-resolution imaging capabilities so that they can capture fine details of key areas or suspected problem spots identified during UAV inspections.

2.2.3. Ai-based anomaly behavior recognition

AI-based anomaly behavior recognition technology serves as a vital innovative means for managing safety on construction sites. This technology deploys intelligent monitoring systems at project sites, utilizes advanced computer vision and machine learning algorithms to capture various behavioral details of construction workers in real time [15, 16]. The system is capable of automatically identifying abnormal behaviors such as the absence of personal protective equipment (PPE) like safety helmets and safety belts, as well as violations of safety regulations. It not only monitors whether workers comply with safety rules but also predicts potential safety risks through behavior analysis. This recognition technology can rapidly process and accurately judge large amounts of real-time video data without the need for continuous manual monitoring so that it can significantly enhance the efficiency and accuracy of safety management.

2.3. Post-event emergency response mechanism

Achieving seamless integration between Internet of Things (IoT) devices and emergency command platforms is crucial for enhancing emergency response capabilities on construction sites. Leveraging IoT technology, various devices and sensors deployed at construction sites can obtain real-time data on environmental conditions, equipment operation status and personnel activities [17], and transmit this information swiftly to the emergency command platform. The platform has advanced data processing and analytical capabilities so that it can continuously monitor and evaluate the collected data. Upon detecting an emergency situation, it can immediately trigger the corresponding emergency response plan.

This seamless integration ensures the real-time and accuracy of information, enabling the emergency command platform to swiftly make scientific decisions, coordinate various emergency agencies, and achieve effective resource response. It not only accelerates the response to emergencies and improves handling efficiency but also enhances the safety of construction personnel [18]. The close collaboration between IoT devices and the emergency command platform shifts construction site safety management from passive response to proactive prevention and rapid response, effectively reducing the risk of accidents and enhancing the level of construction safety management.

3. Conclusion

3.1. Summary of research findings

This study delves into the technology-empowered prevention and management of construction accidents, and constructs a relatively comprehensive accident prevention technology system from multiple facets, including pre-construction, during-construction, and post-construction.

Before construction, pre-construction risk mitigation is achieved through BIM technology, big data and machine learning, and intelligent personnel training systems. BIM technology enables precise simulation of construction risks and adaptive responses to changes. In-depth data analysis

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and hazard prediction can be achieved through the integration of big data and machine learning. Meanwhile, intelligent training systems enhance personnel skills by leveraging cutting-edge technologies. During the construction phase, on-site monitoring is conducted using a multi-sensor integration system, UAVs paired with smart cameras, and AI-based behavior recognition to anticipate potential dangers in advance. The multi-sensor integration system collects environmental data comprehensively, while environmental dynamic inspection system integrating UAVs and smart cameras provides efficient coverage and precise detection of hazards. AI-based behavior recognition technology monitors personnel behavior in real time to reduce human-related risks. In the event of an accident, IoT is seamlessly connected with the command platform to handle the accident efficiently and minimize losses.

3.2. Insufficient research and future outlook

This study summarizes a management system that utilizes technology to prevent construction accidents, but there are still some shortcomings. On the one hand, the interactivity among various technologies needs to be further enhanced. At present, there may still be issues such as unsmooth data transfer and low collaborative work efficiency among different technology systems, which affect the general efficiency of the accident prevention technology system. On the other hand, the high cost of some advanced technologies in practical application limits their use in some medium and small-sized construction projects.

Looking ahead, in terms of technology integration, it is imperative to intensify research and practice endeavors. The development of more efficient and unified data interaction standards and collaborative platforms is crucial to facilitate the deep integration of various technologies. Concurrently, as technology continues to evolve and innovate, there is an expectation that application costs will be further reduced, thereby enhancing the use of these technologies. The application of this technology system holds the promise of reducing the occurrence of construction accidents. It is poised to provide robust theoretical support and practical guidance for the safe and stable development of the construction industry. Additionally, it will bolster public confidence in the construction sector and foster social harmony and stability.

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