Integrating Digital Art into a Safety Management Platform for the Construction Industry through GIS and BIM in the Internet of Things Context

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Abstract. The civil engineering safety management platform is a security management system based on Internet technology, aimed at providing comprehensive security management support for the civil engineering field. This platform provided comprehensive safety planning and monitoring, timely warning and prompts, and other full process applications by collecting, organizing, and analyzing key data in civil engineering projects, effectively improving project safety and management efficiency. However, traditional security management platforms have many limitations and are no longer suitable for the current environment. Through IoT technology, Geographic Information System (GIS), and Building Information Modeling (BIM) technology, this disadvantage can be optimized. In this project, with the background of the Internet of Things, a security information model based on BIM technology was used to construct a civil engineering safety management platform. By conducting comparative experiments, the performance of the civil engineering safety management platform in civil engineering construction was studied before and after its use, in order to evaluate its specific performance. Through experiments, it has been proven that compared to before using the civil engineering safety management platform, the detection time for fall accidents, electrical accidents, fire accidents, operation accidents, and ordinary accidents was 135 seconds, 145 seconds, 147 seconds, 184 seconds, and 161 seconds. After using the platform, the detection time was shortened to 35 seconds, 32 seconds, 38 seconds, 57 seconds, and 87 seconds, respectively, significantly reducing the detection time for various types of accidents. This would effectively improve the safety level of the project and ensure the safety of workers' lives. Through experiments, it has been proven that the civil engineering safety management platform has a good safety protection effect, effectively improving the safety of the project, and making contributions to the research of Internet of Things technology in the field of engineering safety.

Keywords: Civil engineering, Security management, Internet of Things, Building Information Modeling, Integrating Digital Art.
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1 INTRODUCTION

The civil engineering safety management platform based on the background of the Internet of Things combines GIS and BIM technology, and is an innovative and intelligent safety management system. By adding sensors and other IoT devices to civil engineering projects, various data in the project can be obtained in real-time. The platform uses GIS technology to analyze, process, and visualize these data, providing high-precision risk assessment and visualization display. At the same time, combined with BIM technology, three-dimensional modeling of engineering projects can be combined with real-time data to achieve real-time monitoring, early warning, and management of construction processes, further improving the safety and management efficiency of engineering projects. Develop interactive training modules and safety simulations using digital art. These simulations can help users practice safety procedures and emergency responses within a virtual construction environment.

Based on the relevant literature review, the following scholars' research on civil engineering safety management platforms has been listed. Liang Huakang believed that construction safety management practices and systems have become important topics for stakeholders to focus on human resources. He carried out a comprehensive literature metrology review based on a variety of methods, and checked several papers related to construction safety management. He also studied the structure and emerging trends of building safety management platforms, and tracked the temporal evolution of construction safety management, discussing major research trends and potential research directions [11]. Shan Hu conducted research on the intelligent supervision platform for engineering construction from the perspective of data fusion, laying an information foundation for the subsequent management and operation of smart cities. He analyzed the data fusion methods and processes of the system based on the concept of data fusion, which can provide a certain reference for the data integration design of intelligent supervision platforms for other new area engineering construction [14]. Liu Zhansheng discussed the safety management elements and complexity involved in the lifting operation of prefabricated building during the construction process. He pointed out that the current lifting safety risk management methods have problems such as low intelligence, unreliable prediction accuracy, and inaccurate time control of safety management itself. To address the above issues, he introduced the concept of digital twins in the framework of lifting safety risk management, and proposed modeling methods for physical lifting processes, virtual lifting processes, and virtual and real information interaction. This method provided theoretical and technical support for digital twins in the safety risk management of lifting equipment [12]. Jiang Weiguang believed that building safety has always been a long-term issue in the development of the construction industry, and comprehensive intelligent construction site safety management solutions and applications still need to be developed. Therefore, he proposed an intelligent construction site security management framework based on network physical systems, which established risk data synchronization mapping between virtual and physical construction sites through scene reconstruction design, data perception, data communication, and data processing modules, and warned and controlled personnel, machinery, and other risks on site. His research has established an intelligent construction site management system, which played an important role in promoting the development of the future intelligent construction industry [7]. Through reading the above literature, although these articles have conducted detailed research on civil engineering safety management platforms, they have provided many valuable information.

After consulting the materials, the following research literature on civil engineering safety management platforms, BIM and GIS technologies was found. Lee Pin-Chan pointed out that risk management in deep excavation engineering has always been an important issue. One of the core issues is to accurately simulate and predict the displacement time series collected from on-site sensors to monitor changes in risk. At the same time, the application of BIM and GIS can integrate the building structure with the surrounding environment, make all kinds of information visualization visible, and provide support for the decision-making of risk treatment. He proposed a BIM-GIS framework constructed by BIM and GIS, as well as a risk management system for risk monitoring, to monitor the risk changes of deep excavations, improve the efficiency of system operation and interact with the risk management platform. This can effectively monitor the risk changes of deep excavations and provide visual decision support [10]. Zhao Linlin believed that the characteristics of construction projects are usually large scale, complex technology, and difficult collaboration. Therefore, he proposed a new method of integrating BIM into GIS. In addition, he provided a method for automatically georeferencing BIM models in the GIS field and developed an integrated network platform based on BIM+GIS, allowing various stakeholders to access project information in different geographic regions, thereby strengthening information sharing and promoting project management. The results indicated that the developed platform can help manage large-scale projects correctly by providing the necessary information and functionality [15]. Specifically, the above literature combines BIM and GIS technologies to conduct in-depth integration research on civil engineering safety management platforms. However, these studies are only theoretical and lack practicality and authenticity.

In this article, a civil engineering safety management platform was constructed using the Internet of Things technology and a security information model based on BIM technology. According to the experimental results, before using the civil engineering safety management platform, the average number of low-level, intermediate, and high-level hazardous accidents per month was 78.83, 23.08, and 4.50, respectively. After using the management platform, the average monthly occurrence of low-level, intermediate, and high-level hazardous accidents decreased to 62.75, 14.75, and 2.08, respectively. This indicated that the safety management level of civil engineering and construction enterprises has significantly improved, and the incidence of dangerous accidents has been effectively reduced. The innovation of this article lied in the use of Internet of Things technology and the construction of a civil engineering safety management platform, which improved the safety of the project.

2 EVALUATION ON CIVIL ENGINEERING SAFETY MANAGEMENT PLATFORM

2.1 Main Parts of Civil Engineering Safety Management Platform

The civil engineering safety management platform is a comprehensive application platform based on a combination of computer technology, network communication technology, and civil engineering safety management theory, aiming to achieve comprehensive monitoring, analysis, evaluation, and decision support for civil engineering safety management [1],[9]. Its main parts include the following aspects:

1) Data collection module

The data collection module is a tool used to collect and record safety data on civil engineering sites. Through this module, various safety indicators on the construction site can be monitored and corresponding measures can be taken in a timely manner to ensure the safety and health of workers. These data mainly include the following categories:

Safety records: The safety records of the construction site include daily, weekly, and monthly safety inspection records, safety meeting records, and various safety operation specifications.

Safety checklist: For different stages and types of civil engineering projects, corresponding safety checklist is developed to inspect various construction processes, identify existing safety hazards, and provide feedback to the data processing module of the platform.

Accident report: When a construction safety accident occurs, on-site personnel need to report the accident situation in a timely manner and fill out the corresponding accident report, including the cause of the accident, casualties, and handling measures.

2) Data processing module

In civil engineering safety management, the data processing module is a very important part. It can analyze and process the collected data, identify potential safety hazards and risk points, and provide corresponding warning and monitoring measures to help people better understand the safety situation of civil engineering, thereby preventing accidents from occurring. Specifically, the data processing module can achieve the above functions through the following aspects:

Sorting and cleaning data: There may be various noises or outlier in the collected data, which need to be eliminated by data cleaning to ensure the accuracy and reliability of the data.

Analyzing data characteristics: Analyzing the collected data can help people better understand the safety status of civil engineering, such as temperature, humidity, etc. These data characteristics can provide precursor signals for accidents in civil engineering.

Establishing a data model: By establishing a data model, it is possible to predict and analyze civil engineering data, identify potential risk points and hidden dangers, and provide strong support for safety monitoring.

3) Security management module

The safety management module is the core of civil engineering safety management. It can design corresponding safety management plans, standards, and processes through scientific, standardized, and effective methods based on data processing results, thereby improving the safety and reliability of civil engineering. Among them, the above functions can be achieved through the following aspects:

Developing a security management plan: Based on the results of data processing, the security management module can develop corresponding security management plans, and clarify security management objectives, security risk assessment methods, and data analysis methods, providing clear guidance and support for security management.

Developing safety management standards: The safety management module can develop corresponding safety management standards based on data processing results, clarify the specifications, processes, and operational requirements of safety management, and standardize and constrain the implementation of civil engineering safety management.

4) On-site monitoring module

In the process of civil engineering safety management, video monitoring, sensor equipment, and other means can be used to monitor various safety indicators, parameters, status, etc. of the civil engineering construction site in real time, and timely alarm and handle abnormal engineering situations, thereby ensuring the safety and reliability of the construction site. The on-site monitoring module mainly includes the following aspects:

Installation of sensor equipment: Various sensor devices, such as temperature, humidity, air pressure, wind force, etc., are installed on the construction site of civil engineering. The status and operational data of the equipment are monitored in order to promptly detect equipment faults and abnormal situations.

Real-time monitoring of various safety indicators: Through the video monitoring system and sensor equipment, the safety indicators of civil engineering construction sites, as well as the operation status and safety behavior of construction personnel are monitored in real time so that abnormal situations can be detected in time.

Timely alarm and handling of abnormal situations: The on-site monitoring module needs to alarm and handle abnormal situations in a timely manner. For early warning information and abnormal states, relevant personnel should be notified in a timely manner for handling, including emergency rescue, shutdown and maintenance measures, to ensure the safety and reliability of the construction site.

5) Data display module

The function of the data display module is to process and analyze these data, and present them in the form of charts, reports, etc., providing managers and relevant personnel with a more intuitive and clear way of presenting data. This operation is beneficial for managers and relevant personnel to have a clearer understanding of the safety situation of civil engineering, so as to make corresponding decisions and adjustments. Specifically, the detailed information of this module is as follows:

Data summary and analysis: The data display module needs to summarize and analyze data to provide decision support for managers and relevant personnel, including making decisions on safety management plans, safety standards, and determining safety processes.

Chart and report display: The data display module can display the collected and processed data in the form of charts, reports, etc., providing intuitive and clear information for managers and relevant personnel, including statistical analysis, real-time monitoring, trend analysis, and other aspects.

The main part of the civil engineering safety management platform is shown in Figure 1.

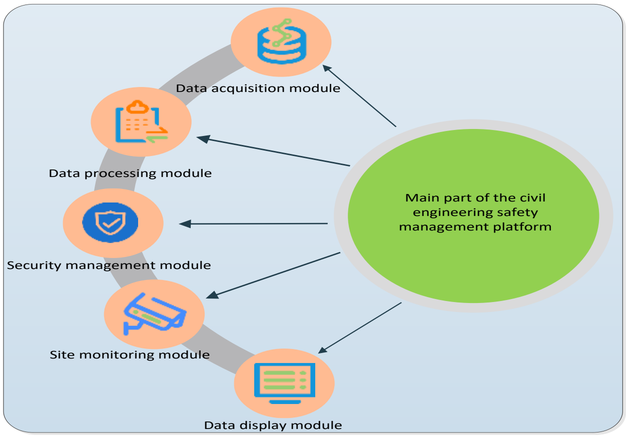

Figure 1: Main Components of the Civil Engineering Safety Management Platform.

2.2 Role of BIM Technology in Civil Engineering Safety Management

BIM is a technology that converts various parts of a building and related information into three-dimensional modeling through digitization [4],[8]. The BIM model not only includes the geometric shape of buildings, but also includes information such as their construction, attributes, and performance [3],[5]. The role of BIM technology is very important in civil engineering safety management. The following wouold provide a detailed introduction to the role of BIM technology in civil engineering safety management:

1) Understanding building structure

BIM technology can transform various parts of a building and their related information into digital models through 3D modeling, providing designers with a more intuitive and clear perspective to understand the spatial layout, material matching, and various design details of the building structure. Designers can use BIM technology to establish digital models of buildings in a three-dimensional virtual environment, making it easier for them to locate and understand the positions, interrelationships, and features of all different components. They can also quickly change different design plans, providing them with more refined and comprehensive design solutions.

2) Obtaining design information

BIM technology can achieve efficient acquisition and management of design information. Through this technology, designers can quickly obtain various design information, allowing them to accurately and quickly obtain the required design information, thereby avoiding the problems of incomplete, missing, or erroneous information collection in traditional design processes. In this way, various information can be better grasped during the design phase, and it is also easier to manage buildings during maintenance, repair, and improvement work.

3) Information sharing and collaboration

Information sharing and collaboration are another important feature of BIM technology. By utilizing BIM technology, members of the design team can collaborate on the same BIM model, and share design information and resources, greatly improving design efficiency and quality. In addition, various departments can also use the same BIM model for collaborative design at the same time, such as architects, structural engineer, electromechanical engineers and other professionals, which can quickly achieve collaborative work. This BIM-based multidisciplinary collaborative design can effectively solve the problems of poor communication and insufficient collaboration among various professions in traditional design processes, making the design more comprehensive, accurate, and coordinated.

4) Safety drill

BIM technology can build virtual scenarios for security drills, and by repeatedly simulating real situations, various security accidents can be better prevented and managed. Firstly, BIM technology can digitize elements such as building information, structure, and equipment, and construct virtual building scenes based on actual situations. Interactive exercises can be conducted through various devices, such as holographic projection and virtual reality, to achieve a realistic experience. This digital scene can enable participants to have a clearer understanding of the changes in the entire scene and potential hazardous situations, enhancing the effectiveness of the exercise.

In summary, BIM technology plays a crucial role in civil engineering safety management. Through digital means, risks can be better identified; decision-making can be optimized; the level of engineering safety management can be improved. The role of BIM technology in civil engineering safety management is shown in Figure 2.

2.3 Role of GIS Technology in Civil Engineering Safety Management

GIS technology is a computer software technology that combines geographic location information, spatial data, and attribute information [13],[2]. It can play an important role in civil engineering safety management. Firstly, GIS technology can be used for the design and planning of civil engineering. By collecting spatial data including terrain, soil, water system, climate, and using GIS software for analysis, necessary building plans, elevation maps, oblique photography maps, etc. for civil engineering construction can be drawn. This can save a lot of time and manpower, and avoid design defects and construction accidents caused by incomplete or incorrect information.

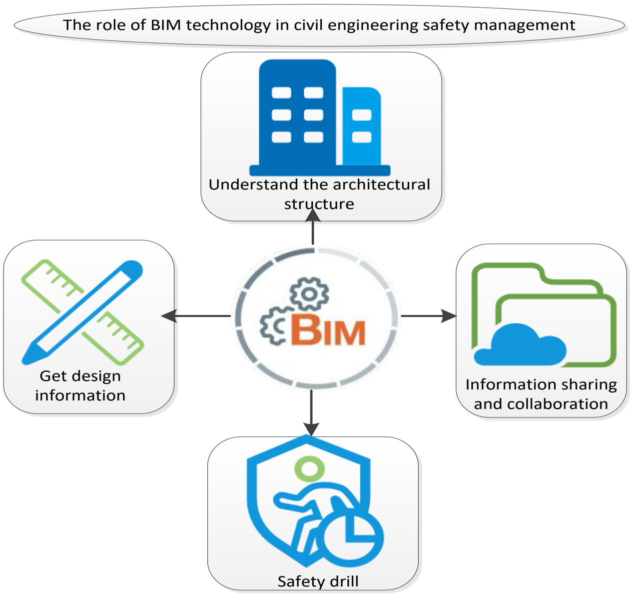

Figure 2: The Role of BIM Technology in Civil Engineering Safety Management.

Secondly, GIS technology can be applied to on-site safety monitoring in civil engineering. By equipping sensors and network devices, real-time monitoring and early warning of civil engineering sites can be achieved. For example, when sensors detect problems such as building deformation and temperature anomalies, GIS technology can quickly generate warning information and prompt on-site management personnel to take timely measures to prevent accidents from occurring. Finally, GIS technology can also be used for post investigation and analysis of civil engineering accidents. After an accident occurs, GIS technology can be used to reconstruct the location of the accident and its surrounding environment in 3D, and combined with on-site data and relevant information to analyze and study the cause of the accident. This can provide experience and reference for the design and construction of similar projects in the future, and avoid similar accidents from happening again.

3 EVALUATION ON INTERNET OF THINGS TECHNOLOGY AND SECURITY INFORMATION MODEL

3.1 Civil Engineering Safety Management in the Context of the Internet of Things

With the continuous development and application of Internet of Things technology, it is gradually penetrating into various fields, including civil engineering safety management [6]. In traditional civil engineering construction, safety management is mainly achieved through manual inspection and monitoring, and there are problems such as incomplete information and inaccurate data. In the context of the Internet of Things, terminal devices such as sensors, wireless communication devices, and video surveillance can be connected through a network to achieve functions such as data collection and transmission, environmental monitoring, and intelligent alarm, thereby improving the efficiency and accuracy of civil engineering safety management.

Specifically, in the context of the Internet of Things in civil engineering safety management, sensors can be used to collect data on building structures, environmental parameters, and personnel behavior, and these data can be transmitted in real-time to the cloud for storage and processing. By analyzing and processing data, real-time monitoring and prediction of the safety status of civil engineering can be achieved; potential safety hazards can be identified in a timely manner; relevant personnel can be reminded to handle them through an intelligent alarm system. At the same time, IoT technology can also achieve real-time positioning and supervision of engineering personnel and equipment, improving management efficiency and accuracy.

In summary, utilizing IoT technology to achieve intelligent monitoring and early warning in civil engineering safety management can effectively improve management efficiency and accuracy, reduce safety risks, and ensure the safety of personnel and property. It has broad application prospects.

Among them, the civil engineering safety management platform is shown in Figure 3.

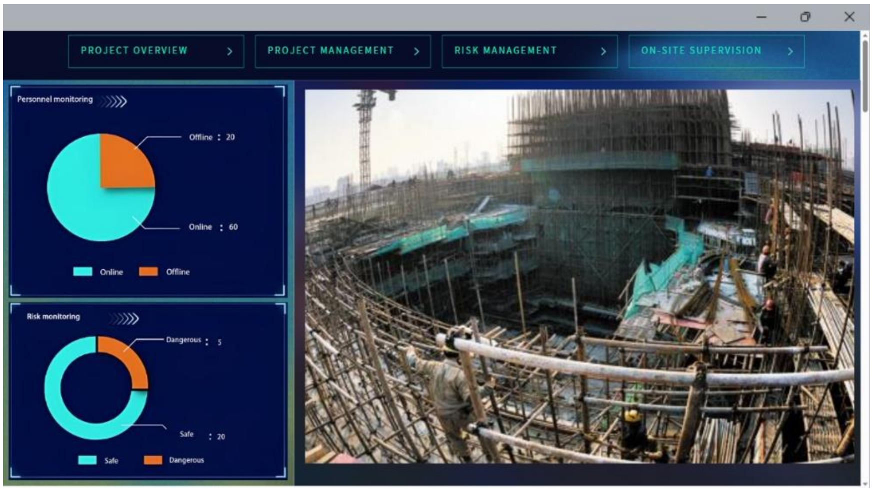

Figure 3: Civil Engineering Safety Management Platform Diagram.

3.2 Security Information Model Based on BIM Technology

For current safety risk issues or tasks, a series of safety control measures need to be implemented throughout the entire process of building industrialization to control risks. When a security risk control measure can solve the current security risk problem, it would automatically update to a new planned security risk control measure and store it in the BIM database. Therefore, the development and presentation of safety control measures throughout the entire process of building industrialization is considered a process of implementing safety tasks or solving safety problems.

In solving security risk issues, there are the following relationships:

$$\mathrm{CON} = \mathrm{PR} \cup \mathrm{RE} \tag{1}$$

Among them, CON is all the constraints for the current security task or security issue. PR is the initial state condition and a prerequisite for safety tasks or safety issues. RE is the result of the target state condition being a safety task or safety issue.

In the BIM case database, similar cases or the best safety risk resolution measures are extracted based on the safety issues that occurr during the construction process. The new problem is represented by Q; the stored problem is represented by P; the structural similarity between the case object sets is calculated using a feature comparison model. The calculation process is as follows:

$$\mathrm{sim_f}(Q,P) = \frac{\alpha|Q \cap P| - \beta|Q/P| - \gamma|P/Q|}{Q \cup P} \quad (2)$$

Among them, α, β, and β represent the importance of the problem. Then, structural similarity standardization can be achieved through the following formula:

$$\mathrm{sim_s}(Q,P) = \frac{\mathrm{sim_f}(Q,P) + \max(\alpha\beta,\gamma)}{1 + \max(\alpha\beta,\gamma)} \quad (3)$$

Then, the content similarity is calculated as follows:

$$\mathrm{sim_c}(Q,P) = 1 - \frac{\sum_{i=1}^{n}(Q_i - P_i)}{n} \quad (4)$$

Finally, the comprehensive similarity is calculated using the following formula:

$$\mathrm{sim_o}(Q,P) = w_s * \mathrm{sim_s}(Q,P) + w_c * \mathrm{sim_c}(Q,P) \quad (5)$$

All weights can be determined based on the specific situation and experience of the construction problem, and can be stored for future use. When the solution to the safety problem or task is retrieved, the entire calculation process ends.

When corresponding safety tasks or problems arise during the entire process of construction industrialization, the entire process safety risk control system would scan the entire construction industrialization process safety risk control case library through safety risk control case scanning and case reasoning technology, searching for cases that are most similar to the current safety task or problem. At the same time, by combining the similarity calculation method with the safety risk control requirements of the construction site, it is possible to directly extract similar cases or safety risk control measures from the current situation and provide answers to the questions.

4 EXPERIMENTAL TESTING OF CIVIL ENGINEERING SAFETY MANAGEMENT PLATFORM

After constructing a civil engineering safety management platform using a security information model based on BIM technology, it is necessary to test the engineering management capabilities of the platform to ensure its performance and reliability. Firstly, the following common accidents in civil engineering construction are listed, as shown in Table 1.

Types of accidents	*Examples*	*Danger level*
Fall accidents	*Falling from high places, causing casualties*	*High*
Electrical accidents	*Power explosion , and electric shock*	*High*
Fire accidents	*Welding fires, and combustible material fires*	*High*
Operation accidents	*Accidents caused by improper operation involve trucks, heavy machinery and other equipment.*	*Medium*
Ordinary accidents	*Heat stroke, frostbite, cuts, stabbing, etc*	*Low*

Table 1: Common Accidents in Civil Engineering Construction.

Through the information in Table 1, common accident types, examples, and hazard levels in civil engineering construction can be understood. The types of accidents listed in the table include fall accidents, electrical accidents, fire accidents, operational accidents, and ordinary accidents. According to the information provided in the table, it can be seen that fall accidents, electrical accidents, and fire accidents had a high level of danger, and special attention and strengthening of safety management measures were needed to prevent the occurrence of these accidents.

The first step is to analyze the discovery time of various engineering accidents before and after using the civil engineering safety management platform. By quickly identifying and responding to accidents, it is beneficial to avoid greater hazards. The experimental data is shown in Figure 4.

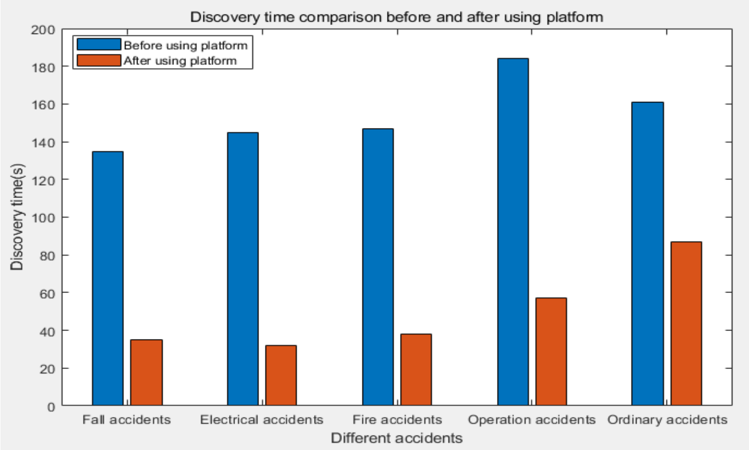

Figure 4: Comparison of Accident Detection Time Before and After Using the Management Platform.

From the data in Figure 4, it can be seen that before using the management platform, the detection time for fall accidents, electrical accidents, fire accidents, operation accidents, and ordinary accidents was 135 seconds, 145 seconds, 147 seconds, 184 seconds, and 161 seconds, respectively. After using the management platform, the detection time for fall accidents, electrical accidents, fire accidents, operation accidents, and ordinary accidents was 35 seconds, 32 seconds, 38 seconds, 57 seconds, and 87 seconds, respectively. Obviously, after using the civil engineering safety management platform, there was a faster detection time for various engineering accidents, which was conducive to improving the level of engineering safety and ensuring the safety and health of workers.

After a civil engineering accident occurs, reasonable handling of the accident is also necessary, to ensure personnel safety and reduce accident losses. Therefore, it is also necessary to test and analyze the processing time of various engineering accidents before and after using the civil engineering safety management platform. The experimental data is shown in Figure 5.

According to the data in Figure 5, before using the management platform, the processing time for fall accidents, electrical accidents, fire accidents, operational accidents, and ordinary accidents was 512 seconds, 544 seconds, 556 seconds, 496 seconds, and 386 seconds, respectively. After using the management platform, the processing time for fall accidents, electrical accidents, fire accidents, operation accidents, and ordinary accidents was 133 seconds, 141 seconds, 136 seconds, 138 seconds, and 128 seconds, respectively. Obviously, after using the civil engineering safety management platform, the handling speed of various engineering accidents has been greatly improved, which helped to shorten the accident handling cycle, reduce accident consequences and losses.

Finally, the number of accidents with different hazard levels was studied before and after using the civil engineering safety management platform. The experimental data is shown in Figure 6.

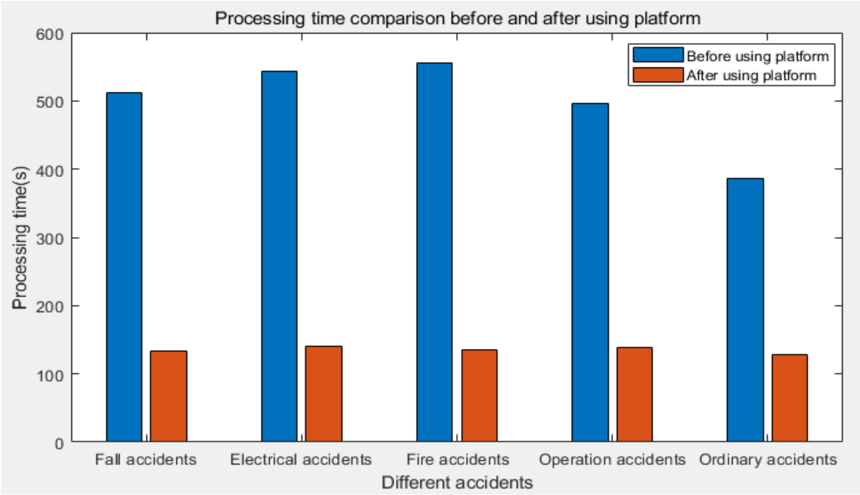

Figure 5: Comparison of Processing Discovery Time Before and After Using the Management Platform.

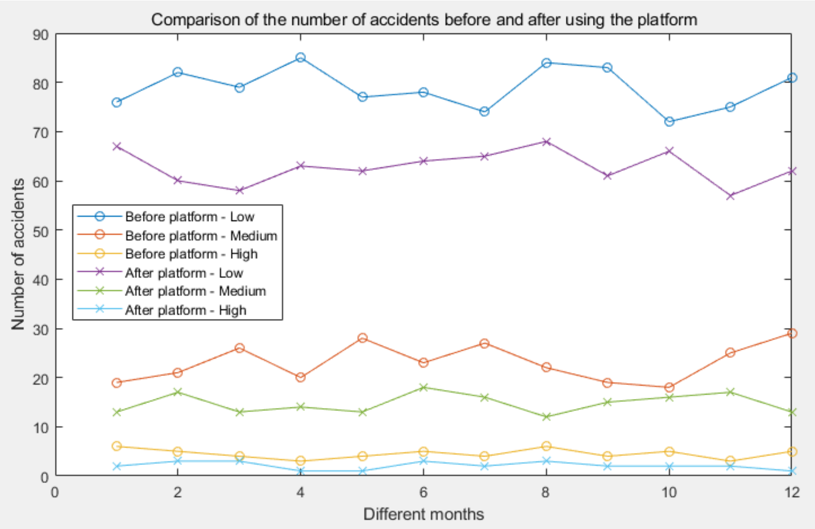

Figure 6: Comparison of the Number of Accidents Before and after Using the Management Platform.

According to the data in Figure 6, before using the management platform, the monthly average number of low-level, intermediate, and high-level hazardous accidents was 78.83, 23.08, and 4.50, respectively. After using the management platform, the monthly average number of low-level, intermediate, and high-level hazardous accidents was 62.75, 14.75, and 2.08, respectively. It was evident that after the use of the civil engineering safety management platform, the incidence of dangerous accidents has significantly decreased, reflecting an improvement in the safety management level of civil engineering.

5 CONCLUSIONS

In the context of the Internet of Things, the civil engineering safety management platform based on GIS and BIM is a hot research direction in the field of civil engineering. This platform provided advanced visualization and analysis capabilities for civil engineering projects, significantly improving the efficiency and accuracy of safety management. By integrating real-time monitoring and early warning systems, this platform can prevent accidents and ensure the safety of construction workers and the public. With the continuous development of the Internet of Things, this platform has great potential for further development and application. In this article, a security information model based on BIM technology and the Internet of Things technology were used to construct a civil engineering security management platform. Through experiments, it has been proven that after using the civil engineering safety management platform, the discovery and handling speed of various engineering accidents have been significantly improved, which helps to shorten the accident handling cycle, and reduce accident consequences and losses. Overall, the practical application effect of this study is significant. This platform helps to identify potential safety hazards early and take corresponding measures to deal with them, avoiding the occurrence of safety accidents. Although the civil engineering safety management platform based on GIS and BIM has many advantages and potential in the context of the Internet of Things, there are still some shortcomings. These shortcomings may include the following aspects: firstly, in civil engineering security management platforms, the stored data involves confidential information of enterprises, such as map data, construction plans, etc. Therefore, more measures need to be taken to protect data security and prevent data from being maliciously attacked or leaked. Secondly, the threshold for using the platform also needs to be lowered, and optimization needs to be made in terms of usability, user friendliness, and interaction effects, so that more users can use the platform more conveniently and achieve better security management results.

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