

Research Article

Research on Safety Management Application of Dangerous Sources in Engineering Construction Based on BIM Technology

Langni Deng,¹ Mengjun Zhong ,¹ Ling Liao,¹ Lai Peng,² and Shijin Lai ¹

¹School of Civil Engineering and Architecture, Guangxi University of Science and Technology, Liuzhou 545006, China

²Department of Architectural Engineering, Guangxi Communications Vocational and Technical College, Nanning 530000, China

Correspondence should be addressed to Mengjun Zhong; 1915461385@qq.com

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The construction industry is a high-risk industry, so many scholars have done research on how to reduce safety accidents at the construction site. However, due to the existence of hidden dangers in construction, accidents at the construction site still plague the development of the construction industry. Therefore, effective management of construction hazards is an important step to strengthen construction safety. At present, the technology of BIM has been gradually applied to various fields of construction projects, providing strong support for the smooth development of construction projects. Therefore, the purpose of this paper is to create a construction hazard source safety management module through secondary development of the Revit platform. At the same time, the Navisworks software is used to simulate the emergency rescue of construction safety accidents and formulate the corresponding emergency management plan. Finally, an engineering example is used to verify the performance of the development management module. The results show that (1) the security management module created in this paper is highly operational, easy to use, and real-time data update, which has important guiding significance for actual construction safety management; (2) simulation of construction safety accidents through Navisworks software can provide emergency management plans for engineering projects.

1. Introduction

The construction industry is one of the most dangerous industries in the world, and its work injury and death rate are extremely high [1]. As a high-risk industry, safety accidents in the construction industry will have a major impact on the social economy, people's lives, and natural environment [2]. Therefore, preventing the construction safety damage is essential to promote workers' safety and health, maintain the productivity level of construction projects, and reduce compensation for work-related injuries [3]. However, researchers and practitioners have been studying how to reduce the safety risks on the construction site and reduce the occurrence of safety accidents on the construction site. But it seems that no fundamental method has been found to solve this problem and the construction site safety accidents are still constantly plagued [4–7]. According to the theory of Heinrich's Law, construction hazard is one of the root causes

of construction safety accidents. Hinze et al. [8] and Carter [4] have also pointed out that the important measures for building construction to prevent safety accidents are to effectively grasp the various hazards that cause safety accidents and pay attention to the real-time status of these hazards. Therefore, effectively identifying and managing various hazard sources will be one of the ways to fundamentally solve the frequent occurrence of safety accidents at construction sites. However, the current level of identification of safety hazards is far from ideal. It is necessary to propose an efficient method for the safe management of construction hazards.

As innovative technology has become a prominent topic in today's construction industry [9], the Building Information Model (BIM) has become the focus of attention in the latest developments in the construction industry [10]. In recent years, BIM technology has been gradually applied to various fields of construction projects [11], effectively

solving some problems that have long plagued the construction industry [12, 13]. Compared with the traditional working mode, the BIM method can help us to coordinate, cooperate, and integrate while improving and processing the information flow [14], which reflects the advantages of BIM technology in the field of construction engineering.

In the management of hazard sources, some scholars have begun to use BIM's own functions or functions based on the BIM platform to carry out secondary development around a specific project. For example, Gao et al. used BIM technology to carry out hazard source management for a large steel structure construction site [15]. Ding et al. carried out hazard source management of the steel structure construction process of a project based on the BIM and RFID technology [16]. Their research and application have achieved certain results for the management of dangerous sources in the construction process. However, there are some limitations in the function of BIM itself. Therefore, we need to carry out secondary development of its platform, further improve its functions, and improve the application value of BIM technology.

In view of the above advantages of BIM technology in the construction industry, this article will apply the technology of BIM to the safety management of engineering construction hazards, focus on the creation of safety management modules based on the secondary development of Revit platform, and establish a safety management system. Real-time monitoring and management of hazard sources such as safety signs, dangerous goods, and large machinery at the construction site use Navisworks software to simulate the rescue scene after the emergency of the construction site and respond to the emergency management rescue plan. Finally, the practicality of the research method proposed in this article is verified by combining specific engineering cases.

2. Creation of Secondary Management of Security Management Module Based on Revit Software

2.1. Design Ideas. In this paper, BIM technology is applied to the safety management of construction hazard sources. The BIM core software Revit is used as the development platform, and the C# language is used as the development language to build the RevitAPI secondary development environment. According to the secondary development process of Revit, the development and construction of dangerous source safety management module and its functions include the establishment of three types of construction hazard source management research on safety signs, dangerous goods, and large machinery. At the same time, the display class can be expressed in the solid modeling. The development technology implementation plan is shown in Figure 1.

2.2. Development Environment. Visual Studio is a software integration development environment developed by Microsoft, which encapsulates a large number of classes and

methods that are frequently used in Microsoft development for developers to call. The C# language is an object-oriented, high-level programming language that runs on the NET Framework. The C# language is derived from the C language and the C++ language. It not only inherits the powerful functions of the C language and the C++ language but also removes some of their complex features, such as not allowing reinheritance and no macros and templates, and is simple, secure, and stable with other advantages. Winform forms have a rich set of controls to use and can connect to multiple databases. This article uses BIM core software Revit as the development platform, Visual Studio 2012 as the front-end development tool, C# as the programming language, and Winform form and uses the classes and methods encapsulated in Revit API to implement the security management module.

2.3. Revit Secondary Development Interface. In the Revit software provider, there is an open-source data interface. By inheriting the interface, the user can access the model data in the Revit software and can also recombine the new function module through the subfunction modules in the software. Revit API.dll and Revit APIUI.dll must be referenced in the integrated development environment for secondary development of Revit software. Revit API.dll mainly includes all data sets of Revit, currently open-model files, such as the application, document, element, and parameters of the model file. Revit APIUI.dll mainly includes external command-related interfaces, external application-related interfaces, user interaction selection, and task dialogs.

In the secondary development of Revit, there are two main methods: external application and external commands. The external application is a container for various external commands, mainly providing function-panel generation functions and implementing various specific function modules. External commands are used more frequently.

The interface of the external command must call the Execute function. The three parameters contained in the function are shown in Table 1. The CommandData parameter contains a reference to the application and view required by the external command to obtain the program object and document object of the current Revit model. ExternalCommandData contains some common view properties. The message represents the outgoing parameter. When the external command is executed, it will return a result. The message will pass the returned result as a string to the function panel. Elements, like the message, also represent outgoing parameters, but elements are mainly used to display the returned information in the model.

The interface of the external application is a container for external commands to run and can identify and load the addin file corresponding to the external command. Users can inherit the IExternalApplication interface and call the OnStartup and OnShutdown functions to achieve the required functionality. Its function parameters are shown in Table 2. The common functions for developing applications are shown in Table 3.

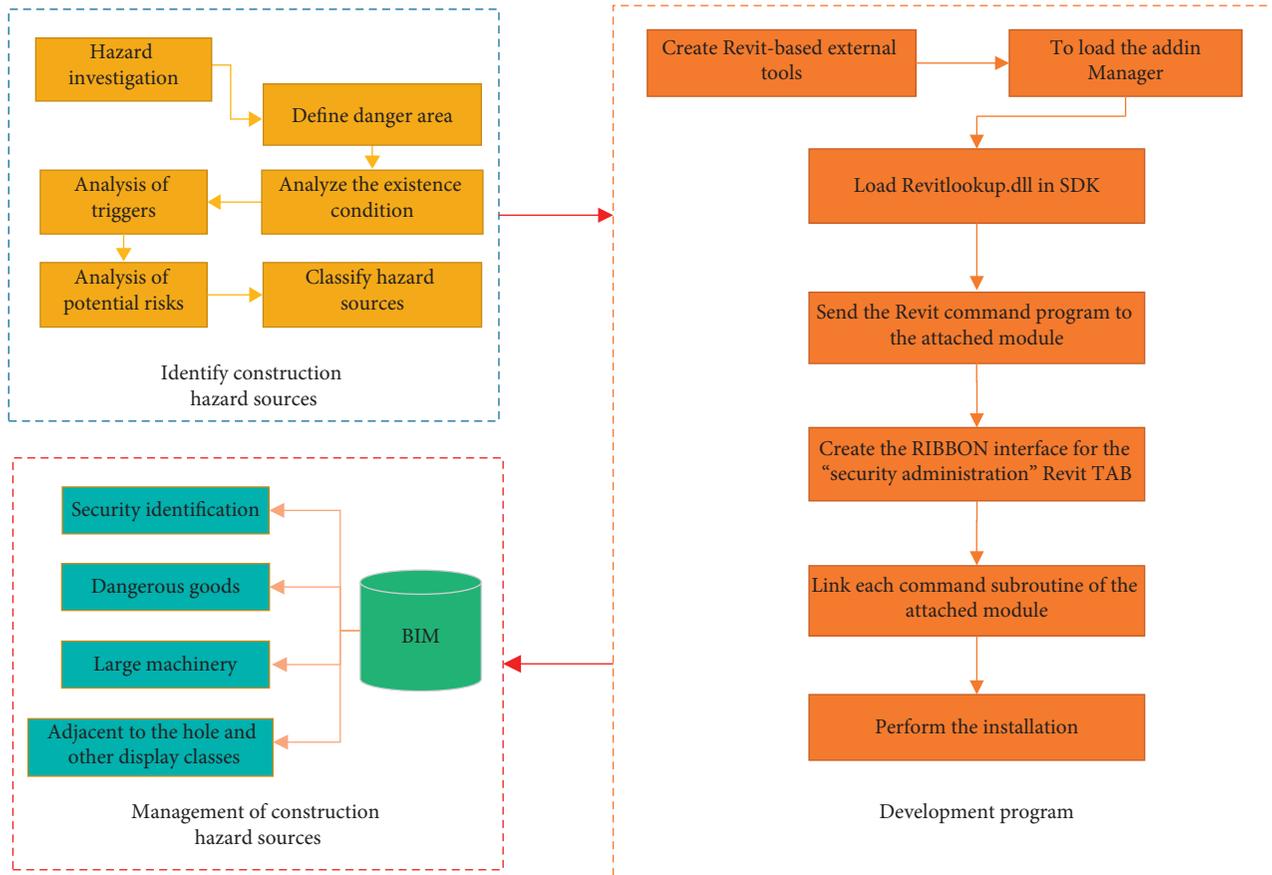


FIGURE 1: Development technology road map.

TABLE 1: Parameters of external command.

Development method	Method	Parameter
External commands	Execute	CommandData (ExternalCommandData), message (String), elements (ElementSet)

TABLE 2: Parameters of external application.

Development method	Method	Parameter
External application	OnStartup(), OnShutDown()	Application (UIControlledApplication)

TABLE 3: Function of external application.

Method	Features
Application.CreateRibbonTab()	Create a level one label
Application.CreateRibbonPanel()	Create a function panel
Panel.AddItem()	Add a function key to the function panel
BitmapImage()	Insert a picture for a function key

2.4. *Revit Secondary Development Process.* The process of Revit secondary development is shown in Figure 2. The specific steps are

- (1) Create a class library project in Visual Studio 2012.
- (2) Add two assemblies, Autodesk.RevitAPI.dll and Autodesk.RevitUI.dll, to the project. To reduce the system memory consumption of Revit runtime,

change the “copy local” attribute of the above two assemblies to “False.” A reference to the PresentationCore assembly is also required for external application development.

- (3) Call the Execute method to automatically generate the corresponding interface and write the relevant function code.

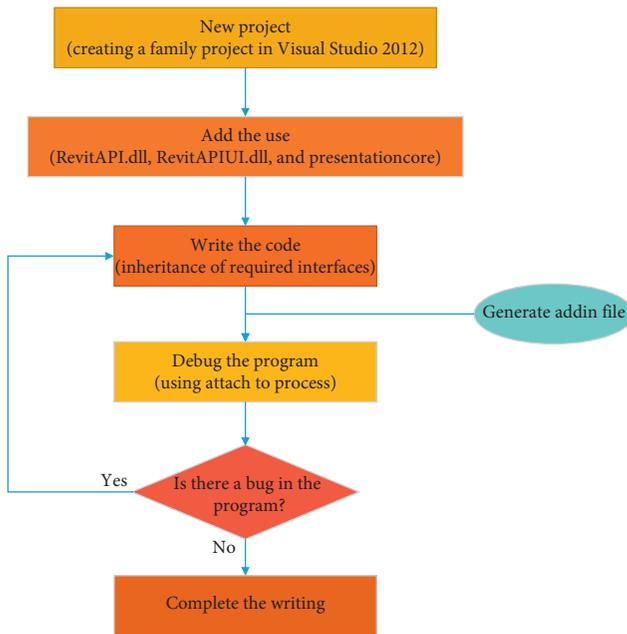


FIGURE 2: Revit secondary development process.

- (4) Debug the program, use the method of attaching to Revit to debug the program in visual studio, and modify and adjust if there is any functional defect.
- (5) Generate the addin file with the compiled code and register.
- (6) Write external application function panel code.
- (7) Register the addin file of the function panel.

2.5. Implementation of the Security Management Module. According to the above development process, the dangerous source safety management module is programmed and developed. Finally, the program is debugged to confirm that the program has no bugs and the construction danger source security management module is completed as shown in Figure 3. Then, according to the actual construction conditions of the construction project, the relevant hazard sources can be created in different ways (as shown in Table 4) in the BIM, and then, a series of work can be carried out on the safety management of the subsequent construction hazard sources based on the BIM. Construction safety risks are minimized to promote worker safety and health.

3. Case Study

3.1. Project Overview. The project is a public rental housing project in Liuzhou, with a total of 9 residential buildings. In this case, the 8# building is mainly used as a research application, which has 1 basement and 18 floors above ground. The total height of the building is 52.20 m; the building base area is 1127.27 m²; the total construction area is 20474.6 m²; the building structure is frame shear wall structure; the architectural structure category is C grade;

the seismic fortification intensity is 6 degrees; the design life is 50 years. According to the design drawings, Revit's parametric modeling of the 8# building is shown in Figure 4.

3.2. Application Based on Revit Software Security Management Module. Using the already created BIM, combined with Navisworks software to simulate the construction plan of the project, according to the 3D visualization advantages of BIM, the hazard sources existing in the construction process are identified in advance and then various types of signs are loaded by adding new decal-type functions, as shown in Figure 5.

After identifying the existing hazard source in the BIM, the security mark is pasted in the form of a decal at the corresponding model position and the effect is shown in Figure 6. The placement of safety signs, dangerous goods, and large machinery in the BIM must be consistent with the actual construction site, and then, the actual process of the project is controlled in real time. The management personnel can effectively manage the hazard source through the developed construction safety management module, through the three-dimensional BIM. The model clearly controls the real-time information of the hazard source and can also count and manage the hazard source of the project through the development of the enhanced function list. Finally, the real-time construction safety management of the project is carried out through the mailbox in the construction safety management module. The mode is sent to the owner, supervisor, and other users to realize multiparty real-time monitoring and management to ensure the project is safe and efficient.

There are some high-risk parts during the construction process, such as stairs, elevator shafts, reserved openings, passage openings, balconies, picking platforms, elevators, scaffolding, cranes, and other parts. These parts are the focus of construction safety management, and protection measures must be taken in accordance with the requirements of the regulations. In order to effectively prevent the work, protective measures for these high-risk parts are created in the BIM (as shown in Figure 7) and the corresponding safety signs are attached to implement the interaction between the construction site and the BIM. The BIM can be used to control the management of multiple users, avoiding the individual factors of the manager to make incorrect decisions, and the installation and dismantling of protective measures are scientific and reasonable.

3.3. Application Based on BIM Technology Emergency Response Rescue Simulation. Once a construction safety accident occurs, timely and effective rescue work has become a crucial link. This link not only affects the cost of the project but also seriously affects people's life safety. Therefore, it is very necessary to draw up an emergency plan. The emergency plan is the basis for emergencies and the "bottom line" for emergency rescue [17]. Due to the unpredictability of construction projects, the formulation of emergency plans

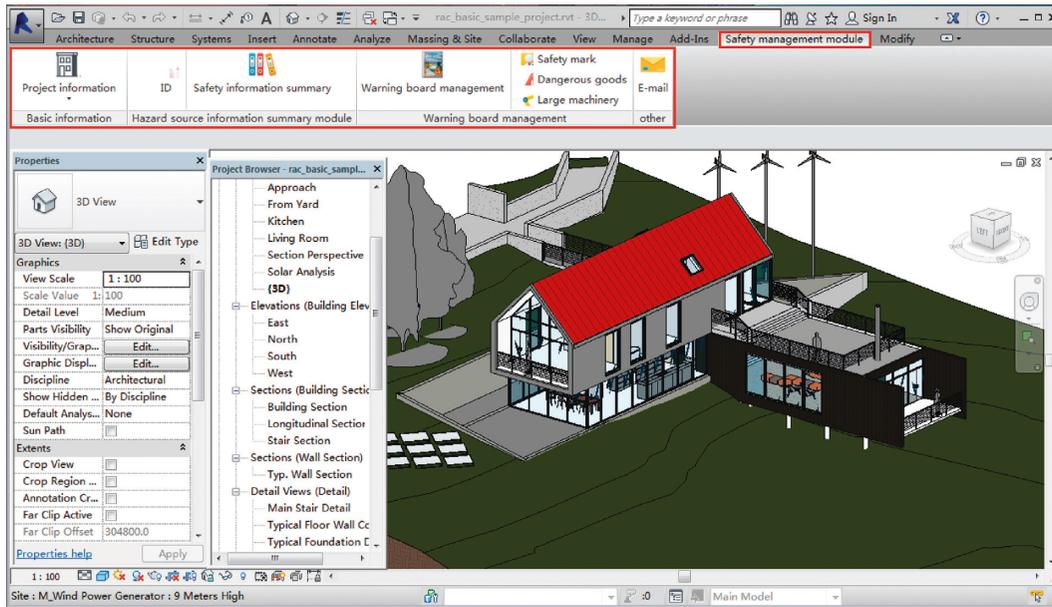


FIGURE 3: Construction danger source security management module based on Revit platform.

TABLE 4: Application name.

Security management name	Revit's own commands
Safety signs	Placing decals
Dangerous goods	Placement component
Large machinery	Project parameters
Project parameters	Select by ID
Selection of the ID number	Decal type
Warning sign management	List
Summary of hazard information	Load family

using traditional thinking methods will be difficult to do. With the Animator animation tool, you can easily implement custom animations for each object in the model and you can create a simulation animation of a security incident emergency rescue [18]. Therefore, by using Navisworks software and Animator animation production tool, taking the 8# building as an example, according to the actual situation of the scene, the emergency rescue simulation of the construction workers of high-altitude falling objects is carried out. The animation is mainly divided into the following, according to the progress of the accident development section:

- (1) Accident: the main body of a public rental project residential-area 8# building has been completed, the construction waste is being cleaned up, and a construction worker A does not even take a piece of discarded gypsum block out of the 4th floor balcony and is just walking in the middle of the building. Downstairs, there is a construction worker B wearing an uncovered helmet. B is smashed and he falls to the ground; a lot of blood is flowing, and he is in a coma. The whole simulation process of the

high-altitude falling of the object on the construction worker B is shown in Figure 8.

- (2) Accidents found: at this time, two scene management personnel pass by and find the accident. One of them immediately runs to the injured person to check the casualty situation. The other person immediately goes to the safety engineer to briefly report the accident location and personnel. Casualty: the safety engineer knowing the situation quickly reports the accident to the on-site commander, immediately dials the 120 emergency center to the scene to carry out the rescue, and then informs the project rescue team to handle the scene of the accident and the person in charge is asked to timely carry out rescue work, within the prescribed time. It is necessary to report to the director's office and relevant departments at the higher level. The entire accident simulation animation process is shown in Figure 9.
- (3) Rescue: the engineering medical team rushes to the scene in time to immediately perform medical examinations and rescues, waiting for the ambulance to arrive. The safety and security team of the engineering department arrives at the scene, pulls up the cordon, blocks the scene. To ensure that the road is smooth and the ambulance reaches the accident site smoothly. Then, an employee is dispatched as a guide to convey the scene of the accident to the medical team, so that the medical team could prepare for the emergency rescue and at the same time guide the ambulance to the scene of the accident in the shortest path and the shortest time. The entire simulation process of the ambulance arriving at the accident site is shown in Figure 10.

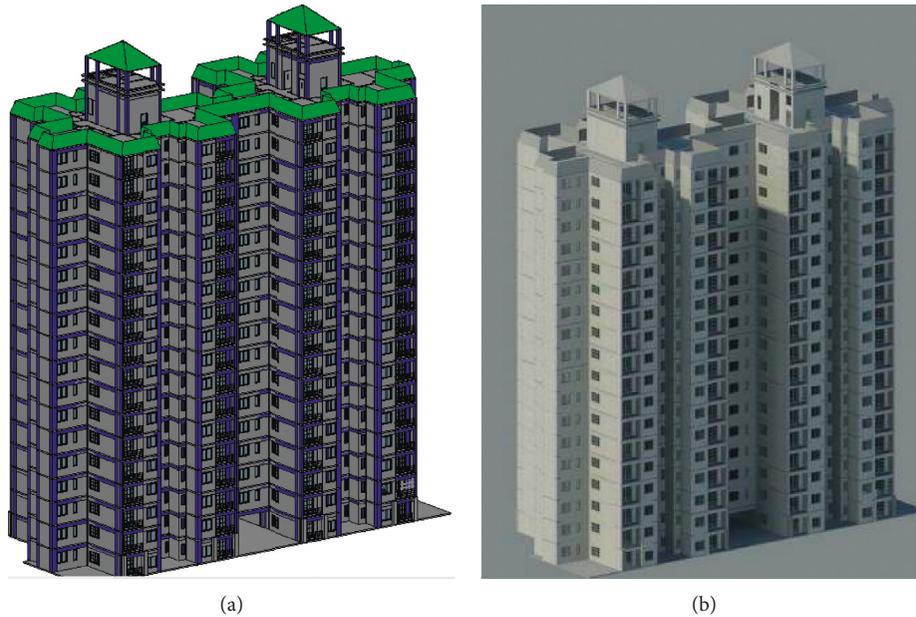


FIGURE 4: 8# floor renderings.

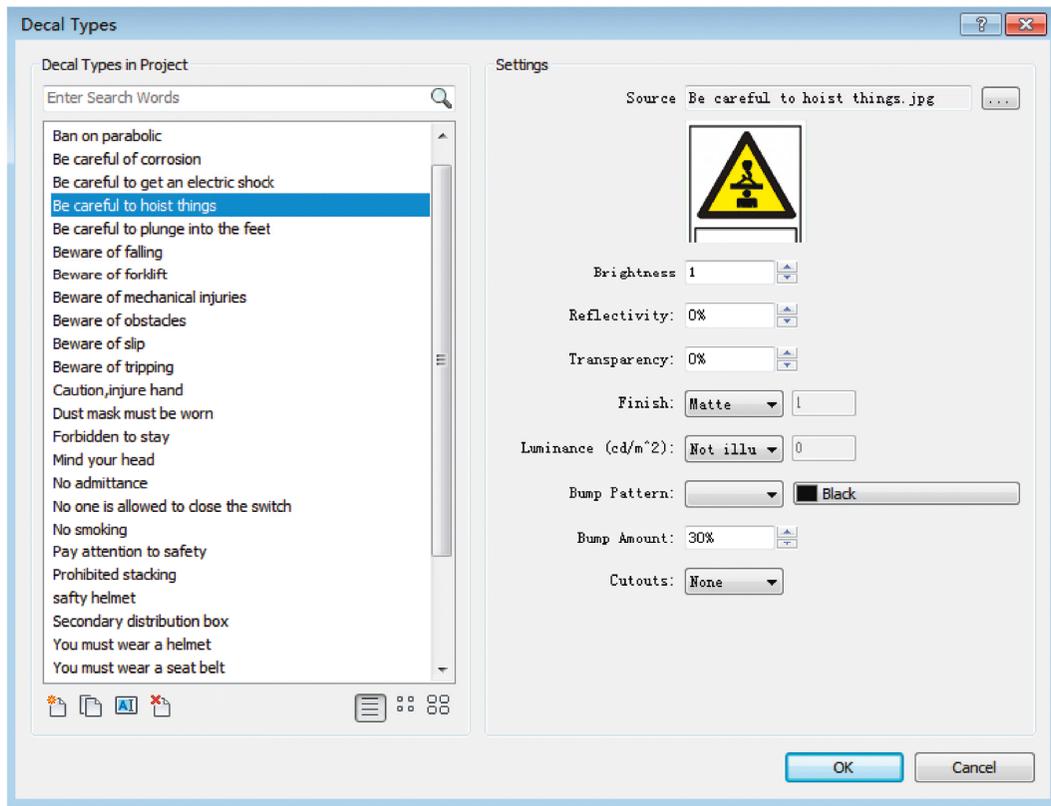


FIGURE 5: Schematic diagram of security ID loading.

(4) Based on the Revit software safety management module, the safety signs, dangerous goods, and other dangerous sources on the construction site are monitored and managed in real time, and the visual characteristics of BIM technology are used to

manage the dangerous sources such as the border hole. At the same time, the Navisworks software was used to carry out emergency rescue simulation on the construction site emergency situation, and the emergency rescue site of the accident of high-altitude

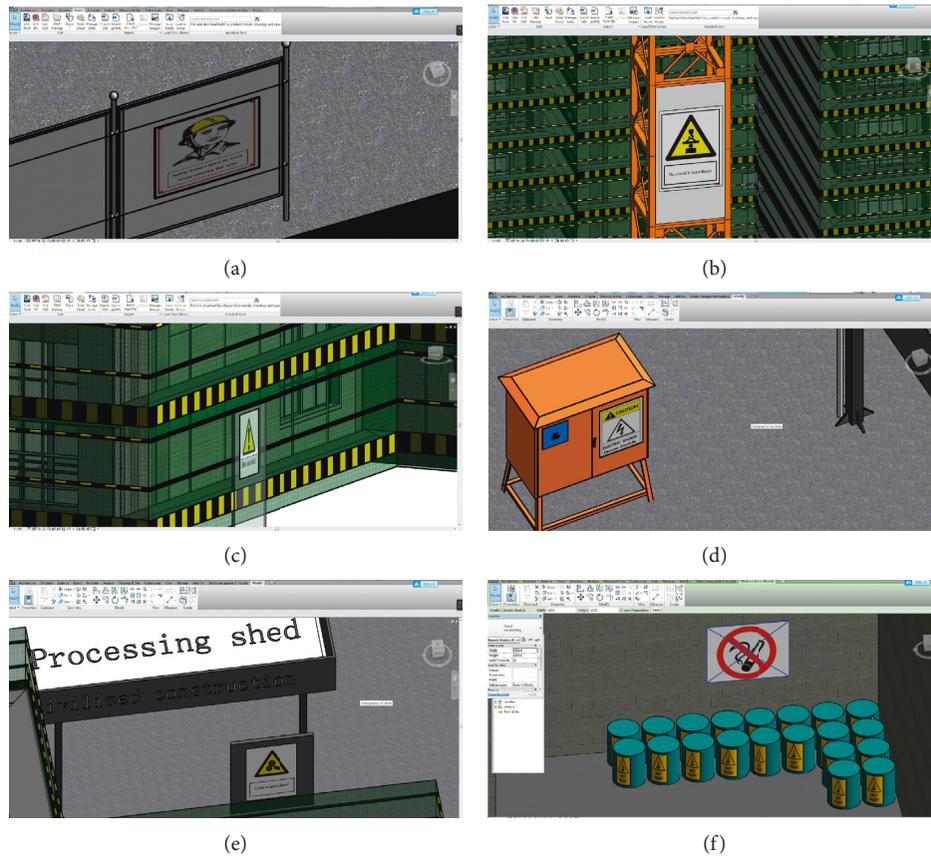


FIGURE 6: Schematic diagram of hazard source identification.

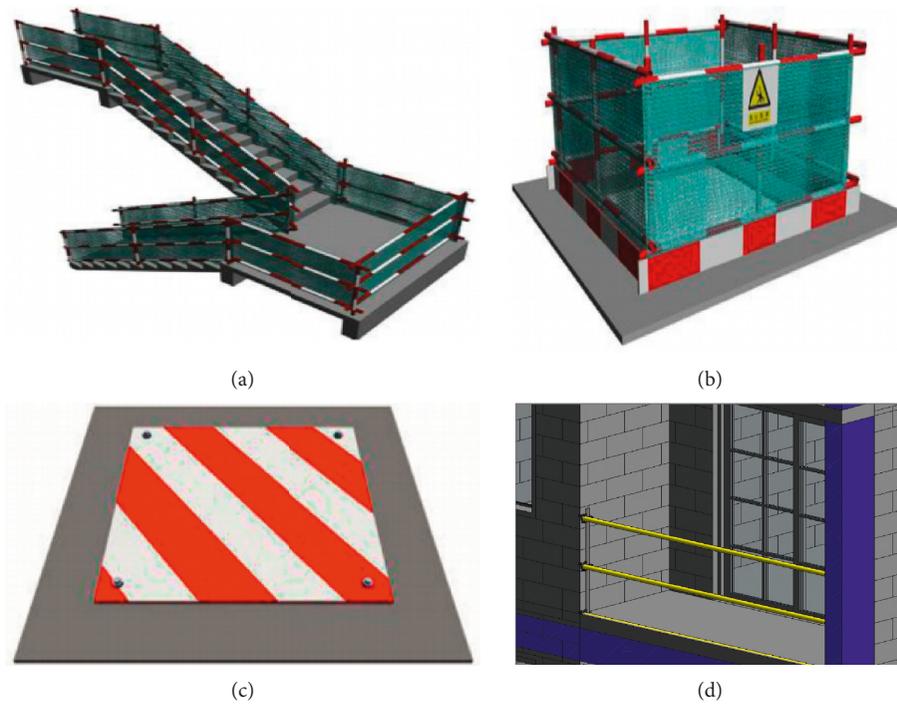


FIGURE 7: Protection measures for the edge and the entrance.

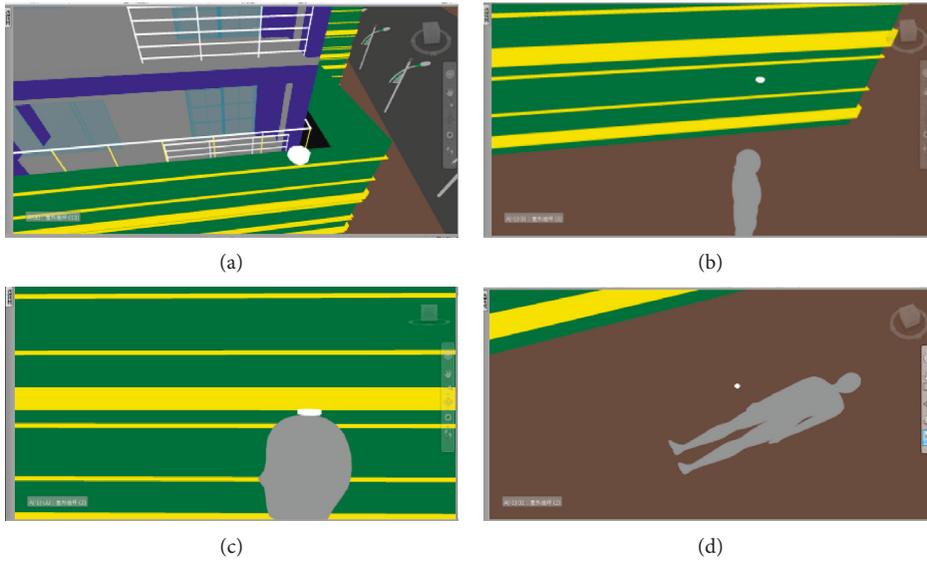


FIGURE 8: Schematic diagram of the animation of the accident.

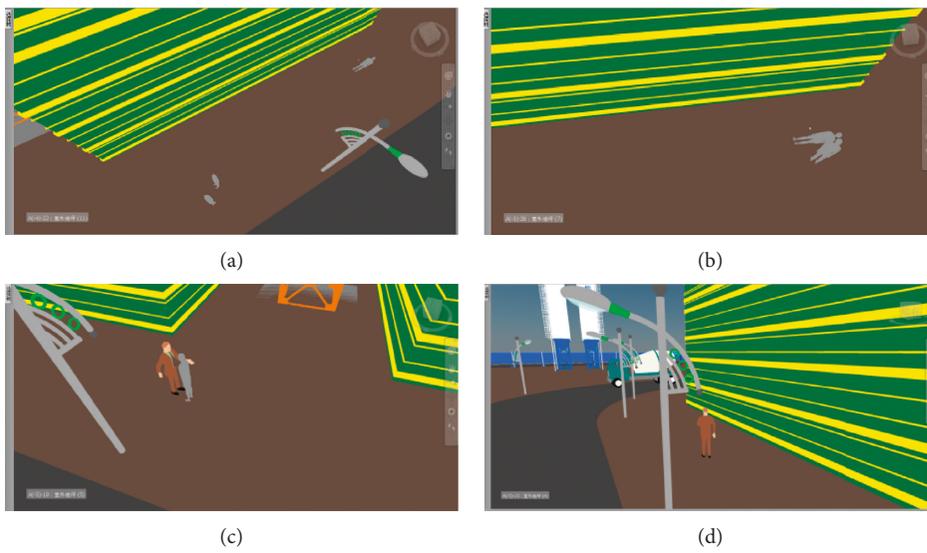


FIGURE 9: Schematic diagram of the accident animation simulation.

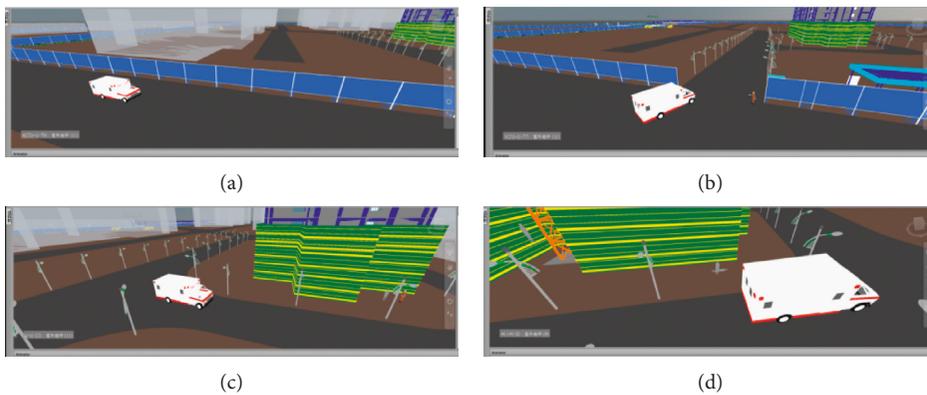


FIGURE 10: Schematic diagram of the animation simulation of the ambulance arrival accident scene.

falling of objects on the construction worker at the high altitude was displayed. Through the research and application of this case, we can know the following:

- (i) The BIM information is comprehensive and interrelated. The function of “one modification, everywhere modification” greatly reduces the workload and time of information processing and improves work efficiency.
- (ii) Based on the secondary development of Revit software security management module, we can realize the safety management of construction safety signs, dangerous goods, large machinery, and other construction hazards. The content is intuitive and clear, and the information parameters are easy to collect and manage. And it provides new technical means and management ideas for the safety management of dangerous sources in the construction site.
- (iii) In the preconstruction preparation stage, the BIM can be used to rationally plan and arrange the construction site, master the direction and circulation of each road, eliminate the occurrence of fires and emergency roads, and clarify the safety management priorities and control measures during the construction process.
- (iv) From the emergency rescue simulation based on BIM, the image is easy to understand, the response information is more intuitive, and the preparation of the emergency plan is optimized, which can impress the owner and the construction staff. At the same time, an important safety education and training can be conducted to guide the construction workers to safe construction to reduce accidents and reduce casualties and economic losses after the accident.

4. Conclusion

This paper studies the application of BIM technology in the construction process of safety management of construction projects. Based on the Revit platform, the C# language is used for secondary development and, together with the functionality of the Revit software itself, ultimately creates a hazard source security management module. Module features include project information, hazard source management, safety information digests, and other subfunctions. Through the actual construction project, the real-time monitoring and management of the safety signs, dangerous goods, large machinery, and other hazard sources on the construction site are carried out by using the Revit software safety management module, and the visual sources such as BIM technology are used to display the dangerous sources such as the edge of the tunnel. Visual port management was carried out, and the emergency rescue simulation of the construction site emergencies was carried out with Navisworks software to demonstrate the emergency rescue scene of the construction workers falling. The advantages and

application effects of BIM technology for construction safety management can be summarized as follows:

- (1) The BIM information is comprehensive and interrelated. The function of “one modification, everywhere modification” greatly reduces the workload and time of information processing and improves work efficiency;
- (2) Based on the security management module developed by Revit platform, the content is intuitive and clear, and the information parameters are easy to collect and manage, providing new technical means and management ideas for the safety management of dangerous sources on the construction site;
- (3) In the preconstruction preparation stage, the BIM can be used to rationally plan and layout the construction site, grasp the direction and circulation of each road, eliminate the occurrence of fire and emergency roads, and clarify the safety management priorities and control measures during construction;
- (4) From the emergency rescue simulation based on BIM, the reaction information is more intuitive and can be used for safety education and training, guiding construction workers to safe construction, combined with the preparation of emergency plans to reduce accidents, casualties, and economic losses.

5. Discussion

BIM technology has good research value in the safety management of construction hazard source, but the research in this paper is only a preliminary exploration of BIM technology in the safety management of engineering construction hazard, only due to the unsafe state of the construction work. Safety signs, dangerous goods, and large mechanical equipment were considered, and other hidden hazard sources were not identified. The safety management module developed has not yet achieved safety warning.

Data Availability

The data used to support the findings of this study have not been made available because the plug-in development involves many Chinese places and the use of the plug-in address is also involved in the code, for some computers need to change part of the code.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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