Engineering Safety Early Warning Platform Based on BIM and Internet of Things

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Abstract: In view of the rapid development of China's economy and the continuous expansion of construction scale, the casualties and economic losses caused by engineering accidents are becoming more and more serious. This paper studies and puts forward a project early warning platform based on BIM Technology and Internet of things technology. Through the feasibility study of BIM Technology and Internet of things technology applied in engineering projects, and various risk assessment in engineering construction, it provides a reliable scheme. Combined with the simulation, through the modeling in revit software and the data processing and Analysis on the platform, the early warning processing is carried out. It shows the practicability and reliability of this technology in engineering safety early warning.

Keywords: BIM Technology, Internet of Things, Engineering Safety, Early Warning Platform

1. Introduction

With the rapid development of China's economy and the continuous expansion of the scale of urbanization, China's construction industry is more and more developed, the construction level and requirements are far higher than those of other countries, and the engineering quantity of key small and medium-sized cities is increasing, which indicates that China has entered the stage of rapid urbanization. However, the implementation of construction projects has many internal factors, such as large investment, long construction period, many types of engineering projects, complex and changeable technology, unpredictable risks and great social influence. At the same time, it is also faced with external factors such as complex environment, numerous buildings in urban area, complex underground pipelines, engineering geology and hydrogeology, which are easy to induce quality and safety problems in engineering construction, Even cause accidents and disastrous results. With the continuous progress of China's urbanization process, China's urban engineering construction quantity
increases, which brings about practical problems such as the lack of construction personnel technology and management personnel. Since the 20th century, the average annual death toll of construction workers caused by construction safety accidents has reached 1600, and the direct economic loss caused by construction accidents exceeds 10 billion yuan every year. The traditional management mode of "people in charge of people" has been difficult to meet the development process at this stage, so it is necessary to use a safe, reliable, stable and convenient engineering safety early warning system to cooperate with domestic engineering construction.

With the development of the construction industry, engineering construction technology is also in continuous progress. BIM Technology can simulate all the real information of buildings. It has the advantages of digitization, visualization and authenticity, which is conducive to the realization of dynamic visual management, information sharing and decision support in the whole project cycle from design, construction to operation and maintenance. BIM Technology was first studied in the United States, and then entered other countries. American scientists believe that BIM Technology can make the carrier of information integration in various stages of construction engineering, and provide reliable information for engineering decision-making. With the relevant documents issued by the Ministry of construction in the 10's of the 20th century, the basic research of BIM Technology in China has been promoted, and the industrialization process of corresponding software in China has been accelerated. It is expected that BIM Technology will be fully applied to all construction industries in China this year, which will be used in the planning, survey, design, construction and later operation of construction projects, so as to popularize Bim in all construction projects Technology [2].

The Internet of things is one of the products of the development of the Internet. At the end of the 19th century, the concept was formally put forward. The technology realizes the online management of physical objects through sensor, radio frequency identification and positioning technology, including the collection of sound, light, point, heat, force, chemistry, location and various required information, and then through data analysis and processing, real-time monitoring and control of an object can be realized. With the Internet of things technology plays an important role in the current road construction, bridge construction, construction, railway laying, tunnel construction and even oil mining and natural gas pipeline layout, it has brought great convenience and important role to modern engineering construction. Based on the unique technical characteristics of BIM Technology and Internet of things, it can effectively improve the success rate of early warning system in engineering construction, so it can effectively solve the security problems in the construction of engineering projects [4].

2. BIM Technology and Internet of Things Technology Theory

2.1 Using BIM Technology to Determine Risk Assessment Analysis

Analyze the target project and determine the basic risk factors set:

\[ U = \{X_1, X_2, X_3, \ldots, X_N\} \]  

(1)

Determine the weight of each basic risk:

\[ W = \{W_1, W_2, W_3, \ldots, W_N\} \]  

(2)

Determine the occurrence probability level of basic factors, and organize various evaluation results into occurrence probability sets

\[ V = \{V_1, V_2, V_3, \ldots, V_N\} \]  

(3)

In this experiment, it is divided into three grades, namely

\[ V = \{V_1, V_2, V_3\} = \{\text{slight, more, serious}\} \]  

(4)

Establish risk factor rank matrix
The subordination relation is determined, the mapping from \( u \) to \( V \) is established, and the fuzzy relation matrix \( R \) is determined:

\[
R = \{ r_{ij} : i = 1,2,\ldots,n, j = 1,2,\ldots,n \} \tag{5}
\]

The index \( I \) belongs to the \( j \) rating level. Using the fuzzy statistical method, the following matrix is obtained:

\[
R = \begin{bmatrix}
    r_{11}, r_{12}, r_{13} \\
    r_{21}, r_{22}, r_{23} \\
    \vdots \\
    r_{n1}, r_{n2}, r_{n3}
\end{bmatrix} \tag{6}
\]

The first level fuzzy operation is carried out to obtain the single factor rating vector:

\[
B_i = W_i \cdot R_{ij} = (b_{1j}, b_{2j}, b_{3j}) \tag{7}
\]

After calculating \( A_{i1} \sim A_{in} \) according to the above formula, the fuzzy matrix \( B \) is obtained:

\[
B = \begin{bmatrix}
    B_1 \\
    B_2 \\
    \vdots \\
    B_n
\end{bmatrix} = \begin{bmatrix}
    b_{11}, b_{12}, b_{13} \\
    b_{21}, b_{22}, b_{23} \\
    \vdots \\
    b_{n1}, b_{n2}, b_{n3}
\end{bmatrix} \tag{8}
\]

Through the above calculation, the risk factors are obtained \( A_{i1} \sim A_{in} \) weight of the impact on the corresponding risk events of the target:

\[
W_i = \{ W_{i1}, W_{i2}, W_{i3}, \ldots, W_{in} \} \tag{9}
\]

Then, the fuzzy comprehensive evaluation level is obtained:

\[
C = W \cdot B = (W_{11}, W_{12}, \ldots, W_{n1}) \cdot \begin{bmatrix}
    b_{11}, b_{12}, b_{13} \\
    b_{21}, b_{22}, b_{23} \\
    \vdots \\
    b_{n1}, b_{n2}, b_{n3}
\end{bmatrix} = (C_{11}, C_{12}, C_{13}) \tag{10}
\]

Among \( C_{ij} \) is the membership degree of the evaluation results belonging to the comment set. According to the parity set, the weighted average algorithm is used to determine the consequence level of risk events, take \( C_{ij} \) as the weight, formaldehyde treatment was applied to each element in the parity set \( V = (V_1, V_2, V_3) \), namely[5]:

\[
V_s = \frac{\sum_{j=1}^{k} c_j \cdot v_j}{\sum_{j=1}^{k} c_j} (k = 3) \tag{11}
\]
2.2 Internet of Things Technology Used in Early Warning Platform

Internet of things (IOT) is a technology based on Internet to realize automatic identification, automatic data transmission and information exchange through modern network data transmission, information analysis and processing and learning cognitive technology. At present, the Internet of things has three key technologies in information technology, namely: data detection technology, communication technology and information processing technology. The key technologies are as follows:

(1) Radio Frequency Identification Technology

The basis and core of Internet of things technology is radio frequency identification (RFID). Its principle is to use radio frequency signal to carry on the information non-contact transmission through the space link, in order to achieve the purpose of identifying information. The technology consists of tag, reader and antenna.

(2) Sensor Technology

The sensor has a specific detection function for the tested object, which can be converted into the corresponding signal output device or component according to certain rules and regulations. The accuracy and accuracy of the data received by the sensor become the main factor of its work.

(3) Video Capture And Processing Technology

The traditional video management system is difficult to play the role of early warning and alarm, and its operation is limited. Smart city needs intelligent video technology, such as detection of abnormal behavior, identification of abnormal behavior, prediction of abnormal behavior, abnormal state alarm technology, to help managers complete various tasks.

(4) Network Communication Technology

2.3 platform function design

(1) Remote Data Acquisition and Computing

Generally, the remote acquisition and calculation of monitoring system is related to the brand and model of field data acquisition equipment, so secondary development should be carried out based on the acquisition of local machine development interface. At the same time, it has the efficiency of compatible development and the common and convenient use of information management platform. Through the monitoring management platform, the remote control of the network of on-site monitoring station can be realized. According to the requirements and construction standards, a variety of data acquisition methods and thresholds can be set on the platform, so as to obtain various measurement data and diagnose the fault module conveniently.

(2) Data Analysis and Mapping

Through the monitoring information management platform, the risk degree of monitoring data can be calculated, and the route, correlation map, distribution map and layout diagram can be automatically drawn. The report can be made according to the needs of the main users of the platform. The data table can be displayed and output. The observation data can be manually input and the event log can be recorded. The data processing function can carry out continuous real-time data processing and calculate the collected data Calculate, generate statistical data. The information data processing can adopt the data calculation formula and related parameters set by the main body of the platform, the way of monitoring the background process and using the data on time to process the data and the calculation results. The chart customization function provides the query, input and maintenance functions of professional individual data monitoring, group monitoring and preventive monitoring, and displays the detailed data of the construction project through various graphs and reports; it can
generate real-time measured value process line, measured value and other special distribution map, multi factor correlation map, isoline map and various statistical reports such as hour, day, month and extreme value statistical report.

(3) Early Warning Analysis
The function of early warning analysis includes weather data early warning, monitoring data early warning analysis and alarm, monitoring and early warning index warning, etc. Through the establishment of disaster forecast and early warning analysis and evaluation mechanism, the data are taken as input parameters, combined with weather related information and construction project attribute data, based on the early warning index threshold judgment and accident probability statistics, the correctness and reliability of early warning information are ensured, and the early warning conclusion is finally analyzed and generated. At the same time, the quantitative analysis and calculation method of monitoring data are provided, and the analysis forecast model and early warning basis can be established according to different accident types.

(4) Early Warning Information
Through logging in the monitoring and early warning information platform, it provides information query function, releases early warning through SMS, Bluetooth broadcast, sound and light alarm, and issues external early warning after professionals confirm the relevant situation. Through the portal web way, the accident information and accident briefing are released to the staff, so that the staff can deal with it in time. The sending device sends the request sending service to the short message sending device through the platform. The sending device sends the short message to each terminal through the server, or sends the relevant command of accident broadcast to the broadcasting station to carry out automatic voice broadcast alarm [7-8].

3. Design of Engineering Safety Early Warning Platform Based on BIM Technology and Internet of Things Technology

3.1 Modeling with BIM Technology
Building information model is a building model with information, which is also the core difference with traditional design. BIM Technology breaks the traditional design for the point, line and surface of the single space geometric relationship design. According to the practical application of BIM Technology in engineering, it can be concluded that the engineering model designed by BIM Technology not only improves its visual expression, but also can set its parameters and endow it with actual attributes. In the follow-up, various applications can be carried out according to the setting of its parameters, such as statistical related parameters for engineering quantity calculation, lighting analysis and energy analysis for building models.

Through the cooperation between the construction unit and the design unit in the early stage, the construction information is completely presented in the building information model components of the platform in front of the inland river high pile wharf, so that each wharf component created by BIM Technology is the substantial carrier of information integration, and realizes the integration of building information. It provides a very convenient and detailed data source for information and parameter extraction of platform construction safety risk in front of inland river high pile wharf.

In this paper, the data of the default rule building model is created by using the Revit software. The dimensions of the pile cap component model are: width 2000mm, length 2000mm, thickness 1000mm; the straight pile of pile foundation is phcl200mm pipe pile, the inclined pile is 1000mm, the wall thickness is 18mm. Select "place component" and "edit type" in the "architecture" or "structure" tab of the Revit software, and then load the "pile cap rectangular" in the system in the type properties, and modify the pile cap of the rectangular model according to the size of the required model.

The revit software is used to set the construction information and parameters of the pile cap
components of the platform in front of the inland river high pile wharf. Taking the parameters of "start time", "construction unit" and "end time" as examples, the steps are as follows:

1. In revlt software, the rectangular pile cap mold family of the platform in front of the inland river high pile wharf is edited.

2. In the rectangular pile cap family editor, modify its family type, add parameters "start time", "construction unit" and "end time", and enter corresponding parameters "January 1", "construction unit a" and "February 1".

3. Save the family and name it pile cap parameter settings.

4. Open the project template in the Revit software, select place component and edit type in the architecture or structure tab of the revlt software, and load the pile cap parameter settings of the family you just created in the type properties.

5. Select the created pile cap component, and the component property panel will display the set parameters [9-10].

4. Platform Test Results

4.1 Platform Reliability Test

The network transmission ability of the platform directly determines the real-time operation speed and stability of the system. Therefore, the success rate of early warning is used to measure the reliability of the platform.

At the same time, the distance between the terminal node and the coordination device is set to 100m, 200m and 300m respectively.

![Communication success rate in different environments](image)

As shown in Figure 1, when the communication environment distance is less than or equal to 100 meters, the success rate of early warning of each environment is higher than 95%; when the communication distance is 200 meters, the success rate of early warning of each environment is more than 90%; when the communication distance is 300 meters, the success rate of early warning of each environment is higher than 90%.

| Place    | 100m | 200m | 300m |
|----------|------|------|------|
| ROOM1    | 97%  | 96%  | 93%  |
| ROOM2    | 96%  | 94%  | 92%  |
| ROAD1    | 97%  | 93%  | 92%  |
| ROAD2    | 95%  | 95%  | 94%  |
As shown in Table 1, when the distance between the platform and the sensor is 100-300 meters, the success rate of the sensor transmission data is maintained above 90% whether in the room or outdoors, and the transmission rate is as high as 97% even when the distance between the platform and the platform is 100 meters. Based on the simple situation of the sensor and the simple platform, the quality of the sensor can be improved in the application of the actual engineering projects in the future To improve the transmission success rate and achieve the corresponding reliability.

4.2 Data Collection of Early Warning Platform

![Figure 2](image)

**Figure 2.** Various risk assessment score

According to Table 2, the calculation of the platform shows that the risk index of the composite longitudinal beam project of the pile foundation project is higher than 4000 points, while the risk score of the beam and pile cap project is about 3000; according to the unified three-dimensional model, the risk value calculated by referring to other platforms a, B and platform a is basically the same as the risk value calculated by the design platform in this paper, and the error is not more than 100, The error of risk value calculated by platform B is large, so the platform has certain reliability.

**Table 2.** Various risk assessment levels

| Fn  | Sub item       | Score calculation | Risk level | Risk alert color |
|-----|----------------|-------------------|------------|------------------|
| F1  | pile foundation| 4631              | III        | Yellow           |
| F2  | Pile cap       | 2985              | II         | Blue             |

According to Table 2, the calculated score of pile foundation project is 4631, the risk level is grade III, and the color of risk warning light is yellow flashing; the score of pile cap project is 2985, the risk level is grade II, and the color of risk indicator light is flashing blue.

This chapter uses revlt software to do three-dimensional modeling of pile foundation and pile cap in the project, carries out the simulation test of early warning platform through the Internet of things technology, realizes the whole process of project early warning based on BIM Technology and Internet of things technology, successfully displays the construction safety assessment results of each sub item, and carries out early warning through lighting.

5. Conclusion

The project safety early warning platform based on BIM and Internet of things is designed in this paper. Through BIM modeling and Internet of things technology, the project early warning function is realized by using traditional equipment such as monitor, sensor, data memory and alarm equipment. This platform provides an auxiliary technical means for engineering construction safety evaluation and early warning. In practice, most domestic projects can be introduced In the project, different BIM 3D models are selected according to the different construction projects. The platform can further improve
the construction safety and safety accident warning reliability of the project.

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Reference
[1] Ilter D, Ergen E. BIM for building refurbishment and maintenance: current status and research directions[J]. Structural Survey, 2015, 33(3):228-256.
[2] Xu Z, Zhang Z, Lu X, et al. Post-earthquake fire simulation considering overall seismic damage of sprinkler systems based on BIM and FEMA P-58[J]. Automation in Construction, 2018, 90(JUN.):9-22.
[3] Yang, Gang, Zhang, Qianqian, Liang, Ying-Chang. Cooperative Ambient Backscatter Communications for Green Internet-of-Things[J]. IEEE Internet of Things Journal, 2018, 5(2):1116-1130.
[4] Balda J C, Mantooth A, Blum R, et al. Cybersecurity and Power Electronics: Addressing the Security Vulnerabilities of the Internet of Things[J]. IEEE Power Electronics Magazine, 2017, 4(4):37-43.
[5] Prevost G P, Pradines A, Brezak M C, et al. Inhibition of human tumor cell growth in vivo by an orally bioavailable inhibitor of human farnesyltransferase, BIM-46228[J]. International Journal of Cancer Journal International Du Cancer, 2015, 91(5):718-722.
[6] Ni J, Zhang K, Lin X, et al. Securing Fog Computing for Internet of Things Applications: Challenges and Solutions[J]. IEEE Communications Surveys & Tutorials, 2018, 20(99):601-628.
[7] Rajan, J, Pandia, et al. An Internet of Things based physiological signal monitoring and receiving system for virtual enhanced health care network[J]. Technology and health care: official journal of the European Society for Engineering and Medicine, 2018, 26(2):379-385.
[8] Chang C, Srirama S N, Buyya R. Mobile Cloud Business Process Management System for the Internet of Things: A Survey[J]. Acm Computing Surveys, 2016, 49(4):1-42.
[9] Miriam, Roux, Azevedo. Salas de coordenao de projetos em BIM: proposta de um método de avaliacao.[J]. Ambiente Construido, 2017, 17(4):403-423.
[10] Prevost G P, Pradines A, Brezak M C, et al. Inhibition of human tumor cell growth in vivo by an orally bioavailable inhibitor of human farnesyltransferase, BIM-46228[J]. International Journal of Cancer Journal International Du Cancer, 2015, 91(5):718-722.