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The Application Research of BIM and IoT Technology Integration in Construction Engineering

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Abstract: *BIM Technology is more and more widely used in construction engineering. This paper analyses the application of BIM in the whole life cycle of buildings and the integration framework of BIM and IOT technology. On this basis, it discusses the application of the integration of IOT technology and BIM in smart construction sites and smart city construction. With the continuous development and innovation of emerging information technologies such as IOT technology, the integration of BIM and IOT technology is of great significance in the field of construction engineering.*

Keywords: *BIM, Internet of Things Technology, Smart Construction Site, Smart City*

1. Introduction

In the last decade, the Internet of things, cloud computing, big data and other new generation information technologies have developed rapidly. Many aspects of the frontier research of the construction industry are focused on their integration with the building information model (BIM). The integrated application of information technology and BIM, such as Internet of things and cloud computing, big data, has great advantages in engineering practice. It can realize the collection, storage, processing and sharing of construction project data to achieve better project management decisions. Combined with the continuous emergence, development and innovation of various new technologies, engineering technology researchers are paying more and more attention to the application of the integration of new Internet of things technology and BIM in construction engineering [1]. The IOT technology has developed rapidly in recent years. The integration of BIM and Internet of things technology has considerable technical advantages and broad development prospects in the theoretical research and engineering practice application in the whole life cycle of construction projects. In the future construction project practice, the integration and application of BIM and IOT technology is bound to go deep into the production line and more efficiently improve the benefits and value of construction projects.

2. Application of BIM in Building Life Cycle

BIM Technology is an innovative three-dimensional architectural design technology after the expansion of two-dimensional space. After adding relevant architectural information on the basis of BIM model, it can realize the creation of three-dimensional digital models in engineering design, construction and management. The building information contained in the BIM model, such as the data of engineering materials, three-dimensional pipelines, engineering structures, construction progress, construction costs, etc. these important building information parameters and visual models can be combined with the IOT, big data, cloud computing and other technologies to realize data sharing and co construction. The engineering practice application of BIM can find the hidden dangers in the design stage more efficiently and accurately before construction, which is convenient for effective management [2].

As the pioneer and promoter of digital transformation in the construction field, BIM can realize the intelligent management of the whole life cycle of construction projects with its advantages of informatization, visualization, collaboration and intelligence. BIM Technology is an important basis for engineering practice and Application Research on green building, energy conservation and thermal

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insulation and carbon emission in the whole life cycle of construction projects. The promotion of BIM Technology is an important guarantee for the digital development of the construction industry[3]. The application of BIM Technology in the whole life cycle of a construction project is shown in Figure 1. BIM models are created for each stage of the construction project as a whole, and the tasks of this stage are completed in each stage. In the whole process, data are transmitted and shared in real time. BIM models are updated and iterated in real time according to the work tasks of each stage.

2.1. Application in Planning Stage

2.1.1. Auxiliary Investment Decision

In the feasibility study stage of the project, it is necessary to explain the necessity of the project construction, in which the economic indicators occupy a very important position, which determines the implementation of the project to a great extent. When BIM Technology integrates information technologies such as the IOT, it can accumulate and store economic data of completed buildings so as to establish corresponding databases. Through artificial intelligence technology call analysis, the economic indicators of the project can be preliminarily judged to provide data support for investment decision-making. At this stage, this aspect is affected by the amount of data accumulation, and there is less application and research.

2.1.2. Establishment of Planning Indicators

In addition to controlling the appearance effect of the construction project, the approval of the project planning and design scheme is also based on certain planning economic and technical indicators. Such as the determination of green space rate, plot ratio and building density. Among them, the calculation rules of some economic indicators are relatively complex, and it takes relatively long time to calculate manually and there is no actual output in the calculation process. The use of relevant BIM software can easily directly correlate the planning scheme innovation with the actual planning economic and technical indicators, effectively avoid the planning and design scheme innovation from going in the wrong direction, and greatly improve the efficiency of scheme design.

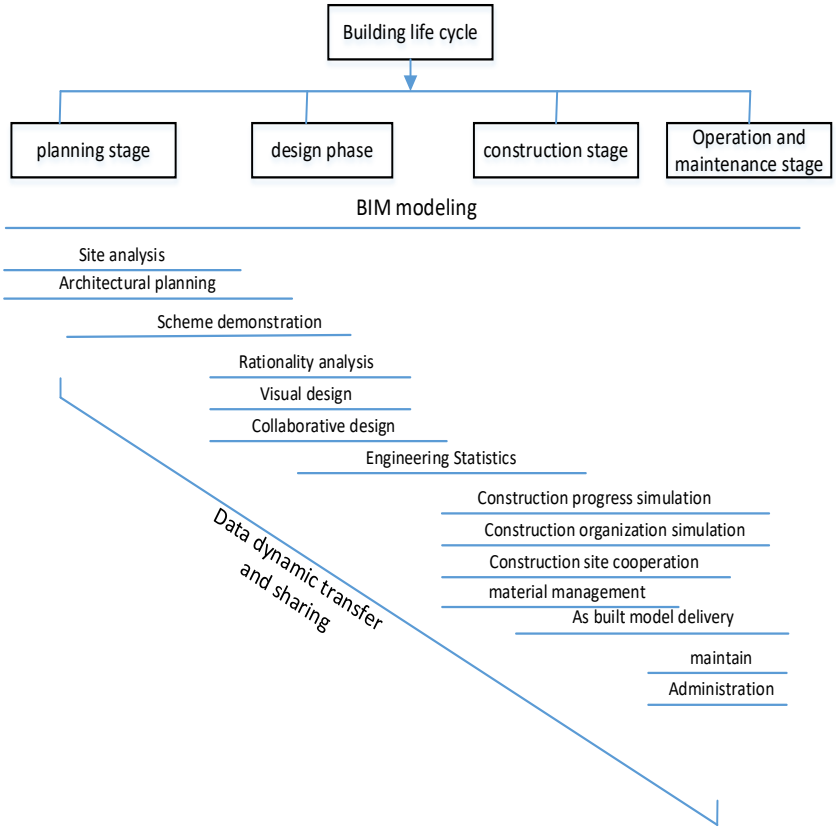

Figure 1: Application of Bim in the whole life cycle of buildings

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2.1.3. Establish Economic and Technical Indicators

In the architectural scheme design stage, it is necessary to determine some economic and technical indicators of the building, such as energy consumption[4] of the building, wind environment and acoustic environment of the building. This kind of problem is relatively complex, and the designer's accuracy and comprehensiveness through manual calculation are poor. At present, computer simulation analysis can be carried out through BIM Technology, IOT, big data and other information technologies, so as to analyze the relevant information of buildings that people need to know under specific boundary conditions. This application is a simplification of the actual situation. The accuracy of the analysis results depends on the designer's abstract assumptions and simplifications about the interaction between boundary conditions and buildings. If the assumptions or simplifications are reasonable, the reliability of the analysis results obtained is also high.

2.2. Application in Design Stage

2.2.1. Model Integration

In the construction drawing design stage, Architectural design, Structural design, Water supply and drainage design, HVAC design, electrical and other disciplines often design independently. Although the architecture discipline takes the lead and coordinates in the design process, very few technicians are proficient in the whole discipline. In addition, the construction drawing is often produced by different professions. The structure and equipment discipline lacks intuitive understanding of the appearance and internal overall effect of the building. Generally, after the drawing is produced, the production unit is entrusted to produce the effect drawing, and there is more or less deviation between the effect drawing and the actual situation. BIM Technology can integrate the design contents of various disciplines into the same building model in the design process, and the time period of model integration in the design process is advanced, so that engineers and technicians can grasp the overall view of the building earlier.

2.2.2. Design Optimization

Although there are experienced designers in the design unit who check the quality of drawings after final review, everyone's energy is limited. In addition, it is difficult to cooperate within each discipline and among different disciplines. BIM Technology can effectively carry out collaborative design, intuitively display design results in real time, and conduct collision inspection on parts that are difficult to be accurately observed by the naked eye [5] These functions undoubtedly bring great convenience to designers, which can greatly reduce the workload and improve the quality of construction drawing design.

2.2.3. Quota Design

Once the budget estimate of the project is approved, it is not allowed to break through in principle. Since the construction of the project adheres to the principle of "construction according to drawings", the construction drawings largely determine the amount of project cost. This requires that in the process of construction drawing design, the design unit should carry out quota design in each discipline and each sub item of the project to avoid exceeding the corresponding budgetary estimate. Using BIM Technology to correlate the price information of building structures, equipment and materials, the approximate amount of the corresponding system can be obtained in real time, and even the cost information of construction (such as fees, measure fees [6], taxes, etc.) can be correlated, so that the cost information is more accurate and can better assist designers in quota design. On the one hand, the project cost can be controlled within a reasonable range, On the other hand, it helps the construction unit to better balance the project quality and cost.

2.3. Application in Construction Stage

2.3.1. Positioning of Components and Pipes

Error control is required in the construction process. The allowable error range of building construction is also specified in the national code[7]. When formulating the construction scheme, control measures shall be formulated in advance. Locate components and pipes in the drawings. For example, curtain walls are used more and more frequently on the facade of buildings. The installation quality of curtain wall embedded parts directly affects the later curtain wall installation quality[8]. In addition, the size of equipment pipes, especially ventilation pipes, is large, which generally occupies more ceiling space, affects the indoor net height, and brings defects to the use function. Prepositioning

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and clear height analysis of three-dimensional components and pipes with BIM model can satisfy the requirements of final construction quality control and use function.

2.3.2. Construction Organization Design

The preparation of construction organization plan involves the layout of temporary construction site. BIM software can realize the function of simulating site layout and optimize site layout in BIM software. The site shall be arranged according to the specific construction process to achieve the optimal scheme of resource allocation and coordination. While reducing the construction cost, it can also cooperate with special management such as safe and civilized construction.

2.3.3. Progress Control

At present, the BIM software that can realize the preparation of the schedule is highly reliable. Generally speaking, it organizes and arranges all the sub projects or construction processes of the project in order, effectively overlaps them in combination with existing resources, and completes the specified construction tasks within the specified construction period or construction time nodes. The intelligent double code network diagram, bar chart[9], key route and front line through BIM software can help the project to quickly and effectively manage the schedule and realize dynamic tracking and control of the schedule.

2.3.4. Production Informatization

When a large number of products of the same type but different specifications are required in the construction and production process, the classification management of different components or products is particularly important, especially the rise of prefabricated construction technology in recent years, which realizes factory prefabrication of various types of components. The forming process of main components is in the factory production link, and only the construction and splicing of various components are carried out on site. The premise of prefabrication is the standardization of components. Standardized component identification can use BIM software to informatize products and generate specific identity information that belongs to specific components. It can be combined with two-dimensional code and other image recognition technologies for production information management[10], which can effectively avoid the error rate of component use and reduce the number of spare parts.

2.4. Application in Operation and Maintenance Stage

2.4.1. Information Storage

In different management stages of the building, different people participate in it. It generally takes decades or even hundreds of years for the building to go from investment and construction to demolition. The operation and maintenance management unit is inconsistent with the unit undertaking the construction task itself, or due to the replacement of internal management personnel, when the whole building enters the operation and maintenance management stage, building information is often lost, which brings inconvenience to the operation and maintenance management of the whole building. Therefore, saving the information of the whole building with BIM software (model or other forms) from the beginning can effectively avoid the loss of information and bring convenience to the call of building information.

2.4.2. Maintenance of Building Equipment Pipeline

The operation and maintenance phase involves the maintenance and repair of various systems. BIM can be integrated with relevant detection electronic components to develop corresponding management software systems. The status and specific location of these electronic components can be centrally displayed in the software. When alarm information is displayed on one or several electronic components in the computer, rapid diagnosis can be made according to the specific location of the electronic components and the system to which they belong, so as to find problems in advance and eliminate hidden dangers. BIM Technology can high efficiency improve the accuracy and timeliness of system fault diagnosis in buildings, ensure the effect of maintenance and repair, and extend the overall service life of buildings.

2.4.3. Internal Navigation and Roaming

For buildings with large size and complex internal functional divisions, once the building model is established, it can be combined with GIS technology to further develop the internal navigation

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system[11]. For example, real-time navigation and display from a specific location to a target location can be realized in a large shopping mall. BIM virtual roaming technology[11] can be used for spaces inside the building that are inconvenient for people to enter or control the flow of people, especially for tourist buildings, so that tourists can have an immersive feeling without entering the corresponding space.

3. Integrated framework of BIM and IOT Technology

In the practice and application of construction projects, BIM and information technology have their own advantages. The effective integration of BIM and IOT technology can give better play to their advantages. As shown in Figure 2, data collection relies on IOT technology, data sharing and management in the cloud are realized by cloud computing technology, and data deep mining is realized by big data technology. The integrated application of IOT technology, cloud computing and big data can more fully reflect the engineering value of BIM.

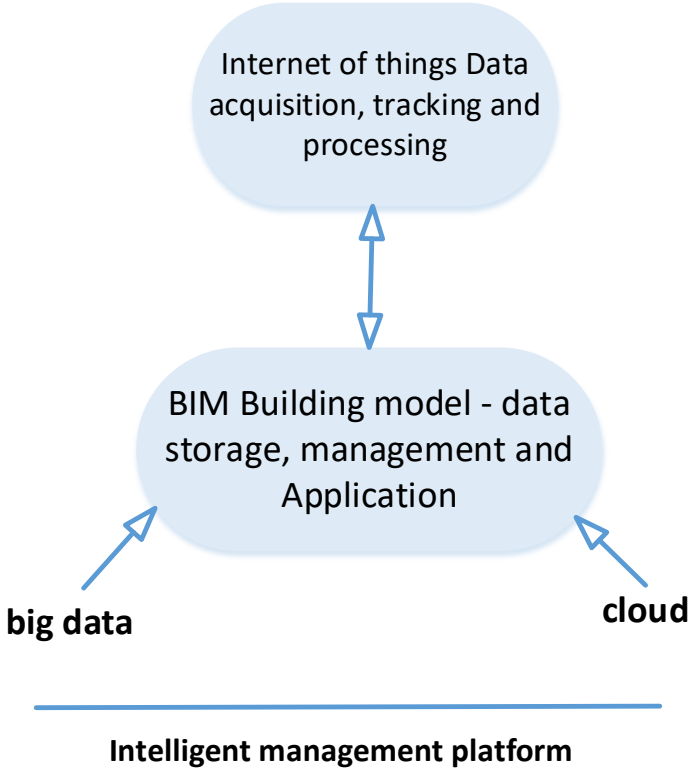

Figure 2: Relationship between BIM and IOT Technology

Various integrated applications of IOT technology, such as integration with sensors, can provide better means for collecting and sensing data[12]. At present, the basic framework of the IOT and BIM fusion system is to integrate the BIM model on the basis of the IOT architecture composed of the perception layer, the network layer and the application layer[13]. The integrated application research of IOT technology and BIM Technology basically adopts this framework mode.

4. Application of IOT Technology and BIM Integration in Smart Construction Site

With the innovation and development of various technical applications of the IOT, the general definition of the IOT in China is as follows: through radio frequency identification equipment, infrared sensors, global positioning system, laser scanners and other information sensing and execution equipment, according to the agreed agreement, the IOT is connected, information is transmitted and shared, so as to realize intelligent identification, positioning, tracking, control and management[14]. In the application of construction projects, through the deployment of sensors, two-dimensional codes, RFID electronic tags and other data collection equipment, it can effectively realize the all-round and all-weather real-time monitoring of the human, machine, material and other links in the construction projects.

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4.1. Smart Construction Site

With the constant development of information technology, the management mode of the traditional construction site of the current construction project urgently needs to be reformed and improved. Meanwhile, various new technologies emerging have been widely used in the construction site management. This comprehensive application makes the management of the construction site more intelligent, and the monitoring and decision-making of each link more intelligent, so the intelligent construction site appears[15].

The integration of BIM and various information technologies is an important foundation for the development of smart construction sites[16]. The development of smart construction site is mainly based on the BIM model and the data collection and analysis means of the IOT. It has important application value to realize the informatization and intelligent management and decision-making of the construction site[17].

4.2. Structure Diagram of Smart Construction Site

On the basis of intelligent demand analysis of construction projects, combined with the basic architecture diagram of IOT technology (perception layer, network layer and application layer), the structure diagram of smart construction site is shown in Figure 3. Information is collected at the perception layer, real-time data transmission and sharing are realized at the network layer, and application analysis and decision-making are carried out in all fields and links of construction projects at the application layer. Through the research on the application of smart construction site structure chart, we will create a system of integrated application of IOT technology and BIM building information model, and finally achieve the goal of efficient, intelligent and intensive project management of smart construction site in combination with the construction progress change of construction project site.

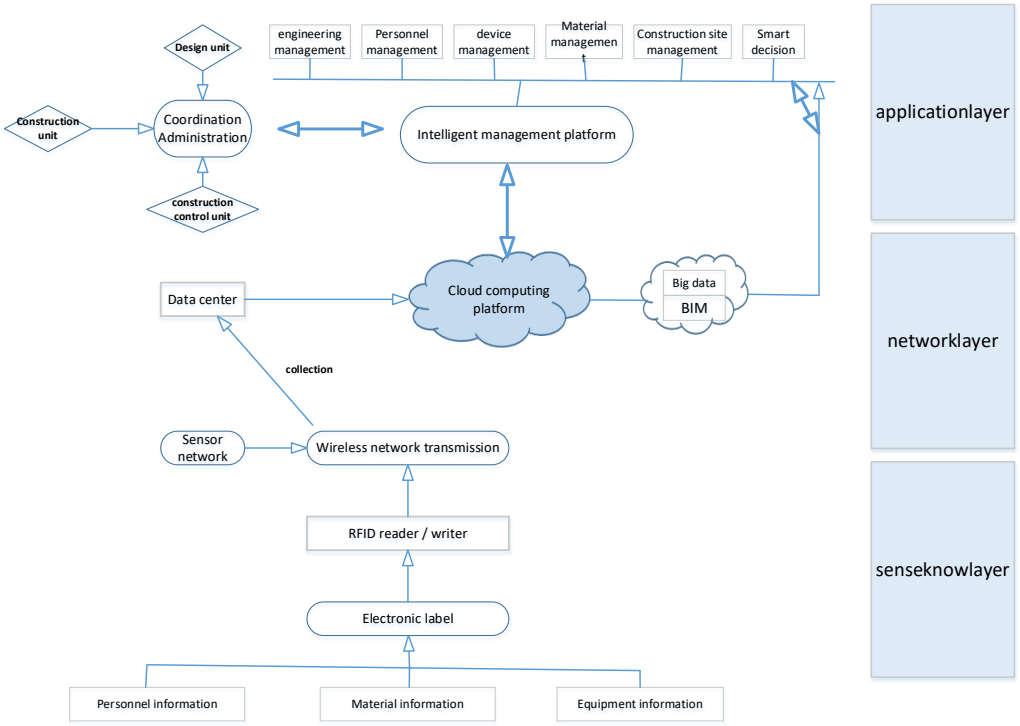

Figure 3: Structure of smart construction site

4.3. Application in Typical Modules of Intelligent Construction Site

4.3.1. Security Management

The intelligent construction site of construction projects emphasizes the real-time sharing, co construction and processing of information data. The IOT technology can connect the goods and people in the Internet, and then integrate BIM Technology to realize the all-round and all-weather tracking,

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positioning, alarm and other functions in the construction process[18].

4.3.2. Engineering Material Management [19]

Based on BIM building information model, integrating IOT technology can make the management of building materials and equipment more efficient. The material management link in the construction project is very important. The cost of materials accounts for a high proportion in the project cost. Therefore, the material management link should be paid more attention in the whole process management of the construction project. The implementation of the material management link is closely related to the project quality management. Through continuous optimization of the material management link, the construction cost can be effectively reduced. In combination with the key and importance of material management in the whole construction process of construction projects, it is necessary for relevant managers and technicians to continuously improve their technical level and management ability, master the integrated application of BIM Technology and IOT and other information technologies, effectively combine the new technology of BIM and IOT with building material management, realize the optimized management of materials in construction projects, and finally save the project cost.

The application model of BIM and IOT technology integration in the material management of construction projects is shown in Figure 4. RFID electronic tags are added to the building materials, and the collected information is transferred to the BIM building model information library in time. The real-time monitoring and tracking of building materials can realize the material transportation and acceptance, the storage and storage of materials can be realized by summarizing the information of building materials, and the efficient operation of material use management can be realized through material traceability control.

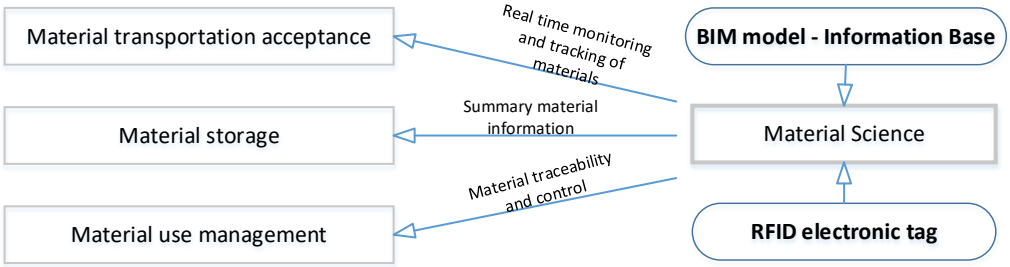

Figure 4: Application model of BIM and IOT in material management

4.3.3. Project Quality

The three-dimensional design, collision detection and construction simulation of BIM Technology have played a very especially important role in the innovation of traditional construction methods, and have been widely used in the construction of deep foundation pit, reinforcement engineering, formwork engineering, curtain wall engineering, prefabricated and other projects[20], providing a reliable guarantee for the construction quality. Jinling Zhong[21]studied the application of BIM Technology in deep foundation pit modeling, collision detection, drawing joint review and technical disclosure, dynamic layout of construction site, 4D construction simulation and technical disclosure of key and difficult construction points in actual cases. Jibo Yang[22]studied the construction simulation technology of rock foundation pit based on BIM Technology, combined the rock foundation pit model with the construction schedule, so as to determine the overall construction sequence of the project and analyze the key and difficult points of construction. Tailong Hu[23]accumulated experience for the design and construction of reinforcement at dense nodes and ensured the quality of reinforcement works at dense nodes. Li Yang[24]used NavisWorks to simulate the construction of formwork model and steel reinforcement model on the basis of analyzing the design and construction problems of loose formwork, so as to ensure the safety and quality of formwork works during construction. Chengcai Wang[25]used BIM Technology to improve the curtain wall construction method, and carried out construction simulation and analysis. BIM Technology provides solutions for the key and difficult points in the actual construction stage of the project, and lays a solid foundation for the transformation, upgrading and intelligence of traditional construction sites,As shown in Figure 5.

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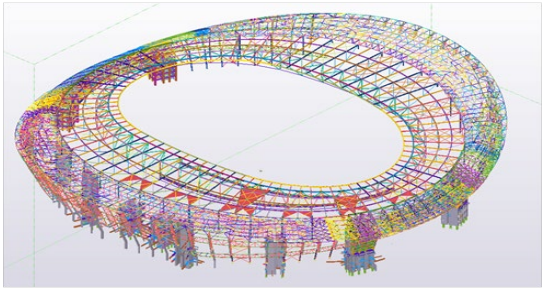

Figure 5: Construction simulation and analysis of BIM technology

4.3.4. Project Progress

It is common for the construction progress to stagnate and delay in the project construction stage, and the traditional project management method can not achieve real-time and effective progress control. BIM emphasizes the concept of information sharing and refined management in the whole life cycle of the building. The construction schedule prepared by the integrated software can make up for the deficiency of the schedule management of the bar chart and network chart of the construction operation plan. The advantages of BIM Technology in progress control are reflected in the visual observation of the construction process of the three-dimensional model, the preparation of the progress plan based on the information of materials, equipment, personnel and time, the collection of site construction information and the comparison of deviations with the original progress plan, and the construction of a whole process system of progress preparation, optimization, monitoring and correction. Kuang Jing et al. [26]took the progress management of a large underground garage as an example, and applied NavisWorks to import 3D models and project schedules to intuitively understand the construction situation at various times. At the same time, through on-site real-time monitoring, an integrated platform system was built to adjust the construction progress. Defu Liu et al. [27]took the project management of Chongqing Xiantao data Valley phase III project as an example, and applied the BIM platform that imported the construction section and schedule to simulate the daily construction situation. Through the platform, managers can clearly understand the comparison between the construction progress within the set period and the original progress, and make optimization and adjustment.

4.3.5. On Site Real Name Management

The application of IOT technology can carry out intelligent access control management in the construction site, manage contractors and suppliers related to construction, avoid irrelevant personnel and vehicles from entering the construction site, and eliminate unstable factors on the construction site. As the most critical and complex management factor during the construction of construction projects, relevant personnel can manage the construction personnel by real name system through intelligent access control management, and input the name, gender, age, photo, position / type of work, position, job number, contact information, vehicle unit and license plate number of the construction personnel into the intelligent access control system. When vehicles and employees enter the site, Real name registration can be completed under the application of IOT RFID radio frequency identification technology. At the same time, real name management reports can be output in units of month, quarter and year to record in detail the number of employees, working hours and attendance of employees, vehicle types, affiliated units and other data information of smart construction sites in a specific period of time. Data can be output in the form of bar charts and pie charts to standardize the access management of personnel and vehicles on construction sites.

4.3.6. Panoramic Video Monitoring

In order to achieve the full penetration of IOT technology in construction projects and build a comprehensive smart construction site, a video monitoring system should be set up to install high-definition real-time monitoring on key positions such as the site perimeter, construction area and site roads. Once an emergency occurs in the construction site, the details of the emergency can be understood and handled in time through video monitoring to avoid the continuous deterioration of the problem. The three-dimensional real scene model is the main application of IOT technology in smart construction sites. It can be linked with the comprehensive video monitoring system to comprehensively supervise and supervise the construction site, control the construction progress, safety and materials, and ensure the standardization of construction projects, As shown in Figure 6. In the construction stage of the construction project, Hawkeye panoramic cameras can be arranged on the construction site to achieve full monitoring coverage, and based on this, a bird's-eye view can be

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formed to assist managers in mastering the overall situation of the construction site. Panoramic video monitoring is the main content of smart construction site construction, which can be used to accurately represent the actual production situation of the construction site, realize global backtracking, detail monitoring, information enhancement and panoramic monitoring of the construction site, realize scene target locking and independent tracking under the application of ball machine and gun machine linkage cameras, and strengthen on-site management. Panoramic video monitoring can cruise the path of the construction site, display the association of various areas on the construction site, and capture the situation of not wearing safety helmets, so as to strengthen the control effect of the construction site with the assistance of technology. During the on-site management, the monitoring data can be normalized with the help of algorithms, and the application value of data can be calculated with the help of remote inspection standardization. The calculation method is as follows:

$$X = X - \min/(\max - \min) \tag{1}$$

Where x is the current data; Min is the minimum value of data; Max is the maximum value of the data. With the help of formula (1), the difference of data variables can be eliminated to make the obtained data more accurate [28].

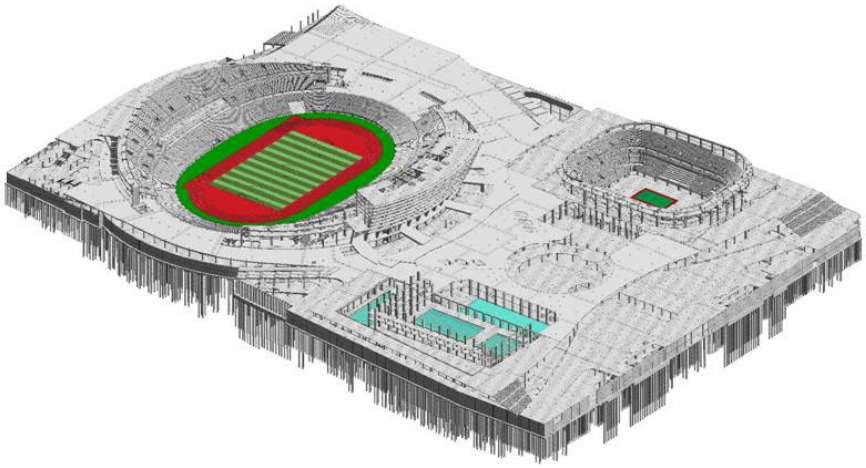

Figure 6: BIM panoramic video monitoring application model

4.3.7. Set up Local Area Network

(1) Strengthen network security. In order to satisfy the all-round control of the smart construction site, a local area network is built to communicate with all kinds of intelligent systems and satellite positioning base stations. A local area network is built in the construction site by building a "wireless transmission + optical fiber ring network" mode to ensure the quality of data transmission and lay a foundation for the smooth construction of the construction project. The on-site local area network is the result of the in-depth application of the IOT technology in smart construction sites. In order to ensure that the Internet of things technology can effectively play its role, attention should be paid to strengthening network security, strictly deploying network firewalls, dividing network security domains according to the division of construction sites, and launching targeted security protection.

(2) Satellite positioning transmission. The smart construction site is divided into two parts: wide area network transmission and LTE network transmission. The wide area network transmission relies on "L2TP VPN + wide area network" to complete data encapsulation, and further applies IPSec and chap encryption to improve data security. LTE network transmission can realize two-way authentication of the network, mainly using tunnel technology to complete data confidentiality. One of the key functions of the IOT in smart construction sites is the positioning of people and vehicles, and the realization of this function mainly depends on the Internet of things and satellite systems. The WAN transmission and LTE network transmission mentioned above have strong security and can keep satellite positioning data confidential. Therefore, during the construction of smart construction sites, the security of satellite positioning data can be maximized by using the Internet of things private network transmission, Avoid data leakage during data transmission [29].

(3) Internal and external network isolation. The construction of on-site local area network can complete the efficient transmission of internal and external network data on the basis of ensuring the safety of private network and internal network data, and complete the isolation of internal and external networks with the help of local area network, so as to make network data more stable and orderly. The

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internal and external network isolation scheme of the local area network of the intelligent construction site can complete the data conversion and transmission through the data interface, build a special firewall for the intelligent construction site with the support of the WAN special line, and isolate the IP address, so as to achieve effective isolation between the Internet and the data of the intelligent construction site. At the same time, the one-way gateway is applied to complete the transmission of data to the internal network boundary, and then it is connected to the smart site server after being transmitted through the internal router, so as to ensure the safety of data and realize the safe and complete input of Internet of things data. As shown in Figure 7.

Figure 7: Site LAN based on point cloud scanner+Internet of things system

5. Conclusions

The integrated application of BIM Technology and IOT technology is the direction of integrated development of construction industry and advanced information technology, and its application in construction engineering has become an inevitable trend. Intelligent construction site is a brand-new management concept, which lays a foundation for green construction, informatization, intelligent management and intelligent decision-making of construction projects. IOT technology is an important guarantee for real-time data collection, transmission and processing, and can also meet the needs of intelligent construction site management of construction projects.

The application research of emerging frontier information technologies such as the IOT, cloud computing and big data in various fields has gradually risen, and has also received extensive attention in the construction industry. In particular, the integrated application with BIM has become the focus of frontier research in the discipline in the last decade. The integration and integration of BIM Technology and IOT technology can optimize the management of each stage of the project in the whole life cycle of intelligent buildings. It is of great value to the development prospect of the construction industry. The application and Realization of BIM Technology in the construction of smart cities provide strong data support for the development of all-round and all-weather management of cities, and IOT technology is an especially important technical means for data collection.

Combined with the current discipline theory and practical engineering application, the integrated application of IOT technology and BIM is still in the exploratory stage, and there are many bottleneck problems that need to be solved. It also faces many challenges in application research. With the continuous development and innovation of new technologies and the vigorous promotion of national policies, it is bound to promote the development of these cutting-edge advanced technologies. Thus, it is helpful to realize that information technologies such as BIM and IOT play a more important role in the application research of building engineering.

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