Research on Intelligent Building Management and Application Based on Building Information Modeling

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Abstract. As an information tool of the construction industry, Building Information Modeling (BIM) technology has promoted the transformation of the construction industry from two-dimensional dynamic to multidimensional dynamic. This paper studies three aspects of intelligent building management (IBM) based on BIM, including intelligent upgrading of energy management, innovation of material recycling and waste management, and construction of intelligent monitoring and early warning system. The research results show that BIM technology realizes the intelligent upgrading of building energy management through digital modeling and data analysis. Combined with other technologies, the energy consumption is accurately analyzed and predicted, and the energy-saving effect is remarkable. In the field of materials recycling and waste management, BIM technology enables accurate material statistics, classification and recycling, as well as waste volume forecasting through three-dimensional (3D) visual modeling and data integration. In addition, BIM technology builds an intelligent monitoring and early warning system to realize real-time data monitoring and dynamic risk early warning. In the actual project, the key indicators are accurately monitored and potential risks are timely warned to ensure the safety and efficiency of the project. Through the analysis of three aspects of BIM based IBM and application, this paper lays a solid foundation for the future in-depth development of BIM.

Keywords: Building Information Modeling; Intelligent building; Building management.

1. Introduction

Construction is a broad industry that involves the planning, design, construction and maintenance of buildings and infrastructure. It is an important part of the national economy and plays a vital role in the urbanization process, economic development and social well-being. Although traditional buildings have aesthetic value, historical and cultural significance, local adaptability and other advantages. There are also some shortcomings: high energy and resource consumption, lack of disaster resistance, low construction efficiency, functional deficiencies, environmental protection and sustainable issues etc. With the continuous development of economy and social progress, people's demand for the built environment is also increasing. Today, buildings that can provide a comfortable and healthy living experience, safe and reliable security, efficient and convenient functions, as well as modern equipment and technology to meet the needs of the information society are gradually becoming the ideal choice. As an important infrastructure in the information society, intelligent buildings have attracted more and more attention. It not only reflects the comprehensive economic strength of a country, but also becomes an important symbol of the competitiveness and image of multinational enterprises [1].

Intelligent technology is a kind of technology that makes equipment, systems, processes and services intelligent, autonomous and adaptive by means of artificial intelligence, machine learning and big data [2]. The development of intelligent technology includes many fields, artificial intelligence, Internet of Things (IoT), robotics, etc. BIM belongs to the field of building intelligence in intelligent technology. The standardized use of intelligent technology in engineering construction can not only create a good living environment for users, but also provide convenient support for daily life. In addition, the standardized application of this technology can also accurately process a variety of data information and help relevant staff to timely discover potential problems that may exist in construction projects. Then it can provide an important guarantee for improving the quality of construction projects [3].

BIM technology integrates all kinds of complex information in construction projects into a data set through advanced data processing and transmission algorithms. It also builds a real, real-time and visual BIM system, which provides support for project managers and helps them make smarter decisions and evaluations. At present, BIM technology has been widely used in the field of construction engineering, both in the design stage and the construction stage [4].

According to the search results, this paper examines several research papers on BIM technology in intelligent buildings, summarizes the IBM and application based on BIM, and discusses the application cases of this technology on this basis.

2. Intelligent Management based on BIM

2.1. Intelligent Upgrading of Energy Management

Traditional energy management mainly relies on artificial energy data collection, and traditional meters cannot provide operation and maintenance personnel with data to understand energy use patterns. It leads to problems such as not timely reporting of building energy consumption data and prone to errors and omissions. Unclear building energy situation brings trouble, especially when the upper level requires energy conservation and emission reduction and energy cost reduction, cannot grasp the clear energy situation, it is difficult to do a targeted energy management. In order to solve these limitations, the introduction of BIM technology for intelligent upgrading of energy management has become an effective means [5].

BIM technology provides an accurate database for building energy analysis by creating digital 3D models. It can be used to simulate the impact of building geometry, material properties and equipment systems on energy consumption. The main applications include: thermal performance analysis of heat transfer coefficient of enclosure structure, sunshine analysis of natural light utilization efficiency, airflow simulation of ventilation scheme optimization, equipment energy analysis of Heating, Ventilation and Air Conditioning (HVAC) system efficiency. BIM can also compare multiple scenarios to quickly assess energy saving strategies. Combined with energy simulation software, energy consumption prediction and optimization of the whole life cycle are realized, which provides scientific decision-making basis for energy saving design and transformation.

The intelligent building energy management module consists of three parts: data acquisition, analysis and decision making, and control and execution. The data acquisition layer monitors energy consumption, environmental conditions and equipment status through sensors and intelligent instruments. The analysis and decision level uses artificial intelligence algorithms to process data, identify anomalies, predict trends, and formulate optimization strategies. The control executive layer realizes fine management by automatically adjusting system parameters. In addition, the module also has energy consumption visualization and report generation functions, which can collaborate with other systems to achieve global optimization and fully tap the energy saving potential of the building.

The integrated framework of BIM and intelligent building system realizes the seamless docking of information model and operational data, and intelligent energy management. The framework consists of data layer, service layer and application layer. Data layer integrates BIM model and real-time data to build a unified database. The service layer provides data processing, analysis and visualization functions. The application layer develops management tools for different user needs. The framework adopts an open architecture and supports the access of third-party systems through standardized interfaces and protocols to ensure the smooth flow of information, thus realizing the intelligent management of the whole life cycle of the building [6].

2.2. Innovation in Material Recycling and Waste Management

The construction industry is a large consumer of resources, and the heavy use of raw materials wood, steel, cement, etc. accelerates the depletion of natural resources. Through the recycling of materials, energy consumption in the mining of natural resources and raw material processing can be reduced, the service life of resources can be extended. It can reduce the carbon footprint of the construction industry, thus responding to the challenge of climate change. Construction waste accounts for a considerable proportion of urban waste. If the waste is not properly treated, it will cause land pollution, air pollution and water pollution. Effective waste management reduces the risk of pollution and protects the ecological environment.

2.2.1. Material recycling

The application of BIM model and BIM collaborative management platform in material management is as follows:

(1) BIM model application

The 3D visualization model created by BIM technology can not only query the size information of each component, but also add the physical property information of the component. The information includes the material quantity, material type and material model information, which can quickly calculate the material quantity of the project, and quickly formulate a reasonable material procurement plan according to the construction schedule.

(2) Application of BIM collaborative management platform

The application of BIM technology in material management is mainly reflected in three aspects. Firstly, information sharing facilitates the leadership and relevant material management departments to grasp important information such as material inventory and material plan in real time, and avoids unreasonable decisions caused by information communication problems. The second is to realize the online business process. According to the traditional material management business process, the corresponding business process is set in the BIM collaborative management platform, and the offline and online personnel are matched one by one to improve the efficiency of the material management business process. Thirdly, the management process can be traced back to ensure that each detailed material management process is responsible to the person, which not only improves the responsibility of all posts, but also facilitates the quick search for the root cause of problems when they occur [7].

2.2.2. Waste management

BIM technology, with its powerful data integration and visualization capabilities, provides an efficient solution for waste management and treatment in construction projects. The following are the specific roles of BIM in waste treatment:

(1) Accurate prediction and monitoring of waste volume

BIM models can accurately calculate the amount and type of waste that may be generated during construction through comprehensive simulation of building design and construction. This precise forecasting helps to plan waste management plans in advance to reduce waste and optimize resource use.

(2) Waste classification and recycling

BIM technology can attach attribute information to each type of building material, indicating its composition and treatment, and help management teams effectively separate waste during construction or demolition. This classification information can also guide recycling and promote the recycling of building materials.

(3) Waste management support during construction

The BIM collaborative management platform can monitor the waste generation at the construction site in real time, record the waste generation data at each stage, and adjust the construction plan in time to reduce unnecessary waste. This dynamic approach can significantly improve the efficiency of waste management.

The role of BIM technology in material recycling and waste treatment is not only reflected in accurate data support and process optimization, but also effectively promote the implementation of resource recycling and environmental protection concepts. This provides a technical guarantee for the green transformation and sustainable development of the construction industry.

2.3. Construction of Intelligent Monitoring and Early Warning System

Traditional construction usually relies on manual inspection or simple monitoring instruments, the monitoring range is limited, cannot achieve real-time, all-round monitoring, the dynamic change of complex working conditions response is slow. Moreover, data collection and collation are time-consuming, and real-time feedback cannot be achieved. The data analysis ability is weak, and the warning is often issued after the danger occurs, and the potential risks cannot be warned in advance. Traditional systems rely on manual analysis and judgment, and subjective factors can easily lead to monitoring errors or negligence. At night or in bad weather conditions, the effectiveness of manual inspections is greatly reduced.

In the safety management of building construction, the use of BIM-RFID sensor technology can effectively identify the source of danger. These hazards fall into two categories: specific hazards and random hazards. Specific hazards are usually clearly identified at the construction site, are closely related to building structures or temporary facilities, and can be controlled by artificial means. Random hazards are risks caused by changes in internal and external environment. These risks exist objectively and may be exacerbated by the interaction of multiple factors. By integrating sensor technology with BIM models, an intelligent early warning system can be built to automate project detection and risk assessment. The construction model established by BIM technology can conduct process simulation and conflict detection, analyze the suitability of structural components, optimize the construction process, and avoid safety problems caused by improper design or process. Secondly, the operation status, working range and carrying capacity of the construction equipment are checked to eliminate the hidden trouble of the equipment. Finally, the potential risks involving personnel, materials and equipment during construction are identified, and these data are integrated into the BIM platform for unified management. At the same time, combined with the real-time monitoring function of sensors, the construction process is dynamically tracked, and random hazard sources are transformed into controllable unique hazard sources, so as to achieve effective pre-control and management of safety risks [8].

The core of ensuring construction safety lies in accurately identifying potential risks that may lead to accidents and developing effective preventive measures before construction. By leveraging the six core features of BIM technology - digital, spatial, quantitative, inclusive, available and permanent - combined with advanced information technology, project participants can interact in 3D to simulate the entire construction process before construction. Based on a reasonably designed structure, an information simulation platform that is both generic and project-specific is created, enabling project members to identify safety hazards more accurately and present construction conditions and potential risks in a more intuitive way. This visualization method can support the in-depth analysis and evaluation of construction risks, so as to formulate more reasonable safety prevention strategies and optimize decision-making efficiency.

In addition, BIM technology can dynamically identify site safety issues during construction and adjust construction plans in real time. The construction safety management system based on BIM consists of three main modules: database module, BIM virtual construction module and safety management module. The project model is established, the basic data of initial management elements are collected, and the attributes of these elements are integrated into the dynamically updated construction database to lay the data foundation for construction safety management. By combining BIM and positioning technology, standardized data of risk events can be processed modularly, which can effectively warn potential construction safety risks and provide decision-making basis for managers. With the help of early warning information and specific decision-making schemes, the construction plan, personnel allocation and equipment scheduling will be dynamically optimized, thus comprehensively improving the level of construction safety management [9].

3. Intelligent Application based on BIM

3.1. Application of Intelligent Upgrade of Energy Management

In the project of a smart office building in Beijing, the BIM model was built by Revit. This model lays a comprehensive digital foundation for subsequent energy consumption analysis and optimization, and can accurately simulate energy consumption and formulate equipment operation strategies. The energy consumption data acquisition system includes multiple sensors and smart meters, covering all energy systems such as HVAC, lighting and outlets. Data is collected at 1-minute intervals and transmitted to a central server for data cleaning and preprocessing, and processing of outliers and missing data. The energy consumption curve is decomposed into trend, seasonality and random fluctuation by time series decomposition method. Table 1 shows the annual distribution of energy consumption for different energy-using systems.

Based on the BIM and energy analysis results, a number of energy-saving measures were implemented, including intelligent HVAC regulation, adaptive lighting management, and equipment operation optimization. The HVAC system introduces a predictive control algorithm based on deep reinforcement learning, which combines weather forecast and historical data to dynamically adjust operating parameters. The lighting system uses daylight sensing and personnel positioning technology for precise adjustment. Office equipment reduces standby energy consumption through smart sockets and power consumption behavior analysis. These strategies were validated for six months after implementation. Table 2 shows the changes of major performance indicators before and after the implementation of the strategy. The results show that the energy consumption of HVAC system is reduced by 23.5%, the energy-saving rate of lighting is 31.2%, and the standby energy consumption of equipment is reduced by 40.7%. Indoor environmental quality maintained good, and PMV index pass rate increased from 85% to 97% [6].

Table 1. Annual energy consumption distribution [6].

Energy use system	Energy consumption ratio	Annual energy density (kWh/m^2)
HVAC	55%	82.5
Illumination	20%	30.0
Socket	15%	22.5
Elevator	7%	10.5
Else	3%	4.5

Table 2. Comparison of implementation effects of intelligent control strategies [6].

Index	Before implementation	After implementation	Improvement rate
HVAC energy consumption ($kWh/m^2 \cdot a$)	82.5	63.1	23.5%
Lighting energy consumption ($kWh/m^2 \cdot a$)	30.0	20.6	31.2%
Standby power consumption (kWh/d)	350	207.5	40.7%
PMV pass rate	85%	97%	14.1%

Through the organic integration of BIM technology and intelligent building systems, building energy efficiency can be significantly improved. Through the digital capability of BIM, building energy consumption management can achieve fine control, reduce energy waste, and achieve higher energy conservation standards. Driving green building development: The application of BIM in energy management can help to achieve low carbon environmental goals and promote the development of the construction industry in a sustainable direction. Reduce operation and maintenance costs: Optimize energy consumption patterns and equipment operation strategies to reduce energy consumption and maintenance costs; Improve the level of intelligence: BIM technology is deeply integrated with intelligent buildings to provide technical support for smart city construction and improve the overall building operation efficiency and environmental quality. Through the application of BIM, the intelligent upgrading of building energy management not only optimizes energy utilization, but also significantly improves the sustainability and operational efficiency of the building.

3.2. Application of Material Recycling and Waste Management

The Xinghai Life Plaza Project on Suzhou Metro Line 1 is a large underground commercial complex with a construction area of 52,000 square meters, covering a variety of functions such as dining, shopping and leisure. As an important commercial project in Suzhou, it is characterized by large construction area, complex underground space and various pipeline layout, which makes it difficult for traditional design and construction methods to meet the needs of the project. In the face of many challenges such as pipeline conflicts, construction coordination and resource optimization, the most advanced BIM technology is selected to achieve full digitization of design and construction management [10].

In the construction process, Revit was used to establish BIM model, and a virtual model containing a large amount of building data was built in the computer to provide accurate support for design and construction [10]. The application of BIM technology in the project covers not only the establishment of the building model, but also the construction simulation, collision detection and subsequent design optimization and analysis. This technology allows the design team to identify and adjust possible pipeline conflicts in advance in a virtual environment, thereby reducing rework during construction and significantly reducing the waste of labor and materials caused by rework. Through this refined construction management method, not only improves the utilization efficiency of resources, but also effectively guarantees the construction quality.

At the same time, the application of BIM technology has shown strong advantages in construction simulation. Through the dynamic simulation of the construction process, the project team was able to identify potential problems in the construction plan in advance and optimize the allocation of resources and the construction sequence. This visual and digital simulation means helps the efficient cooperation between the professional teams, significantly improves the coordination ability of the construction site, and avoids the delay and misunderstanding caused by information asymmetry in traditional construction. In addition, BIM model also provides accurate engineering quantity statistics and cost control basis for project managers, and effectively reduces the overall project cost by optimizing the design scheme and resource allocation.

It is worth mentioning that BIM technology supports the concept of collaborative design and sustainable development. Through the shared BIM model, the design team can realize the collaborative design of architecture, structure and mechanical and electrical engineering, which reduces the phenomenon of information silos and improves the design efficiency and accuracy. At the same time, in the construction process, the BIM model helps to accurately calculate the material demand and energy consumption distribution, reducing the waste of resources, reflecting the concept of green construction and sustainable development. According to statistics, compared with traditional design and construction methods, the benefits obtained by using BIM technology are shown in Table3

Table 3. Evaluation of BIM implementation effect of Xinghai Life Plaza Project [10].

Serial number	Index	Benefit (%)
1	Reduce information requests	30
2	Reduction of miscommunication	10
3	Reduced coordination time among majors	20
4	Acceleration of work progress	20
5	The secondary purchase of equipment is reduced	5
6	The impact of construction schedule is reduced	10
7	Reduced waste of manpower and materials	20

To sum up, the Project successfully solved various challenges brought by large volume, complexity and coordination through the comprehensive application of BIM technology. It not only shortens the overall construction period, but also reduces the project cost and resource waste, which brings huge economic and social benefits to construction enterprises. It significantly improves the quality and efficiency of the design and even the entire project, avoids unnecessary material waste, and reduces the generation of construction waste. It provides valuable experience for the design and construction of similar large-scale underground commercial complex projects.

3.3. Application of Intelligent Monitoring and Early Warning System

In recent years, the construction industry has gradually introduced BIM technology to improve the level of intelligent management. In the integrated transportation hub project of Beijing City Sub-center, BIM has been successfully applied to the construction of intelligent monitoring and early warning system. It effectively realized multi-dimensional real-time monitoring and risk early warning, and provided guarantee for the safety and management efficiency of the project.

The underground structure of the Beijing City Sub-center comprehensive transportation hub project is complex, including three layers of space. The railway station and yard are about 1.8 kilometers in length, with the deepest foundation pit reaching 32.5 meters and some areas reaching 40 meters deep. The project faced multiple challenges, including complex hydrological and geological conditions. The ground is mainly composed of fine sand and clay, and the groundwater level is high, so it is very difficult to control the water. In addition, the surrounding environment of the project is highly sensitive, and the south side is close to the Beijing-Harbin Railway, the nearest place is only 2 meters. The west side is adjacent to the North Canal, and there are important buildings (structures) such as houses, roads and subway tunnels distributed around it, and the safety risks are prominent [11].

The project is located in an underground area with complex geological conditions, and faced a variety of potential risks during construction. Such as the uncertainty of earthwork excavation, the impact of groundwater level fluctuations on the structure, and the difficulty of coordinating complex pipeline construction. Therefore, the project team built an intelligent monitoring and early warning system based on BIM technology, and realized real-time monitoring and dynamic early warning of construction status by integrating sensors, IoT equipment and big data analysis technology.

In the process of system construction, the project used Revit to create a high-precision BIM model. It integrated multi-professional information such as architecture, structure and mechanical and electrical information, and loaded the location and monitoring parameter information of monitoring equipment. In order to ensure the safety of the surrounding environment, a variety of monitoring points are set up. In addition, the displacement of piles is tracked and monitored in the area with great influence of unloading in the middle of the foundation pit, and the monitoring points are gradually increased with the progress of construction to ensure the safety and control of the project. Sensors are arranged in key construction areas, such as foundation pit supporting structure, main bearing components and groundwater control points, and real-time data is uploaded to the BIM model through the IoT technology to achieve dynamic monitoring. The monitoring scope covers key indicators such as deformation monitoring, stress changes, underground water level and construction progress [12].

The intelligent early warning system is based on the dynamic data input of the BIM model and determines the risk by setting a threshold range. Once a monitoring parameter exceeds the safe range, the system will automatically issue an early warning prompt and locate the abnormal area through the visual interface. For example, in the process of foundation pit excavation, the system monitors that the deformation of local supporting structure is close to the critical value, and the abnormal points are accurately marked through the early warning interface. Therefore, the construction team can adjust the construction plan in time to avoid the risk of structural instability.

In addition, the system also supports multi-party collaboration and data sharing, and managers, design teams and construction personnel can obtain real-time monitoring data and analysis results through the BIM platform, improving management efficiency. For complex pipeline problems during construction, BIM models help analyze potential collision points and avoid rework in subsequent construction. At the same time, after the completion of the project, the BIM model can still be used as a monitoring tool in the operation and maintenance stage to provide continuous support for subsequent use.

Through the application of BIM technology, the intelligent monitoring and early warning system of the project has realized the transformation from traditional passive management to active safety prevention, effectively improving the project safety and construction efficiency. This case fully proves that BIM has broad application prospects and important value in the construction of intelligent monitoring and early warning system, and provides practical reference for the management of similar projects.

4. Conclusion

This paper mainly studies the IBM and application based on BIM, and draws the following conclusions:

(1) The IBM has been upgraded in many aspects in the construction field. In terms of energy management, BIM technology is used to achieve accurate analysis and automatic control of energy consumption, providing energy-saving optimization solutions for the whole life cycle. In material recycling and waste management, BIM accurately counts the amount of materials, realizes waste classification and recycling, and promotes resource recycling through 3D modeling and collaborative platform. In the field of intelligent monitoring and early warning system, BIM technology dynamically monitors construction site data, identifies potential risks in advance, and realizes visualization, intelligence and real-time early warning of construction safety management.

(2) In terms of energy management, an intelligent office building in Beijing accurately simulates building energy consumption and optimizes equipment operation strategies through BIM technology and energy consumption data acquisition system, resulting in significant energy-saving effects. In terms of material recycling and waste management, the project of Suzhou Xinghai Life Plaza uses BIM to optimize resources, reduce material waste, achieve accurate resource allocation, reduce project costs, and reflect the concept of green construction. In terms of intelligent monitoring and early warning, the Beijing City sub-center Transportation hub project integrates sensors and IoT technology through BIM to monitor multiple indicators in real time, establish an intelligent early warning system. It improves safety management efficiency, and successfully prevents construction risks.

(3) In the future, construction projects can combine BIM with technologies such as the IoT, big data, and artificial intelligence to form intelligent building and smart city management systems to achieve real-time data monitoring and intelligent decision-making. At the same time, it is necessary to further promote green building and sustainable development, optimize energy utilization and resource allocation, and achieve the sustainable development goal of the construction industry. The application of BIM technology in IBM will also continue to promote the development of the construction industry in the direction of digitization, intelligence and lean, and will bring more efficient, more controllable and more sustainable management and construction mode to the industry.

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