Research on Promoting the Sustainable Development of Green Building through BIM Application-From the perspective of the whole building lifecycle

Hong Cheng Ma[1], Ping Wang [2]

[1]Infrastructure Construction Department, GuangXi University for Nationalities,
E-Mail: 40796422@qq.com

[2] International Colleges, Krirk University, , Thanon Ram Intra, Khwaeng Anusawari, Khet Bang Khen, Krung Thep, Maha Nakhon10220, Thailand

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Abstract: Building Information Modeling (BIM) is a digitalized technology on the basis of a collaborative working platform that can offer effective solutions in the entire building lifecycle. Abundant building information can be integrated through the application of BIM technology to solve the problems that are otherwise difficult to deal with at various stages of construction projects including preliminary planning, schematic design, construction management, as well as operation and maintenance. New means can also be provided through the innovation driven by BIM to reduce the impact of construction projects on environment during the process of construction and development in the building lifecycle. Based on relevant application research, this paper focuses on the sustainable development in the entire building lifecycle of green building, puts forward some suggestions, and points out the problems that should be paid attention to in BIM application. At the same time, the paper proposes some application plans based on BIM technology to promote data sharing in the lifecycle of green building projects, to achieve sustainable development of green building at different stages including project planning, design, construction, as well as operation and maintenance management, and to develop the BIM application system for the sustainable development in the entire building lifecycle of green building.

Keywords: Building Information Modeling (BIM); application plan; data sharing; application system

1 Introduction

The attention of the world has been focused on the sustainable development of the environment. The concept of sustainability has transformed the construction industry, reducing the energy consumption in the building lifecycle. Although the concepts of green building, green construction and sustainable development of construction environment were put forward in the construction industry many years ago, China's construction industry still consumes huge amount of energy today. According to the *Annual Report on China Building Energy Consumption (2019)*, the total building energy consumption in 2017 reached 947 million tons of standard coal equivalent, accounting for 21.10% of China's total energy consumption, a proportion that should not be ignored. This paper discusses how to improve the productivity and environmental sustainability in the building lifecycle based on the theories of BIM, green building and sustainable development.

Building Information Modeling (BIM) has been highly valued by academia and industry circle in recent years. BIM not only technically benefits the development process, but also provides an innovative and comprehensive work platform to improve the productivity and environmental sustainability in the entire project lifecycle. As far as sustainable development is concerned, it is necessary to consider not only the economic efficiency, but also its impact on the environment and society. To promote environmental sustainability, the basic requirements in three fields, namely, society, economy and environment, are usually the indicators to measure the level of sustainable

development.

This paper explores how to fully exert the advantages of BIM technology in green building, and focuses on the four stages in the lifecycle of green building based on the theories of BIM, green building and sustainable development. The paper also attempts to propose a sustainable development system for green building based on BIM technology and link BIM software with the application of actual construction projects, so as to deepen and promote the application of BIM technology in the lifecycle of green building. Therefore, this paper is of great theoretical and practical significance in combining the application research of BIM technology, green building and sustainable development. The research Questions is as follows:

⑴. What is the BIM application plan for the sustainable development in the lifecycle of green building?

⑵. What is the BIM-based application system for the sustainable development in the lifecycle of green building?

⑶. How to prove the feasibility and application advantages of the system through a specific project?

2 Literature Review

2.1 BIM Technology

BIM is the abbreviation for Building Information Modeling. The concept of BIM was first proposed by Charles Eastman (1975), who also put forward the idea of describing buildings through computer technology in his Building Description System to improve the quality and efficiency of construction projects. Robert Aish (1986) put forward the concept of Building Modeling. Van Nederveen and F. Tolman (1992) perfected Building Modeling and proposed the concept of Building Information Model.Tolman (1999) further improved this system and named it Building Information Modeling. Limited by the level of computer hardware, BIM theories were basically confined to academic research.

2.2 Green Building

The American Italian architect Paola Soleri (1969) put forward the concept of ecological architecture for the first time when he combined the two simple words, namely, Ecology and Architecture, into Arcology. The key of ecological building is to achieve the harmonious development between building and natural environment on the premise of reaching the design standard. The combination of architectural design and natural conditions should be considered as far as possible to maximize the use of natural resources, reduce energy consumption and reduce the impact on the environment.

The world's first green building standard, the Building Research Establishment Environmental Assessment Method (BREEAM), was published in UK in 1990. In 1992, the United Nations Conference on Environment and Development held a consensus on the idea of "sustainable development" in the world. According to the Agenda 21st adopted by the UN General Assembly, sustainable architecture considers not only the impact of architecture on environment and resources, but also its impact on economy, society and culture;it even changes our understanding of human development. Despite uneven distribution of natural resources, different process of development, and various standards on healthy residence and environmental protection in the world, different countries have basically reached a consensus on the understanding of sustainable architecture.

2.3 Sustainable Development

In 1987,the Brundtland Report defined sustainable development as "development which meets the needs of the present without compromising the ability of future generation to meet their own needs." The two United Nations Conference on Environment and Development (Rio de Janeiro in 1992 and Johannesburg in 2002) focused on the theme of environment and sustainable development, and established three major dimensions of sustainable development and construction, namely, the environment, the economy and the socio-culture, incorporating the concept of sustainable development into building lifecycle.

Many countries around the world have their own concepts of green building. Some developed countries in Europe proposed the concept of "Sustainable Building"; Japan pointed out the need to create "environmental symbiosis buildings"; and North American countries promoted "green building". In the early 1990s, the UK took the lead in the world to propose the Building Research Establishment Environmental Assessment Method (BREEAM). In 1992, the United Nations Conference on Environment and Development studied and discussed this system and uniformly adopted and recognized the concept of "sustainable development", marking the formation of the concept "green building".

3 Research Methods

3.1 System Analysis

System analysis is a method to solve complex problems by adopting research approach of system science as well as concepts and theories of mathematics. Specifically, in system analysis, the problem to be solved is taken as a system with its own objective, function, context, cost and benefit. Firstly, we need to define the boundary of the system according to the nature and relationship of this system. Secondly, we need to determine the system objectives and make plans to achieve them on the basis of collecting, analyzing and processing the information obtained through full investigation and research. Thirdly, we need to carry out simulation experiments and optimization analysis, and conduct comprehensive evaluation on various plans to facilitate the design, decision-making and implementation of the system.

3.2 Empirical Research

Empirical research is the general term of various methods to establish and test knowledge propositions based on the observation of empirical facts under the condition of value neutrality or value free. Value neutrality means that researchers should not let their own specific value standards and subjective bias affect the data and conclusions in the process of research, so as to ensure the objectivity of the research. Empirical research can be summarized as a research method in which objective materials are obtained through a large number of observations, experiments, and investigations of the research objects, and the essential attributes and development laws are drawn from the individual to the general. Empirical research is carried out through methods of observation, conversation, test, case study, and experiment.

3.3 Research Content

Based on system analysis and empirical research, this paper analyzes the basic concepts of BIM, green building and the lifecycle, as well as the application status at home and abroad, and summarizes the feasibility and inevitability of improving the performance of green building by using BIM technology. The paper conducts systematic research on the characteristics and advantages of BIM application in the lifecycle of green building, selects the appropriate coding system to meet the functional requirements of construction projects, and builds the framework of BIM application in the lifecycle of green building.

4 Results and Case Analysis

4.1 Research Results

4.1.1 BIM application plan for the sustainable development in the lifecycle of green building

(1) Sustainable BIM application at the stage of preliminary planning of green building

Preliminary planning is the primary decision-making stage that can decide the sustainability, energy use and environmental design of a building. This paper analyzes a large amount of basic information and data through BIM technology, and prepares for a systematic and effective design at the stage of conceptual design (table 4.1), so as to better determine the space scope and general appearance of the building, and to establish the relationship between the building and the surrounding environment.

Preliminary Planning Analysis Table 4.1

Phases of Analysis	Analysis Method
Analysis and collation of basic information	At the initial stage of architectural design and conceptual design, it is necessary to analyze a large amount of basic information and data, and design a systematic and effective concept.
Conceptual model analysis	In the early stage of schematic design, architects usually need to conduct field research and environmental analysis of the construction site to obtain specific information and data related to climate, topography, humanities, etc..
Degree of multi-party participation	It is necessary to use corresponding sunshine analysis software, wind environment simulation tools, and terrain models to make quantitative analysis with the conceptual model of the building; various design parameters should tend to reach a balance after data analysis; a calculation basis should be produced according to the formula calculation and analysis to provide parameter reference with high reliability for architectural designers.

(2) Sustainable BIM application at the stage of schematic design of green building

At the plan design stage, it is necessary to consider the specific aspects of style, space function, and component combination of the architecture. It is also necessary to simultaneously design the architectural structure, building materials and energy-saving. BIM can be used in 3D dynamic visualization design by displaying the traditional plane model in a new 3D stereoscopic effect. The model can adjust the view from various angles and directions according to our needs, and optimize the architectural design through various considerations in the switching expression of plane layout and 3D mode.

The architectural models can be professionally visualized after the structural model is established. We can use BIM for collision inspection, sum up the results of interference check in the building installation model, appropriately adjust the 3D model, and carry out the comprehensive design of electrical pipelines based on the comprehensive consideration of the priority levels and influencing factors of each specialty, so as to improve the efficiency of comprehensive pipeline design.

Using BIM to analyze realistic energy consumption simulation in green building projects can not only better meet the mandatory requirements of the green building standards, but also reduce building energy consumption while ensuring the basic functions of the building. Strategies and plans for carbon emission control can be proposed through predicting carbon emissions based on the environmental impact of the building design, so as to make important decisions such as environmental protection and energy saving. The integration of BIM and simulation software of performance analysis can improve the quality of architectural design to achieve environmentally sustainable design at a relatively small cost.

(3) Sustainable BIM application at the stage of construction management of green building

The 3D site layout based on BIM Technology can first simulate the construction of vertical transportation equipment such as tower crane and construction elevator through the visualization of the model, so as to ensure the widest coverage without interference, then rationalize the layout of the processing plant, and finally guide the site layout through the BIM model, which can save time and play a decision-making role in vertical transportation management.

BIM can be used for construction simulation design, in which VR technology enables architectural designers and constructors to analyze the working process feeling personally on the scene, grasp the procedures and key links

of each construction environment, practice the construction process in advance, ensure the safety of construction environment, shorten the construction period, save costs, and improve the construction efficiency, so as to coordinate the construction allocation and management as a whole, check the construction progress according to the project schedule, and avoid project lag, quality problems and potential safety hazards. The civil engineering, pipeline and industrial equipment of the project can be checked by BIM application software, which can eliminate the interference between equipment, reduce the engineering error, and improve the construction efficiency and quality.

Cost management software makes use of the information provided by BIM model for engineering quantity statistics and cost analysis. Supported by structured data of BIM model, BIM-based cost management software can provide the data needed for cost management according to the schedule and progress of project construction plan, which is known as the 5D BIM application.

(4) Sustainable BIM application at the stage of operation and maintenance of green building

In terms of facility management, BIM application can improve building management efficiency at the operation stage. Equipment management can be carried out through BIM model to achieve accurate and timely property management, and improve building operation and maintenance management to the height of intelligent buildings, making new projects more energy-saving and environmental protection. BIM Technology can promote efficient construction operation, improve the quality of customer service, reduce the occurrence of emergencies at the stage of construction operation, improve safety performance and avoid resource waste.

At the stage of building maintenance, renovating existing buildings can promote the protection of natural resources, greatly reduce energy consumption, and bring a safer and cleaner living environment. With more and more attention paid to the energy efficiency of existing buildings in operation, building managers are looking for ways to improve their structural sustainability. Approaches to this goal include adding sustainable design attributes, reducing operating costs, limiting environmental impacts, etc. All of these goals have become a top priority in the renovation of existing buildings.

4.1.2 Building the BIM-based application system for the sustainable development in the lifecycle of green building

(1) Main Functions

Building Information Modeling (BIM) is characterized with information completeness, consistency and relevance. Therefore, it is necessary for BIM-based application system for the sustainable development in the lifecycle of green building to build BIM database for the first place to store information in the lifecycle of green building. The engineering information in this database should be comprehensive and should be updated frequently and rapidly.

BIM-based application system in the lifecycle of green building needs to provide a unified working platform for all participants in the construction process, which should have the management functions in terms of quality, cost, schedule, safety, energy saving and environmental protection in the whole process.

(2) Key Technologies

The establishment of a unified coding system is the basis of BIM Application. The same coding mode should be used in the whole process of the construction project, that is, at the stages of planning, design, construction, operation and maintenance. Only in this way can the models and data at each stage of the construction project be connected together, which is conducive to the supervision of the management personnel.

The core of BIM-based application system for the sustainable development in the lifecycle of green building is the establishment of the BIM model. And the application programming interface can extend the function of BIM Technology. Through the combination of API interface and Revit model, more professional energy consumption analysis, structure analysis and cost analysis can be carried out, which provides a common platform for each

participant in the whole process of construction project to achieve expected effect of BIM-based application system for the sustainable development in the lifecycle of green building.

(3) Workflow

Planning

The planning in the lifecycle of green building is mainly about investment estimation and site selection in the early stage of construction project. Firstly, the basic information of the construction project is input into the BIM system to build the basic model, or the traditional 2D model built by CAD or PKPM is imported into Revit, a BIM core modeling software, and the preliminary analysis is carried out based on the unique 3D visualization of the BIM model. The historical data in BIM database is used for planning comparison and selection, and the appropriate site and building orientation are decided after the analysis of the surrounding environment. At the same time, the investment estimation of each plan is carried out to help the decision-making, during which the best plan is selected. It is necessary not only to reach the standard of green building, but also to control the capital investment as far as possible, so that the construction project can meet the requirements of green building at the planning stage.

Design

At the design stage in the lifecycle of green building, designers of various specialties and BIM technical engineers cooperate to transform the traditional 2D drawings into well visualized 3D drawings with Revit, improve the design effect through simulation and rendering, and carry out interference check among various specialties to find out potential problems as soon as possible. The feature of 3D visualization can also be used to analyze the basic energy consumption of green building, make rational use of existing resources and natural environment around the buildings, reduce waste and pollution to the surrounding environment, so as to achieve the standard of green building. More professional and systematic energy consumption analysis can be done by using external software through API interface, which is also applicable to buildings with higher level in energy saving and environmental protection.

Construction

At the construction stage in the lifecycle of green building, the BIM collaborative platform can also assist the arrangement of plane layout at the construction stage by locating the construction materials and equipment in a reasonable position to minimize the transportation time and waste of materials in the transportation process. And the information in the construction site can be timely feedback through the collaborative platform, which enable the owners to update the progress of the project, to check whether the target progress of each construction section has been achieved, and to further allocate the resources of personnel, materials and machines after comparing the actual progress against the target schedule, which is conducive to the progress management and cost control of the project. The feature of BIM construction simulation can be used to simulate the key technical points which are prone to quality problems, fulfilling the task of quality management of the project in the early stage of construction, so as to prevent the occurrence of any accident. Meanwhile, dangerous sources in the construction process can also be identified and confirmed by referring to the construction plan and simulation construction, which is conducive to the safety guarantee in the construction process.

Operation and Maintenance

At the operation and maintenance stage in the lifecycle of green building, property and management personnel can track and manage building components in later period with the database generated at the construction stage of the project. The feature of BIM 3D visualization can create escape simulation in BIM model, monitoring the emergency exit at any time to ensure smooth escape routes, as well as timely and efficient emergency response in case of accidents. Since the energy consumption analysis of green building have been carried out in terms of sunshine, acoustic environment, ventilation environment and emergency evacuation at the design stage of the project, the data of these professional analysis recorded in BIM database can help formulate specific green

operation plans for a green and sustainable operation of the building in the later stage.

(4) Framework Construction

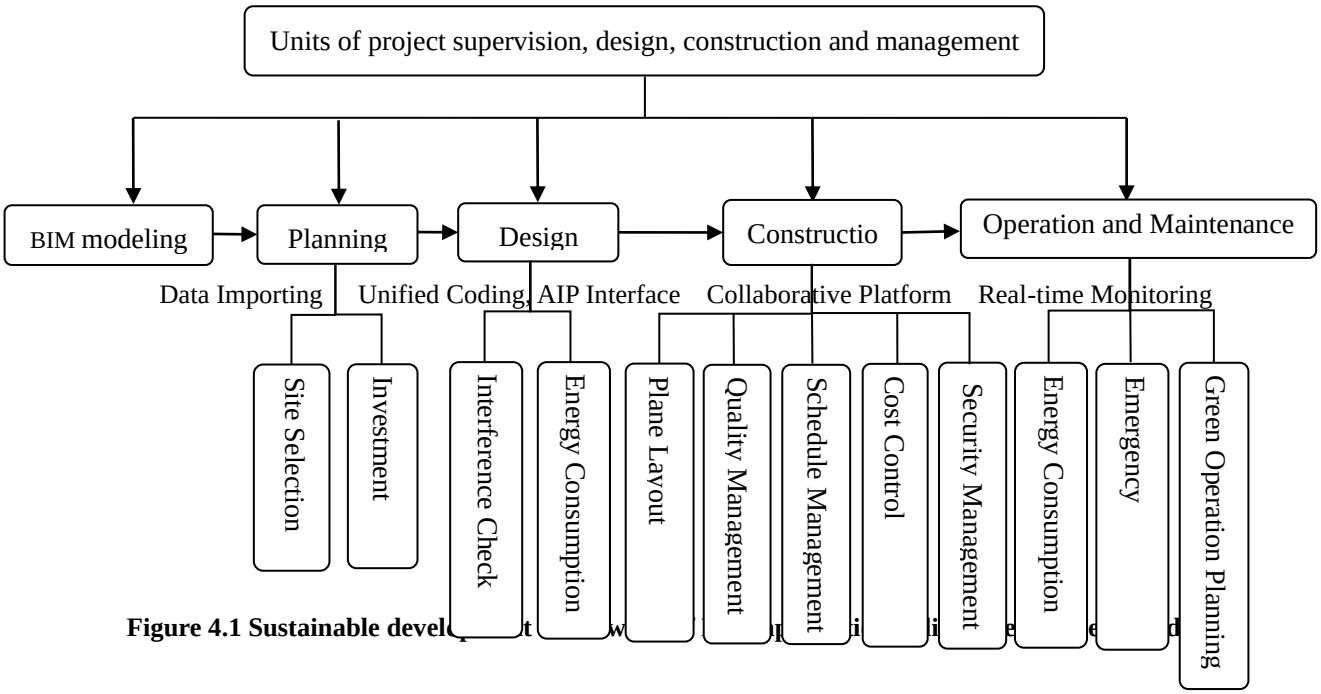

Figure 4.1 Sustainable develo t w i i e d

4.2 Case Analysis

The student activity center of a university (Fig. 4.2)

Figure 4.2 Project rendering

4.2.1 Preliminary Planning

In the early preparation of this case, a BIM team was jointly set up by all the departments in the project such as design and project management, etc., making it possible for all the personnel involved in the project to communicate and interact through the collaborative platform. In addition to completing their share of task, the personnel can also participate in the whole process of the project and put forward constructive suggestions for tasks at other stages, which saves much time and cost that would have been spent in separate handover, and promotes the project to advance smoothly and quickly.

Autodesk Revit series was adopted as the BIM modeling software in this project with Autodesk NavisWorks being the BIM model browsing software. The 2D drawings of buildings on paper were transformed into 3D BIM information model (Fig. 4.3), and the digitalized system is established through BIM technology. The 3D visualization of the building model offers a clearer modeling result which is easier to perceive.

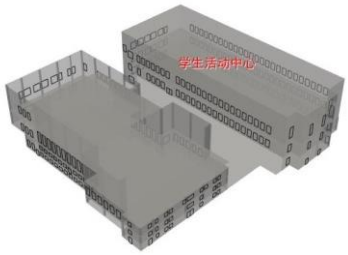

Figure 4.3 3D information model

This 3D model enabled the construction unit, designer and consultant to have a direct and overall understanding of the project; on this basis they could analyze the construction plan and investment cost, and comprehensively evaluate various alternatives. The cost of project in building lifecycle was then estimated through the evaluation model in BIM database to control cost, improve quality and shorten construction period at the stage of planning and decision-making. In terms of technology, BIM can analyze a number of building performance, including lighting, environment, noise impact, ventilation, etc. It can put planning project into the current environment, demonstrate its environmental and economic benefits, and analyze the changes of environmental indicators of new buildings, so that users can determine the most appropriate building plan.

4.2.2 Construction Design

(1) Collaborative Design

BIM can provide reliable technical support for collaborative design to effectively improve the technology in architectural design. Designers of different specialties and regions can coordinate through internet. BIM application in engineering design can demonstrate independent design results of multi-system and various specialties in a unified 3D collaborative design environment, greatly improving the quality and efficiency of architectural design.

(2) Interference Check

In this case, BIM Technology was used to build the building model in each group. Interference checks were carried out, whose results were summarized in the building installation model (Fig. 4.4). in this basis, the 3D model was adjusted appropriately. Then based on the consideration of the priority and influencing factors of each domain, the comprehensive design of electromechanical pipeline was carried out to improve the efficiency of the overall pipeline design. BIM application in pipeline design can eliminate conflict and interference, reduce design change, save cost and speed up efficiency in the construction process; what's more, it can provide corresponding data for the maintenance and management of the building in the later stage.

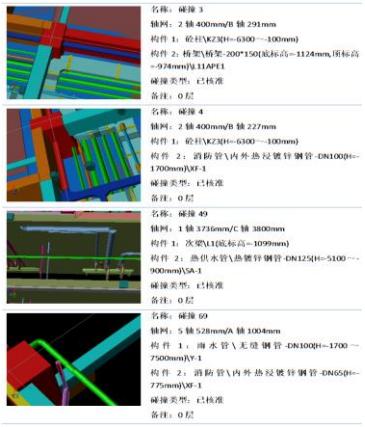

Figure 4.4 Results of interference checks

Many potential problems were found through BIM interference analysis at the design stage, which are summarized as follows:

1. Interference in structural design;
2. Insufficient space of pipe shaft;
3. Interference between the electrical pipelines and wall stringers in civil structure;
4. Unreasonable position of embedded parts;
5. Asynchronous between structure and electrical pipeline design.

(3) Energy Consumption Analysis

The wind environment simulation (Fig. 4.5), daylighting environment analysis (Fig. 4.6) and outdoor noise simulation (Fig. 4.7) were made in the project at the same time. The influence of air circulation, light and sound field on the building were taken into consideration, so that the air conditioning system can cooperate with natural wind, and energy-saving lamps can cooperate with natural light. The sound pollution to the surrounding buildings was also considered to save resources and energy as far as possible and to maximize the advantages of green building.

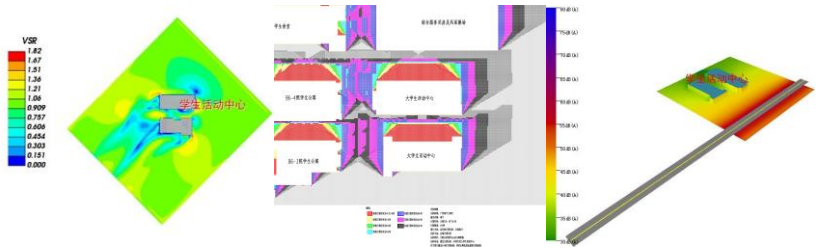

Figure 4.5 Wind environment simulation Figure 4.6 Daylighting environment analysisFigure 4.7 Outdoor noise simulation

4.2.3 Construction Management

(1) Quality Control

BIM model can store information such as the model, price, component property, performance and manufacturer of the materials and equipment used in construction, which is convenient for construction units to update their information on the use of materials and equipment, and to effectively control their quality. BIM can be integrated with wireless network technology to facilitate quality management of the construction project. In this case, photos of the construction site were uploaded in the BIM system for the construction unit, the supervisors and other management departments to grasp the actual situation of the construction site at any time, achieving a dynamic monitoring of the construction site during the whole process. If the management personnel want to better catch up with the site conditions of concealed works and key projects, they can associate site photos and documents with corresponding BIM model to improve the management of construction site.

(2) Progress Control

Progress management in the process of construction through BIM can be achieved by construction information model which is established when time factors are added to the initial model. BIM visualization platform can improve construction layout, resource allocation, quality management and safety management in the construction process. Construction simulation can reveal some hidden problems appearing at the design stage for us to modify and solve in time, which can shorten the construction period.

(3) Cost Control

When the user specifies the construction object and selects the time in the BIM environment, the system can generate the 3D image of the current progress according to the construction schedule. The simulation can be displayed in both the progressive order and the reverse time order. It can also obtain the information of engineering quantity and construction resources such as personnel, materials and equipment at any time, so as to achieve a

dynamic control of the whole construction process. According to the actual completed quantities of a certain stage, the budget can be prepared in combination with the budget quota, and then the total cost of the stage can be calculated. With the continuous progress of each construction section of the project, it can also calculate the cost changes in the construction process, providing reference for the cost control of construction projects.

4.2.4 Operation and Maintenance

After the completion of the project construction follows the stage of operation and maintenance. Both building and equipment should be maintained regularly in the service lifecycle of the building. The seamless transfer of project assets from the construction stage to the stage of operation and maintenance can be achieved through BIM model. The data information required by project operation and maintenance depends on BIM model, too. We can build an operation and maintenance platform for the construction project to link BIM data with operation and maintenance plan, so as to carry out remote monitoring of construction equipment and property management. According to the data obtained from the monitoring, we can judge the equipment operation. On this basis, we can formulate a scientific and reasonable equipment maintenance plan to minimize the rate of equipment failure and to save the cost of project operation and maintenance. At the same time, BIM Technology enables us to analyze the energy consumption in the process of equipment operation, formulate corresponding energy-saving measures, analyze the use of building space, and reasonably allocate the effective space of buildings, so as to improve the utilization efficiency of space resources. The dynamic association between 2D drawings and 3D models helps conduct the integrated management of drawings and models, which can provide drawing support for decision-making, management and operation of relevant personnel, meet the needs of project management of green building, solve the problems of scattered drawings and inconvenient management, and ensure the sustainable application of original drawing resources. (Fig. 4.8)

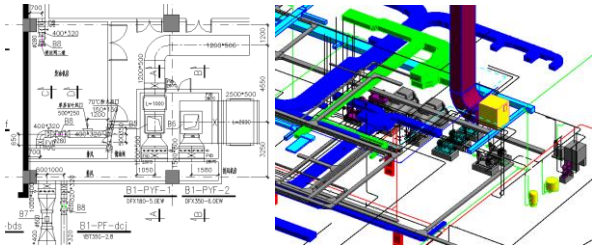

Figure 4.8 Drawing-model integration management

5 Conclusions and Suggestions

5.1 Conclusion

5.1.1. BIM Application Plan for the Sustainable Development

This paper analyzes the basic concept of BIM and sustainable development of green building, as well as relevant research at home and abroad, and summarizes the BIM application plan for the sustainable development in the lifecycle of green building on the basis of the concept, basic characteristics and standard of BIM, the concept and standard of green building, and the concept of building lifecycle.

5.1.2 BIM System in the Life Cycle of Green Building

This system has a huge and complex database for building energy efficiency simulation and real-time participation of all participants. The information in the construction process can be coded and stored by category, and then connected with specialized energy consumption analysis software by API interface. With the IPD collaborative platform based on BIM Technology, it can help achieve the sustainable development in the lifecycle of green building.

5.1.3 Feasibility and Application Advantages of Project Case

Through specific case of project, it is proved that BIM-based application system for the sustainable development in the lifecycle of green building can give full play to the advantages of BIM Technology, raise the green level of construction project, improve the technology of the construction industry, promote the comprehensive informatization and modernization, and bring greater development for the construction industry in a more sustainable and healthy direction.

5.2 Suggestions

5.2.1 Suggestions on Research Contents

At present, the construction industry is still faced with some obstacles to the BIM application and development, which are mainly caused by the lack of BIM personnel, incomplete BIM software for China's construction industry, the lack of coordination and cooperation among project participants, and the over-application of BIM to meet the green building standards. In the future, we can focus on BIM application combined with 3D printing to double highlight the BIM 3D model. We can combine BIM with prefabricated buildings to further reflect the difference between green building and traditional building. We can also combine BIM with big data and Internet to facilitate the storage and selection of information in the database, making it more convenient to collect and manage information in construction projects.

5.2.2 Suggestions for Case Study

In practical project, BIM can be applied to set up a reasonable model database of building information to improve the accuracy of architectural design, as well as construction quality and safety. The BIM-based system of operation and maintenance can be linked with construction equipment operation to achieve efficient management of building such as maintenance planning, space management and disaster prevention.

5.2.3 Suggestions on Research Methods

The technologically powerful BIM model can facilitate the management research of sustainable development in the lifecycle of green building. However, BIM is usually cross applied with methods in other fields such as computer science, numerical method, finite element method, control theory, and database management, etc. And collaborative work of multi-disciplinary is needed to ensure that the complicated structure can be treated with standard and rigorous research and processing means, so as to guarantee a good foundation for the development of the construction industry. In the future, we should integrate BIM with other technologies, and strengthen the research on renewable energy in building materials. All in all, we need to make full use of the powerful analysis capacity of BIM as the green building lifecycle database to achieve the goal of green and sustainable development in building lifecycle.

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