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Analysis and prospect of green building engineering based on BIM technology

Yitong Chai[1,2]

[1]School of Civil Engineering, Central South University, Changsha, 410083, China

[2]8406200101@csu.edu.cn

Abstract. Accelerating the application of information integration technology, represented by Building Information Modelling (BIM) technology, in green building projects is important to meet the demands of sustainable and high-quality development of the construction sector. According to the development status of BIM technology, the specific application of BIM technology in green building design and construction is first introduced. On this foundation, the importance of the appropriate BIM technology functions to the creation of green buildings is examined. It shows the outstanding advantages of green building projects based on BIM technology. In the architectural design stage, BIM technology can accommodate more architectural details than traditional design, and greatly improve the efficiency of information communication between project parties during the design process. In terms of building construction, building details being planned using BIM technology can greatly reduce the waste of resources. Thus, it can meet the requirements of green construction and provide guarantee for the construction period and quality. This paper can provide technical reference for the BIM-based green building design and construction stage application of similar projects by relevant practitioners and construction enterprises.

Keywords: BIM technology, green building, design, construction.

1. Introduction

The growth of the construction industry, one of the foundational sectors of the Chinese economy, has greatly benefited society as a whole. Since the 18th National Congress of the Communist Party of China (CPC), the construction industry has maintained a steady and healthy development in the face of the impact of the novel coronavirus epidemic. The added value of the construction industry has always maintained around 7% of the Gross Domestic Product (GDP), ensuring its stable position as a key sector of the economy of the country [1]. However, with the rapid economic growth and social progress of China, the simple GDP growth can no longer be used as the only indicator to measure economic development. With the issuance of the "14th Five-Year Plan" comprehensive work plan on energy saving and emission reduction, it has become the main goal of China's economic development at present to accelerate the establishment of a green, low-carbon and circular development economic system and promote the all-round green transformation of economic and social development.

According to the Research Report on Building Energy Consumption and Carbon Emissions in China (2022), the total energy consumption of China's construction industry in 2020 has reached 2.27 billion tce, representing 45.5% of the nation's overall energy usage [2]. It can be seen that being a conventional

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energy-guzzler, the construction industry has been quite urgent to transform the green energy saving work. The Chinese government has produced hundreds of green building laws to encourage and promote the widespread adoption of green building, spurred on by the benefits of such buildings. Over the past ten years, China has seen a surge in the number of new green buildings as a result of legislative support for their promotion [3]. According to the Ministry of Housing and Urban-Rural Development, by the end of 2020, China had built more than 6.6 billion square meters of green building space [1]. Industrial transformation and upgrading must be driven by corresponding technological innovation, and the development of green buildings is made possible by the use of information integration technologies in the construction sector. As one of the representative technologies of information technology, the application of Building Information Modelling (BIM) technology has made great contributions to the transformation and energy saving and emission reduction of the construction industry.

As a computer-aided technology popularized in the recent past, the core function of BIM is the three-dimensional engineering technology model established on the basis of data information. Information model is the digital and visual expression of the features and functions of a construction project. This technology makes it possible to handle and control all of the project information for construction. As a new visual information interaction platform, BIM technology can be applied to the whole life cycle of a project, including architectural design and construction. BIM technology has becoming widely adopted in western industrialized nations as the subject of green construction continues to flourish. Relevant professionals from other nations have also carried out pertinent further studies regarding the system of theory and technology of BIM and made significant advancements [4]. For the research and application of BIM technology, China has not lagged behind. However, as the development of China's construction industry is mainly driven by small and medium-sized enterprises, BIM technology is an emerging technology and has not been popularized by relevant national norms. Most of these enterprise managers lack of understanding of the functions and application advantages of BIM technology. These factors lead to the overall recognition of BIM technology in China is still at a low level, which also seriously restricts the construction industry to the transformation of green environmental protection mode. To sum up, it is particularly crucial to integrate the application of BIM technology in the engineering field and briefly describe its main functions and advantages, so as to provide technical guidance and reference for traditional design units and construction units.

Starting from the design and construction of green building engineering, this paper introduces and analyses BIM model construction, work flow and detail control. On this basis, combined with its practical application in engineering projects, the particular use of BIM technology and its benefits in the current industry transformation stage are demonstrated.

2. BIM technology

2.1. BIM model definition

The application of BIM technology is realized through the form of computer software. However, to realize the comprehensive management and analysis of information through BIM, it relies on a BIM technology system composed of several or even more than ten pieces of software. Each software in this system has its own unique function, and has its corresponding application during different periods of construction work. After the summary of the data and literature, the main application functions can be listed, as depicted in Figure 1. Therefore, for the definition of BIM technology, it must be a very broad concept, rather than a general description of its specific functions. The origin of BIM technology can be traced back to the "Building Description System" proposed by Chuck Eastman in 1974. Through this concept, he put forward the processing method based on architectural attributes and pointed out the future trend of information integration technology. According to Wikipedia, BIM technology includes information on supplier data as well as geometry, spatial linkages, geographic information systems, and the nature and quantity of different building components. BIM building information model can be used to directly obtain the whole life cycle state of engineering projects, from the initial design stage, to the whole process of construction stage and the final operation stage [5].

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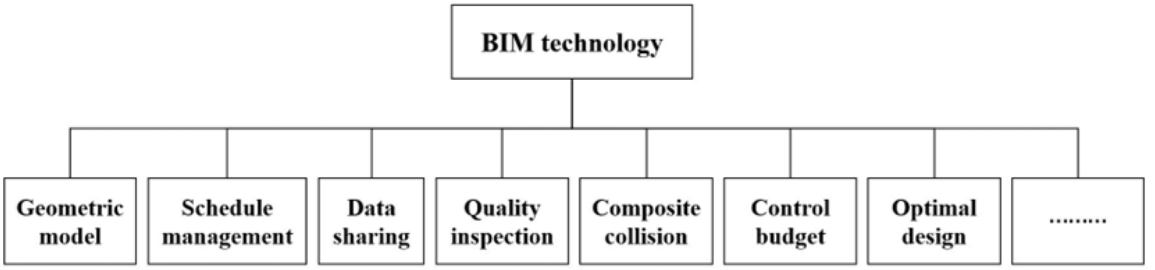

Figure 1. List of main applications of BIM technology.

According to the relevant definition, the data information covered by the BIM model is quite rich. As long as the user can provide enough complete building data, it can realize a series of functions such as multidimensional simulation, design and analysis of the whole building project in the computer. In general, BIM technology can be regarded as a detailed digital model, which is an intuitive presentation of the whole process of effect details and cost cycle of construction projects. The model contains almost all the characteristics of the whole construction project, which has great reference value and practical significance for both the investors and the construction side.

2.2. BIM technology development status

Since the 1980s, Graphisoft has proposed the concept of virtual building model (VBM), indicating that the research on BIM related technologies has started. Later, ArchiCAD software was launched, and more and more enterprises began to participate in the research of BIM technology [6]. Realizing the outstanding advantages of BIM technology application, more and more developed countries begin to invest in related research and software development optimization. After vigorously promoting the development and popularization of BIM technology, BIM is gradually applied in Europe and the United States (US). Take the US for example, as early as 2009, the share of BIM users in the US has increased to 48%. At this time, more than 50% of architectural design enterprises and more than 60% of design projects had already applied BIM technology. While the technology is highly popularized, in terms of standardization, the National Academy of Building Sciences of the US released three versions of the National BIM standard based on Industry Foundation Classes (IFC) in 2007, 2012 and 2015 respectively. Now a complete and feasible BIM technical specification system has been basically formed.

In China, the Chinese government has been hoping to promote the popularization of BIM technology by implementing relevant policies. The 2016-2020 Informatization Development Outline for the Construction Industry was released by the Ministry of Housing and Urban-Rural Development as early as September 2016. The outline suggests four tasks for the construction sector: standardization of information technology, particular information technology application, industry oversight and service informatization. It The outline also states that during the 13th Five-Year Plan period, the informatization level of the construction industry should be comprehensively improved and information technology, such as BIM technology, should be better able to integrate applications. In order to promote the construction industry digitalization, networking, intelligent breakthrough. This is sufficient evidence to support national efforts to encourage the use of information technology in the building industry. Under the guidance of such policy environment, many scholars and enterprises have devoted themselves to the exploration and research of BIM and other technologies, and have made certain progress in this field. In response to some specific problems of the project also began to gradually put into use. However, just a handful of sizable businesses who can afford to hire the necessary specialists are now using BIM technology across the entire construction sector. The ability to penetrate the primary market for small and medium-sized businesses is still quite limited. And there is still a certain gap between developed countries in terms of the overall development process and the formulation of industry-related norms.

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3. Application of BIM technology in green building design stage

Architectural design can be said to be one of the first fields to apply BIM technology. The building information model contains almost all the architectural characteristics required for design and can be presented in the most intuitive way. Especially for green building design work, the coordinated adjustment of all kinds of information can more effectively improve the utilization rate of resources and work efficiency, which has a major impact on the creation and marketing of green buildings.

3.1. BIM design compared with traditional design

Compared with the previous architectural design work, the biggest feature of using BIM technology for design is to abandon the traditional two-dimensional drawing design, and the transformation from two-dimensional to three-dimensional indicates that the design results will contain more architectural details. Moreover, the visualization effect brought by the establishment of the model enables non-professionals to intuitively understand the design details such as the shape and structure of the building.

Through the information interaction platform created by BIM concurrently with the design of the construction project, the stakeholders in other stages of the project are also able to evaluate the design of the construction project in different directions thanks to the improvement of information presented in the design scheme. The communication and interaction of information will greatly improve the work efficiency, and gradually promote the integration process of design work and follow-up work, that is, close to the engineering model of Engineering Procurement Construction (EPC). In the meantime, the integration process of design work and follow-up work is gradually promoted, as shown in Figure 2, that is, close to the engineering mode of EPC design and construction integration [7]. With the emergence of new operation modes, BIM technology will gradually integrate with the current requirements of green building development in the context of industry transformation and the introduction of a large number of green building projects. Finally, it will improve the efficiency of the project and bring benefits in terms of environmental energy saving.

Figure 2. Information transfer and integration in the whole process of BIM [7].

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3.2. Simulation and effect analysis of building model

As an information model technology composed of many kinds of software, after the three-dimensional simulation and construction of the building, the model can also be imported into the relevant analysis software of the exploration direction required by the project. The effect of the subsequent operation stage of the building is further simulated and analysed.

For the green building project, the use of BIM technology in the early modelling stage is a large amount of work. Only with sufficient information parameters can a complete 3D visualization model be constructed and simulated in subsequent analysis software. For green buildings, BIM technology can perform quite rich simulation and analysis work, involving building lighting, indoor ventilation, sound environment, indoor humidity, fire performance and a series of key links in the process of building operation. For example, by loading the building model into Ecotect, a program for environmental analysis, the simulation effect of the building indoor solar radiation can be obtained as shown in Figure 3. The depth of the colours in each position in the diagram intuitively shows the strength of the solar radiation throughout the building. The approximate value of the solar radiation at a certain position can also be obtained by matching the corresponding notes of the colour radiation quantity next to it. Therefore, the indoor lighting effect of the original architectural design scheme can be optimized based on the original model, such as window opening or shading facilities. Finally, the indoor light environment in the design stage has been effectively tested and reached the corresponding national standards [8]. Additionally, BIM technology's tools for fluid computing and acoustic environment simulation can be used to test a building's physical features in the appropriate sectors. For green buildings with high requirements in energy saving and emission reduction, the ability to optimize lighting and ventilation in the design stage can be regarded as one of the most prominent advantages of BIM application in this field.

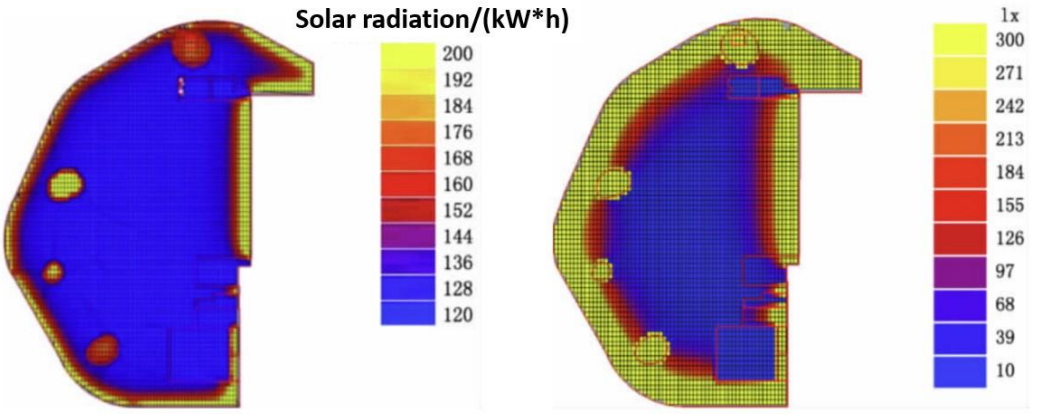

Figure 3. Solar radiation simulation renderings [8].

When the project is in the demonstration stage, BIM technology can be used to select specific objects such as materials and processes for modification. After modification, the simulation operation effect of different versions of the model can be comprehensively compared and displayed. It not only saves the demonstration cost but also visually shows the advantages and disadvantages of the scheme design for other related personnel of the project. Understanding of the details of the project will be improved, which will also facilitate the subsequent work of the project.

3.3. Integration of design process and information data

BIM technology's use in the sector of green construction not only provides a three-dimensional visual model, but more importantly is an information interaction platform built through the digital information provided by the building model. All digital information about the building will be shared with all professionals including designers and builders through this platform. In this way, the construction planning scheme can be crossed with the design scheme to a certain extent, and the traditional sequential

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construction will be replaced. Therefore, a new concept of project Management called Building Lifecycle Management (BLM) is generated. This pattern through constructing a bridge among different areas, make the whole process of the internal contact to coordinate more closely, thus reducing the invalid communication in the traditional process etc. This can reduce ineffective communication in the traditional process, greatly improve the efficiency of construction projects and greatly avoid the possibility of work conflicts between different departments. Part of the construction of the possible problems in the design phase can be timely communication and solution. The simplification of the process will also save a lot of resources, which also caters to the concept of green building design. It can be said that BLM model based on BIM is one of the most effective engineering models at present [9].

4. Application of BIM technology in green building construction stage

4.1. Green construction concept requirements and development status

As early as 2007, the then Ministry of Construction issued the "Green Building Guidelines". In 2011, the Ministry of Housing and Urban-Rural Development issued the "Evaluation Standards for Green Construction of Construction Projects" to actively promote green construction in the construction industry. On April 25, 2012, China Construction Industry Association officially established Green Construction Branch and held the first member representative meeting. According to the Outline of the 12th Five-Year Plan for National Economic and Social Development, the construction industry should promote green buildings and green construction. The significance of green construction as the future development trend of the building sector is becoming increasingly crucial. The notion of green construction is becoming more distinct as the normative system is gradually improved. Generally speaking, "green construction" refers to engineering construction activities that maximize resource savings and minimize environmental harm through scientific management and technological advancement under the presumption of ensuring quality, safety, and other fundamental requirements. The ultimate goal is to achieve the ultimate goal of four sections and one environmental protection, namely energy saving, land saving, water saving, material saving and environmental protection. The application of BIM technology in the field of construction is guided by these five basic requirements, and corresponding research is gradually carried out at the level of technical management, and finally applied in engineering practice.

4.2. Pre-simulation of the construction process

With the high simulation and three-dimensional visibility of BIM technology, not only the design stage can be modelled and displayed, but also the whole construction process can be simulated through modelling and animation in the construction stage. The parts that can be simulated include but are not limited to construction site layout, earthwork calculation, integrated management of water and electricity, pipeline management, etc. It can be said that through these functions and data collected, the simulation and construction of the whole construction site can be basically completed. As shown in Figure 4 shows the construction areas in each phase of the specific conditions. Same as in the design stage, after the model is perfected, relevant facilities can be reasonably placed through the simulated construction site and continuously optimized and adjusted towards the goal of energy conservation and emission reduction. Accurate simulation can help determine the approximate amount of basic building materials such as formwork and scaffolding needed for the project, thus helping the construction team to maximize the savings of water, electricity and consumables. The pre-simulation of the scheme can also be carried out in the arrangement of the equipment and pipeline required by the site, which can also help the construction project land layout more reasonable, and greatly improve the intensity and land utilization of the project site [10].

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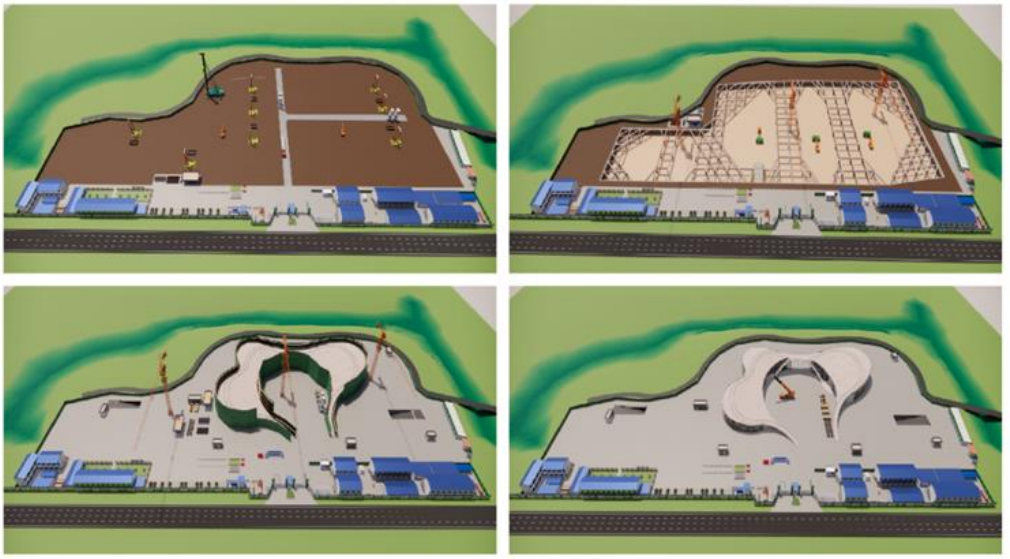

Figure 4. Simulation of the construction site [11].

At the same time, with the continuous improvement of supporting technologies for green buildings, in the design stage of green buildings, numerous gadgets like whole-house intelligence, rainwater recycling, and photovoltaic systems will be taken into account. However, as different technologies have their own independent operating systems, it often causes conflicts and incoordination among pipelines and other problems between different modules in the design summary. This kind of problem is often difficult to find in the manual audit, which will eventually lead to rework or construction stagnation in the construction process. For such problems, the 3D collision simulation function of BIM technology can provide corresponding solutions. Software such as Luban Virtual Collision can help test the possibility of collision in civil construction, pipeline, equipment and other aspects of the whole green building project, as shown in Figure 5. On this basis, not only the existing problems can be corrected, but also the existing network cable can be optimized [12]. The use of simulated collision can greatly improve the construction efficiency of green buildings and effectively improve the utilization rate of internal pipe network space of green buildings, and reduce unnecessary waste of resources.

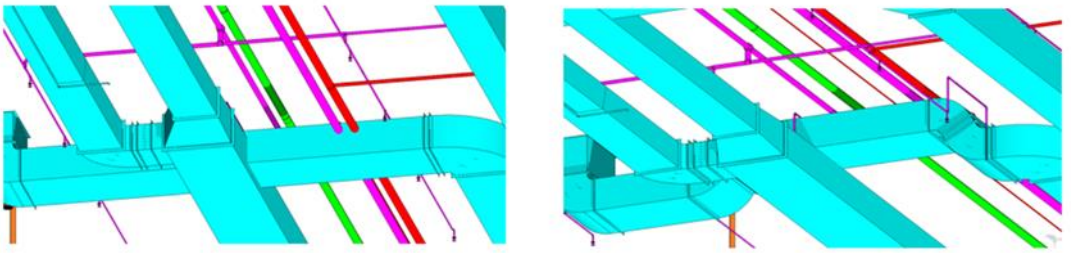

Figure 5. Virtual collision adjustment before and after comparison [13].

In addition, for some large public green buildings or new kind of green buildings involving special materials, higher safety requirements should be put forward for the buildings themselves. Whether in the construction process or in the operation stage, consideration must be given to personnel safety in its whole, that is, personnel evacuation and emergency treatment in the construction area in the event of an emergency. In this regard, the BIM model can be used to match the corresponding disaster simulation system to fully simulate and prepare plans for man-made and natural disasters and secondary disasters. This is also of great significance to the promotion of BIM technology and green building [14].

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4.3. Comprehensive management of construction process

Different from the pre-treatment of construction, the exact scheme should be given in the early stage of construction. The construction management is the work throughout the whole construction process. It is a crucial link to the project's overall smooth development. The standards for construction management become more stringent as green building becomes more prevalent, and the use of BIM technology also brings construction management a little bit closer to information and intelligence. At this stage, a set of green building construction intelligent management system based on BIM technology has been preliminarily formed. This system can integrate and share construction technology, field data, project progress and other aspects to establish a green building intelligent management platform, in order to provide strong support for the development of green construction [15].

For green building projects, the construction process should be environmentally friendly to ensure that the surrounding environment will not be damaged due to construction. This is the inherent requirement of green building engineering, and also the main purpose of BIM technology application. The specific fields of operation mainly include construction noise, dust detection, hydropower monitoring, waste treatment and so on [16]. The realization of the above functions is basically through the real-time detection of intelligent detection equipment and the data is transmitted to the platform built by BIM, and finally accepted by the relevant personnel. Noise and dust generally cause damage to the surrounding environment and affect the daily life of nearby owners. Hydropower and waste can also be regarded as a waste of resources if they are not properly recycled for green building projects. It can be seen that for green building engineering, it is necessary to build a project management platform by introducing BIM technology in the engineering process to manage the whole construction process. At present, the existing engineering examples use the software Dynamo under BIM technology to customize the management system for the corresponding project, and conduct real-time data feedback and processing on the engineering site through the work system corresponding to the list items [17]. This also shows that BIM technology has a broad application prospect and strong adaptability in green building project management.

5. Conclusion

By connecting the specific functions of BIM technology with the relevant specific fields in different stages of green building engineering, this paper demonstrates the application advantages and broad prospects of BIM technology in the field of green building engineering. The conclusions can be briefly summarized as follows.

(1) Compared with the traditional architectural drawing model, the 3D visual model of green building constructed by BIM technology can contain more information elements. It is convenient to display the design details of green building projects and provide more detailed reference for further optimization of energy conservation and emission reduction.

(2) The information exchange platform built by BIM technology can help project parties to communicate and coordinate in a timely manner, and help green buildings to meet the requirements and expectations of all parties as much as possible in the design stage. This avoids discrepancies between the formal construction phase and the project schedule.

(3) The use of BIM technology to simulate engineering construction is conducive to the reasonable allocation of resources and ensure the smooth progress of the construction process. It is necessary to minimize the noise and waste generated during the whole construction process, so that the construction stage of the project meets the requirements of green construction.

(4) BIM technology is used to build a green project construction intelligent management platform, which can monitor the information in the process of project construction in real time. In this way, problems can be found and solved in time. This helps to improve the quality of the project and ensure that the project is completed on schedule.

To sum up, BIM technology must be used to create green buildings because the construction industry is generally going through a crucial time of upheaval. With the help of information technology, green buildings will surely usher in new development, which will bring not only the iterative upgrading of

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building technology, but also the environmental dividends of energy conservation and emission reduction. Perhaps there will be a more comprehensive BIM technology green building integrated working platform in the future, which will greatly reduce the difficulty of operators and promote the popularization of BIM technology. It is hoped that the findings of this study will serve as a resource for further businesses and construction professionals interested in using BIM technology in green building projects.

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