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A Review of Low-carbon Building Applications Based on BIM Technology

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Abstract: *The development of low-carbon buildings relies on the data integration advantages of BIM technology. On the basis of reading relevant literature, this article reviews the research progress and application status of low-carbon buildings based on BIM in recent years. The summary of research can be divided into three aspects: measurement and evaluation of carbon emissions, identification of abnormal carbon emissions, and active control of carbon emissions. Combined with the four dimensions of "low-carbon", "BIM", "performance evaluation", and "full life cycle", this paper finally elaborates on the application framework of low-carbon building based on BIM and provides research prospects.*

Keywords: *BIM, Low carbon buildings, Full life cycle, Carbon emissions, Low carbon assessment*

1. Introduction

The concept of "low carbon building" was first proposed in the British white paper in 2003[1]In summary, low-carbon buildings aim to improve energy structures and enhance energy efficiency throughout their entire lifecycle, from design and construction to operation and demolition, thereby reducing carbon dioxide emissions and meeting the requirements for sustainable human society development. Analyzing the core concept of low-carbon buildings, they can be described as architectural spaces constructed using clean energy, with low energy consumption and low CO2 emissions, throughout the projects life cycle. These buildings will promote more effective and comfortable building ecosystems based on actual energy-saving and emission-reduction practices in construction materials and other aspects of the project. Green buildings, eco-friendly buildings, and sustainable buildings are all forms of low-carbon buildings. Developing low-carbon buildings has become an important aspect of addressing environmental degradation, improving resource scarcity, and achieving sustainable human society development both domestically and internationally[2]In terms of the total carbon emissions and energy consumption, the construction industry accounts for 39% of greenhouse gas emissions and 36% of energy consumption, which shows that the construction industry needs to play an important role in achieving the goal of energy conservation and carbon reduction.

Building Information Modeling (BIM) technology is a massive integration of information databases, lifecycle management, and multi-dimensional entity models, featuring four major characteristics: information completeness, overall goal parameterized modeling, three-dimensional visualization of entity models, and diversified conclusions derivation. It achieves this through digital modeling and data management, supported by computer-aided technology. By collecting data information, it realizes data input and multi-dimensional modeling, integrating all relevant information of construction projects into a visual 3D model. This model is used to coordinate the design, construction, and operational management of various parties throughout the projects entire lifecycle. The data integration capability of BIM can seamlessly communicate structural, material, and process information, as well as integrate various parameters for carbon emission measurement[3], Support dynamic measurement of carbon emissions, automatic optimization, real-time decision analysis and other types of functional modules.

In general, due to the complex structure and long life cycle of buildings, it is difficult to collect data for carbon emission calculation. BIM, as the information carrier of buildings, is an important tool for data integration, simulation and functional analysis throughout the life cycle of buildings, which can provide strong data support for carbon emission measurement[4], Integrating it into the research of carbon emissions in the whole life cycle of buildings is a trend of industry development, and has the potential to provide a foundation for the research and implementation of low-carbon building technologies.

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2. History of BIM Technology Development

Eastman[5]The concept of BIM was first introduced in 1999. In 2003, the United States released its National BIM Guidelines, marking the true emergence of BIM on the historical stage. BIM technology was then introduced to China and widely applied in various engineering projects. In 2011, the countrys "12th Five-Year Plan" explicitly stated that BIM should be a key goal for the development of the construction industry. Prior to this, BIM was merely used as a modeling tool for simple tasks such as 3D model design or collision detection, with its data value not yet fully realized.

In 2014, Building Carbon Emission Measurement Standard (CECS 374:2014)[6]The standard was officially implemented, which combined BIM model and building carbon emission calculation for the first time. Since then, more and more scholars began to study the specific application of BIM technology in the field of carbon emission calculation, such as the measurement method of carbon emission in the physical and chemical stage of building products based on BIM and bill of quantities[7], A BIM-based carbon emission measurement platform for the whole life cycle of buildings, etc., to gradually promote the quantification and automation of carbon emission accounting.

In 2015, Green Building Evaluation Standard (GB/T 50378-2014)[8]Incorporating the calculation of building carbon emissions and their footprint analysis into the innovative scoring system for green building evaluation provides a new entry point for BIM applications in carbon emission calculations. Relevant studies, based on the "Evaluation Standards," have established a dynamic integration mechanism that combines BIM technology with low-carbon green building evaluation indicators to assist in the planning and implementation of low-carbon green buildings[9]At this stage, BIM technology is mainly used in the calculation of carbon emissions during the building design phase, and its application in the operation and demolition phases has not been widely promoted.

In 2020, China clearly set the goals of achieving peak carbon emissions by 2030 and carbon neutrality by 2060, elevating the concept of low-carbon development to the national strategic level. The application of BIM technology in carbon emission calculations has also been accelerated. Besides measuring building carbon emissions during the design phase, many studies have focused on applying BIM technology to building renovation projects. For example, using BIM energy simulation technology to investigate how building performance parameters affect energy consumption and carbon emissions, thereby summarizing optimization methods for building renovations guided by low-carbon objectives[10].

In the international arena, the UK can be considered one of the most mature and standardized countries in the use of BIM. The UKs BIM standards and requirements have been incorporated into ISO BIM requirements. As early as 2011, the UK government included the application and development of BIM in its national construction strategy, covering the periods from 2011 to 2015 and from 2016 to 2020.

In China, Beijing Lizheng Software Co., Ltd. is one of the earliest enterprises engaged in BIM research and application in China. Its Revit series software has a high market share in the domestic market and provides users with comprehensive BIM solutions.

3. Review of Research Process and Status Quo

Kam class[11]The BIM 4D system was developed to realize 4D (3D + time dimension) visualization of construction process simulation. Fu et al[12]Study 5D BIM model, which integrates building performance, schedule, cost and other information, and expands the application of BIM. Wang Beibei et al[13]Combined with the characteristics of BIM technology, this paper analyzes the application methods of BIM technology in each stage of the project, and puts forward the possible problems and solutions in the application process; Li Xuemei et al[14]Taking a residential project in Xinxiang city as an example, the emission coefficient method is used to calculate the carbon emission of buildings, and the bill of quantities data of construction projects is obtained by combining BIM technology. The bill of quantities data is imported into the carbon emission calculation model, and the carbon emission in the production stage and operation stage of building materials accounts for the largest proportion; Yang Yong et al[15]The emission coefficient method and BIM technology are comprehensively considered to calculate the carbon emission of buildings, and GBS software and GIS technology are combined to provide a more convenient and reliable calculation method for the carbon emission of buildings; Li Chunli et al[16]By analyzing the interaction between BIM software and the regional impact of the building environment, a building carbon emission database was established, and the carbon emissions of each stage of the building project were calculated and analyzed with the help of Guanglianda pricing software; Hua Shan et al[17]Based on the calculation of carbon emissions in the construction stage of buildings by BIM technology, it is found that

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concrete, cement mortar, steel bars and wall materials account for more than 83% of the carbon emissions in the construction stage, which is the focus of carbon reduction work in the construction stage.

Research on BIM technology both domestically and internationally mainly focuses on BIM concepts (building information modeling), information integration, software development, standard issuance, BIM modeling, and the promotion of engineering applications, as shown in Figure 1. From Figure 1, it can be seen that due to the demand for informatization in the construction industry, nD BIM information integration technology has emerged; nD BIM information integration technology requires support from relevant software and standards; BIM-related software models building activities; ultimately, the BIM model provides support for the informatization needs of the construction industry (promotion of engineering applications). They form a sequential, interconnected closed loop, which is the industrial value chain of BIM technology. Each cycle represents an advancement, driving the development of BIM technology.

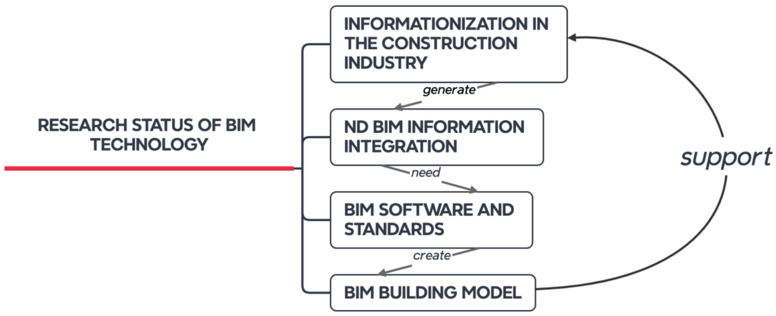

Figure 1: BIM technology industry value chain.

4. Application Process and Framework

4.1. Measurement and Assessment of Carbon Emissions

Estimating carbon emissions is the first step to achieving low-carbon buildings[18]The carbon emission measurement based on BIM mainly uses BIM technology to integrate the model with carbon emission related data (such as material consumption, energy consumption, carbon emission factor, etc.) to realize the carbon emission measurement and evaluation of the whole life cycle of buildings[19]Based on the literature survey, the carbon emission measurement stage, sources and corresponding carbon emission factors are summarized as shown in Figure 2.

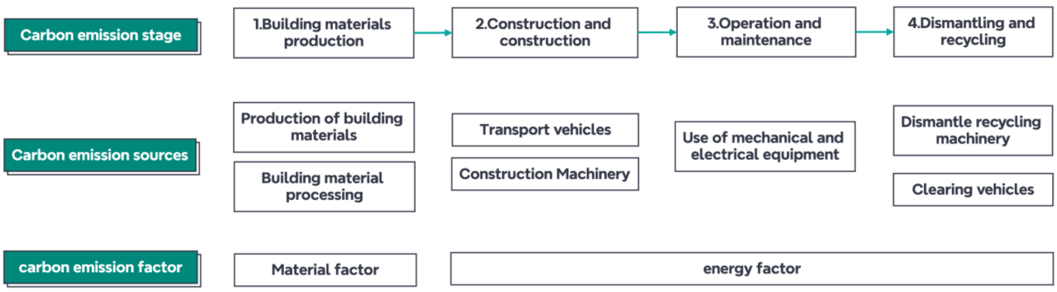

Figure 2: Carbon emission stages, sources and factors

Carbon emissions are generated by the consumption of building materials and mechanical energy in the production stage, construction stage, operation and maintenance stage and demolition and recycling stage. It can be seen that carbon emissions are generated over a long period of time and have complex sources[20]It is difficult to calculate. Therefore, experts and scholars have carried out research on the carbon emission measurement system and method based on BIM.

4.4.1 Staged Measurement

To build a carbon emission estimation framework for each stage of a buildings service life, leveraging the data integration capabilities of BIM to achieve carbon emission monitoring. The phased carbon

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emission estimates based on BIM do not fully represent a buildings total carbon emissions; therefore, combining BIM with lifecycle assessment to estimate carbon emissions has become a hot research area[21].

4.1.2 Life Cycle Assessment

Life cycle assessment is to evaluate the impact of products on the environment in their life cycle. The combination of BIM and life cycle assessment can be used to calculate carbon emissions, which can assess and correct scheme errors in the early design stage and improve the economic and environmental benefits of buildings[22]) Life cycle assessment method is a relatively static evaluation method, which is more suitable for estimating the carbon emission of buildings in the early stage, but cannot realize the dynamic tracking of carbon emission in the process. Therefore, developing a dynamic method for measuring the carbon emission of buildings in the life cycle is a difficult problem to be solved in current research.

4.2 Abnormal Identification of Carbon Emissions

Carbon emission anomaly recognition technology based on BIM identifies abnormal results of carbon emissions, promptly detecting unreasonable energy use in construction and operation processes, providing a foundation for proactive low-carbon building management. By leveraging the characteristics of BIM to integrate static and dynamic data of buildings, it can perform data-driven anomaly recognition of energy consumption during the buildings operation and maintenance period. When the predicted value of energy consumption deviates significantly from the actual value, an anomaly occurs, requiring certain corrective measures[23].

In general, there are several shortcomings in the research on abnormal carbon emission identification based on BIM:

1) The existing research extracts energy consumption data from BIM model and conducts data mining, but lacks effective correlation between energy consumption data and building space entity or construction process, which is not conducive to the identification of carbon emission anomalies from spatial dimension and time dimension;

2) The current research identifies carbon emission anomalies as a whole, but lacks the fine-grained scenario division of carbon emission anomalies, and cannot trace back to which process, room or system has abnormal carbon emissions according to the results of anomaly identification.

4.3 Active Control of Carbon Emissions

Carbon emission active control based on BIM includes one basis, one target, four stages and multiple scenarios, that is, with BIM as the data basis, to achieve the goals of increasing carbon sink, reducing carbon emission, reducing energy consumption and optimizing energy structure in each scenario of the whole life cycle of the building[24]The concept diagram of carbon emission active control based on BIM is shown in Figure 3.

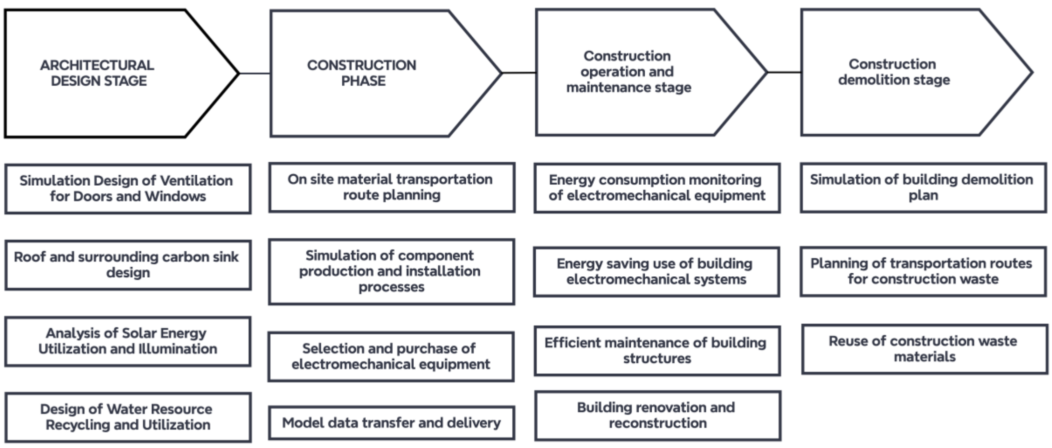

Figure 3: Concept diagram of active carbon emission control based on BIM

In the architectural design stage, BIM is used to simulate the ventilation and lighting of buildings, and artificial intelligence methods are combined to design building schemes that make full use of renewable energy and reduce energy consumption[25]However, the existing research on active carbon emission control focuses more on the pre-proposal comparison and evaluation, but lacks the dynamic control of carbon emission in each process of the project. Therefore, the development of a dynamic carbon emission control system based on BIM is the focus of current research.

4.4 Application Framework

Based on the four dimensions of "low carbon", "full life cycle", "performance evaluation" and "BIM", the application layout diagram of low carbon building based on BIM is proposed, as shown in Figure 4.

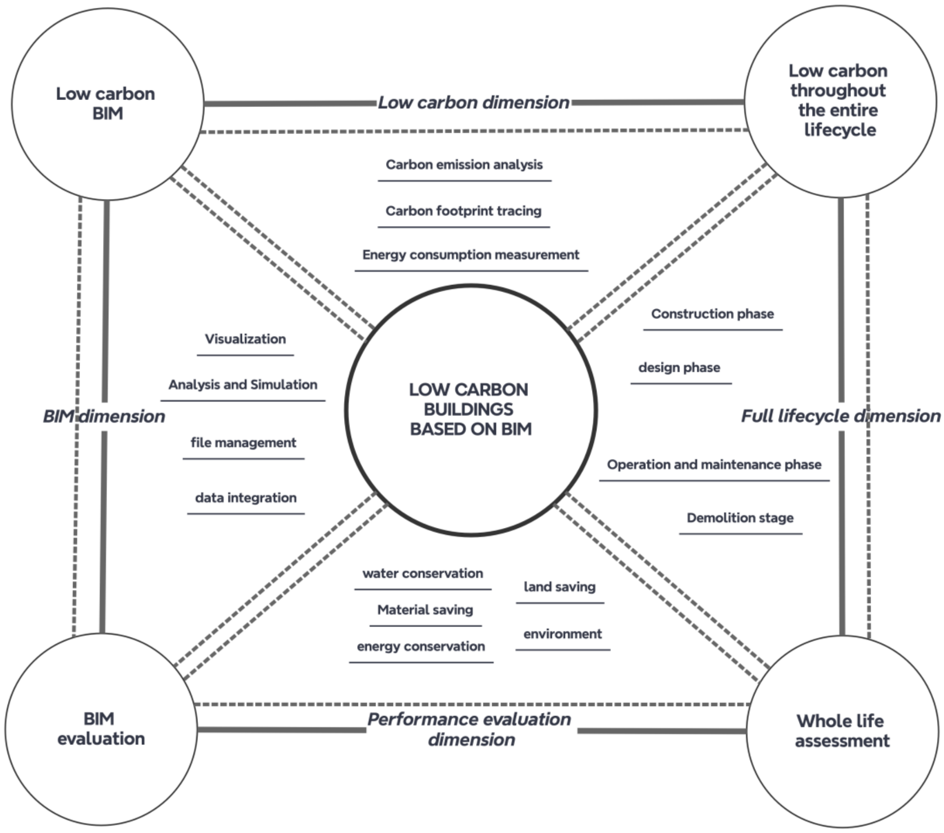

Figure 4: Framework for low-carbon building applications based on BIM

The low carbon dimension includes the traceability of the carbon footprint[26]Carbon emission analysis and energy consumption measurement[27]Functionality, the full life cycle dimension includes the design phase, construction phase, operation and maintenance phase, and demolition phase. Performance evaluation dimensions assess buildings from the perspectives of water conservation, material saving, energy efficiency, land use, and environmental impact. The BIM dimension enables functions such as visualization, analysis and simulation, file management, and data integration. These four aspects intersect to form specialized applications. Full life cycle low-carbon and low-carbon BIM aim to use BIM technology to analyze the carbon emissions over the entire life cycle of a building, optimize its energy structure, and reduce carbon emissions. Full life cycle assessment and BIM assessment primarily rely on a clear low-carbon building evaluation system, employing BIM technology to quantitatively assess the low-carbon effects achieved by buildings[28].

5. Prospects

As society deepens its commitment to low-carbon and environmental protection concepts, BIM technology, with its powerful information integration and visualization capabilities, provides strong support for the design, construction, and operation of low-carbon buildings. Through BIM technology,

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designers can accurately simulate building energy consumption, optimize energy-saving designs, and reduce carbon emissions throughout the buildings lifecycle. At the same time, BIM technology helps construction personnel manage materials precisely, reduce waste, and improve construction efficiency. During the operational phase, BIM technology also offers precise data support to help buildings achieve maximum energy efficiency. In the future, as technology continues to advance and application scenarios expand, BIM technology will play an even more significant role in the field of low-carbon buildings, driving the construction industry toward a greener and more sustainable direction.

6. Conclusions

Low-carbon buildings are not a casual definition but should embody the core concept of sustainable development in low-carbon power projects that align with the characteristics of the construction industry. With the promotion of "zero-carbon buildings" and "zero-carbon communities" abroad, the low-carbon development of Chinas construction industry has become an urgent necessity. Supported by BIM technology, low-carbon buildings will achieve significant expected goals. A crucial step is energy conservation and emission reduction, which involves reducing carbon emissions and energy consumption at various stages, from innovative technologies for energy conservation and emission reduction to technological innovations in low-carbon industrial production of buildings. Although research on BIM-based low-carbon building fields is still insufficient, it still holds promising application prospects in multiple subfields and has the potential to continuously improve the quality of construction projects.

References

[1] Hosseini S M, Shirmohammadi R, Aslani A. Achieving to a lowcarbon-energy commercial building in the hot-dry climate area[J]. Energy sources. Part A, Recovery, utilization, and environmental effects, 2020, 2020 (PT. 1) : 1-19.

[2] Costa A, Keane M M, Torrens J I et al. Building operation and energy performance: Monitoring, analysis and optimisation toolkit[J]. Applied energy, 2013, 101: 310-316.

[3] Cao Yang and Feng Tao. Feasibility of LEED certification model based on BIM technology [J]. Journal of Civil Engineering and Management, 2016,33 (2): 22-29.

[4] Zhu Dandan, Yan Da, Wang Chuang, et al. Comparison of building energy consumption simulation software: DeST and EnergyPlus and DOE-2 [J]. Building Science, 2012, (S2): 213-222.

[5] Ma Xiaoming, Li Xiaofeng and Zhu Yingxin. Cold load prediction model for public areas of subway stations based on TRNSYS [J]. Urban Rapid Rail Transit, 2021,34 (2): 130-136.

[6] Wang Ying, Wang Jian, Li Zhengwei, et al. The current situation and development trend of air conditioning water system simulation technology [J]. Science and Technology & Engineering, 2021,21 (16): 6556-6564.

[7] Liu Wei, Li Huai, Huang Wei, et al. Optimization configuration analysis of HVAC system for a near zero-energy office building based on TRNSYS simulation [J]. Building Science, 2022,38(4):158-168.

[8] Feng Guohui, Wang Xiru, Huang Kailiang et al. Optimization of design parameters of ground radiant heating terminal for nearly zero energy buildings [J]. Journal of Shenyang Jianzhu University (Natural Science Edition), 2022,38(3):512-519.

[9] Zhang Mingyou, Xing Teng, Sun Yao. EnergyPlus Application of energy saving and consumption reduction in building [J]. Building Economy, 2022,43 (S1): 574-578.

[10] Gao Feng, Cheng Yuanda, Jia Jie, et al. Study on energy saving characteristics of double-layer photovoltaic Windows in cold regions during winter [J]. Building Science, 2020,36 (4): 24-32.

[11] Sun Yue, Ren Hongbo, Wu Qiong, et al. Study on simulation and operation strategy optimization of VRV air conditioning system based on EnergyPlus [J]. Building Science, 2022,38 (10): 198-205.

[12] Yang Chuhao, Chen Yixing, Yuan Yue, et al. Comparative analysis of energy consumption modeling of ground source heat pumps based on formula fitting and machine learning [J]. Building Science, 2022,38(4):97-104,168.

[13] Shen Manhong and Wang Longxiang. Review and Prospect of Low-carbon Building Research [J]. Building Energy Conservation, 2012,1 (12): 67-70.

[14] Luo T, Tan Y, Langston C et al. Mapping the knowledge roadmap of low carbon building: A scientometric analysis[J]. Energy and Buildings, 2019, 194: 163-176.

[15] Chong H, Lee C, Wang X. A mixed review of the adoption of Building Information Modelling (BIM) for sustainability[J]. Journal of Cleaner Production, 2017, 142: 4114-4126.

[16] Lu K, Jiang X, Tam V W Y et al. Development of a Carbon Emissions Analysis Framework Using Building Information Modeling and Life Cycle Assessment for the Construction of Hospital Projects[J].

ISSN 2663-1563 Vol. 7, Issue 1: 107-113, DOI: 10.25236/AJAGE.2025.070114

Sustainability, 2019, 11 (22) : 6274.
[17] Sun H, Park Y. CO2 Emission Calculation Method during Construction Process for Developing BIM-Based Performance Evaluation System[J]. Applied Sciences, 2020, 10 (16) : 5587.
[18] Fu Feifei. Research on emission reduction technology in construction process based on BIM [J]. Construction Economy, 2018,39 (1): 95-100.
[19] Lu Y, Wu Z, Chang R et al. Building Information Modeling (BIM) for green buildings: A critical review and future directions[J]. Automation in Construction, 2017, 83: 134-148.
[20] Bao Jianqiang. Low-carbon Building Theory [M]. Beijing: China Environmental Press, 2015.
[21] Zhao Daiqing, Zhang Bu, Cai Guotian. Research on the development path of low-carbon buildings [J]. Construction Economy, 2010, (2): 47-49.
[22] Yao Jiawei, Huang Chenyu, Yuan Feng. Development of low-carbon buildings and their digital future [J]. Architectural Skills, 2020,26 (8):13-17.
[23] Wang Xing. Energy saving application and optimization of BIM technology in low-carbon buildings [J]. Management and Science & Technology for Small and Medium-sized Enterprises, 2022, (4): 178-180.
[24] Chen L, Pan W. BIM-aided variable fuzzy multi-criteria decision making of low-carbon building measures selection[J]. Sustainable Cities and Society, 2016, 27: 222-232.
[25] Zhao L, Zhang W, Wang W. BIM-Based Multi-Objective Optimization of Low-Carbon and Energy-Saving Buildings[J]. Sustainability (Basel, Switzerland) , 2022, 14 (20) : 13064.
[26] Li X, Lai J, Ma C et al. Using BIM to research carbon footprint during the materialization phase of prefabricated concrete buildings: A China study[J]. Journal of Cleaner Production, 2021, 279: 123454.
[27] Khahro S H, Kumar D, Siddiqui F H et al. Optimizing Energy Use, Cost and Carbon Emission through Building Information Modelling and a Sustainability Approach: A Case-Study of a Hospital Building[J]. Sustainability, 2021, 13 (7) : 3675.
[28] Zhang Mingyou, Xing Teng, Sun Yao. EnergyPlus Application of energy saving and consumption reduction in building [J]. Building Economy, 2022,43 (S1): 574-578.