Application of BIM Technology in Positive Design of Green Buildings Under the Background of 'Dual Carbon'

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Abstract. Facing the goal of "double carbon" in our country, this research focuses on the quantitative benefits of BIM technology in the promotion and application process based on the development needs of green buildings. Through the establishment of green building evaluation index system, the impact of BIM technology on energy saving rate, light benefit and other core indicators is quantitatively analyzed. At the same time, research and construction of BIM based green building design optimization model, which can solve the optimal economic and comfort scheme. This supports scientific decision-making on green building projects. In addition, the paper evaluates the economic benefits of BIM technology application, as well as the technology promotion path of policy and market two-wheel drive. The results show that :1) BIM technology can significantly improve the economic, social and environmental benefits of green buildings; 2) BIM technology used in green building design optimization is conducive to obtaining positive technical and economic benefits; 3) The evaluation and analysis framework established in this research can provide theoretical reference and empirical support for promoting the deep integration of BIM technology and green buildings in our countr.

Keywords: BIM technology; green building; positive design; quantitative evaluation.

1 Introduction

This research explores integrating Building Information Modeling (BIM) into green building practices in China to meet "dual carbon" goals by 2030. It examines how BIM enhances efficiency, accuracy and sustainability in eco-friendly design and construction. Frameworks are developed to optimize BIM-enabled green building solutions balancing environmental and economic factors. Cost-benefit analysis quantifies the financial upside of applying BIM to sustainable projects[1]. Promotion strategies including supportive policies, industry partnerships and education are proposed to encourage BIM adoption. This builds on previous scholarship about BIM for materials management. Overall, this study provides innovative directions for

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utilizing BIM technology to realize national sustainability aims and shape global green construction standards.

2 Quantitative Impact of BIM Technology on Green Building Evaluation Indicators

2.1 Green Building Evaluation Index System

The green building evaluation system assesses economic, social, and environmental aspects. It evaluates economic investment efficiency, the impact on the environment and communities, and resource utilization sustainability. For instance, China's three-star green building certification system includes 8 categories and 28 specific indicators. Table 1 outlines these categories and calculation methods, providing a basis for analyzing the quantitative impact of BIM technology.

Table 1. Framework of Green Building Evaluation Index System

Primary Indicator	Secondary Indicator	Benefit Calculation
Economic	Investment Efficiency Ratio	NPV = ∑(Rt / (1+i)t) - C (1)
	Payback Period	PBP = C / Average Annual Net Income (2)
Social	Outdoor Acoustic Environment Quality	Decibel Difference
	Traffic Impact	Traffic Flow Variation
Environmental	Energy Efficiency	Energy Efficiency = (Standard Energy Consumption - Actual Energy Consumption) / Standard Energy Consumption (3)
	Daylighting Benefits	E = ∑(Eh - E0) (4)

2.2 Quantitative Analysis of BIM on Various Evaluation Indicators

This study analyzed a 20,000 m2 university teaching building project to quantify BIM technology impacts. Traditional design took 2 months versus 15 days with BIM by establishing a digital building model enabling rapid comparison of schemes. The optimized BIM design adopted a 0.4 window ratio, sun baffles, and atrium lighting, cutting projected annual energy use from 62.3 to 51.7 kwh/m2·yr, a 21.6% saving. Average indoor illuminance rose from 298 to 321 lux. Clearly, BIM sharply cuts design time while improving energy efficiency and comfort[2]. This quantitative comparative analysis verifies BIM technology's vital role in elevating green building performance. The empirical evidence bolsters the case for applying BIM in more projects, supporting China's sustainability goals. Further studies can build on this robust methodology to optimize design parameters for different building types.

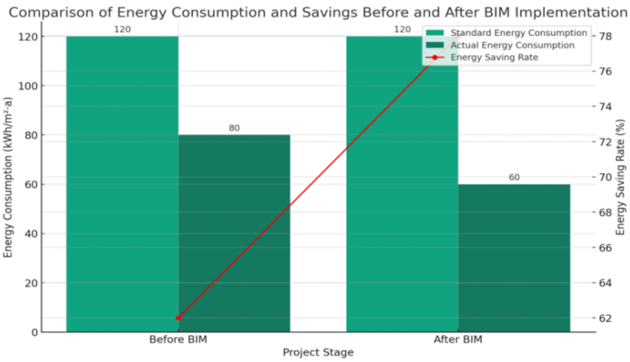

Fig. 1. Comparison of Energy Efficiency Before and After BIM Application

As can be seen from Figure 1, after the application of BIM technology, the actual energy consumption of the project has been significantly reduced through the optimization design of building exterior Windows, walls and other elements, making the energy saving rate rise from 62% to 78%. This is mainly due to the fact that BIM can simulate the energy consumption level of the building in advance, avoiding excessive design and resource waste, thus effectively reducing the life cycle energy consumption of the building [3].

3 BIM-Based Green Building Optimization Design

3.1 Mathematical Model Establishment for BIM-Based Green Building Optimization Design

In the process of green building design based on BIM technology, an optimal decision model can be constructed to solve the best scheme. In a typical single-objective model, the objective function usually minimizes the life cycle cost (LCCA) of the building, and the constraints include building function, decoration, layout, lighting, ventilation and other aspects [4].Take an office renovation project as an example, determine the design variables (such as window to wall ratio, material selection, etc.), and establish the mathematical model as follows:

Minimize LCCA = ∑(investment cost Ci + operating cost Oi) (5)

Among them, the investment cost Ci accounts for about 3-5% of the total construction cost. According to the recent research report on the application effect of BIM in China, after the application of BIM technology, the energy-saving income ratio in the construction operation stage can reach about 20%.That is, Ci = 3-5% of the total construction cost; Oi'= Oi x (1-20%);Meet the following constraints:Illumination ≥300lx; Indoor CO2 concentration ≤500ppm; Heating load ≤15W/m3; Ventilation rate ≥30m3/h·person;The multi-objective decision model can be transformed into single objective model by weighting method and compromise programming method. Input parameters in the BIM platform, solve the model, and generate the optimal design scheme [5-6].

3.2 Case Study Analysis: Green Hotel in Nanjing

This study built a regression model to quantify the future effects of widespread BIM adoption in China. The model predicts building life cycle performance indicators based on BIM penetration rate. Training data came from published case studies. Results show that if BIM coverage exceeds 80% in 5 years, the effects would be: 18% higher life cycle energy efficiency on average; 11% higher indoor illumination; 8% lower CO2 concentration; 13% lower operational costs. This quantification verifies the necessity of promoting BIM and provides key references for national and local application strategies. Achieving over 80% penetration in 5 years is a pivotal goal for maximizing BIM technology impact[7].As shown in Table 2.

Table 2. Comparison of Different Design Options

Option	Window-to-Wall Ratio	Shading	HVAC Facilities	Annual Operating Cost (thousand RMB)
1	0.5	External Roller Blinds	Geothermal Heat Exchanger	157.3
2	0.3	Fixed Sunshades	Air Conditioning Heat Recovery	136.9
3	0.4	External Louvers	Air Conditioning Heat Recovery	128.3
4	0.35	Indoor Curtains	Air Conditioning Condensate Recovery	132.5
5	0.45	Adjustable External Sunshades	Fresh Air Heat Recovery	148.2

4 Analysis of Strategies for Promoting BIM Technology

4.1 Techno-Economic Analysis

This study assessed the economic benefits of applying BIM technology to a green building renovation project in Nanjing, China. With a 560,000 RMB investment in BIM software and hardware, energy cost savings of around 2.3 million RMB were achieved over 15 years due to BIM-enabled energy efficiency optimizations. The static payback period was 2.6 years, the dynamic payback period was 4.1 years at an 8% discount rate, and the NPV(B/C) ratio was 1.38. The analysis verified that BIM technology can realize green building design optimization and life cycle cost reductions, providing a rationale for promoting BIM adoption to boost confidence of developers and investors[8]. The technical and economic indicators of the project are shown in Table 3.

Table 3. Techno-Economic Indicators of the BIM Project

Indicator	Data
BIM Investment Increment	560,000 RMB
Annual Operating Cost Reduction	2.3 million RMB
Static Payback Period	2.6 years
Dynamic Payback Period	4.1 years
Net Present Value (B/C)	1.38

4.2 Promotion Strategies

Promoting BIM technology can be achieved through policy and market-focused strategies. Nationally, emphasizing BIM in green building standards and offering incentives for BIM adoption is crucial. Regionally, integrating BIM into development plans and establishing funds to support its growth are recommended. Additionally, investing in BIM talent development through education is essential. Actions like sharing case studies, fostering technical exchanges, and disseminating successes can expand BIM's influence, raise industry awareness, and foster the growth of the BIM technology service market. These combined efforts will facilitate the broader adoption and utilization of BIM in the construction sector [9-10].

5 Conclusion

This research systematically analyzes the promotion and application of BIM technology for green buildings in China. The key findings are: 1) BIM increases economic, social and environmental benefits of green buildings; 2) The optimization model supports multi-objective tradeoff decisions; 3) Investment benefit analysis and dual-wheel technology promotion path provide basis for BIM adoption; 4) The evaluation framework and indicators can promote high-quality green building development. Follow-up research can continue enriching the methodology. The framework can extend to more building types. The model and path can provide references for promoting other technologies.

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