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Fine-grained Applications of BIM Technology in the Whole Life Cycle of Green Buildings Based on Case Analysis

Qingyuan Hu

School of Civil Engineering and Architecture, East China Jiaotong University, Nanchang 330000, China

Abstract: Against the backdrop of the global decline in environmental resources, in response to the national call for environmental protection, green buildings have gradually become the core of the construction industry's development. As a digital technology that has been continuously innovated in recent years, Building Information Modeling (BIM) technology has played a significant role in many green building projects. This paper, based on the application of Building Information Modeling technology and the requirements of green buildings, combines specific cases to analyze the application of Building Information Modeling technology in each stage of the green building's life cycle and the changes it has brought. The results show that compared with traditional construction methods, Building Information Modeling technology, with its advantages of greater refinement, visualization, and data-driven approach, has had a significant impact on reducing resource and energy consumption in building construction while meeting industry standards and human needs.

Keywords: Building information modeling technology; The entire life cycle; Green buildings; Energy consumption

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1. Introduction

1.1. The concept of building information modeling technology

Building Information Modeling is a building model established based on various relevant information data for construction projects. Through digital information simulation, BIM technology can simulate the actual information of a building [1,2]. The technology integrates building information and various performance data; based on designer requirements, BIM technology conducts evolution analysis of different schemes and generates visualized building models for the decision-making evaluation of construction plans. Throughout the entire life cycle of green buildings, BIM technology can effectively simulate building rationality, comfort, resource utilization, and energy consumption. This process forms decision-making plans that comply with building standards, meet occupant needs, and achieve the most efficient use of environmental resources with the minimum energy consumption.

1.2. Advantages of building information modeling technology

Traditional building projects have long relied on hand-drawn sketches, manually collected data and human-based analyses. This invites calculation errors, slows information exchange among stakeholders, delays communication, and drags out later-stage corrections. The introduction of BIM eases these pain-points in several ways.

(1) For visualization

As a digital technology, BIM translates qualitative green-building targets into measurable data and 3D models. Computers, not people, run the analyses, cutting the risk of error. The three-dimensional, visual model lets designers spot problems immediately and adjust the design on the spot.

(2) For collaboration

BIM provides a single platform where all parties can work together. Design files are pushed to the platform instead of being passed manually, eliminating transfer lag and the data losses that often accompany it.

(3) For energy optimization

The digital model allows precise control of indoor ventilation, daylight penetration and airflow pattern. Coupled with environmental-psychology principles, this yields a minimum-energy configuration [3].

(4) For quantity take-off reliability

Engineering quantities calculated with BIM are also highly reliable. In 2018 Liang Wang et al. studied quantity-information exchange and reuse on a media-tower project. Comparing Revit and GCL models, they exported the Revit model to GCL through IFC and GFC formats. Graphic-element conversion hit 100%, and the quantity deviation from the standard dropped below 1%. Their conclusion: for a civil-engineering Revit model, importing GFC-format data into Glodon BIM-based quantity-taking software gives a dependable take-off workflow [4].

(5) With the improvement of BIM efficiency, labor costs and material costs can be reduced, reducing costs in many aspects.

1.3. Green-building life-cycle

A "green building" is one that still meets all code requirements while cutting environmental resource use, optimizing the allocation of social resources such as labor, and lowering energy demand, ultimately reducing ecological impact and providing a healthy place for people to live and work. The life-cycle of a building spans its entire existence, from cradle to re-use: planning and design, construction, operation and maintenance, and demolition and recycling. The green-building life-cycle takes these four stages and injects concrete green-building targets into each one, producing an optimized, fully integrated life-cycle [5,6].

2. Green building whole-life-cycle: Planning and design, construction, operation and maintenance, and demolition & recycling

2.1. Planning and design

A green building must minimize environmental impact, so as shown in **Figure 1**, on Project planning and feasibility: targets should focus on energy-use optimization and efficient allocation of resources (materials, equipment, labor) while assessing global effects on both environment and occupants. Site selection and analysis: Choose locations after detailed surveys of topography, geomorphology, soil, and hydrology; let the natural context drive the architectural response. Architecture design and Construction drawing design: Integrate external and internal structural solutions, daylighting and natural-ventilation strategies. BIM in planning and design, Solar energy: Link BIM to solar-path tools, simulate annual radiation, adjust window-to-wall ratios for optimum daylight and thermal control; high accuracy, high reliability [7]. Seasonal/daylight analysis: Import hourly/seasonal sky data to preview daylight performance for any moment of the year. Wind energy: Load local wind-rose (prevailing direction, speed, frequency) into the 3D model to set building orientation and identify the best micro-turbine layout. Ground-/water-source heat pumps: Combine soil-temperature and shallow-geothermal data to forecast long-term ground-temperature change, optimize pipe spacing and depth, and maximize renewable-energy yield. After the architectural design is completed, BIM can generate construction drawings design with a three-dimensional model. During this process, generating design drawings through data can save a lot of human, material and time costs. Example: Nanchang Construction-Waste Recycling Plant – Phase I. Tekla was used to optimize the steel structure (material choice, layout, section profiles). The process removed 166 interdisciplinary clashes, saved 90 calendar days and avoided 15 days of re-work [8]. It has reduced the labor and equipment costs associated with rework.

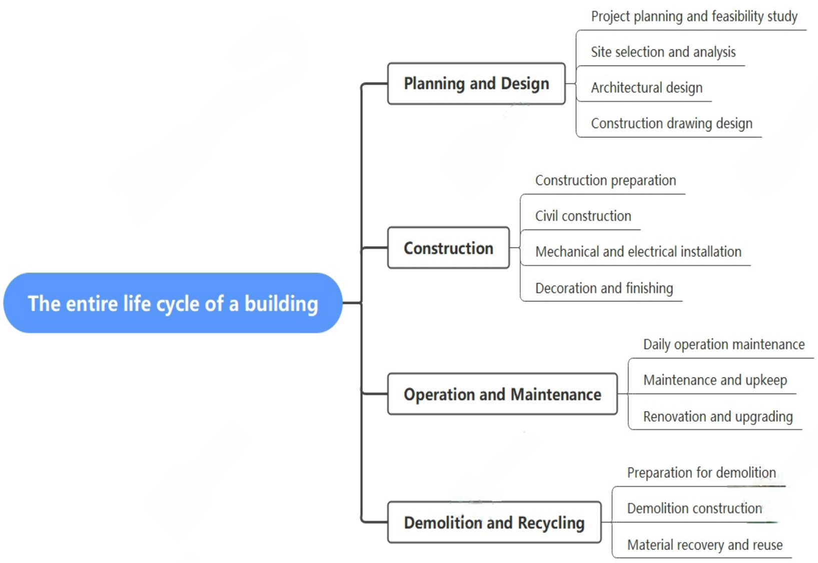

Figure 1. Four stages of the entire life cycle of a building.

2.2. Construction

As shown in **Figure 1** during the construction phase, for construction preparation, a project construction schedule serves as the primary implementation plan, outlining the overall timeline and progress management. This plan should comprehensively address material selection (prioritizing low-energy consumption and recyclable building materials), equipment configuration, technical approaches, and workforce allocation. Concurrently, real-time on-site monitoring enables progress tracking, risk assessment, and timely adjustments. The application of BIM technology in construction scheduling proves particularly valuable. When developing schedules, BIM provides extensive project-related data, allowing precise tracking of construction milestones, process timelines, and specific duration. The visualized final schedule clearly demonstrates inter-process dependencies, critical milestones, and time-frames, facilitating adjustments. For civil construction, engineering quantities can be calculated and costs can be estimated with nim technology. BIM can automatically generate engineering quantity lists, such as earthwork volume, concrete volume, and steel tonnage. It can achieve rapid and accurate cost estimation and dynamic cost control. Digital layout and construction guidance can be carried out: Import the BIM model coordinates directly into total stations, GPS measurement equipment or intelligent construction machinery to realize high-precision automated on-site layout and construction control, thereby improving efficiency and quality. Furthermore, BIM establishes specialized databases containing material properties, regional cost variations, equipment specifications, maintenance schedules, and technical evaluations. By integrating this data with building information modeling (BIM) to create 3D models, it simulates material combinations, structural configurations, and technical implementations. This enables accurate calculation of required resources including materials, equipment, technologies, and labor. By establishing an optimal combination that minimizes energy consumption, maximizes resource utilization, and reduces environmental impact, the project can simultaneously reduce material, equipment, and labor costs. During construction, BIM technology enables real-time regulatory monitoring, facilitates risk simulation assessments, identifies potential issues, and allows timely adjustments. For mechanical and electrical installation, BIM can detect whether there are physical conflicts between pipes and pipes, or between pipes and structures. It can also check whether the required operation space for installation, maintenance, insulation. Moreover, it can verify whether the design complies with the standards, and then divide the complex pipeline system into standard prefabricated components and modules. Processing drawings and data are directly exported from the BIM model and sent to the factory for automated production. For decoration and finishing, on the one hand, BIM can directly attach material textures to walls, ceilings, etc. in the model and adjust colors, joint sizes, and laying methods in real time, down to the millimeter level. This makes the selection of surface materials and design decisions more precise which diminishes the cost and the use of materials. On the other hand, before construction, BIM can automatically detect spatial conflicts between the decoration surface layer and concealed works. Example: New Jiangxi Integrated Chinese-Western Medicine Hospital (Yaohu Branch). BIM-based construction simulation detected design-to-site collisions, optimized tower-crane positions with visual-scripting, and delivered AR models to field crews for MEP installation. Result: 120 days shorter schedule, CNY 8 million direct cost saved (50 days and CNY 0.8 M for structure; 70 days and CNY 1.2 M for MEP) [8].

2.3. Operation and maintenance

As shown in **Figure 1**, for daily operation maintenance, during the operational phase, BIM technology is utilized to visually represent properties in three-dimensional models using color-coded states (e.g., for properties in transaction or rental status), enabling real-time status tracking. For transaction management, it provides intuitive price visualization for properties undergoing transactions. In rental management, it displays tenant details (name, contact information, move-in date, lease term), streamlines rental resource allocation, and reminds tenants to renew contracts promptly, reducing the cost of manual inspection. For maintenance and upkeep and renovation and upgrading, the billing management system handles utility charges for water, electricity, and natural gas. BIM also enables detailed energy consumption tracking and precision calculations to optimize resource usage. The maintenance phase involves structural inspections, upkeep of fire safety systems, elevators, and indoor environmental quality [9]. By integrating BIM with real-time building data, energy consumption is monitored in real-time, while maintenance teams track building performance metrics. This allows proactive equipment adjustments to avoid emergency energy waste. Through networked sensors, BIM analyzes data to identify resource wastage (water, electricity, lighting) and automatically triggers corrective measures, enabling real-time parameter adjustments via network-driven devices. Example: Shanghai No. 1 Intermediate People's Court. An integrated "BIM + system integration + O&M" platform fused big-data analytics, as shown in **Table 1**, cutting coal-equivalent energy use by 24.2 tce and saving CNY 0.596 5 million in 2016–2018 (energy-reduction rate > 10 %) [10].

Table 1. Energy consumption ratio of Shanghai no.1 intermediate people's court from 2016 to 2018

Year	Power consumption (kWh)	Gas consumption (m^3)	Water consumption (t)	Building coal energy consumption (tce)	Total cost (yuan)
2016	5800560	47080	60587	1731.75	5,707,500
2017	6086440	47261	65498	1814.32	5,777,200
2018	5729801	44143	65826	1707.56	5,104,000

Source: Evaluation Report on "Application of BIM Platform for Green Transformation" by the State Administration for Public Institutions.

During the pandemic, BIM technology was found to effectively control disinfectant usage and enable real-time ventilation, achieving optimal sterilization results. Furthermore, BIM technology facilitates public services by integrating information on nearby healthcare facilities, gas stations, and essential goods procurement points into the platform, enabling visualized queries and enhancing residents' convenience [10].

In addition, the pandemic revealed that BIM can ration disinfectant and trigger instant ventilation to achieve sterilization. At the same time the model becomes a citizen-service portal: healthcare facilities, gas stations and grocery pick-up points around the estate are plotted in 3D for quick, visual queries that make daily life easier.

2.4. Demolition and recycling

In Demolition and recycling， as shown in **Figure 1**, for preparation for demolition, a sound demolition plan must reflect structure type, site topography and material categories, then prescribe recovery routes and final destinations so that every component is re-used to the maximum. Data-rich dismantling: the pre-exist BIM keeps exact member sizes, joint details and material properties, allowing a reliable FEM model to be generated without expensive re-surveying; rebar, ducts and cables are visible in 3D so clashes and hazards are spotted before a wall is touched [11]. Method selection: the platform weighs manual, mechanical and implosive techniques against structural behavior and environmental impact, then evolves the optimum scheme. For demolition construction. During the building demolition process, the role of BIM is to ensure the implementation of the initial planning through digital management and dynamic visualization. It also handles unexpected situations on the site and achieves safe, orderly and resource-efficient demolition. On the demolition site, the BIM model guides each operation. Workers can check the BIM disassembly model of a certain area or floor on their computers at any time, which is more convenient than traditional two-dimensional drawings. Managers can use the BIM model for 4D progress tracking. Through drone aerial photography or on-site photography, real-time comparisons of the construction site can be made, quickly identifying delays in progress or deviations in the demolition scope. With BIM, construction personnel can dynamically mark dangerous areas and equipment operation ranges in the model, providing safety warnings for on-site personnel. For material recovery and use, Material inventory: because every element was classified (door, window, wall, column, beam, slab) and its material attribute logged at design stage, BIM can instantly quantify types and volumes with high accuracy [12]. Algorithms then match stock to local topography, what can be back-filled on site, what can be re-sold, what must be recycled, updating the model until the best logistics plan emerges. Example: oil-refinery unit demolition. BIM families were built for 20 + rigs, mobile cranes, scissor lifts, hydraulic breakers and clash-checked against the plant model 153 times. Detecting insufficient access routes and slewing-radius conflicts in advance eliminated stand-downs, shortened the demolition programmed by 10 % and saved USD 1.5 M [13].

3. Case study

3.1. BIM on Chongqing raffles city

3.1.1. Project overview

Chongqing Raffles City sits at the city's core, between Chaotianmen Plaza and the Jiefangbei CBD. The sail-shaped complex totals 1.12 million m^2; Lot B alone covers 630,000 m^2 on a 91,200 m^2 footprint. Four main towers are linked by a "crystal sky-bridge" whose free-form curtain wall was identified early as the most difficult element to design and install.

3.1.2. How BIM was used

(1) Design phase

Designers exploited BIM's 3D visualization to convert 2D drawings into a parametric Rhino model, allowing rapid optioneering for the sky-bridge geometry.

(2) Clash detection

Instead of sending surveyors to site, the Rhino curtain-wall model and the main-steel model were imported into a single BIM environment. Overlay checks revealed seven hard clashes between facade panels and primary structure, problems that would have been discovered only during erection under a traditional workflow.

(3) Construction simulation

All trades met in the unified BIM environment, rehearsed the erection sequence digitally and verified access, crane positions and temporary works before committing resources.

(4) Results

The digital rehearsals eliminated field surprises, cut rework and delivered a measurable saving in both cost and schedule while enabling millimeter-level, fine-tune construction of the complex curtain-wall system [14].

3.2. BIM on Jilin province modern seed industry park construction project

The "Jilin Province Modern Seed Industry Park Construction Project" that won the "Youlu Cup" National BIM Technology Competition. During the construction phase of this project, BIM technology was applied [15]. The project included an office building for enterprise research and an equipment building for the enterprise. For example, as mentioned earlier, BIM can solve problems such as physical conflicts and so on. This project used the BIM model to assist in the review of drawings, effectively identified and solved the "errors, omissions, deficiencies, and collisions" in the design, and further optimized the design scheme. Through BIM technology, the project achieved deepening of drawings, virtual roaming, process simulation and space analysis. Combined with prefabricated construction, the efficiency of equipment installation in the machine room was significantly improved [15]. Through in-depth exploration of this project, it also utilized the BIM management platform to enable multiple parties to communicate and solve drawing problems on the same platform. At the same time, the management platform was used for real-time monitoring and management during the construction process, and the building process of the project was dynamically tracked.

In summary, BIM technology, through digital modeling to establish three-dimensional models and by connecting various professionals through the platform, has significantly improved the efficiency of construction, reduced risks and errors during the construction process, and provided excellent technical measures for reducing energy consumption, minimizing environmental impact, and enhancing the comfort of residents' living. However, as BIM continues to develop, there are also more and more problems in aspects such as data leakage and usage scale limitations that urgently need to be improved.

4. Limitations of BIM technology

(1) BIM technology is not suitable for small-scale or short-term projects, but rather for large-scale projects with ample time. To address this, BIM can be applied to specific phases of smaller projects, allowing them to adopt BIM technology within budget constraints.

(2) In internet data transmission, there exists a risk of data leakage or tampering. To address this issue, block-chain technology can be utilized to mitigate such risks. As a core supporting technology for decentralized distributed storage and peer-to-peer trusted data networks, block-chain serves as the backbone of digital cryptocurrency systems represented by Bitcoin. By writing the hash values of critical nodes in BIM models into the block-chain, it ensures that any data tampering can be detected and traced.

(3) BIM software is tightly integrated with various internet management platforms. Since data analysis tools come from different vendors, there are differences in data formats and communication protocols. To address this, an intermediate converter can be developed to coordinate the conversion of various data formats and protocols.
(4) The maintenance of BIM technology involves costs, and its application in architectural design requires interdisciplinary professionals, which also incurs training expenses. To address this, two solutions emerge: First, in the digital age, educational platforms can be developed to deliver BIM training, consolidating resources to reduce offline teaching costs. For instance, courser offers BIM courses from global universities covering Revit modeling, BIM collaboration, and construction management, enabling systematic learning. Second, during recruitment, companies can set higher requirements for BIM-related positions, such as requiring certifications like BIM modeling engineer or national BIM application certifications, thereby reducing corporate training costs.

5. Conclusion

The application of BIM in construction spans the entire four stages of a construction project, creating a digital building model that incorporates all engineering data information. This change has improved the traditional construction mode and BIM also drives the construction industry towards a green, digital and intelligent transformation. However, during the development of technology, there are still some issues that need to be resolved. The future of BIM technology application remains arduous and long.

Disclosure statement

The author declares no conflict of interest.

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