Proceedings of CONF-FMCE 2025 Symposium: AI and Machine Learning Applications in Infrastructure Engineering
DOI: 10.54254/2755-2721/2025.MH25431

The Application of BIM Technology in Environmentally Friendly Building Projects

Shuxin Zhu

School of Civil Engineering and Architecture, Wuhan Polytechnic University, Wuhan, China
daixin@asu.edu.pl

Abstract. In the context of sustainable development strategies, green construction, as a critical link in the construction industry's energy conservation and emission reduction efforts, urgently demands innovation in its technology applications and management methods. The practical application of Building Information Modeling (BIM) technology in green construction are the main topic of this article. It seeks to create a digital control system that encompasses the whole building cycle by combining 5D schedule-cost management, Geographic Information System (GIS) spatial analysis, drone dynamic monitoring, and IoT real-time sensing technologies. According to research, BIM technology may improve construction productivity, minimize environmental pollution, and maximize resource allocation by utilizing the benefits of 3D models and data interconnectivity. However, a lack of specialized knowledge and obstacles to technical collaboration continue to limit its deep implementation. In order to provide technical support for the green transformation of the construction industry, it will be necessary to advance the intelligent and sophisticated development of green construction in the future through technological innovation and integration, standard system improvement, and the development of interdisciplinary talents.

Keywords: Building Information Modeling (BIM) technology, building operations, green construction

1. Introduction

Green building design and construction have become a major area of research for construction professionals in China as a result of the adoption of sustainable development policies. Building objects, resource allocation, implementation tactics, product acceptance, and control objectives are the five main components of green building as opposed to traditional construction. However, in terms of control objectives, green construction places more emphasis on resource conservation, environmental protection, improving construction efficiency, and construction quality than traditional construction, which focuses on controlling project costs, quality, safety, and schedule [1]. Traditional construction mostly focuses on saving resources and reducing materials to cut costs. Green construction aims to be environmentally friendly by using renewable materials for resource conservation, leveraging technology to efficiently utilize green materials and minimize construction-related environmental damage. Although green construction can increase construction efficiency and quality, it has not yet gained widespread adoption by contractors due to the high number of core

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technical and software skills needed for support and the fact that it frequently raises construction prices [2].

By using BIM technology in green construction, it is possible to achieve comprehensive management of the building lifespan and dissolve the boundaries between owners, design, construction, and operation. In the use of green building construction, BIM technology has already assumed a significant role [3].

This article focuses on green building materials and BIM technology as the foundation of green construction. Integrating these technologies enhances construction processes, reduces waste/dust/noise, mitigates hazards, lowers rework rates, and explores BIM's industry advancement.

2. Standards and requirements for green construction

As defined in DB11/T 513-2018 Green Construction Management Standard, green construction refers to activities that, while ensuring quality and safety, optimize resource conservation and minimize environmental impacts through scientific management and technological innovation, achieving the "four savings and one environmental protection" (energy, land, water, materials, and environmental protection). A key phase in a building's lifecycle, green construction is crucial for emission reduction, energy conservation, and resource efficiency in the construction industry. It follows five principles:

a) Reduce site pollution, respect the base environment.

The site's natural environmental features and existing ecosystems may be significantly impacted by some fundamental engineering construction operations and stages. In order to complete this project, the owner, design unit, and contractor must work closely together, make the most of the terrain resource reserves on the property, and promptly restore the surrounding ecological ecosystem following construction using appropriate intervention techniques [4].

b) The combination of construction and climate

Aiming to decide the construction period, methods, sequence, machinery, and site layout based on the local climate, contractors might first employ technological means to identify the local meteorological data and features before beginning work.

c) Technical Requirements for Green Construction: Water-Saving Key Points and Environmental Protection Measures

The core principles of sustainable development include conserving energy, lowering resource use, increasing productivity, and safeguarding water supplies. Reducing water usage during construction and lowering water expenses can be achieved by collecting rainfall or construction wastewater for reuse as much as possible and assessing its efficacy using the Low Ambient Control technique [5].

d) Reduce environmental pollution, improve environmental quality.

In engineering construction, large amounts of dust, noise, toxic and harmful gases, waste, etc., can cause serious impacts on environmental quality and other relevant personnel. Before earth excavation in engineering, the construction unit shall complete the preparatory work in accordance with the requirements of the Standard for Green Construction Management.

e) Implement scientific management to ensure construction quality.

Implementing green building requires scientific management, improved enterprise governance, and institutionalized-standardized practices to maximize economic benefits and drive sustainable development. ISO 14001 certification is an effective means for enterprises to enhance management and adopt scientific practices [6].

When used in conjunction with scientific construction, BIM technology includes collaborative visual management, early warning of green construction issues, early-stage dynamic scheme

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simulation and resource consumption assessment, operation-maintenance result archiving and full-lifecycle carbon emission tracing, and iterative process optimization. Using “planning simulation-construction monitoring-operation maintenance accumulation” full-cycle data integration, BIM makes it possible for intelligent, digital, and dynamic green construction management throughout the process.

3. Green building construction based on BIM

3.1. Integration of BIM technology with 5D and Geographic Information System (GIS) technology

Building Information Modeling is combined with temporal, geographic, and cost dimensions in a virtual environment to produce a 5D management system. Real-time control over progress, resources, material consumption, and costs is made possible by the system's dynamic modeling of the construction process, which boosts management effectiveness. 5D technology prioritizes early-stage construction predictions over standard 3D modeling technology, which optimizes construction schedule management and layout arrangements, lowers construction risks, and reduces the rate of rework [7].

Through multi-source data integration and visible collaborative platform management, 5D technology reduces risks and achieves refined management in green buildings. It connects a building's full-lifecycle geometric and non-geometric information with WBS schedules (like Primavera) and quantity/cost data (like Glodon) using BIM models as carriers and international standards like IFC/COBie. In order to guarantee real-time cross-dimensional data changes, this is accomplished through API interfaces or specialized data platforms.

Concurrently, BIM and GIS technologies are used in the development of a 5D platform. By combining information about the surrounding terrain, vegetation, and water system, GIS performs a spatial analysis of the construction site to evaluate the influence of site selection on ecologically sensitive areas (e.g., avoiding nature reserves and water source buffer zones). The layout of temporary facilities (such as material yards and processing areas) is then planned using a 5D platform and the BIM model, and an economical pipeline route to reduce collision problems [8]. This technology can reduce damage to the original geomorphology through spatial conflict analysis and optimize the ecological layout of the construction site. In the detection of construction carbon emissions, spatio-temporal modeling is carried out by associating construction processes in the BIM model (such as concrete pouring and steel structure hoisting) with mechanical fuel consumption and power usage data in GIS. Driven by a dynamic timeline, the model displays the construction progress decomposed into visual nodes by week, month, quarter, and year, calculates the carbon emissions of each process, and uses resource consumption histograms to intuitively present the data, forming a data visualization interface to support collaborative decision-making by multiple parties [9]. Visualization engines can be created using Unity 3D and Unreal Engine to display and interact with 3D models in a lightweight manner, quantitatively calculate building resource consumption, effectively control pollution and integrate resources while construction is underway, prevent waste of materials, resources, and labor, and meet green construction standards.

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3.2. The combination of Building Information Modeling (BIM) and Unmanned Aerial Vehicle (UAV) technologies

In the early stages of green construction, BIM technology can create three-dimensional models of the construction site, combining project requirements and site conditions to scientifically plan the layout of temporary facilities, material storage areas, construction roads, etc., thereby avoiding secondary handling and land resource waste caused by unreasonable planning. Smart inspection of drones during construction can be seen in Fig. 1. By equipping drones with high-definition cameras for oblique photography (adding four directional photos to the orthophoto), it can quickly and comprehensively survey the construction site, obtaining accurate and real terrain, topography, surrounding environment, and other information, generating high-precision orthophotos and Digital Elevation Models (DEM) [10]. The integration of these data into the BIM model further optimizes site planning to minimize ecological impacts on surrounding environments while rationally scheduling construction sequences to reduce energy consumption.

Drones frequently take aerial photos of the construction site following pre-planned flight patterns in order to get visual information on the development of the project. Both low-altitude and high-altitude flying paths can be utilized during aerial photography to guarantee thorough data collection [11]. Construction progress in each location may be visibly tracked by comparing aerial photos taken at different times, allowing for the early detection of delays. By comparing UAV-collected image data with BIM models, construction compliance with design is confirmed. For example, building external dimensions and structural component positions are checked against the model, resolving quality issues to avoid resource waste from rework, and meeting the dual quality and efficiency requirements of green construction. Real-time site environmental metric assessments are made possible by drones fitted with environmental sensors (dust, noise, and air quality). These include air quality (measuring PM2.5, PM10, and concentrations of hazardous gases), noise levels, and dust emissions. This allows for the reduction of environmental disruption while enhancing protection [12]. Simultaneously, drones swiftly locate sources of pollution exceedance and notify management of the information. By simulating pollutant dispersion, BIM models incorporate this environmental data and allow for targeted mitigation strategies, such as rescheduling work to minimize noise or placing water sprayers in high-dust locations. This comprehensive strategy successfully reduces environmental pollution brought on by building. Furthermore, real-time aerial inspections enable 24-hour, multi-angle surveillance of construction site safety issues, including deep excavation slope stability, temporary power electrical hazards, and exposed elevated work zones. Safety management staff receive real-time notifications of identified dangers, their visual documentation, and accurate location information, allowing for prompt remedial action [13]. The BIM model helps create safety protection strategies by offering 3D simulation and visualization of on-site safety facilities. Drones can quickly perform reconnaissance of the accident area in the case of a safety mishap or a natural catastrophe, gathering real-time pictures and terrain data to provide precise information for emergency response. Concurrently, the BIM model facilitates the creation of efficient rescue routes and operating plans, which improve rescue effectiveness, reduce casualties and property losses, and make it easier to meet green construction safety standards.

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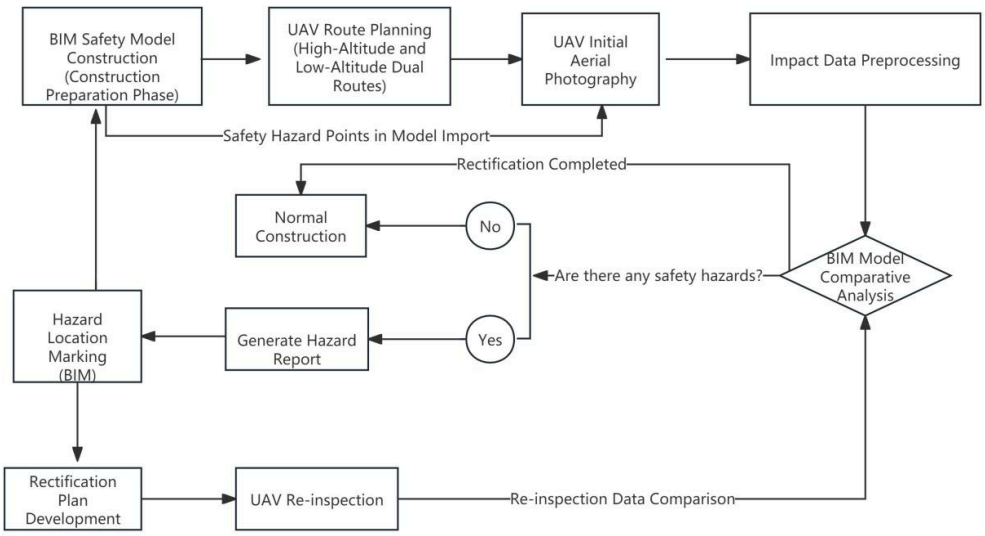

Figure 1. Translation of drone cycle monitoring schematic diagram in construction (photo credit: original)

Meanwhile, the combination of images and BIM models forms a dynamic safety file, which can timely record the construction process and facilitate future traceability and management.

3.3. The integration of BIM technology and Internet of Things (IoT) technology

By utilizing foundational building data obtained via IoT technology, BIM functions as a three-dimensional digital model of the building. By integrating IoT and BIM, building information is consolidated into a single digital framework. In particular, by using data acquisition as the bridge, wearable Ultra-Wideband positioning tags allow for dynamic trajectory tracking and real-time personnel information collection, which ensures construction safety compliance [14]. Construction management is becoming “data-driven” instead of “experience-driven” thanks to sensing devices like environmental detectors and sensors that transform materials and ambient conditions into quantifiable data. This makes it possible to achieve intelligent building site objectives like improved productivity and cost control. [15]. Fig. 2 shows the use of the IoT system in conjunction with the BIM model database for intelligent construction monitoring. By installing sensors on important building energy-consuming equipment, the system transforms analog signals into digital data that is relayed in real time over wired and wireless networks (such as Ethernet, Wi-Fi, and Bluetooth) to a data center. This makes it possible for an energy consumption analysis system to assess future energy trends, track construction energy use in real time for resource conservation, perform multidimensional building energy analysis and establish predetermined energy consumption thresholds using data and computational models. The system immediately initiates an alarm mechanism and produces a thorough analysis report that identifies the source and location of the anomaly when the energy consumption of a particular device or region above the typical range [16]. Additionally, based on analysis, the system automatically creates energy-saving adjustments (such as modifying lighting controls or Heating, Ventilation, and Air Conditioning temps) using AI algorithms. Through an analytics-decision layer, the IoT system disseminates these strategies to equipment controllers, giving facility managers practical guidance or permitting self-adjusting

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devices. IoT sensors gather data on equipment and energy usage during execution, which is then fed back into the analytical system and BIM model to provide a closed-loop control. In order to continually improve energy management efficiency and savings, managers use BIM visualization to track strategy impacts in real time, such as drops in energy usage and changes in equipment status.

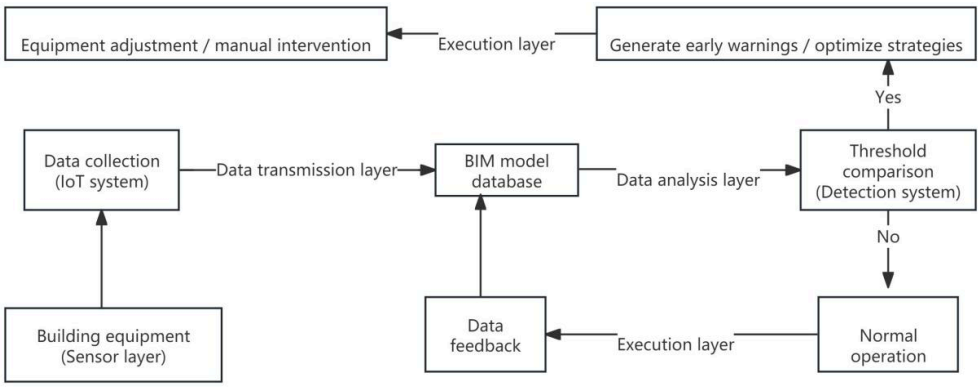

Figure 2. Intelligent detection system based on BIM technology (photo credit: original)

4. Conclusion

BIM is essential for sustainable development in green building, utilizing information integration and 3D visualization to eliminate rework, optimize designs, and cut down on resource waste. BIM creates a "BIM+5D+GIS+Drone+IoT" five-layer structure when combined with IoT for real-time monitoring, drones for accurate resource allocation, and GIS for spatial ecological study. This establishes technological standards for green development and facilitates collaborative management by establishing a “planning-simulation-monitoring-rectification” green closed-loop system.

However, the current application of BIM technology in green construction still has certain limitations. Some enterprises face problems such as insufficient investment in hardware and software, and a shortage of professional talents, making it difficult to deeply integrate BIM technology with green construction. This has restricted the maximization of its application benefits.

Looking ahead, the construction industry's increasing demand for low-carbon and green building practices indicates that BIM will be widely used in sustainable construction. First, increasing the sensing and analytical capabilities of BIM models through deeper integration with future technologies would facilitate intelligent construction regulation and push green practices toward intelligent automation. In the meantime, problems with data interchange, collaboration, and cross-platform compatibility require standardized BIM workflows and technological specifications. Furthermore, developing multidisciplinary talent with BIM and sustainable construction skills is essential, necessitating capacity growth via industry-university cooperation and vocational education. Incentives should be put in place by governments and organizations to support enterprise adoption, stimulate investment, and disseminate successful examples. All of these actions taken together will hasten the industry's transition to a resource-efficient, environmentally friendly model, ultimately assisting China in achieving its carbon neutrality objectives.

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