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Overviewing the Impact of 6D in Green Buildings using Building Information Modelling

Jeyapriya M[1]*, Eunice J*[2]*, Santhosh Kumar P.S*[3]
[1,3]*PG, Department of Construction Engineering and Management, Thiagarajar College of Engineering, Madurai, Tamil Nadu, India*
[2]*Assistant Professor, Department of Civil Engineering, Thiagarajar College of Engineering, Madurai, Tamil Nadu, India.*
Emails: *jeyapriyam@student.tce.edu*[1]*, jeeciv@tce.edu*[2]*, santhoshkumarps@student.tce.edu*[3]

Abstract

In the fast-paced world of architecture, green buildings have emerged as a sustainable development approach, addressing many pressing issues. However, there are shortcomings in implementing quality and subsequent maintenance management aspects. This analysis is based on a comprehensive assessment of green buildings, analyzing their current development, identifying existing problems and suggesting future directions for development. The analysis reveals a lack of comprehensive management planning for the entire process of green buildings. As a solution, the analysis proposes ideas for a green building management planning system that will enable sustainable development from design to completion. Utilizing BIM technology for comprehensive life cycle cost analysis of green buildings can effectively evaluate, quantify and steer all phases of building design, construction and maintenance, effectively fulfilling the requirements for conserving resources and energy. The outcomes of this analysis offer valuable insights for further exploration into the environmental benefits of green buildings based on BIM technology. Current green infrastructure construction technology significantly impacts the preservation and wise use of resources like land, energy, water, air and materials. By converting a conventional building into a green structure, construction costs can be reduced overall and the negative effects of climate change can be mitigated. constructing a structure that optimizes the use of natural resources in its construction and maintenance.

Keywords: *Life Cycle Cost Analysis, Green Buildings, Sustainable Development, Green Infrastructure.*

1. Introduction

The construction industry is increasingly shifting towards sustainable practices to address growing environmental concerns. Green buildings, which are known to minimize energy consumption, reduce waste, and promote healthier environments, have become essential in modern construction. Building information Modeling (BIM) has emerged as a digital solution that supports the planning, design, and management of construction projects. Nonetheless, a considerable gap persists in the use of BIM for green building projects owing to the lack of a dependable and standardized approach [1]. Building Information Modeling (BIM) is a technology used in building design to improve energy efficiency. It helps simulate indoor daylight, artificial lighting, renewable energy use, and cost-saving measures. BIM allows designers to test different energy- saving strategies before the construction begins. In particular, heating, ventilation, and air conditioning (HVAC) systems have been found to be the most effective for reducing energy consumption. By using BIM, buildings can be designed to use less energy, thereby saving both costs and environmental impact [7]. Contemporary green infrastructure construction technologies play a key role in conserving resources, reducing costs, and addressing climate change. These technologies not only promote sustainability, but also support economic growth. The focus is on transforming traditional buildings into eco-friendly structures, particularly in India, by applying green building

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concepts and technologies that enhance environmental performance and reduce energy consumption [9]. The effective design of the envelope, including proper insulation, window placement, and shading, can significantly lower the need for cooling, thus reducing energy usage. These approaches not only help in lowering energy costs but also lead to considerable cost savings during construction and the building's operational life. By integrating advanced tools such as BIM-3D simulation, the overall efficiency of a building can be improved, making it more sustainable and cost-effective in the long run [5]. Building Information Modeling (BIM) is increasingly being recognized for its potential to drive energy efficiency and sustainability in building design, particularly in high-energy-demand environments such as hospitals. In addition to simulating energy behavior, BIM can be employed to assess the energy performance of different building systems across various scenarios, aiding in making well-informed decisions regarding energy consumption and design changes [8]. BIM plays a crucial role in boosting sustainability in small-scale construction by enabling efficient resource management and energy optimization. It facilitates better collaboration among stakeholders, allowing them to visualize the project and make informed decisions early in the design phase. This approach reduces material waste, streamlines the construction process, and ensures that buildings operate with minimal environmental impact [2]. In India, there is an increasing demand for eco-friendly buildings, driven by increased environmental consciousness, government incentives, and the expanding requirement for energy- efficient infrastructure. These drivers are pushing the construction industry to embrace more sustainable practices, with green buildings becoming a key solution for meeting the country's environmental and energy goals [3]. The combined use of BIM and green construction methods is increasingly recognized as essential for modernizing the construction industry, promoting eco-friendly practices, and creating energy-efficient urban spaces. This method not only addresses environmental issues but also enhances the durability and efficiency of urban infrastructure over time. BIM facilitates scenario analysis, enabling teams to evaluate the effects of different design strategies on sustainability objectives before implementation. Additionally, there are numerous ways to improve and mitigate risks by adhering to best practices, as illustrated in Figure-1.1 [11].

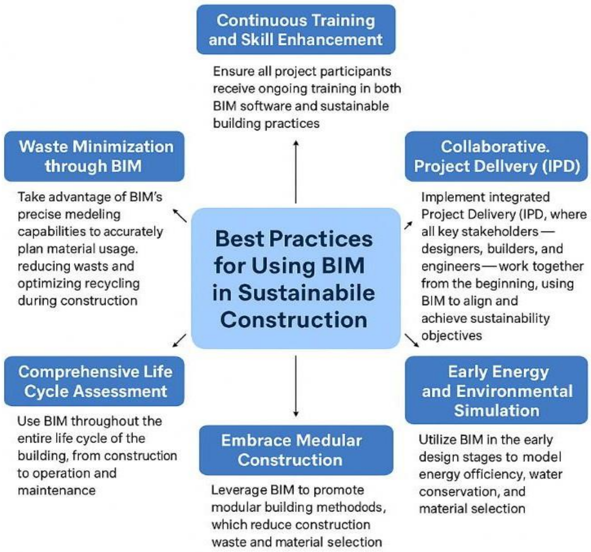

Figure 1 BIM in Sustainable Construction

The integration of Building Information Modeling (BIM) and Green Building Certification Systems (GBCS) aims to enhance sustainability assessments in construction. Currently, the relationship between BIM and GBCS is underdeveloped in literature. The project aims to align with internationally recognized green building certification systems to ensure sustainability, energy efficiency, and occupant well-being as shown in Figure- 1. To improve sustainability assessments, emerging technologies such as the Internet of Things (IoT) and Blockchain could play a vital role. IoT could provide real-time data on a building's performance (like energy use and waste management), which could be integrated directly into BIM models. Blockchain could ensure data security and transparency, helping to maintain the integrity of sustainability certification processes [17].

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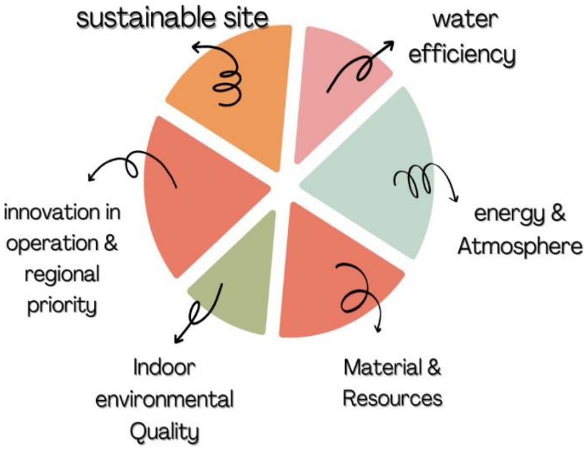

Figure 2 Green Building Credit Certification

2. Methodological Considerations

The reviewed studies commonly employed a combination of literature reviews, case studies, simulation tools, and integrated frameworks to investigate the role of BIM in promoting green building practices. Many utilized Building Information Modeling software such as Autodesk Revit, Insight, and Green Building Studio to simulate energy performance, analyze environmental impacts, and assess alternative design options. Several studies integrated Life Cycle Assessment (LCA) tools and green certification systems like LEED or Malaysia's GBI to quantify sustainability performance. Surveys and expert interviews were used in a few papers to gather stakeholder insights on BIM adoption barriers and success factors. Some researchers applied multi-criteria decision- making methods like the Analytical Hierarchy Process (AHP) to evaluate material choices or design strategies based on sustainability metrics. Overall, the methodologies emphasized a data-driven, design-integrated approach, combining digital tools with performance criteria to support sustainable decision-making across the building life cycle.

3. Literature Review

An integrated approach combining Building Information Modeling (BIM), Life Cycle Assessment (LCA), and the Analytical Hierarchy Process (AHP) to assess the sustainability of concrete structures. This method evaluates the environmental impacts (such as CO_2 emissions and energy consumption) of different concrete types and helps in making informed decisions about material selection. The study compares traditional concrete with green alternatives (using fly ash and slag) and finds that green concrete with 50% Ground Granulated Blast- Furnace Slag (GGBFS) offers the most sustainable option, despite its higher cost [1]. It highlights the importance of considering the entire life cycle of building materials, from production to disposal. The authors advocate for using Life Cycle Assessment (LCA) to evaluate environmental impacts and emphasize the need for integrated design approaches to achieve sustainability in building projects [21]. BIM facilitates environmental performance analysis, energy modeling, and material efficiency, thereby supporting the design and construction of sustainable buildings. The review also discusses the role of BIM in enhancing collaboration among stakeholders and its potential to streamline compliance with green building certification systems [2]. BIM enhances the construction process by improving project quality, optimizing planning and scheduling, facilitating better data management throughout a building's lifecycle, and enhancing collaboration among stakeholders. However, the paper also identifies several challenges in BIM adoption, such as non-uniform data formats, limited interactivity, unclear ownership issues, and insufficient training. The authors emphasize the need for further research to overcome these challenges and optimize BIM's role in promoting sustainable, green building practices [3]. Building Information Modeling (BIM) can be leveraged to enhance sustainable construction practices. It highlights the benefits of BIM, such as improving design efficiency, reducing waste, and supporting better lifecycle management. However, the paper also addresses challenges like the shortage of skilled professionals and the need for effective project management. The authors stress the importance of integrating sustainability into the BIM process to optimize building performance and make informed decisions [6]. BIM helps in assessing energy consumption, carbon emissions, and resource use

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throughout a building's lifecycle. By optimizing building performance, BIM contributes to resource conservation, pollution reduction, and overall sustainability, helping stakeholders make environmentally informed decisions in construction and design [8].The applications of Building Information Modeling (BIM) throughout the entire life cycle of green buildings, from design to demolition. It highlights BIM's role in improving sustainability and efficiency at each stage, such as optimizing design, construction, and maintenance processes [11]. It defines "Green BIM" as a combination of Green Attributes, Project Phases, and BIM Attributes, focusing on aspects like energy use, carbon emissions, and thermal comfort. The authors highlight how Green BIM can be used to calculate green building credits and its potential in improving sustainable building design, construction, and certification processes [22]. This provides a systematic literature review on the integration of Building Information Modeling (BIM) with Green Building Certification Systems (GBCS). It highlights that most studies focus on environmental sustainability, particularly energy efficiency, while social and economic factors are less represented. The review identifies LEED as the most commonly applied certification system in BIM studies and calls for a more balanced approach that includes emerging technologies like IoT and blockchain to enhance sustainability assessments in green building projects [16].

The framework that integrates Malaysia's Green Building Index (GBI) with Building. Information Modeling (BIM) tools to enhance green building assessments. The proposed framework includes the Revit Green Project Template (RGPT) and the GBI Document Assessor, which together facilitate the automatic evaluation of 56 out of 100 GBI points during the design stage. This integration aims to streamline the certification process and promote sustainable construction practices in Malaysia [9]. The best practices for integrating Building Information Modeling (BIM) into green building design, based on insights from architects in Malaysia. It identifies key strategies for successful BIM implementation, such as ensuring a competent design team, using interoperable software, developing structured models for building performance evaluation, and recognizing critical decision points early in the process [15]. Proposes a green model for a conventional building by evaluating energy-efficient design alternatives using Autodesk Insight. The study analyzes energy consumption of a building in Delhi, showing a significant reduction in energy use from 372 kWh/m²/year to 132 kWh/m²/year by modifying design elements like the window- to-wall ratio. The paper highlights how BIM tools like Autodesk Revit can optimize energy performance and promote sustainable building design [10]. It emphasizes that organizations often adopt individual approaches to BIM implementation, which can hinder the effective execution of green projects. The study proposes a framework that optimizes collaboration and enhances BIM maturity levels to improve the efficiency and sustainability of green building projects [12]. Organizations often use individual approaches to BIM, which can limit the success of green building projects. The study proposes a framework that optimizes collaboration and increases BIM maturity to enhance the efficiency and sustainability of green building initiatives [13]. The study identifies key benefits, such as improved sustainability, and challenges, including lack of awareness and high costs. By surveying industry stakeholders, the paper provides valuable insights into the factors influencing the adoption of Green BIM and offers strategies to overcome barriers, helping professionals in the region embrace sustainable building practices [18]. Green Building Information Modeling (Green BIM) approach that integrates energy performance analysis with design optimization to improve energy efficiency in building design. The study outlines a decision-making cycle for building projects that includes defining energy targets, using climate data, and performing energy calculations [5]. Application of Building Information Modeling (BIM) 6D in optimizing the energy efficiency of large office buildings in tropical regions, with a focus on retrofitting strategies. The study emphasizes the

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critical role of the building envelope in reducing thermal loads and enhancing indoor comfort while minimizing energy consumption. By integrating BIM 6D, which encompasses sustainability and operational performance data, the authors propose data-driven actions to improve thermal performance during retrofitting processes [4]. It focuses on the importance of incorporating interior lighting and daylighting in energy simulations to optimize energy performance. The study shows that design improvements, particularly in lighting systems, can lead to significant energy savings and improve energy certifications, contributing to both sustainability and occupant comfort [14]. By using Autodesk Revit and Green Building Studio for energy performance analysis, the study shows that optimizing building orientation and location can lead to significant energy savings, demonstrating BIM's potential in creating more energy-efficient and sustainable buildings [19]. Through a case study of the Deanship Building at Diyala University, it analyzes the impact of design factors like window-to-wall ratio and building orientation on energy performance and costs. The study shows how BIM can optimize energy efficiency, reduce costs, and improve water usage and natural ventilation, ultimately contributing to more sustainable building practices in Iraq [23]. explores how Building Information Modeling (BIM) can enhance sustainability in small construction projects. It discusses the integration of BIM with green building practices to improve energy efficiency, material optimization, and reduce environmental impacts, showing how BIM tools can support sustainable design and help smaller projects meet green building standards. Through a survey and data analysis, the authors identify 21 influential factors, with "program optimization" being the most critical. The study aims to provide insights for better cost management in green building projects throughout their life cycle [24].
Transactive energy enables peer-to-peer energy trading using digital technologies like blockchain, improving grid efficiency and reliability. The authors highlight how TE can reduce transmission losses, lower costs, and increase flexibility in power systems, ultimately supporting more sustainable and resilient energy infrastructures [7]. Digital Twin (DT) technology can be applied to cities for improving urban planning, infrastructure management, and sustainability. The concept involves creating a virtual replica of a city to simulate, monitor, and optimize urban systems, such as traffic, energy, and waste management, to make cities smarter and more sustainable [20]. BIM improves design accuracy, energy optimization, and hazard identification, contributing to better sustainability and efficiency. The study emphasizes BIM's role in advancing green building processes by supporting simulation, management, and standardization, ultimately enhancing the construction industry's sustainability [17].

4. Role of 6D BIM

6D BIM, or Six-Dimensional Building Information Modeling, plays a vital role in enhancing sustainability and lifecycle management within construction projects. It extends the capabilities of 3D, 4D (time), and 5D (cost) BIM by incorporating environmental and performance-related data. The primary function of 6D BIM is to support lifecycle assessment (LCA), enabling project stakeholders to evaluate the environmental impact of a building from design through construction, operation, and eventual demolition. This dimension of BIM also enhances facility management by integrating operational data such as equipment maintenance schedules and energy usage, ensuring efficient long-term building performance. Furthermore, 6D BIM plays a crucial role in achieving green building certifications like LEED, BREEAM, and GRIHA by streamlining the documentation and assessment process. Overall, 6D BIM empowers stakeholders to make informed decisions that balance environmental, economic, and operational considerations throughout a building’s lifecycle. 6D BIM facilitates data-driven decisions, allowing stakeholders to simulate multiple design scenarios based on environmental and operational factors, ensuring that the most sustainable solutions are selected. By linking real-time operational data with design models, 6D BIM also supports the continuous optimization of building performance throughout its lifecycle, ensuring that the building operates efficiently and sustainably well after construction is completed.

5. Material Selection and Sustainable Resources

The model incorporates detailed information about building materials, including their environmental credentials, durability, and recyclability. This enables architects and engineers to select low-impact materials, encouraging resource efficiency and circular construction practices. Material selection plays a vital role in the sustainability of green buildings, as it directly impacts energy consumption, environmental footprint, and indoor environmental quality. In green construction, choosing materials with low embodied energy, high durability, and recyclable properties helps reduce the overall ecological impact of a project. Sustainable materials—such as bamboo, recycled steel, low-VOC paints, and reclaimed wood—not only conserve natural resources but also support circular construction practices. With the help of 6D BIM, these material properties can be embedded into the digital model, allowing project teams to compare options based on environmental performance, cost, and lifecycle impact. This data-driven approach ensures that the materials selected contribute to improved energy efficiency, reduced emissions, and healthier indoor environments. Ultimately, smart material selection supports the goals of green building certifications and enhances the long-term sustainability of built assets.

6. Energy Efficiency and Performance Simulation

6D BIM supports energy modeling by simulating building performance under various conditions. It allows designers to test strategies for heating, cooling, lighting, and ventilation, helping to improve energy efficiency and reduce operational costs. These simulations are especially useful for meeting energy targets in sustainable building certifications. Energy efficiency is a core objective in green building design, and 6D BIM plays a critical role by enabling detailed performance simulations throughout the project lifecycle. By integrating energy modeling tools within the BIM environment, designers and engineers can assess how different design choices affect a building's energy consumption, thermal comfort, and overall performance. These simulations help in optimizing elements such as insulation, glazing, HVAC systems, natural ventilation, and daylight utilization. With real-time data and environmental inputs, the model can predict heating and cooling loads, identify energy loss points, and evaluate the effectiveness of renewable energy systems like solar panels. This predictive capability allows for proactive decision-making during the design phase, reducing energy demand and operating costs over the building's life. As a result, 6D BIM not only enhances compliance with energy codes and green building standards but also supports the creation of buildings that are both environmentally responsible and economically efficient.

7. Lifecycle Assessment and Environmental Impact

Lifecycle assessment (LCA) is a fundamental component of sustainable building design, and 6D BIM enhances this process by embedding environmental data directly into the digital model. LCA evaluates the total environmental impact of a building from the extraction of raw materials through construction, operation, maintenance, and eventual demolition. By using 6D BIM, project teams can simulate and compare different design alternatives based on metrics such as embodied carbon, water usage, energy consumption, and waste generation. This allows for the identification of high- impact areas early in the design process, leading to more sustainable choices. The integration of LCA into BIM workflows also supports transparent reporting and contributes to meeting sustainability targets set by certifications like LEED, BREEAM, and GRIHA. Ultimately, 6D BIM empowers stakeholders to make data-informed decisions that minimize the building's environmental footprint across its entire lifecycle, promoting responsible resource use and climate-conscious construction practices. This not only enhances environmental performance but also supports compliance with government regulations

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and climate action policies. By leveraging these insights, project teams can actively reduce carbon emissions, conserve resources, and create buildings that align with long-term sustainability goals.

8. Cost-Benefit Analysis of Sustainable Building Practices in 6D BIM

One of the most valuable features of 6D BIM in green building design is its ability to conduct comprehensive cost-benefit analysis for sustainable practices. Through the integration of lifecycle data, 6D BIM enables stakeholders to evaluate the financial implications of sustainability measures over the building's entire lifecycle. For example, the initial investment in energy-efficient systems, renewable energy sources, or sustainable materials can be weighed against long-term operational savings such as reduced energy bills, maintenance costs, and extended asset lifespans. With 6D BIM, designers can compare different green building options by factoring in both upfront costs and future savings, providing a clear picture of the overall return on investment (ROI). Additionally, the model supports scenario analysis, allowing project teams to assess how different design or operational strategies might affect the building's financial performance over time. By quantifying the environmental and financial benefits, 6D BIM helps justify the adoption of sustainable practices, making it easier for stakeholders to make informed decisions that align with both economic and environmental goals.

Conclusion

Building Information Modeling (BIM) is playing a vital role in transforming sustainable construction by enhancing project coordination, informed decision- making, and environmental performance across the building lifecycle. Strengthening BIM maturity through a unified organizational framework is essential for aligning fragmented practices, improving stakeholder collaboration, and achieving system interoperability. Tools such as Autodesk Insight 360 support the evaluation of energy-efficient and environmentally responsible design choices. Although BIM adoption still faces challenges like high costs, limited awareness, and interoperability issues, it significantly contributes to better project outcomes and facilitates the achievement of Green Building Certifications. Realizing BIM's full potential requires joint efforts from governments, academic institutions, and industry leaders to overcome barriers, invest in training, and encourage innovation toward a more sustainable and resilient construction industry.

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