

Article

Assessment of Sustainable Building Design with Green Star Rating Using BIM

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Abstract

Globally, construction is among the leading sectors causing carbon emissions. Sustainable practices have become the focus, which aligns with the nation's commitments to the Paris Agreement by targeting a 30% reduction in emissions from the 2005 levels by 2030. However, evaluation for sustainability is critical, and the Green Star certification provides assurance. Building information modelling has emerged as a transformative technology, integrating environmental sustainability into building design and construction. This study explores the use of BIM to enhance green building outcomes, focusing on optimising stakeholder engagement, energy efficiency, waste control, and environmentally sustainable design. This study employed a case study of an educational building, illustrating how BIM frameworks support Green Star certifications by streamlining design analysis, enhancing project value, and improving compliance with sustainability metrics. Findings highlight BIM's role in advancing low-carbon, energy-efficient building designs while fostering collaboration across disciplines. This research investigates the foundational approach required to establish a framework for implementing the Green Star certification in non-residential, environmentally sustainable designs. Further, this study underscores the importance of integrating BIM in achieving Green Star benchmarks and provides a roadmap for leveraging digital modelling to meet global sustainability goals. Recommendations include expanding BIM capabilities to support broader environmental assessments and operational efficiencies.



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Keywords: building information modelling; green star rating; sustainability; energy efficiency; stakeholder engagement

1. Introduction

The rapid development of New Zealand's construction industry, particularly in the Canterbury region following the 2011 earthquake, has raised concerns about the environmental impact of new buildings and infrastructure [1]. Furthermore, there is also a need to minimize the effects of climate change on buildings, which is possible by reducing greenhouse gas emissions [2]. Sustainable buildings have proven economically viable throughout their whole lifetime by reducing waste and efficiently using resources. Nevertheless, these provide a value case for New Zealand [3]. However, the construction of sustainable buildings is mainly influenced by central and local governments, client demand, and social awareness [4]. As a technological factor for sustainable buildings, energy efficiency focuses on energy generation and energy-saving features [5]. However, improving

energy efficiency depends on how much of the whole-of-life embodied carbon emission is reduced, but there is limited awareness within the New Zealand construction industry [6,7]. Similarly, the sustainability rating tools are still in their infancy, such as the Green Star NZ by the New Zealand Green Building Council (NZGBC) [8,9]. Green Star NZ only focus on the environmental aspect of sustainability and is considered the weakest among the building sustainability assessment tools [10]. There are constraints to adopting Green Star NZ, such as the complexity of the certification system, limited supporting policies, and issues related to material supply [11].

The manual operation of the Green Star rating system has several challenges, such as the need for experts, the requirement for documentation, and the assessment of the breadth of the six-star band [12]. It was reported that only half of the accreditation points cover energy, emission, and IEQ, which requires a lot of information to process and evaluate [13]. Nonetheless, automation of the Green Star rating system streamlines the process and is likely to help in the adoption of sustainability practices [14]. Building information modelling (BIM), a digital intervention in building sustainability assessment, provides a 'one-stop shop' to meet the requirements of the sustainability criteria [15], and Green Star is not exceptional. Most common analyses through BIM are related to energy and material [16]. Hence, BIM is still not fully oriented to sustainable buildings, requiring a more integrated approach [14], from conceptual to empirical evidence. In New Zealand, BIM adoption is still in transition due to limited awareness [17] about achieving its potential to improve practices [16], but leadership is inevitable [18]. Nevertheless, BIM can potentially increase the uptake of Green Star [18].

This study aims to map the integration between Green Star rating and BIM functionalities to assess the sustainability of existing and new buildings. Firstly, the studies on the topic were critically reviewed to report on the extent of the work performed. Secondly, an existing sustainable building was selected to assess the potential integration. The Green Star rating was initially scored. Thirdly, the possible support of BIM functionalities was checked. A detailed BIM model was developed for the case building. The findings were reported and discussed in detail. This study aims to automate the sustainability evaluation of new and existing buildings towards achieving a zero-carbon footprint.

2. Literature Review

BIM offers significant advantages over traditional building design methods by enabling early-stage design analysis and simulation, which can reduce project costs and mitigate risks before physical construction or energy rating approval. It transforms traditional design into a sustainable one, with a focus on low-carbon, energy-saving, and emission reduction principles [19,20]. Implementing BIM and a sustainability strategy connects buildings, spaces, people, and communities, resulting in broader benefits [21]. While green BIM strategies are adopted globally, the relationship between BIM and green design requires further exploration [22,23]. Nonetheless, BIM has proven to be a fundamental trend of true sustainability [24]. BIM is now a standard practice in the construction industry, recognized for its contributions to sustainable strategies, becoming an integral part of the project lifecycle for sustainable building design deliverables. For projects in New Zealand, even if official green rating certification is not sought, utilizing a tool framework like Green Star is recommended to identify sustainability objectives and establish a common language for the design and construction teams [25].

Several studies have highlighted the integration of BIM tools and the Green Star rating system. Client demand plays a vital role in urging the exploration of the BIM and Green Star rating, which requires a high level of understanding to establish relationships [26]. Theoretically, BIM supports 75% of the Green Star criteria, but energy efficiency is the

main criterion [14], with the optimisation option. Lu et al. [21] reviewed BIM support for green building assessment for Green Star Australia and reported that 64 out of 110 credits are achievable, but there is no minimum requirement. BIM partially supports site, transportation, energy, and atmosphere/emission-related credits. However, it highly supports water, materials, waste, and indoor environment quality-related credits. There was no BIM support for innovation. Similarly, other studies highlight the limitations of covering sustainability areas such as water, land, biodiversity, acoustics, socioeconomics, and ecology in studies integrating BIM and green building certification [27], as well as culture [28]. Interestingly, stakeholder perception varied towards the potential of BIM applications for Green Star approaches [29].

There is a strong correlation between sustainability and morphological elements in the built environment [30]. However, there is no clearly defined relationship between BIM and Green Star. This created a space for a new criterion to determine the building sustainability. Nevertheless, there are barriers to integrating BIM and Green Star, including distinct processes, a lack of understanding, insufficient client demand, the requirements of Green Star submissions, and a low Level of Development (LoD) in BIM [31]. Gandhi and Jupp [32] presented a case study of a commercial building to evaluate gaps in BIM applications for green building certification. There was misalignment between design activities, certification criteria, and issues around internal project coordination. Ly and Kiroff [33] conducted a case study on six green star-rated head office in Auckland and found no or weak connection between green building certification and BIM. There were issues of low-quality modelling, inefficient procurement, and a lack of coordination at multi-disciplinary levels. Li et al. [34] used a cloud-based BIM platform for a case study to validate the envelope thermal transfer value calculation, as a key criterion for the green mark score. Further, simulation tools of BIM were used for the energy and daylight performance through design and operational phase optimisation [35].

The development of Green Star tools follows ‘district’ to ‘product’ (from macro to micro), but for BIM, the focus is on ‘product’ to ‘element’ to ‘entity’ and ‘precinct’ (from micro to macro) [36]. There is research confusion when investigating the integration of BIM tools with the Green Star rating system, as to which direction of support is more beneficial; however, the most common is BIM support [37]. However, this integration makes the overall process towards sustainability more standardised and agile [38]. The concept of Level of Development (LoDev) is crucial for Green Star rating, encompassing both Level of Detail (graphical representation) and Level of Information (properties of the object). For Green Star assessment, LoDev is suggested as the sum of LoI and LOD. BIM provides benefits across various dimensions, from 1D (research, concept design) to 6D (performance assessment, value engineering, save estimation, re-design) [39]. The architectural, structural, and MEP (mechanical, electrical, and plumbing) BIM models provide specific information essential for Green Star assessments. For example, architectural BIM defines the building’s footprint, exterior, internal design, roofs, and sun shading. Structural BIM includes foundations, load-bearing walls, openings, and framing. MEP BIM covers cooling and heating pipework, HVAC services, lighting, and waste/waterworks [40].

The BIM framework leads this integration, and its adoption eventually overcomes the barrier [41]. The BIM and Green Star integration helps the designers gain awareness of the specific green building rating system, ultimately improving the design for sustainable buildings [42]. By aligning project designs with Green Star principles, teams can establish a common language and objectives for a sustainable outcome [43]. The adoption of Green Star ratings in New Zealand reflects a commitment to environmental sustainability and resilience in building design. By leveraging BIM’s capabilities, projects can achieve higher performance ratings, minimise waste, and optimise energy consumption [44]. This

framework also ensures compliance with evolving regulatory requirements and global environmental targets, reinforcing BIM's role as a fundamental element of modern sustainable design practices [45]. The integration of BIM with Green Star certification provides significant benefits by offering a strong platform for documenting, analysing, and improving compliance with the rating system's requirements [46]. This study helps to develop an evaluation criterion for comparing existing and newly constructed buildings.

Nevertheless, there was no clear standard or uniformity for integrating BIM and Green Star in relevant studies to develop a holistic framework. Limited studies provide empirical evidence of integration using proper case studies. Furthermore, there is no clarity about mapping the integrations. This study starts with exploring sustainable design options within the context of BIM. The Green Star rating system is applied to identify the potential sustainability credits achievable through BIM. The influence of BIM on sustainability outcomes and ratings is then assessed. The strategies proposed are to incorporate Green Star principles into the project workflow. This study reports on the benefits of achieving Green Star certification through BIM applications.

3. Research Methodology

3.1. Selection of the Case Building

This study focuses on leveraging BIM to meet Green Star certification requirements for the Ara Institute of Canterbury's Kahukura Block (K Block), refer to Figure 1a,b, located in the inner city of Christchurch, New Zealand, with an area of 6500 sqm and three floors. This is a public building, and the data for this property are accessible through an official request. This project was unique due to sustainability considerations from the start, aligning with institutional values. The project cost was around 38 million and was completed between 2014 and 2017. This project employed an early contractor involvement procurement strategy, suitable for complex projects [39], which resulted in timely completion and budget adherence through the use of BIM for scheduling quantities and administering project costs, as well as design authoring, review, and engineering analysis [47]. This building won several awards for educational facility, green building, timber design, spatial built environment, and public and institutional space [48]. The case building is selected for public use (educational) based on access to key information, documentation, and stakeholders.



(a)

Figure 1. Cont.

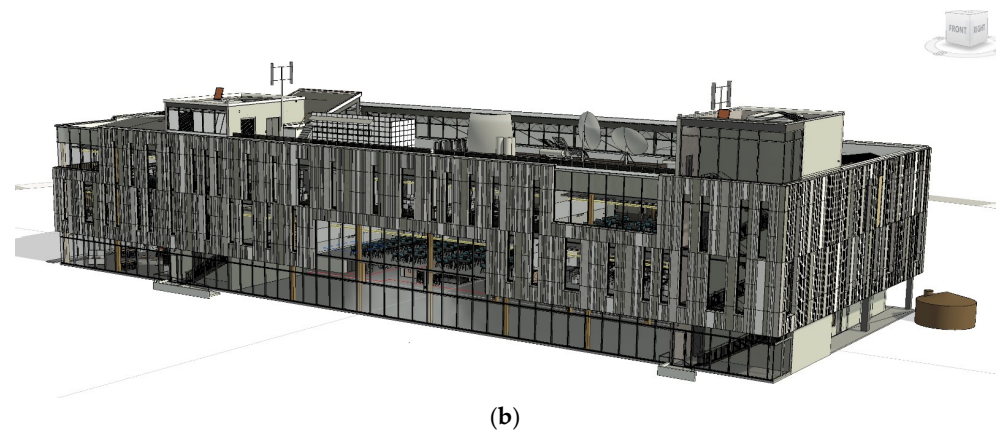


Figure 1. K Block building views (Source: authors' own work). (a) Real view photograph. (b) BIM 3D-model view.

3.2. Green Star Rating Calculation

The Green Star rating system, developed by the NZGBC, offers a systematic approach to evaluate and certify sustainable building performance. It uses a point-based system across nine categories, with each category including specific credits that indicate compliance with sustainability criteria [49]. Achieving Green Star certification requires meeting a minimum point threshold. Ratings from Four Stars to Six Stars indicate increasing excellence in sustainable practices.

The Green Star rating system promotes sustainable building practices by encouraging resource efficiency, energy and water savings, reduced operational costs, and healthier work environments [44]. It evaluates projects across nine categories, awarding star ratings based on total credits achieved, ranging from four stars to six stars, as shown in Figure 2. This system ensures that all project team members actively engage with sustainability goals by assigning documentation responsibilities and compliance tracking. Green Star Accredited Professionals play a critical role by coordinating teams and verifying documentation during various project stages.

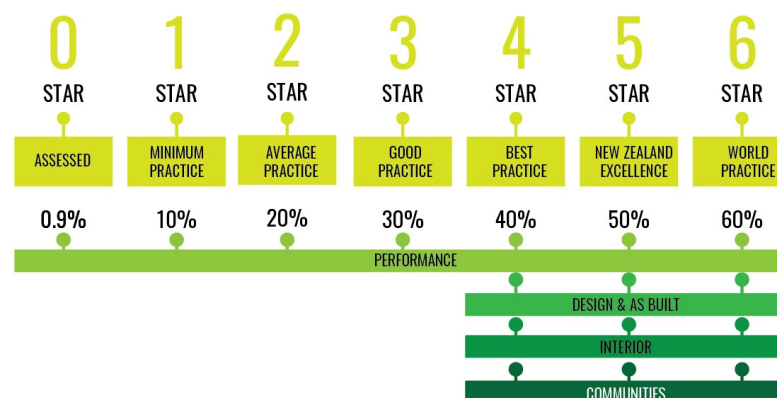


Figure 2. Green star rating system (adapted from [49]).

The Green Star framework and its associated categories are pivotal to the sustainable objectives of this research. The scope of this study encompasses four primary categories [50], excluding land use and ecology and emissions:

Management: it includes commissioning processes, building tuning, metering and monitoring, and operational waste management strategies.

Indoor Environment Quality (IEQ): it focuses on improving indoor air quality (ventilation), acoustics, lighting, and visual comfort, minimizing indoor pollutants, and optimizing thermal comfort.

Energy: it considers thermal envelope performance, mechanical systems, lighting efficiency, and on-site renewable energy generation (e.g., solar energy).

Materials: this section addresses the use of low-environmental-impact materials, including steel, concrete, timber, adhesives, sealants, flooring, ceilings, applied coatings, insulation, PVC, and furniture.

The Green Star certification process imposes specific requirements for services across multiple disciplines, including mechanical, electrical, hydraulic, civil, and fire systems [51]. These requirements, detailed in the Green Star Office Interiors, emphasize promoting sustainable building practices by establishing a common language and demonstrating the tangible benefits of green buildings [52].

The Green Star rating assessment involves a structured methodology that identifies achievable sustainability credits aligned with specific project goals, constraints, and regulatory requirements. Detailed technical simulations and modelling, such as energy, thermal comfort, and daylight analyses, are then conducted to substantiate the targeted credits. Comprehensive supporting documentation—including drawings, product certifications, and performance calculations—is prepared and submitted for rigorous review by an independent expert panel appointed by the New Zealand Green Building Council (NZGBC). This panel verifies compliance, finalises scores, and determines the project's Green Star rating.

In this study, documentation was analysed for a Green Star rating. This includes 2D drawings (architectural, structural, and mechanical, electrical, and plumbing), a schedule of quantities, and specifications. Maximum points available for the Green Star rating were identified, and target points also met the four-star rating for K Block.

3.3. Building Information Modelling

BIM has emerged as a transformative digital technology in the construction industry, offering a comprehensive platform. It has revolutionized the construction industry by providing a unified model integrating physical and functional building characteristics. Since its emergence in the late 20th century, BIM has become a central repository of knowledge, facilitating well-informed decisions throughout a building's lifecycle, from initial design to decommissioning [53]. BIM adoption is determined through n-dimensions (nD) of BIM, demonstrating different functionalities, which include 3D and 4D scheduling and sequencing, 5D cost estimating, 6D procurement, 7D facilities management, 8D risk assessment, 9D lean construction, and 10D prefabrication and continuing [54].

The design model, developed on Revit 2017 with LOF350, was initially received from the consultant; see Figure 3. Revit has a proven BIM tool to integrate well with green building assessment systems [38]. An as-built model was then developed based on real-time information about the building features. The model was checked for sanity, tagging, annotation, and connectivity. It was cleaned for errors to maintain its integrity. The graphical and material information was also checked.

The BIM process for the K Block project involved several iterative stages, beginning with creating an initial conceptual BIM model. The model was initially developed with basic geometric representations and general spatial configurations to outline project feasibility and preliminary sustainability goals. Throughout the design development phase, detailed elements such as structural frameworks, interior partitions, and facade components were progressively refined, enhancing the model's graphical accuracy and completeness [55].

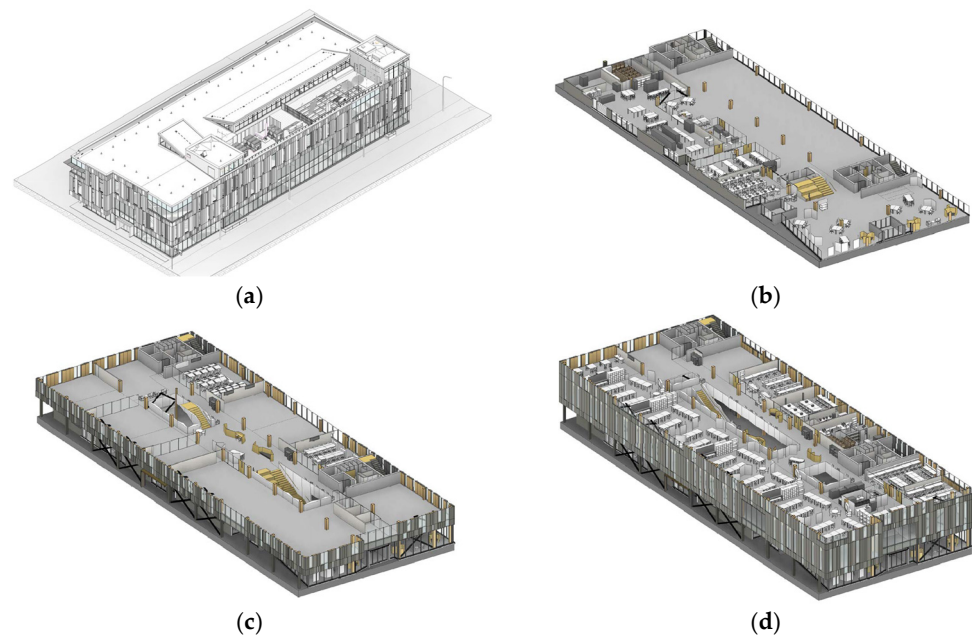


Figure 3. BIM model views for K building. (a) Building isometric view. (b) First floor plan with section view. (c) Second floor plan with section view. (d) Third floor plan with section view.

Significant changes were implemented before the sustainability analyses, including the integration of specific material specifications, energy-related properties, and detailed mechanical, electrical, and plumbing (MEP) systems. Adjustments to the model involved optimising window-to-wall ratios, updating insulation specifications, refining HVAC system designs, and incorporating precise occupancy and operational schedules. These refinements ensured the BIM model accurately reflected the building's anticipated real-world performance, providing robust input data for subsequent analyses using tools like Autodesk Insight and Green Building Studio (GBS) [56]. Ultimately, these updates facilitated accurate energy performance simulations and supported the project's compliance with Green Star sustainability requirements.

3.4. BIM Utilisation for Green Star Rating

BIM enables projects to meet Green Star requirements through advanced modelling frameworks such as Levels of Development, which integrates Level of Detail and Level of Information, as mentioned in Table 1. Architectural, structural, and mechanical, electrical, and plumbing BIM models capture vital design details, including demolition, HVAC systems, lighting fixtures, and structural elements, providing a comprehensive framework for sustainability assessment. BIM helps in an interoperable automation approach for certification [57]. BIM cloud helps to synchronize design models for different disciplines [58].

Table 1. BIM methodology and LOD for Green Star process.

Green Star Process	BIM Methodology	LoD
Meet the requirements	BIM approach and plan	100–200
Design and submission	BIM development and coordination	200–400
Assessment	BIM documentation review and management	200–500
Certification	Add value through the BIM lifecycle	100–500

A three-stage framework for integrating BIM with Green Star certification includes the following: developing a matrix to correlate BIM technologies with Green Star criteria,

validating the matrix through case studies, and auditing as-built BIM models for compliance [51]. This structured approach underscores BIM's role in achieving certification efficiency by reducing manual documentation and improving stakeholder coordination. The Green Star framework acknowledges local considerations, reflecting a commitment to advancing sustainable construction practices in the region. One approach, for non-residential projects, is to understand the Green Star rating and then explore the relationship with BIM through analysis of the criteria, followed by a case study for illustration [31]. Another approach is to apply Green Star design principles during the BIM process and to monitor and evaluate Green Star rating outcomes through BIM tools and workflows [59].

The model was then analysed with Autodesk Insight for building performance [60]. Autodesk Insight provides a comprehensive platform for analysing building energy and environmental performance. Its cloud-based accessibility enables team members to collaborate and review projects from any device. Early-stage design reviews using Insight help address sustainability concerns, with energy analysis data generated in Green Building Studio and displayed on an intuitive dashboard. This functionality allows users to identify design inefficiencies and implement energy-saving measures early.

Revit offers a familiar drafting and modelling environment, seamlessly transitioning from concept design to construction and facility management. Its built-in tools enable users to simulate building performance, meeting standards such as LEED and ASHRAE while predicting sustainable outcomes. Revit's energy analysis options assist in aligning projects with Green Star rating requirements, facilitating informed design decisions.

Autodesk GBS is a cloud-based energy analysis tool designed to optimise energy efficiency and reduce the carbon footprint of building designs [31]. GBS directly integrates with BIM data from Revit models, ensuring a streamlined workflow for performance evaluations. By incorporating energy engineering at the project's inception, GBS ensures that sustainability objectives are addressed during the design phase rather than as post-design modifications. This proactive approach maximises the value of BIM in achieving Green Star credits and highlights how Revit can model energy settings for sustainable outcomes [61].

The selection of Autodesk GBS software (version 2023) for sustainability analysis in the K Block project was based on its ability to integrate and analyse BIM data directly from Revit models efficiently. GBS offers a streamlined, cloud-based platform that significantly enhances the accuracy and speed of energy simulations and carbon footprint analyses. It is particularly suitable for detailed energy assessments required by the New Zealand Green Star certification process [11]. Moreover, GBS's intuitive interface facilitates early-stage engagement with sustainable design, enabling rapid evaluations of energy-efficient measures and fostering real-time collaboration among architects, engineers, and sustainability consultants. The software's capability to seamlessly generate comprehensive performance data directly from BIM models simplifies compliance documentation, enhances decision making, and ultimately supports higher Green Star ratings [62].

Autodesk GBS significantly supports the Green Star certification process through its integration with BIM. GBS efficiently generates precise energy and carbon footprint analyses by directly processing BIM data from Revit models. Its cloud-based platform facilitates early design assessments and collaborative evaluations, enabling project teams to test and optimise sustainability measures rapidly. Furthermore, GBS's automated and streamlined documentation simplifies compliance verification and reduces potential errors. This ensures a more reliable, efficient path toward achieving higher Green Star certification levels, ultimately enhancing overall project sustainability outcomes.

4. Results and Discussion

4.1. Green Star Rating for Case Building

The case building was evaluated using the Green Star rating tool. Achieving a preliminary score of 56 points, surpassing the 45-point threshold for a four-star rating, as reported in Table 2. The Green Star scoring for the K Block project was calculated by systematically assigning points across multiple sustainability categories based on the detailed Green Star rating sheet. This rating sheet, provided by the NZGBC, served as a structured framework outlining specific sustainability criteria and associated credits across nine primary categories: management, indoor environment quality, energy, transport, water, materials, land use and ecology, emissions, and innovation. Each category includes defined credits, and each credit is awarded a set number of points upon successful documentation and compliance verification. The cumulative total of these points determines the project's final Green Star rating, with thresholds for ratings clearly specified (e.g., 45–59 points for a four-star rating, indicating the best practice) [63].

Table 2. Green Star rating.

Category	Maximum Points Available	K Block Target Points
Management	15	10
Indoor Air Quality	17	10
Energy	22	12
Transport	10	7
Water	12	5
Total	76	44

In the K Block example, scoring involved detailed evaluations, technical modelling (including energy performance and thermal comfort analyses), and comprehensive documentation demonstrating compliance with each targeted credit. Autodesk Green Building Studio (GBS) and other BIM-integrated tools were instrumental in providing precise evidence required for these credits.

Challenges encountered during the Green Star rating process primarily concerned coordination and accurate data management. Specific difficulties included ensuring comprehensive documentation aligned precisely with Green Star requirements, maintaining consistency and accuracy across multiple interdisciplinary inputs, and handling revisions necessitated by changing project specifications or outcomes from technical simulations. Additionally, effectively managing the alignment between BIM model data and Green Star documentation requirements proved challenging, emphasizing the need for meticulous data tracking and robust interdisciplinary communication throughout the project lifecycle.

4.2. BIM and Green Star Integrations

There is no guidance available to determine the suitability of a software package for the Green Star rating system [27]. This study reported key integrations of the Green Star rating and BIM dimensions.

The K Block project's Green Star scoring was calculated using the Green Star rating sheet provided by the NZGBC. This structured framework outlines sustainability criteria across nine categories: management, indoor environment quality, energy, transport, water, materials, land use and ecology, emissions, and innovation. Each category comprises specific credits, and points are awarded based on thorough documentation and compliance verification. The cumulative total of points determines the project's final Green Star rating.

The integration of BIM and Green Star significantly enhances sustainability assessments by providing a centralized platform for managing graphical and non-graphical data,

streamlining documentation, and ensuring real-time data updates, ultimately promoting sustainable construction practices nationwide. This comprehensive approach not only improves project coordination and minimizes risks but also facilitates the achievement of targeted Green Star rating points through advanced analysis and simulation tools. A total of 297 integrations were mapped. There were 41 integrations for ‘management’, 36 for ‘indoor environment quality’, 13 for ‘energy’, 2 for ‘transport’, 5 for ‘water’, 18 for ‘materials’, 2 for ‘land ecology and use’, 9 for ‘emissions’, and 29 for ‘innovations’. This study demonstrates that BIM supports 52% of the Green Star criteria using extended BIM dimensions, whereas previously, theoretically, BIM supported 75% [14].

The BIM integration analysis for each Green Star criterion followed these steps:

1. Management: BIM models facilitated comprehensive management strategies, incorporating building information commissioning and tuning, environmental management plans, and ongoing monitoring through precise BIM data tracking and reporting.
2. Indoor Environment Quality: Simulations conducted through BIM tools ensured optimal air quality, hazardous material management, thermal comfort, acoustic performance, and visual comfort, verifying compliance through detailed model simulations.
3. Energy: Autodesk GBS and BIM-enabled energy modelling validated greenhouse gas emission reductions and optimized peak electricity demand, ensuring efficiency criteria were robustly met.
4. Transport: BIM helped visualize and plan alternative transportation programs, enhancing accessibility and efficiency through integrated transport mode surveys and simulations.
5. Water: Water conservation strategies were validated through BIM-based simulations of potable water use and fire protection services, demonstrating significant reductions against baseline consumption.
6. Materials: BIM facilitated sustainable procurement processes, waste management during construction, and refurbishment phases by embedding environmental product declarations directly into the BIM model.
7. Land Use and Ecology: The ecological value and biodiversity contributions were assessed using BIM tools to plan and optimize site landscaping and maintenance practices.
8. Emissions: Stormwater management, light pollution control, and refrigeration impact assessments were modelled and analysed through BIM, ensuring adherence to Green Star emission reduction criteria.
9. Innovation: Innovative technologies, processes, and strategies for global sustainability benchmarks were identified, modelled, and documented through advanced BIM functionalities.

Table 3 outlines the aspirations and contributions of BIM processes across Green Star rating categories. These contributions encompass management practices such as commissioning and tuning, ongoing monitoring, and environmental management. For indoor environment quality, BIM supports improvements in air quality, lighting, thermal comfort, and acoustics through detailed modelling and simulation. The energy category benefits from reductions in greenhouse gas emissions and peak electricity demand, achieved through optimised building designs and systems, while alternative transportation programs and surveys support transport credits. Additionally, BIM facilitates sustainable procurement, operational waste reduction, and refurbishment management under the materials category. The integration of BIM into green building design optimizes design from initial stages, leading to more sustainable and economically efficient outcomes [64]. BIM-driven methodologies also enhance contributions to biodiversity, emissions control, and innovation, such as adopting transformative technologies.

Table 3. BIM and Green Star integrations.

Green Star Rating Subcategory	BIM Functionalities								
	BEP	GBS	Insight	2D	3D	4D	5D	6D	7D
1. Management									
Green Star Accredited Professional	✓	✓	✓	✓	✓	✓	✓	✓	✓
Building Information	✓	✓	✓	✓	✓	✓	✓	✓	✓
Commissioning & Tuning		✓	✓	✓	✓			✓	
Ongoing Monitoring & Metering	✓	✓	✓	✓	✓			✓	
Environmental Management	✓	✓	✓	✓	✓			✓	✓
Green Cleaning	✓	✓	✓	✓	✓			✓	✓
Commitment to Performance	✓	✓	✓	✓	✓			✓	✓
2. Indoor Environment Quality									
Quality of Indoor Air	✓	✓	✓	✓	✓			✓	
Hazardous Materials	✓	✓	✓	✓	✓			✓	
Lighting Comfort	✓	✓	✓	✓	✓			✓	
Daylight & Views	✓	✓	✓	✓	✓			✓	
Thermal Comfort	✓	✓	✓	✓	✓			✓	
Acoustic Comfort	✓	✓	✓	✓	✓			✓	
Occupancy Comfort Survey	✓	✓	✓	✓	✓			✓	
3. Energy									
Greenhouse Gas Emissions	✓	✓	✓	✓	✓	✓		✓	✓
Peak Electricity Demand		✓	✓	✓	✓			✓	
4. Transport									
Alternative Transportation Program				✓					
Transportation Modes Survey				✓					
5. Water									
Potable Water			✓	✓	✓				
Fire Protection Services				✓	✓				
6. Materials									
Procurement & purchasing	✓	✓	✓	✓	✓	✓	✓		
Waste from Operations		✓	✓	✓	✓	✓	✓	✓	
Waste from Refurbishments	✓	✓	✓	✓	✓	✓	✓		✓
7. Land Use									
Biodiversity and Ecological Value				✓					
Groundskeeping Practices				✓					
8. Emissions									
Stormwater Control				✓	✓			✓	
Light Pollution				✓	✓			✓	
Impacts from Refrigeration				✓	✓			✓	

Table 3. *Cont.*

Green Star Rating Subcategory	BIM Functionalities								
	BEP	GBS	Insight	2D	3D	4D	5D	6D	7D
9. Innovation									
Innovative Technology or Process	✓			✓	✓	✓	✓	✓	✓
Market Transformation	✓			✓	✓			✓	✓
Improving Green Star Benchmarks		✓	✓	✓		✓		✓	✓
Global Sustainability		✓	✓	✓			✓		✓
Innovation Challenge		✓	✓	✓			✓	✓	✓

BIM's contextual excellence, enabled by rich information within a collaborative 3D environment, ensures effective project coordination and minimises risks across all project phases. The ability to selectively target Green Star rating points through the BIM process, using advanced analysis and simulation tools, further strengthens its role in advancing sustainable design while minimizing impacts on the design and construction program. The integration of BIM and Green Star ratings represents a significant step forward in achieving sustainability goals for the construction industry, promoting more efficient, environmentally responsible, and economically viable building practices [65].

4.3. Performance Evaluation

Integrating BIM on the K Block project significantly improved the Green Star rating process. BIM enhanced the overall efficiency and effectiveness of sustainability assessments by streamlining data management and facilitating precise simulation analyses. The intervention of BIM significantly reduced the time required for conducting critical sustainability analyses, including energy performance, daylight optimisation, and thermal comfort, by enabling real-time model adjustments and immediate feedback [56].

Resourcefulness improved markedly as the BIM model consolidated essential documentation and facilitated accurate, cross-disciplinary data sharing, eliminating redundant processes and minimizing errors. This integration led to efficient resource use, enabling project teams to focus more directly on sustainability improvements than on administrative tasks [66].

Furthermore, conduit modelling, a specific application within BIM, provided precise visualisation and planning capabilities for mechanical, electrical, and plumbing services [67]. This capability improved accuracy in resource allocation, reduced material waste, and optimised service layouts, enhancing building performance and compliance with Green Star rating criteria. Overall, BIM intervention dramatically streamlined the certification process, enhanced accuracy, and improved resource efficiency throughout the project lifecycle.

5. Conclusions

This study evaluates the potential improvements and value that BIM offers in achieving Green Star certification. Through the case of the K Block project, this research demonstrates how the integration of BIM enhances Green Star rating credits, facilitating sustainable construction practices. The findings underscore the advantages of implementing BIM for Green Star-certified buildings, including its ability to provide a shared data environment for enhanced data access and collaboration, reduce risks during the design and construction phases by enabling better clash detection and issue resolution, create a rich and accurate record of the project lifecycle for improved facility management, and increase efficiency in the Green Star certification process [68]. The study demonstrated that integrating BIM significantly enhances the efficiency, accuracy, and overall effectiveness of achieving Green

Star certification. BIM streamlined the assessment process by enabling precise sustainability simulations, effective resource management, and improved cross-disciplinary coordination, collectively facilitating higher sustainability ratings.

The study's scope was limited to the educational building, focusing primarily on the management, indoor environment quality, energy, and materials categories. The exclusion of other Green Star categories, such as land use and ecology and emissions, restricts the broader applicability of findings. Additionally, reliance on a single case study limits the generalizability of the conclusions. This study reveals 155 integrations, indicating 52% coverage of the Green Star rating.

Theoretically, this research contributes to existing knowledge by demonstrating how BIM can be instrumental in achieving sustainability goals systematically within building certification frameworks. It reinforces BIM's potential in facilitating integrated design practices that align with sustainability certification criteria.

The findings provide actionable insights for architects, engineers, and sustainability consultants on effectively leveraging BIM for Green Star certification. The demonstrated methodology offers a practical framework for streamlining the sustainability certification process, potentially reducing project timelines and costs.

The integration of BIM significantly improved the efficiency, accuracy, and effectiveness of achieving Green Star certification for the K Block building at the Ara Institute of Canterbury. The building, a key subject of this assessment, successfully demonstrated compliance with specific Green Star sustainability criteria, such as management, indoor environment quality, energy, and materials. The positive assessment signifies that K Block has achieved substantial sustainability benchmarks, including optimized energy performance, improved indoor environmental conditions, efficient resource management, and effective cross-disciplinary collaboration.

This positive outcome confirms K Block as an exemplar of sustainable educational facility design, meeting and exceeding the stringent sustainability requirements outlined by the NZGBC. Practically, this demonstrates the robust capability of BIM tools to streamline sustainability certification processes, reduce administrative burdens, and enhance resource efficiency. Theoretically, this research reinforces BIM's critical role in aligning building design and construction practices with contemporary sustainability objectives.

Future research should explore BIM integration in broader sustainability categories not covered in this study, such as land use and ecology and emissions. Comparative analyses across multiple diverse building projects are recommended to enhance generalizability. Additionally, further investigation into the integration of advanced BIM technologies, such as digital twins and real-time monitoring systems, would provide deeper insights into enhancing sustainability performance throughout a building's lifecycle.

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Abbreviations

The following abbreviations are used in this manuscript:

BEP	Building Energy Modelling
BIM	Building Information Modelling
GBS	Green Building Studio
IEQ	Indoor Environment Quality
NZGBC	New Zealand Green Building Council

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