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Systematic Review

The Effects of BIM Maturity Levels on Modularization and Standardization in the Construction Industry: A Systematic Literature Review and Case Studies

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Abstract: The increasing demand for efficient, sustainable, and coordinated construction practices has intensified interest in the integration of digital tools such as Building Information Modelling (BIM) with modularization and standardization strategies. This study aims to examine the relationship among BIM maturity levels, modularization grades, and standardization levels, and to assess their combined impact on construction project outcomes. A mixed-methods approach, including a systematic literature review and New Zealand-based case studies, is used to develop and validate an evaluative framework. The SLR identifies key themes and determinants, while the case studies provide empirical evidence on the interactions between BIM maturity levels, modularization grades, and standardization levels. The study identifies that higher BIM maturity levels significantly enhance modularization and standardization practices. Advanced BIM capabilities foster improved design coordination, collaboration, and data management, leading to more efficient construction processes. A guideline for mapping BIM maturity against standardization levels is proposed to assist stakeholders in evaluating and optimizing project outcomes. This research offers a novel perspective on integrating BIM maturity with modularization and standardization practices. While it is applied in the New Zealand context, the proposed framework and methodology are designed to be transferable to international settings. It provides actionable insights for policymakers and industry stakeholders seeking to refine standards, promote BIM adoption, and enhance construction project efficiency worldwide.

Keywords: Building Information Modelling; BIM maturity levels; construction industry; modularization grades; standardization levels; technology integration

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1. Introduction

The construction industry operates within a dynamic landscape, constantly driven by the pursuit of innovative strategies that enhance efficiency, sustainability, and efficacy in creating the built environment [1]. Central to this quest is the emergence of modularization as a transformative force, introducing a paradigm shift to conventional construction practices [2,3]. Modularization techniques are anticipated to increase with the implementation of BIM, advanced technologies, and automation [2]. By nature, projects and their components are not of standardized design and there is significantly less repetition of tasks and activities than highly standardized and operation-based industries. Accordingly, to effectively implement modularization without restrictions, it is imperative to have a high degree of standardization that corresponds to and supports modularization processes [4]. Modularization often includes a combination of elements, where modules can be mixed and matched to create new product variants. Moreover, the modular approach leads to an in-depth exploration of a product's functional dimensions, fostering a deep comprehension of optimizing and efficiently assembling component-based functions [5]. On the other hand, standardization is using identical components in a one-per-product setting, but in various products [6]. Standardization may also be used for construction processes to enhance efficiency and quality [7,8].

BIM's capacity to streamline project processes and foster collaboration has been particularly evident in the Chinese construction industry [9]. Singapore's vigorous promotion of modular construction highlights the crucial role of regulatory frameworks while reflecting the seamless interconnectedness of technology and policy in shaping construction practices. This approach underscores the country's ability to advance modular construction without encountering significant challenges in technology assimilation [1,10,11]. These observations form a baseline to understand the global progress, impact, and adaptability of BIM.

However, notwithstanding this global growth of OSC and BIM, their integration in many countries, including New Zealand, has been approached with varying degrees of attention [12]. Modularization and standardization have been advocated and progressively implemented within the New Zealand construction industry, particularly in the construction of prefabricated building components such as precast concrete panels and steel framing. Financial constraints and a lack of opportunities for economies of scale are the most significant barriers to the uptake of automation and corresponding processes in a small market such as New Zealand, where OSC manufacturers prefer manual labour because it is easily scaled up or down [13].

Although there is a strong policy framework to promote modular construction in different construction sectors, even to the level of the strongest of initiatives and regulatory frameworks such as Singapore's construction sector [1], there is a lack implementation and advancements and processes such as modularization and standardization [1,7]. Tools such as BIM in creating collaborative platforms are a facilitator for the implementation of new technology-related processes and providing pathways to standardization [14]. The integration of BIM within the landscape of modular components in Off-Site Construction (OSC) projects, as demonstrated in China, has significantly enhanced project performance and cooperative dynamics. This integration of modularization with standardization and advanced technologies, notably BIM, represents a critical stage in the evolutionary journey of construction methodologies. Beyond streamlining processes, it addresses the complexities of diverse product variants and the dynamic contours of the industry [1,15]. Accordingly, the maturity and level of utilization of BIM-related tools are significant for the implementation of advanced processes and creating opportunities for standardization, which can in turn support modulation. Exploring how BIM maturity levels influence modularization and standardization in New Zealand's construction industry is a field that still needs deeper investigation [16]. While this study focuses on the New Zealand construction sector, the conceptual framework and methodological approach developed herein are structured for potential transferability to comparable construction contexts internationally, subject to further validation. The integration of BIM, a mature technology, with modularization and standardization strategies addresses universal challenges faced by the construction industry across diverse regions.

This study aims to investigate the relationship between BIM maturity levels, modularization grades, and standardization levels in the construction industry. It seeks to develop and validate an evaluative framework that links these dimensions, using a mixed-methods approach comprising a systematic literature review and two New Zealand-based case studies. The goal is to offer insights that support more efficient and standardized modular construction practices, particularly in digitally evolving markets. The remainder of the manuscript is structured as follows: Section 2 presents the background; Section 3 outlines the methodology; Section 4 presents the literature review and conceptual framework; Section 5 details the case study analysis and discussion; and Section 6 provides practical implications and the conclusion.

2. Background

2.1. Modularization and Standardization in Construction

Following on from a global paradigm shift from traditional construction, modularization has gained popularity in New Zealand for residential and non-residential projects, similar to other industries worldwide [17]. According to [2,18], "modularization is the project business/execution strategy that involves the transfer of stick-build construction effort from the job site to one or more local or distance fabrication shops/yards, to exploit specific strategic advantages". Moreover, the term "modularization" refers to a process in which the primary construction method is the use of off-site-prefabricated, wholly preassembled, and pre-finished modules [19]. However, to maximize the benefits of modularization, it is critical not only to increase levels of modularization but also to increase levels of standardization [20]. Standardization has been defined in different ways. Based on [4], it involves "the extensive use of components, methods, or processes in which there is regularity, repetition, and a background of successful practice and predictability". Furthermore, according to [21,22], the repeated production of standard sizes and/or layouts of components or entire structures is referred to as standardization.

2.2. BIM and Its Maturity Levels

BIM is a working process that utilizes a shared digital representation of a constructed asset. The modern application of BIM in construction provides features for design, communication, project management during construction, and also post-construction services [14,23]. It is scaled from level 0 (with no BIM dimension) to level 4, as shown in Figure 1, which contains the concepts of improved social outcomes and well-being, providing projects with more integration and collaboration through a life cycle [24,25]. These levels indicate the advancements introduced by new technologies and the development of mature practices over the period. The earlier levels in the 1990s mainly involved the application of computer-aided 2D illustrations and, later, 3D visualizations in the 2000s. This further evolved into the incorporation of coordination and collaboration capabilities [26]. It also demonstrates the dynamic and progressive nature of the maturity model, which currently involves capabilities ranging from integrated and interoperable data, real-time data management, simulation, cloud collaboration, and digital twin; this model is constantly progressing and gaining maturity [27].

2.3. Global Practices and Policy Support

Government mandates and advocation of BIM and digitalization, such as the AEC BIM Technology Protocol, have also contributed significantly to furthering the maturity of BIM tools and processes [28]. This has also created pathways and potential for the integration of other concepts and technologies within BIM tools [23,24]. The exploration of BIM maturity levels takes on a central role in the pursuit of transformative solutions, offering the potential to develop pathways towards further efficacy in modularization and standardization practices within the construction sector [29]. Accordingly, increased implementation of mature BIM capabilities in construction, such as real-time data management, simulation, cloud collaboration, and digital twin, can also be a significant facilitator of modularization and standardization within the construction sector [2,3,30].

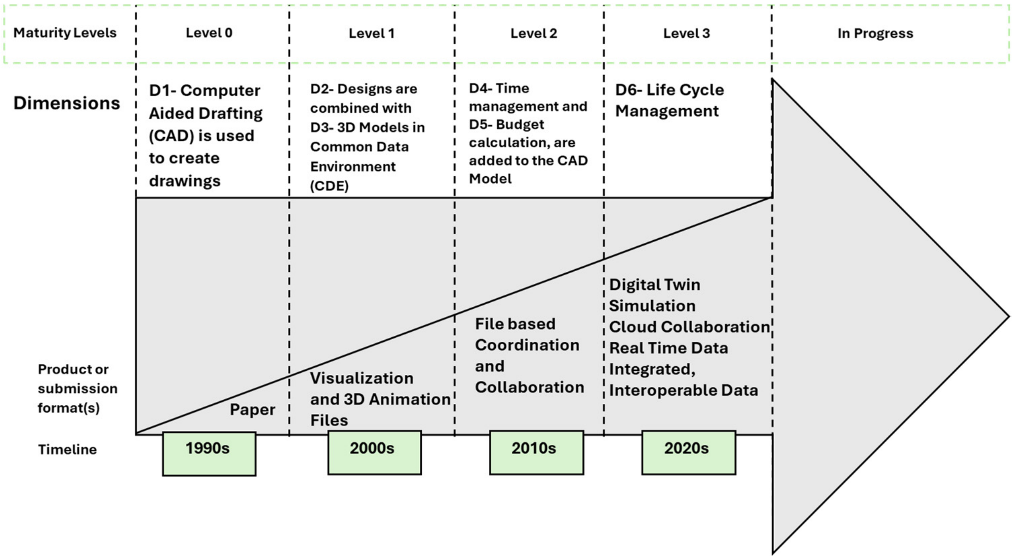

Figure 1. BIM maturity levels.

2.4. The Knowledge Gap in the New Zealand Context

While Wu [5] reviewed nine diverse BIM maturity measurement tools and highlighted their distinct attributes, Smits [31] offered a contrasting perspective, suggesting that despite BIM's high potential, there is no reliable association between BIM maturity aspects and improved project performance. This perspective underscores the multidimensional nature of the BIM–performance interface. According to the bibliometric research of Yin [29], the focus of studied research in BIM includes improving interoperability, sustainability, and collaboration, while OSC research focuses on construction process management and product design. Thai [32] believes that to improve the AEC industry, design practices need to accommodate modularization, balance demand–production, and try to integrate BIM.

Wang [33] led a literature review between 2010 and 2020 and found that developed countries are researching the adoption of digital technologies for OSC, and BIM is in a central position to link other technologies in Industry 4.0. In another study performed by Kordestani Ghalenoei [34], the integration of OSC and BIM was investigated, challenges and strategies to mitigate the challenges reviewed, and a framework presented. Despite the compelling attraction of BIM integration, its widespread adoption within New Zealand's construction sector, especially when aligned with modularization and standardization paradigms, remains a challenge.

Investigating the area of BIM maturity levels as a motivation for enhanced construction methodologies has become a crucial endeavour that warrants accurate examination and elucidation. While many studies have explored modularization, standardization, and BIM integration in countries such as China and Singapore, only a limited number have examined these dynamics within the New Zealand construction context [7,12,34]. This research assumes significance by addressing this void, exploring the impact of varied BIM maturity on modularization and standardization within New Zealand's construction domain.

This study, beyond its theoretical contributions, aims to influence policies and industry practices. Successful outcomes could transform construction's operational and strategic landscapes, fostering an enhanced and productive environment. The anticipated findings have the potential to enhance efficiency and redefine performance benchmarks, contributing to New Zealand's construction sector.

Offering a detailed exploration of how BIM maturity levels impact modularization and standardization practices in New Zealand, the study aims to unravel the complex relationship between BIM maturity and these practices, thereby uncovering strategies for optimization.

Concluding the paper, the study not only summarizes its findings but also elucidates the practical implications of these insights. Additionally, it charts a course for future research, aiming to further enrich the understanding of BIM integration and its impact on modularization and standardization in the dynamic realm of New Zealand's construction industry.

3. Methodology

As recommended by Sutrisna [35] and Thomas [36], this study adopted a mixed-methods strategy with the inclusion of qualitative methods in a subsidiary role. This method enables a more holistic conclusion through triangulation, even in the presence of paradoxes or contradictions [37].

Based on the nature of this research, a hypothesis was developed to examine the relationship between BIM maturity, standardization, and modularization within construction projects. In view of this, two methodologies in stages were applied for an evaluation of the magnitude and significance of the relationships between BIM maturity, standardization, and modularization. The results were then very carefully compared to the hypothesized relationships for the validation or fine-tuning of the initial assumptions.

This study follows a constructivist research philosophy, consistent with Stake [38] and Yin [39], which posits that knowledge is co-constructed through contextual inquiry. Accordingly, this study employs an exploratory, theory-building case study design, drawing on Eisenhardt's approach [40]. We adopted a two-case study design to evaluate the internal coherence and conceptual viability of the proposed BSM maturity framework. Rather than aiming for empirical generalization, our objective was to test the framework's applicability across distinct project contexts and delivery settings. The case selection was therefore based on the principle of theoretical replication, allowing us to compare differing project typologies (infrastructure vs. biosecurity) while controlling for BIM maturity levels (L2). This design enhances analytical richness and supports the framework's early-stage validation.

The research framework comprises two stages. In the first stage, an SLR is conducted to thoroughly study the existing literature and conceptualize the research themes related to standardization, modularization, and BIM maturity models, drawing upon studies by Kordestani Ghalehnoei [34], Razkenari [41], and Cavalieri [42]. The SLR is conducted via a well-established Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology [43].

Complementary data sets were collected for the analysis through case study research during the second stage [44]. The case studies provide in-depth insight into the level of BIM maturity models and the standardization and modularization indicators. The indicators on the identification of the standardization, modularization, and BIM level were presented based on the findings of the SLR. The second stage involved carrying out statistical analysis to test the hypotheses upon which the research framework is founded. Figure 2 illustrates the research framework, the stages of the methodology, and how they match the objectives. The SLR and case study process are shown as dashed-line rectangles, indicating how the findings of one stage are used to feed into the other. The stage-by-stage information of the methodologies is discussed below.

The framework suggests two hypotheses, which would explain the inter-link between the variables involved. The first hypothesis is that high BIM maturity levels are associated with high standardization levels, thereby establishing a direct relationship between the adoption of technology and the use of modular construction practices [29]. With further maturity, BIM is likely to lead to greater standardization of the components and the processes, leading to a higher level of efficiency and cost-effectiveness with regard to modular construction projects. Third, positive relationships between BIM maturity levels and modularization grades are hypothesized to show the contribution of more advanced BIM adoption to this cause, as in [5].

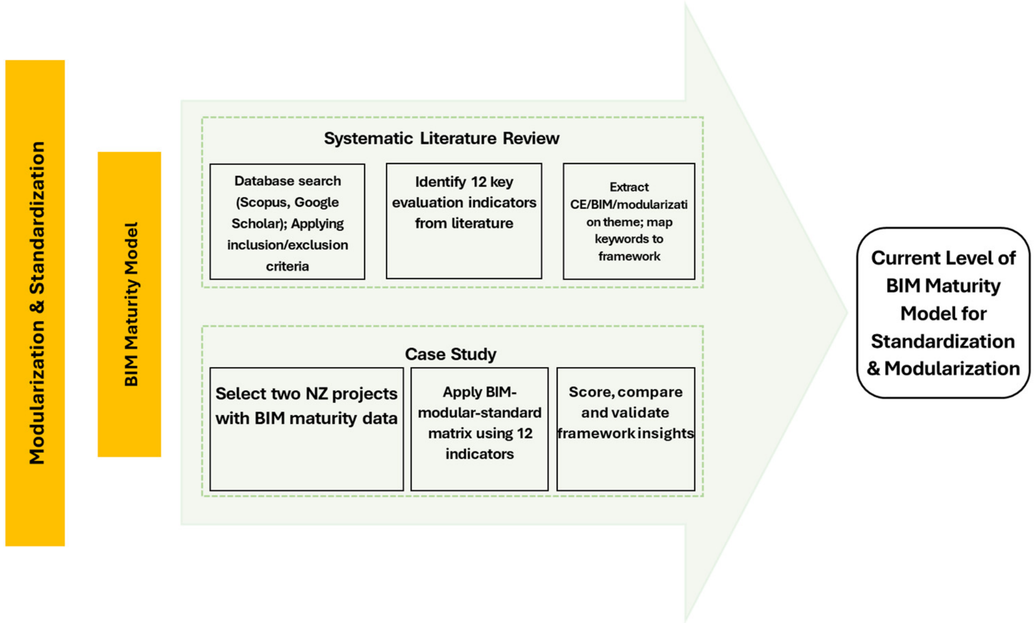

Figure 2. Research methodology.

The case study technique for this research is justified by three key considerations. The first point is that this methodology permits the comparison of two or more empirical cases in different settings based on the study parameters, with specific outcomes chosen for this comparison [45]. Moreover, this approach enables the collection of specific data that will aid in the study's discussion of progressing towards a theoretical conclusion, which is the author's intention for this study [45,46]. Finally, this methodology enables the researcher to investigate the operational and strategic involvement of the study cases in a particular region or area [45].

This design aligns with Stake [38] and Yin's [39] principle of theoretical replication, which suggests that a two-case structure can strengthen the analytical validity of findings. According to Yin [39], "analytic conclusions independently arising from two cases... will be more powerful than those coming from a single-case". Thus, using two New Zealand construction projects provides a robust basis for testing the study's conceptual framework and contributes to the generalizability of the findings within similar construction contexts.

The chosen case studies were intentionally selected for their embedded variation in procurement strategy and team composition. Although both exhibited the same BIM maturity level (L2: Full Collaboration), they provided different contextual and structural characteristics. This helped to explore how variations in design coordination, stakeholder interaction, and regulatory compliance affect the relationship between BIM maturity and the outcomes of modularization and standardization.

Figure 3 depicts the development of a framework for multiple case study analysis. In addition to the material needed for exploration, the framework displays the relationship between the projects and cases chosen for this study [23].

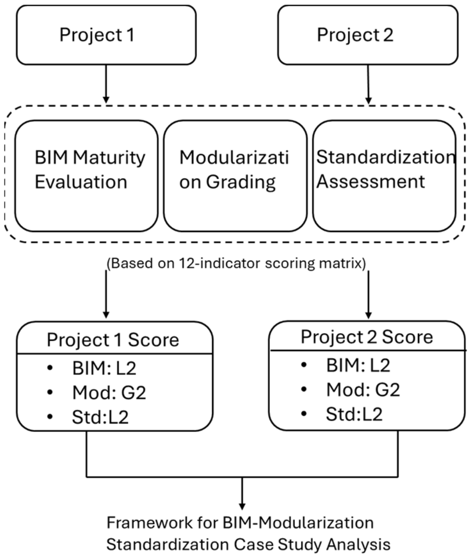

Figure 3. Case study methodology framework.

4. Systematic Literature Review and Conceptual Framework

BIM, modularization, and standardization work together as essential strategies to boost efficiency, sustainability, and productivity in construction. An initial SLR identified underlying patterns, relationships, and insights concerning BIM maturity, standardization, and modularization. As BIM technologies enable better visualization, collaboration, and data management, construction projects are more likely to achieve higher degrees of modularization through improved prefabrication methods such as panelized modular systems, sectional modular construction, and volumetric modular approaches. The framework suggests that higher modularization grades positively correlate with higher standardization levels, signifying a mutual reinforcement of modular practices and standardized components [10]. This relationship contributes to a streamlined and efficient construction process, with improved BIM integration eventually leading OSC projects toward Lean Manufacturing principles [32,47]. Table 1 illustrates how BIM maturity levels align with modularization grades and standardization levels:

Table 1. BIM maturity levels and corresponding modularization grades and standardization levels.

BIM Maturity Levels	Modularization Grades	Standardization Levels
Level 1: partial collaboration	Grade 1: Panelized Modular	Level 1: Basic Standardization
Level 2: full collaboration	Grade 2: Sectional Modular	Level 2: Adequate Standardization
Level 3: full integration	Grade 3: Volumetric Modular	Level 3: Advanced Standardization

To build upon these findings, a rigorous trial-and-error approach and advanced search techniques were used to gather the most representative results within Scopus.

The systematic review followed PRISMA guidelines. The search was conducted using the Scopus database with the following filters:

- Keywords: “BIM”, “Modularization”, “Standardization”, “Prefabrication”, and “Off-site Construction (OSC)”;
- Timeframe: 2018–2023;
- Language: English.

Inclusion criteria (applied during screening and full-text review):

- Peer-reviewed journal articles;

- Explicit discussion of BIM in relation to modularization and/or standardization;
- Clear research design (quantitative, qualitative, or mixed methods);
- Relevance to the construction industry, particularly digital workflows or prefabrication;
- Full-text availability.

Exclusion criteria:

- Conference papers, editorials, and grey literature;
- Non-construction-related studies;
- Studies focusing on ICT without relevance to BIM/modularization integration;
- Articles lacking methodological transparency or practical relevance.

Screening Results: The initial search returned 2024 records. After removing duplicates (n = 271), 1753 articles remained for title and abstract screening. Of these, 1623 were excluded for not meeting the inclusion criteria. The full text of the remaining 130 articles was assessed. After applying exclusion criteria (e.g., lack of BIM–modularization linkage, insufficient methodological detail), 95 articles were excluded. This resulted in 35 studies that met all criteria and were included in the final analysis. The PRISMA flow diagram (Figure 4) summarizes this process.

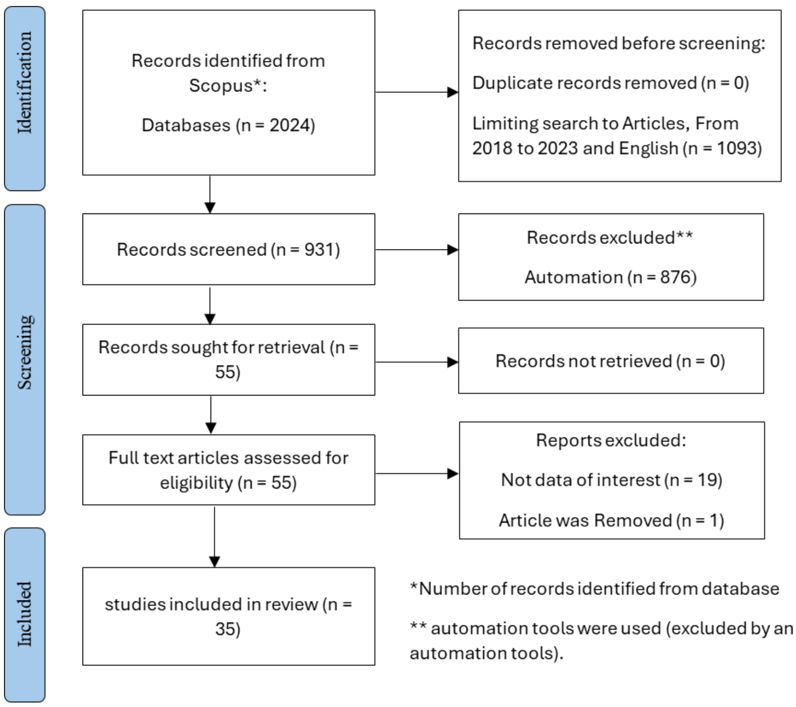

Figure 4. PRISMA flowchart diagram.

Then, they were divided into six groups depending on the objective. These publications emphasize that the integration of BIM with modularization will support key improvements in efficiency, waste reduction, and project management, as was demonstrated in previous studies [34,48].

The findings reveal that BIM's role in supporting modular construction is multifaceted, with applications such as digital twins, rule-checking systems, and decision support frameworks enhancing project precision and sustainability. For instance, Fan [49] discusses BIM-based rule-checking systems, while Wang [50] highlights life cycle assessments for reducing environmental impacts. Integrating BIM with OSC has been shown to foster collaboration among stakeholders, promote standardization, and drive technological advancements, including optimization models for logistics scheduling and prefabrication [51].

Additionally, frameworks like those proposed by Barkokebas [52] underscore the importance of lean principles in enhancing productivity and reducing waste.

Challenges remain, particularly in regions like New Zealand, where limited knowledge, coordination issues, and inadequate standardization tools hinder modular construction adoption [53]. The literature highlights the need for better stakeholder collaboration, regulatory support, and training to address these barriers. In addition, studies like those of Almashaqbeh [54] and Cho [55] recognize optimization models and decision support systems as crucial enablers in overcoming project delays and inefficiencies. Higher levels of BIM maturity and the integration of new technologies continue to be the most important milestones for higher efficiency and sustainability in OSC practices.

The systematic review underscores the consistent benefits of modular construction, including improved productivity, quality, and waste reduction. By leveraging BIM's capabilities in visualization, data management, and collaboration, the construction industry can achieve streamlined operations and enhanced project outcomes. Moving forward, BIM integration with other methodologies and technologies, such as automated compliance checking and optimization of prefabrication, will be important in overcoming the challenges presented and in pushing the industry's evolution towards sustainability and Lean Manufacturing.

The conceptual framework presented in this study aims to integrate variables and aspects to provide valuable insights into the relationships and interactions between BIM maturity levels, modularization grades, standardization levels, and their impact on construction project outcomes, as shown in Figure 5.

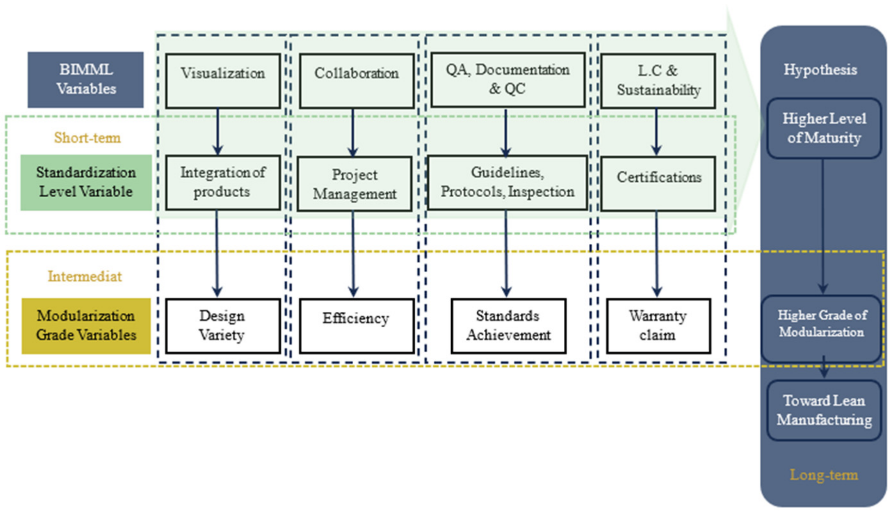

Figure 5. The case study conceptual framework.

Modularization as a key concept refers to the degree to which components of a construction project are able to be standardized and integrated easily to develop new variants of the product. On the other hand, standardization involves the strategic use of identical components across several products for the realization of efficiency and cost-effective outcomes within a one-per-product context [6]. BIM is an innovative digital approach that forms the core of this study; it acts as a transformative tool in the construction industry for designing, creating, and managing building projects with increased collaboration and data management capabilities [29].

The framework considers three fundamental variables related to the research's objectives. BIM maturity levels, classified into four distinct stages ranging from low collaboration to full integration, are expected to shape the degree of technological advancement and adoption within construction projects [33]. Modularization grades, categorized into four levels that range from component prefabrication to volumetric modularization, evaluate the level of modularization achieved in construction practices. Similarly, standardization has four levels from non-standardization to advanced standardization, assessing the extent to which standardized components are employed across various projects.

The literature findings after applying the criteria were used to evaluate the status of the case studies. BIM maturity levels in the prefabrication construction industry are an inclusive framework that has been used to assess the industry's capability in terms of the effective adoption and leveraging of BIM technologies and processes throughout the prefabrication project life cycle [12]. The assessment includes categories such as the integration of BIM with prefabrication processes, advanced BIM technologies, BIM-enabled collaboration, prefabrication quality control, and BIM-enabled prefabrication efficiency [12,13].

The development of modularization grades considers several main factors to ascertain the level of modularization attained in a project. The factors involve standardization, which entails the devising and imposition of standard guidelines, specifications, and practices within an industry or a system [56].

The objectives of standardization are to ensure uniformity, efficiency, communication, quality and safety, and innovation, as well as entry into the market [56]. Lastly, the purpose of standardization is to achieve uniformity, consistency, and compatibility in processes, products, and services in order to ensure efficient performance, effective communication, and high-quality results [52]. Table 2 shows the relationship between the BIM maturity model, standardization, and modularization, which is used to assess the case studies in the current study. Each row represents a specific aspect related to BIM maturity, standardization, and modularization, and the columns represent the corresponding criteria for evaluation. The table is designed to present the correlation between these criteria across levels of BIM maturity, standardization efforts, and the extent of modularization achieved in the projects.

Table 2. Relationship between different levels of BIM maturity, modularization, and standardization.

Asp.	BIM Maturity	Standardization	Modularization
1	Design in CAD	Adherence to design guidelines	Adherence to reg.
2	Manufacturing and fabrication processes embodied in drawings	Standardized fabrication processes	Percentage of production capacity utilization
3	On-site logistics and assembly catalogues	Implementation of standardized logistics planning	Cost reduction in modular manufacturing
4	3D modelling and visualization	Utilization of 3D modelling	Diversity of standardized design model usage
5	Automation and AI utilization	AI-driven process optimization	Modular installation time reduction
6	Stakeholder collaboration	Collaboration via BIM platforms	Modular manufacturing cost reduction
7	Information exchange and data Management	Cloud-based data management	Documentation regulation
8	Quality assurance processes	Adherence to standards and building codes	Reduction in safety incidents
9	Regulatory compliance and Standards	BIM-based quality control implementation	Warranty claims received
10	Lean construction principles	Adoption of lean construction practices	Inventory turnover rate
11	Supply chain and material tracking	Integration of BIM and supply chains	Modular manufacturing cost reduction
12	Energy efficiency and sustainability	BIM tools for energy analysis and optimization	Focus on sustainability (life cycle) design

For example, the first row indicates that within the "design using Computer-Aided Design (CAD)" aspect of BIM maturity, adherence to design guidelines is evaluated in terms of standardization, while adherence to regulations is assessed in terms of modularization. Similarly, each row delineates specific criteria and provides a framework for evaluating the case studies' status in the prefabrication construction industry.

To assess project levels, a thorough examination of the aforementioned aspects was conducted and subsequently scored. The scoring system for this purpose can be outlined as follows:

To mitigate bias, each aspect was rated on a scale from 0 to 5 and the collected ratings were then utilized through a weighted summation process. Table 3 presents the minimum rates for each level, maintaining consistency in approach.

Table 3. Minimum rates of the levels.

Levels	Rates in Different Levels			Levels Weight			Weighted Rate			WΣ	Total WΣ of the 12 Aspects
1	1.25	0	0	1			1.25	0	0	1.25	15
2	2.5	1.25	0	1	2		2.5	2.5	0	5	60
3	1.25	3.75	1.25	1	2	3	1.25	7.5	3.75	13	155
	3.75	2.5	1.25	1	2	3	3.75	5	3.75	13	

For the calculation of the minimum rate, the weighted summation of the rates (WΣ) for a level 3, for instance, would be as follows: weighted summation of the rates (WΣ) = (1.25 × 1) + (3.75 × 2) + (1.25 × 3) = 1.25 + 7.5 + 3.75 = 12.5, or, alternatively, the following: = (3.75 × 1) + (2.5 × 2) + (1.25 × 3) = 3.75 + 5 + 3.75 = 12.5. And the total WΣ of the 12 aspects = 12.5 × 12 = 150.

In this rating scheme, case studies with rates below 15 were categorized as Level 0, those with rates between 15 and 60 as Level 1, between 60 and 150 as Level 2, and rates above 150 as Level 3.

5. Case Study Analysis and Discussion

5.1. First Case Study

The first case study is a water project that included a 37 km steel pipeline, a modern treatment facility, and a raw water pump station with a cap completed across the Waikato and Auckland regions. The rapid growth of Auckland has put immense pressure on its water supply network, forcing Watercare, the organization responsible for water management, to take up this challenge using the enterprise model. To overcome this, the Waikato River to Redoubt (R2R) project was introduced. This raised the treated water supply by 50 million L per day from the Waikato River to Auckland. The key components of the project included Phase 1 in Tuakau and a booster pump station in Papakura. BIM Maturity level is Full Collaborated (L2).

The BIM maturity assessment of the R2R Program revealed that it was a highly integrated project, categorized as "L2: Full Collaborated." This shows that the project had advanced collaboration and data management capabilities among the stakeholders, enhancing design coordination and on-site logistics. The results of the assessment are shown in Table 4.

Grade of the modularization is Sectional Modular (G2) and Adequate Standardization (L2).

The modularization grade assessment for the R2R Program indicated a "G2: Sectional Modular" level. This demonstrates an intermediate level of modularization achieved in the construction practices, incorporating sectional modular construction approaches. The standardization level assessment for the R2R Program indicated an "Adequate Level" of standardization.

Table 4. First case study's level and grade results.

Asp.	Maturity Level 1	Maturity Level 2	Maturity Level 3	Basic Standard-ization	Adequate Standard-ization	Advanced Standard-ization	Grade 1	Grade 2	Grade 3	WΣ BIM	WΣ St. and Mod.
1	4.7	3.7		3.0			3.0		-	12.2	3.0
2	3.7	2.9		2.0			2.0	3.0		9.6	5.0
3	4.3	3.5				2.6	2.0	3.0		11.3	7.9
4	5.0	4.0		3.0	2.0		2.0	4.0		13.0	8.5
5	4.0		2.0			-	2.0	4.0		10.0	5.0
6	4.7		3.7		4.0	4.0	3.0		-	15.9	11.5
7	5.0		4.0		4.0		3.0		3.5	17.0	10.8
8	4.0		3.2		3.0		3.0		3.5	13.6	9.8
9	4.0		2.0	3.0			3.0		-	10.0	3.0
10	4.3		3.5			4.0	3.0		-	14.7	7.5
11	1.7		1.3		3.7		3.0		4.0	5.7	11.2
12	4.3		3.5			1.7	2.0	4.0		14.7	7.5
Total Weighted Sum										147.6	90.6

This case was intentionally selected based on its distinct infrastructure typology, enterprise delivery model, and publicly available BIM documentation. Its inclusion is grounded in the study's constructivist research orientation, which emphasizes contextual richness over sample size [38,39]. Although the R2R project shares the same BIM maturity level as the second case, it differs in sector focus (water vs. biosecurity), organizational hierarchy, and technical scope, offering a contrasting lens on how BIM maturity interacts with modular and standardized practices.

By comparing this case with a distinctly scoped project under similar BIM maturity, the study follows Eisenhardt's [40] model of theoretical replication—allowing for conceptual triangulation rather than statistical proof. As such, this case provides an essential piece in evaluating the feasibility and internal logic of the BIM–Standardization–Modularization (BSM) maturity framework.

5.2. Second Case Study

The MPI-IPEQ Facility project (Ministry of Primary Industries—Interim Post-Entry Quarantine) has a specific objective of establishing a specialized facility in compliance with New Zealand's bio-security regulations for quarantining imported plants. This project includes the design and construction of various elements, such as 12 connected greenhouses, a headhouse, an alley that connects the headhouse with the greenhouses, an area set aside for the mechanical plant room, and a parking lot. The combined area covered by greenhouses and the alley is approximately 500 square meters, while that of the headhouse is about 240 square meters. The New Zealand's PC3 quarantine standards must be strictly followed for the successful implementation of this facility. BIM Maturity level is Collaborated BIM (L2).

The BIM maturity assessment for the MPI-IPEQ Facility Project also indicated a high level of BIM integration, classified as "L2: Full Collaborated." The same as that for the first case study, this level of BIM maturity suggests advanced collaboration and data management among stakeholders. The results are simplified and presented in Table 5.

Table 5. Second case study's level and grade results.

Asp.	Maturity Level 1	Maturity Level 2	Maturity Level 3	Basic Standard-ization	Adequate Standard-ization	Advanced Standard-ization	Grade 1	Grade 2	Grade 3	WΣ BIM	WΣ St. and Mod.
1	3.3	2.7		4.0			3.0		2.5	8.7	6.5
2	2.7	2.1		3.0			2.0	3.0		7.0	5.5
3	4.0	3.2		1.0		1.0	2.0	3.0		10.4	6.0
4	3.0	2.4		4.0	2.0		2.0	4.0		7.8	9.0
5	3.7		2.9	1.0			2.0	4.0		12.5	5.5
6	4.7		3.7	1.0	3.0		3.0		3.0	15.9	9.5
7	4.3		3.5	1.0	3.0		3.0		3.0	14.7	9.5
8	3.7		2.9	1.0	3.0		3.0		2.0	12.5	8.8
9	3.0		2.4	2.0			3.0			10.2	2.5
10	4.0		3.2	1.0		3.0	3.0		2.0	13.6	9.5
11	4.0		3.2	1.0	3.0		3.0		3.0	13.6	9.5
12	3.3		2.7	1.0		1.3	2.0	2.0		11.3	5.5
				Total Weighted Sum						138.1	87.2

Grade of the modularization is Sectional Modular (G2) and Adequate Standardization (L2).

The MPI-IPEQ Facility Project was given a "G2: Sectional Modular" modularization grade. This demonstrates that it achieved an intermediate level in terms of construction practices and incorporating sectional modular construction approaches. The standardization level assessment for the R2R Program indicated an "Adequate Level" of standardization.

Although both case studies share the same BIM maturity level (L2), their inclusion remains analytically significant. Guided by a constructivist research philosophy [38,39], this study does not seek statistical generalizability but rather explores contextual variation and depth through real-world project inquiry. The two projects were purposefully selected to reflect distinct procurement models, stakeholder configurations, and design objectives, offering embedded insights into the relationship between BIM maturity, modularization, and standardization.

In line with Eisenhardt's [40] logic of early-stage theory building, this two-case design prioritizes conceptual testing of the proposed BIM–Standardization–Modularization (BSM) maturity framework. The goal is not to confirm generalizable patterns, but to evaluate framework feasibility, internal consistency, and analytic utility.

5.3. BIM Maturity as a Driver of Modularization and Standardization

The underlying relationship between higher BIM maturity levels and the advancement of modular and standardized practices is evident when comparing the results from both case studies, as shown in Tables 4 and 5. Achieving a BIM maturity level of L2: Full Collaborated, the two cases also achieved a modularization grade of G2: Sectional Modular and a standardization grade of L2: Adequate Level. Such synergy signifies that the highest BIM maturity enables the integration of effective collaboration and data management, which greatly fosters effective modular construction combined with standard component inclusion [5,29].

The integration of BIM technologies at "L2" facilitated improved design coordination, smoother on-site logistics, stakeholder collaboration, and fluid information exchange. These factors collectively contributed to enhanced outcomes, resulting in intermediate modularization levels. Furthermore, the projects displayed notable advancements in adopting standardized fabrication processes, BIM-driven quality control, and alignment with industry-specific norms. This "Adequate Level" of standardization highlights the affirmative influence of BIM integration on achieving both standardized and modular construction practices, ultimately bolstering operational efficiency and cost-effectiveness.

In-depth analysis of the case study data reinforces the robust positive correlation existing between the ascending levels of BIM maturity and the consequential enhancement of modularization and standardization practices within the distinct backdrop of the New Zealand construction sector [57]. The data unequivocally endorses the notion that higher BIM maturity levels precipitate heightened integration of construction processes, manifesting in an improved rhythm of streamlined and standardized construction activities [32]. This alignment perceptibly underpins the presupposition that the evolutionary trajectory of BIM maturity bears a direct impact on the augmentation of modularization and standardization, consequently resulting in the mitigation of project complexity while concurrently optimizing the overall effectiveness of the project [33].

A salient outcome of research and exploratory investigations is the attainment of "L2: Full Collaborated" within the BIM maturity continuum [57]. As a highpoint, this level of BIM maturity provided the opportunity for an encompassing platform with diverse users and capabilities, thereby nurturing an environment for stakeholder collaboration that caters for design and construction integration [58]. This harmonization creates a means for the integration of disparate knowledge silos towards a holistic design philosophy that effectively reduces inefficiencies and inaccuracy, pivotal to elevated efficiency thresholds and, consequently, standardization [59].

While both case studies share the same BIM maturity classification (L2: Full Collaboration), their contextual differences—in project type, delivery model, and technical scope—allow for meaningful analytical contrast. This approach aligns with the study's exploratory and theory-building purpose, which follows a strategy of theoretical replication rather than statistical generalization, as outlined by Stake [38], Yin [39], and Eisenhardt [40]. The intent is not to draw broad empirical conclusions, but to test the internal coherence and practical utility of the proposed BSM maturity framework in real-world settings. These findings should be viewed as preliminary, and future research is needed to expand the empirical base across a broader range of BIM maturity levels and project types.

5.4. Key Enablers Supporting BIM-Driven Modularization

Important factors alongside modularization and standardization:

Our case study analysis recognizes several points of consideration that emerge and affect modularization and standardization procedures for various levels of BIM maturity in the construction project.

BIM Maturity Level: This largely defines the degree of modularization or standardization that would be achieved by a construction project. Code projects with higher BIM maturity will have features with better design coordination, collaboration, and data management capabilities. This fosters the seamless integration of modular components and encourages the adoption of standardized processes.

Design Coordination and Stakeholder Collaboration: Increased BIM adoption enhances design coordination and fosters better collaboration among project stakeholders. This fosters the smooth integration of modular components and encourages the use of standardized fabrication processes, along with compliance with industry norms.

Information Exchange and Data Management: BIM permits effective information exchange and data management during the life of a project, thus assuring real-time and correct information and enabling well-informed choices. This will, therefore, streamline modularization and standardization processes considering well-informed choices.

Automation and AI Implementation: The moderate level of automation and usage of AI in case studies brings a further potential enhancement of modularization and standardization. Automation will ease the job of manufacturing and assembly, and AI will optimize planning for project schedules, resource management, and quality control.

Integration of Lean Construction Principles: This can further enhance modularization and standardization practices. Minimizing waste, reducing rework, and improving project delivery times can be realized by merging lean principles with BIM-based workflows.

5.5. Strategic Role of Digital Integration in Construction Outcomes

The pivotal role of heightened BIM maturity in facilitating design coordination and fostering stakeholder collaboration is underscored by this study's meticulous inquiry [9]. In addition, the advanced visualization and simulation capabilities intrinsic to mature BIM interfaces empower cross-functional teams to predict and resolve potential conflicts during design development. This proactive approach minimizes costly retrofits during construction, thereby enhancing modularization and standardization through a collaborative approach [60].

The function of mature BIM in the realization of problem-free information exchange and effective data management is an impetus towards the improvement of modularization and standardization. The availability of augmented data repositories ensures that decisions are based on accurate, current information, reducing inconsistencies [61].

This dynamic flow of information cements the ability of standardized practices to promote uniformity by promptly identifying and addressing deviations.

The current research also discusses the possibilities of automation, Artificial Intelligence (AI), and Lean Construction within modularization and standardization. All these new technologies have future potential to offer, while converging together to increase the benefit of BIM maturity. The automation aspect prevents human error that could occur from inconsistent outputs, while AI supports improving modularization strategies. In contrast, incorporating the principles of Lean Construction increases process efficiency while also emphasizing standardization [62].

6. Practical Implications and Study Limitations

This study reinforces the importance of BIM maturity in advancing modularization and standardization practices in the construction industry. The framework and findings are particularly relevant to New Zealand, where digital construction transformation is underway but still evolving. The evidence confirms that projects achieving higher BIM maturity—particularly "L2: Full Collaboration"—are more likely to support sectional modularization strategies and higher levels of standardization. These insights are highly valuable for project managers, design consultants, contractors, and policymakers aiming to optimize project performance and streamline construction processes. The framework also provides a tool to guide data-driven decisions in early-stage project planning, stakeholder engagement, and digital coordination.

However, there are several limitations. The study relied on two case studies within the New Zealand context, both showing similar BIM maturity levels. While this limits the comparative depth between contrasting BIM maturity scenarios, it still provides meaningful insight into how similar maturity levels can manifest in varied modularization and standardization outcomes due to project-specific factors. These subtle variations helped test the consistency of the evaluation framework and highlighted the influence of contextual variables such as design approach, contractor strategy, and prefabrication readiness. The research also drew on secondary data sources, which may not fully reflect the evolving dynamics and regional nuances of BIM adoption. In addition, while BIM maturity was the central variable, other important factors such as organizational culture, regulatory environments, and economic conditions were outside the scope of this paper. Furthermore, the absence of universally accepted standards for evaluating BIM maturity and its integration with modularization and standardization required the adaptation of varied frameworks.

While this study includes only two case studies, it is designed as an exploratory investigation to evaluate the conceptual validity and practical application of the proposed framework. The case design follows a theoretical replication strategy, not statistical sampling, and is suitable for early-stage model development.

Future research will expand the empirical base by applying the framework to additional projects with varied BIM maturity levels and delivery contexts, supporting broader validation and potential generalization.

7. Conclusions

This study set out to examine the interrelationship among BIM maturity levels, modularization grades, and standardization levels, and to assess their combined influence on construction project outcomes within the New Zealand context. Through a mixed-methods approach integrating a systematic literature review and empirical case studies, the study developed and applied an evaluative framework to explore how digital maturity can enable greater modular efficiency and standardization across project delivery. Using a mixed-methods approach—combining a systematic literature review and two empirical case studies—the study developed and validated a 12-indicator evaluation framework. The results confirmed that higher levels of BIM maturity, particularly "L2: Full Collaboration", are closely associated with improved modularization (especially sectional modular systems) and higher standardization.

These findings provide conclusive evidence that BIM maturity facilitates more advanced design coordination, stakeholder engagement, and data management. This supports a more structured and efficient path toward modular construction that is both scalable and replicable. While this study focused on New Zealand, the framework is adaptable and holds potential for transferability to other contexts with similar characteristics, contingent on further empirical investigation. The results also align with previous findings such as those in [60,61], reinforcing the generalizability and relevance of the relationship between BIM maturity and industrialized construction methods.

The research contributes to the growing body of knowledge in digital construction by establishing how BIM maturity operates as a key driver in modularization and standardization. It offers a practical roadmap for construction professionals seeking to align their digital practices with the benefits of prefabrication and standard component use.

Future Research Directions

- Applying the framework to projects with a broader range of BIM maturity levels.
- Validating the model through primary data collection and cross-regional case studies.
- Exploring the influence of organizational, economic, and policy factors on BIM adoption and modular standardization.
- Developing unified standards for measuring BIM maturity in relation to modular construction.
- Investigating barriers to achieving higher BIM maturity in real-world projects.
- Extending the framework through additional case studies.

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