CHAPTER 93

Leveraging BIM for Sustainable Construction Practices and Integrated Project Delivery

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ABSTRACT

The research proposal aims to promote and implement eco-friendly housing and construction practices, to address the growing concerns regarding sustainable design associated with the construction industry. By adopting sustainable building materials and environmentally friendly design approaches, we can differentiate as well as mitigate the negative impacts of construction on ecosystem. The application of Building Information Modeling (BIM) emerges as a powerful tool in project to address the challenges by enabling sustainable design and construction practices. This project investigates the potential of BIM to optimize building design for reduced environmental impact, improved resource efficiency, enhanced economic performance and promotes framework for energy efficiency. Evaluation of economic feasibility of BIM enabled sustainable construction, comparing upfront investments against long-term cost savings through operational efficiency and resource savings. The project outlines the primary objectives which consists of the barriers for the Sustainable Development in construction industry in questionary survey along with the activities undertaken to achieve project barriers in terms of research and Experimental methods, to anticipate the Expected outcomes by implementing the Sustainable Design and BIM tool that transform the Construction Industry by integrating Sustainability principles into every phase of building's lifecycle. Also improve construction site efficiency and reduce waste generation, leading to cost savings and environmental benefits.

Keywords: BIM; Economy; Energy efficiency; Sustainability; Systematic literature Review.

1.0 Introduction

1.1 Background and context

Architecture, engineering, and construction (AEC) is changing dramatically in favour of sustainable methods. Traditional design techniques have challenges in meeting the needs for decreased ecological footprint and resource efficiency as the environmental impact of buildings becomes more apparent.

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In this context, Building Information Modelling (BIM) emerges as a transformative technology with the potential to revolutionize sustainable design and construction (Ning GU, 2010). The importance of BIM in accomplishing sustainable construction objectives will be covered in detail in this chapter. We'll start by discussing the growing significance of sustainability in the AEC sector and the environmental problems caused by traditional building methods. We will then review the fundamental features and capabilities of building information modelling. To prepare for a more thorough analysis of the factors that encourage and hinder its use, we will conclude by giving a summary of how BIM might support sustainable design and construction. There is growing concern about the necessity of acknowledging the significance of sustainable construction. The goal of sustainable construction can be greatly aided by the cutting-edge technologies used in the sector. There are many different sustainability rating systems in use worldwide, but they all strive to enhance a building's overall performance to meet the objectives of establishing a healthy built environment. Green construction initiatives present obstacles and problems for Building Information modelling (BIM). The requirement for standards and rules, a lack of BIM knowledge and experience, the high expense, and a lack of research and BIM implementation are some of the difficulties. Non-uniform data formats, a lack of interaction, unclear ownership, inadequate BIM training, and reluctance to adopt BIM are some of the obstacles to using BIM in the construction of green buildings. The perception of extra effort during implementation and a lack of client demand are two possible drawbacks of BIM in green construction projects. These obstacles and difficulties make it difficult to apply BIM effectively in green construction projects, which affects the overall sustainability objectives, cooperation effectiveness, and project quality. Policymakers and construction personnel should address these challenges and barriers to promote the utilization and optimization of BIM capabilities in the construction of green buildings (Kineber *et al.* 2023).

1.2 Research objectives

There is a great chance to address the environmental issues facing the AEC sector by combining sustainable design principles with Building Information Modelling (BIM). The objective is to find research papers and journals that address the integration of sustainable construction practices with integrated project delivery (IPD) using PRISMA:

- To assess the research methodology, hypotheses, traits, and contextual background.
- To determine effective tactics and barriers to their implementation.
- To make recommendations for future research directions on how to improve the construction industry's integration of sustainable construction methods and integrated project delivery (IPD).

1.3 Research problems

There is a great chance to address the environmental issues facing the AEC sector by combining sustainable design principles with Building Information Modelling (BIM).

Nonetheless, several important research issues necessitate additional study:

- *Quantification of sustainability benefits:* In order to support sustainable decision-making throughout the design stage, this study will investigate how BIM can be integrated with performance simulations and life-cycle assessment tools.
- *Interoperability and data exchange:* It's possible that sustainability assessment tools and current BIM software programs can't interchange data easily. The technical issues surrounding interoperability will be examined in this study, along with potential solutions for effective data sharing and teamwork over the project lifecycle.
- *Skill and knowledge gaps:* This study will pinpoint the knowledge gaps and suggest ways to modify training curricula to close them and promote a sustainable design culture in the AEC sector that incorporates BIM.

This study aims to explore the potential benefits of Building Information Modelling (BIM) for environmentally friendly construction practices. By analysing and incorporating research paper findings, the study will look into how BIM encourages resource efficiency, energy optimization, and waste reduction throughout the project lifespan. Important subjects, including BIM's capacity to improve energy efficiency modeling, integrate with green building materials, and support sustainable design, will be the focus of the examination. To provide users with a comprehensive grasp of how BIM impacts sustainability in the building industry, a wide range of case studies, technical advancements, and frameworks are covered in the selected literature.

The growing global awareness for sustainable construction techniques has led to substantial advancements in Building Information Modelling (BIM) technology. The interdisciplinary platform that BIM provides for cooperation ensures better project outcomes and supports sustainable development initiatives. The potential of BIM to enhance structural design, increase energy efficiency, and speed up the building process has been extensively studied.To solve the issues of carbon emissions, resource management, and lifecycle cost optimization in construction projects, the integration of sustainability ideas with BIM has shown to be crucial (Motawa and Carter 2013).

2.0 Literature Review

2.1 Introduction to literature review

The reviewed papers explore various aspects of Building Information Modeling (BIM) and its possible interaction with technology to enhance the sustainability and efficiency of buildings. One research shows how BIM and IoT can be applied to logistics and facility control, highlighting the need for more case studies and practical uses (Tang, Shelden *et al.* 2019). Another addresses challenges to BIM adoption in developing nations, like limited government support, and promotes a larger range of case studies beyond those from China, India, and Malaysia (Bui *et al.* 2016).

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The benefits and drawbacks of BIM are looked at in further detail in a number of contexts, particularly difficulties with interoperability and the need for greater industry and academic interaction(Costin *et al.* 2018). The paper highlights the benefits of BIM and IPD and proposes more case studies for enhancing understanding of sustainable practices (Oraee *et al.* 2019). The investigations focus on the benefits and challenges associated with implementing Building Information Modeling (BIM) in the construction industry.

One study finds 28 connections among BIM abilities and legal structures to enhance understanding of contractual challenges (Abd Jamil & Fathi 2018). Another addresses the insufficient use of BIM in Malaysia, bringing out advantages like better scheduling and cost control, but also difficulties with interoperability and a skills gap. Additional study suggests that in order to enhance design partnership and project management, technical and legal barriers have to be addressed (Azhar *et al.* 2008). In order to promote adoption, an analysis carried out in Hong Kong identifies barriers like the lack of industry standards and recommends setting up specialist BIM departments and training efforts (Chan *et al.* 2019). Another study highlights companies a refusal to create new BIM models due to contractual constraints, yet praising advances in internal protocol(Farnsworth *et al.* 2015). Ultimately, study on Sustainable Construction Management Practices shows the value for ongoing training, involvement of stakeholders, and rules regarding procurement that emphasize sustainability for effective implementation (Goel *et al.* 2019).

Every study shows that effectively applying BIM may lead to major benefits in project delivery and makes suggestions for future government support. (Liao & Teo 2017). The research explores the advantages and uses of Building Information Modeling (BIM) to increase efficiency and sustainability in the building industry. Another study gives information on a real-world example and suggests frameworks for post-occupancy evaluations and energy simulations (Motawa & Almarshad 2013) and use of Case-Based Reasoning in conjunction with BIM to improve maintenance methods (Motawa & Almarshad 2013). Also, research gives more recent case studies by highlighting the potential of BIM in the AFC sector and looks at historical trends (Latiffi *et al.* 2014). This paper generally highlights the value of BIM in project management, reduction in wastage, and increasing efficiency in the building industry.

Research has been conducted on collaboration and sustainability techniques used in the building industry. They relate the BIM to Integrated Project Delivery (IPD) and emphasize how it enhances collaboration, low errors, and maximizes the resources used while suggesting further research be done on implementation difficulties(Zou *et al.* 2017). There are obstacles to using BIM like financial constraints, complexity, and lack of knowledge (Manzoor *et al.* 2021). Further research visualizes how programs (like Autodesk) will improve energy and resource efficiency (Khan & Ghadg 2019). They find the connection between the usage of BIM and environmentally friendly building practices, using structural equation modeling to fix the key variables in nations like China and Nigeria (Manzoor *et al.* 2021). Lastly, analyses highlight how BIM can evaluate sustainability standards, automate assessments, and improve project

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design decision-making (Carvalho *et al.* 2019), also it tackles the non- technical and technical obstacles to prevent the AEC sector from using BIM (Gu & London 2010).

Table 1: Barriers to Implementing BIM for Sustainable Construction with Decarbonisation & Circularity

Sr. No.	Parameters	Codes	Authors and Year
1	Lack of understanding hampers sustainability adoption	BBIM1	Häkkinen, 2011.
2	High initial cost deters sustainable practices.	BBIM2	Liu, 2015
3	Costly errors for circular construction.	BBIM3	Azhar, 2008
4	Insufficient market demand for BIM-based sustainable practices.	BBIM4	Walasek, 2017
5	Difficulty in justifying the long-term ROI for decarbonization.	BBIM5	Liu, 2015
6	Economic downturn reduces BIM investment for sustainability.	BBIM6	Abdalla, 2021
7	Lack of Standards and Guidelines for Sustainable Practices.	BBIM7	Memon, 2014
8	Inequities in workforce development limit the participation of marginalized groups.	BBIM8	Azman, 2014
9	Lack of equity policies hinders the progress of sustainable construction.	BBIM9	Häkkinen, 2011
10	Complex and unclear environmental regulations.	BBIM10	Rahman, 2014
11	Insufficient human resources with expertise	BBIM11	Carvalho,2019
12	Difficulty in integrating sustainability with financial tracking systems.	BBIM12	Walasek, 2017
13	Requires a longer project timeline, leading to higher costs.	BBIM13	Khan, 2019.

Table 2: Risk Factors for Implementing BIM for Sustainable Construction with Decarbonization& Circularity

Sr. No.	Parameters	Codes	Authors and Year
1	Fluctuating Market Conditions	RBIM1	Khan, 2019.
2	Increased complexity of projects	RBIM2	Mok, 2008
3	Insufficient management support for sustainability	RBIM3	Liao, 2017
4	Project complexity may cause errors	RBIM4	Leung, 2008
5	Neglecting comprehensive life-cycle assessments.	RBIM5	Wong, 2015
6	Focus on short-term costs over sustainability.	RBIM6	Barszcz, 2017
7	Risk of data breaches and loss.	RBIM7	Jones, 2017
8	Managing diverse sustainable construction regulations.	RBIM18	T. & Belloni, 2011.
9	Integrating BIM with existing systems is difficult.	RBIM9	Migilinskas, 2013
10	Challenges in tracking sustainability metrics.	RBIM10	Motawa, 2013

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Table 3: Success Factor to Implement BIM for Sustainable Practices with Decarbonization & Circularity

Sr. No.	Parameters	Codes	Authors and Year
1	Evaluates embodied carbon of materials	SBIM1	Khan, 2019
2	BIM aids in reducing lifecycle emissions	SBIM2	Singh, 2011
3	Optimizes energy via simulations.	SBIM3	Wu, 2017
4	Encourages reuse, lowers environmental impact.	SBIM4	Almarshad, 2013
5	Facilitates disassembly and material recovery.	SBIM5	Bragança, 2019
6	Supports circular economy building design	SBIM6	Azhar, 2009
7	BIM tracks sustainability performance metrics.	SBIM7	Barszcz, 2017
8	Enables decisions via environmental assessments.	SBIM8	Carvalho, 2019
9	Enhances transparency of construction's environmental impact.	SBIM9	Zanni, 2017.
10	BIM adoption driven by policies.	SBIM10	Othman, 2021.
11	Clear KPIs foster accountability, improvement	SBIM11	RRA Issa, 2009
12	Clear data protocols improve interoperability	SBIM12	Chen, 2018
13	IPD enhances collaboration and decisions.	SBIM13	Latiffi, 2014

3.0 Methodology

3.1 Research methodology

A detailed research design was created following the conclusion of the literature review to act as a guide for the investigation, detailing the goals, methodology, sample strategies, and data gathering methodologies. Then, using the knowledge gleaned from the literature research, a thorough questionnaire was meticulously created to guarantee that pertinent data could be efficiently collected. To guarantee the precision and dependability of the information gathered, data collection was then conducted methodically with a well-defined sample in mind. This study follows a quantitative research approach using Structural Equation Modeling (SEM) via Smart PLS to analyze the relationships between variables.

The research investigatres how Building Information Modeling (BIM) Contributes to sustainable Construction Practices and Integrated project delivery. The Conceptual model consists of BIM Implementation as the independent variable, Sustainability practices and integrated project delivery as mediating variable and project performance as the dependent variable. The following hypothesis are proposed to analyze the data.

Once the research design is finalized, the data set is imported into Smart PLS, a specialized software for PLS-SEM analysis. Next latent variables and indicators are defined ensuring that the constructs used in the model are appropriately specified and measured. Sub sequently, a structural model is built, establishing the relationship between the latent variables.

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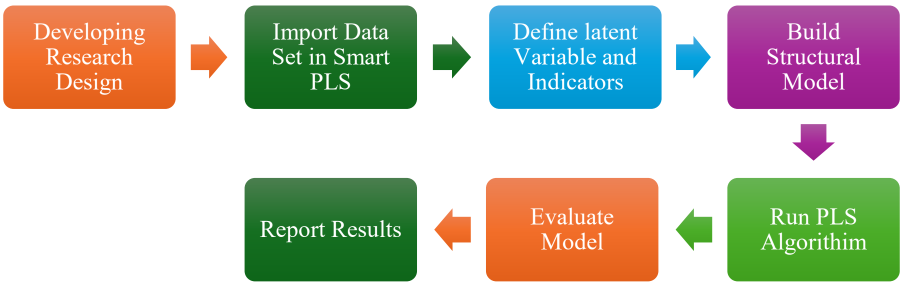
To assess the model, the PLS algorithm is executed, which computes path coefficients and evaluated the strength of relationships within the model. Following this, the model is evaluated using reliability, validity and Cronbach's alpha value to ensure its robustness and accuracy. Finally, the results are reported, interpreting key findings and drawings conclusions based on the analysis. This methodology ensures a systematic and rigorous approach to examining the research hypothesis.

Figure 1: Proposed Hypothesis



3.2 Hypothesis

Based on the findings of the literature review, the following hypothesis was formulated. The creation of the questionnaire as well as the techniques of data collecting and analysis, were all influenced by this hypothesis.

- *Hypothesis 1:* Barriers to BIM Implementation (BBIM) negatively influence Leveraging BIM for Sustainable Construction & Integrated Project Delivery (LBIM).
- *Hypothesis 2:* Leveraging BIM for Sustainable Construction & Integrated Project Delivery (LBIM) is adversely affected by Risk Factors in BIM Implementation (RBIM).
- *Hypothesis 3:* Leveraging BIM for Sustainable Construction & Integrated Project Delivery (LBIM) is positively impacted by Success Factors for BIM Implementation (SBIM).
- *Hypothesis 4:* Barriers to BIM (BBIM) and Risk Factors in BIM (RBIM) have an indirect negative influence on leveraging BIM for Sustainability (LBIM) through Success Factors for BIM (SBIM) as a mediating variable.

3.3 Data collection

3.3.1 Sampling strategy

The sample approach used for this study focused on well-known construction industry specialists to streamline the data collection process. Data were gathered regardless of the respondents' geographic location, other demographic characteristics, or their particular area of competence within the construction industry. Based on professionals' knowledge and

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comprehension of the industry overall, this technique was chosen to collect a wide range of perspectives. The approach made sure that the responses represented knowledgeable viewpoints on the research topic by concentrating on seasoned people. 110 samples in all were collected for analysis, offering a thorough foundation for evaluating the results.

3.3.2 Questionnaire design

The questionnaire was designed to assess respondents' qualification, experience and knowledge of BIM in sustainable construction, focusing on three main area; barriers, risk factors and success factors related to decarbonisation and circularity. Responses were collected using a 5-point Likert scale ranging from "Strongly Agree to Strongly Disagree". The survey was created using Microsoft Forms for ease of use and visualization, with data exportable to MS excel for further analysis.

3.3.3 Data collection strategy

A standardized questionnaire was used to collect primary data, and it was sent by email, WhatsApp, and LinkedIn to prominent construction industry individuals. To gather both quantitative and qualitative data, the survey had a combination of closed-ended and open-ended questions. To promote truthful answers, confidentiality was guaranteed, and an attempt was made to keep the questionnaire simple and short. This method made sure that the information gathered was trustworthy and pertinent for additional study.

4.0 Data Analysis

4.1 Descriptive analysis

The section aims to systematically examine and interpret the data collected to address the research objectives outlined earlier. In this study, the focus is on evaluating the integration of Building Information Modeling (BIM) with sustainable design practices within the construction industry. The parameters for the analysis were meticulously identified through an extensive review of existing literature, encompassing insights from numerous research papers. These parameters serve as a foundation to assess the effectiveness, challenges, and opportunities associated with BIM implementation for achieving sustainability goals. Through an analysis of survey responses from seasoned professionals, this part aims to identify trends, connections, and important variables affecting the adoption of BIM and how it affects sustainable building practices. The results' interpretation will aid in comprehending the useful applications of BIM and offer practical advice for improving project outcomes and promoting ecologically friendly building practices.

4.2 Smart PLS analysis

Smart PLS was used to analyse the data that was gathered. Because of its efficiency in managing intricate models with several variables and its capacity to yield trustworthy outcomes

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even with comparatively small sample sizes, this approach was chosen. Four different models were created based on the data gathered, using a range of independent factors to investigate how they affected the results. To provide a thorough grasp of the underlying linkages, each model was created to capture distinct facets of the study subject. These models' specifics and justifications are shown below.

4.2.1 Structure equation model

SEM model on BIM implementation for sustainable construction:

Independent Variables (Exogenous Constructs)

- Barriers to BIM Implementation (BBIM)
- Risk Factors in BIM Implementation (RBIM)

Mediating Variable: This variable acts as a bridge, influencing the dependent variable:

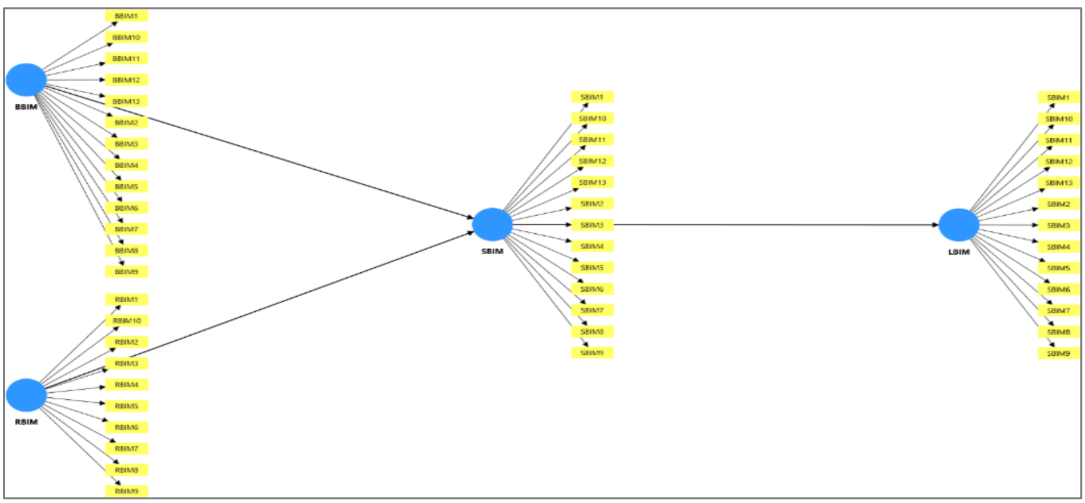
- Success Factors for BIM Implementation (SBIM)

Dependent Variable (Endogenous Construct): This is the outcome influenced by other variables:

- Leveraging BIM for Sustainable Construction & Integrated Project Delivery (LBIM)

4.3 Hypothesis testing

Figure 2: PLS Model



4.3.1 Measurement model assessment

To guarantee the accuracy of the findings, the validity and reliability of the constructs employed in the structural model were assessed under this model. By looking at the outer loadings of each observable variable connected to the latent constructs, indicator reliability was

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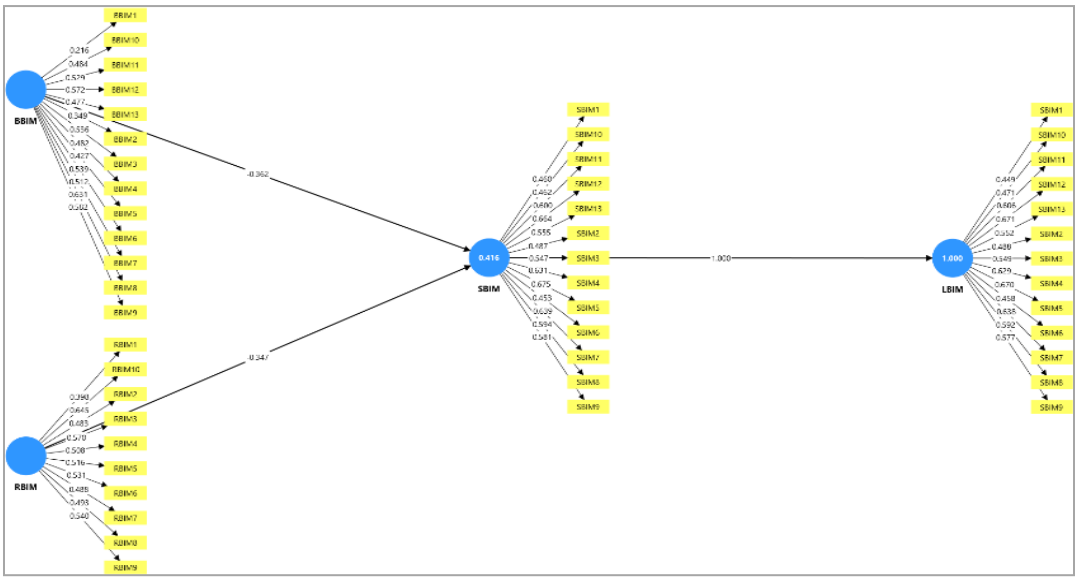
evaluated; values greater than 0.7 were considered acceptable. Cronbach's alpha and composite reliability were also used to assess internal consistency reliability; both of these metrics were above the suggested cutoff point of 0.7, indicating that the items were consistent. Figure 3 shows that the Leveraging BIM for Sustainable Construction & Integrated project delivery is not significantly impacted by the Barriers to BIM implementation (BBIM), but the path coefficient (β) is negative for BBIM -> SBIM due to the reversal of the likert scale (Strongly disagree, disagree, neutral, agree, strongly agree) for the BIM success factors (SBIM). This implies that obstacles by themselves do not significantly affect the adoption of BIM for sustainability. Rather, SBIM (Success factors for BIM) mediates their influence.

Figure 3: PLS-SEM Algorithm Graphical Output



4.3.2 Model evaluation

Reliability & Validity Checks Requirement:

- Cronbach's Alpha (>0.7), Composite Reliability (>0.7).
- AVE (Average Variance Extracted) > 0.5.
- Fornell-Larcker Criterion for discriminant validity.

Overview: Convergent dependability issues are indicated when AVE values are less than 0.5. Poor validity is shown by BBIM's (0.248) and RBIM's (0.271) excessively low AVEs, as seen in Figure 4.

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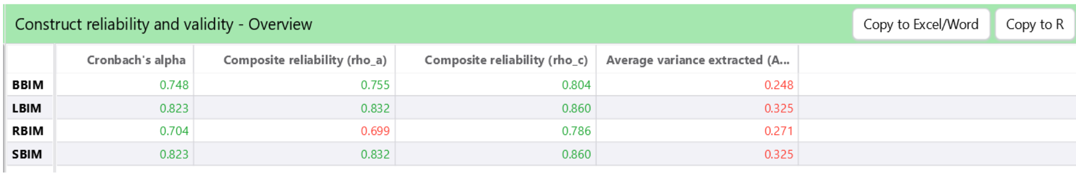
4.3.3 Cronbach's alpha – Bar chart

The result for each construct meets the acceptable threshold (>0.7), according to the Cronbach's Alpha Bar chart in Figure 5. However, if RBIM is closer to the lower limit, the reliability of the indicator may need to be reconsidered.

Figure 4: Construct Reliability and Validity Overview


Construct reliability and validity - Overview

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	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (A...
BBIM	0.748	0.755	0.804	0.248
LBIM	0.823	0.832	0.860	0.325
RBIM	0.704	0.699	0.786	0.271
SBIM	0.823	0.832	0.860	0.325

Figure 5: Cronbach's Alpha- Bar Chart

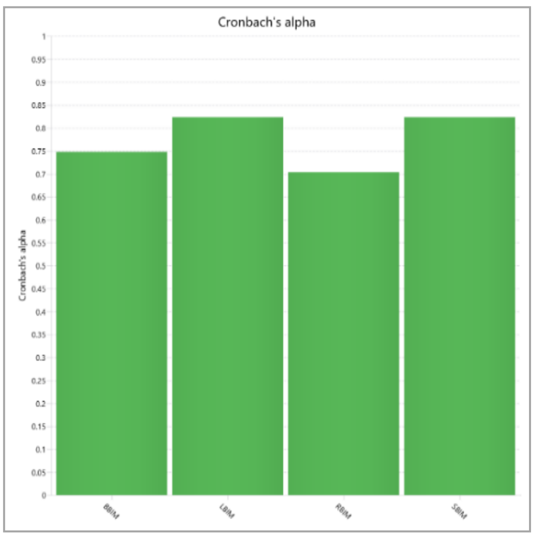
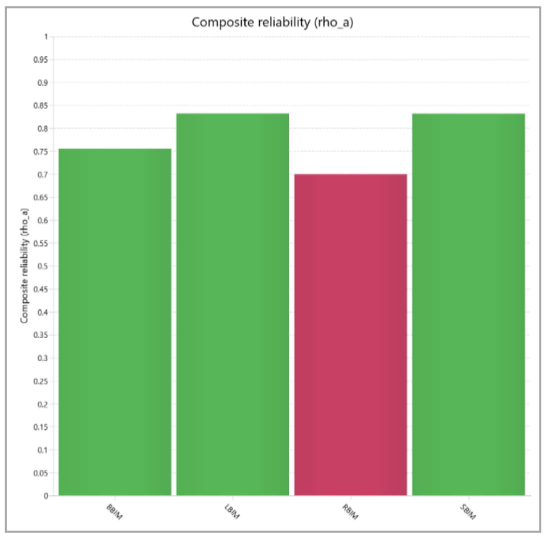


Figure 6: Composite Reliability (rho_a) - Bar Chart



4.3.4 Composite Reliability (rho_a) – Bar chart

RBIM has a composite reliability of 0.699, which is below 0.7, this means RBIM does not exhibit strong internal consistency while other constructs are above 0.7, indicating good reliability (Figure 11).

4.3.5 Composite Reliability (rho_c) – Bar chart

Figure 7 confirms the internal consistency of constructs where all the values are above 0.7 which is good.

4.3.6 Average Variance extracted (AVE) – Bar chart

The AVE indicated that the values for constructs are below the acceptable threshold of 0.5 as shown in Figure 8. This suggests that the constructs may not adequately explain the variance in the respective indicators, raising concerns about the poor convergent validity of the measurement model.

Figure 7: Composite Reliability (rho_c) - Bar Chart

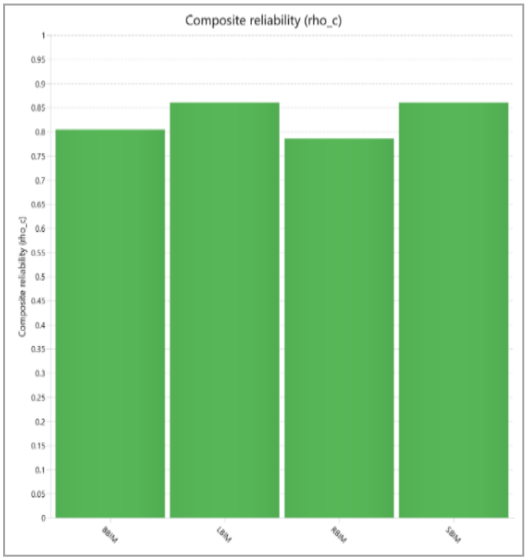
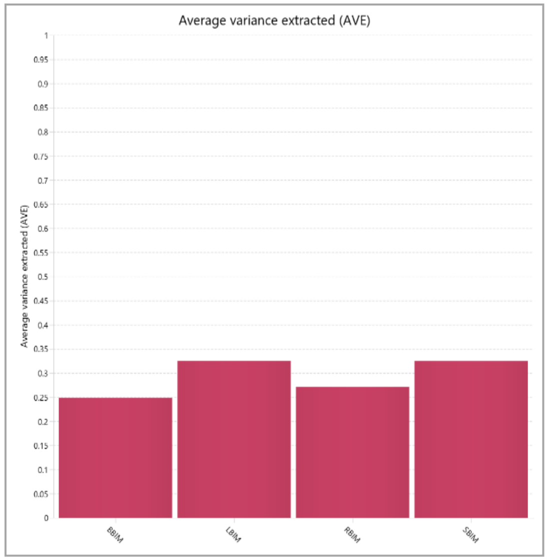


Figure 8: Average Variance Extracted (AVE)- Bar Chart



4.3.7 Fornell – Larcker Criterion for discriminate validity

In contrast, BBIM's score, 0.498 (see Figure 9), is lower than its correlations with other constructs, indicating poor discriminant validity, and the diagonal values are bigger than the off-diagonal values.

Figure 9: Fornell-Larcker Criterion for Discriminant Validity

Discriminant validity - Fornell-Larcker criterion

	BBIM	LBIM	RBIM	SBIM
BBIM	0.498			
LBIM	-0.585	0.570		
RBIM	0.656	-0.581	0.521	
SBIM	-0.589	1.000	-0.584	0.570

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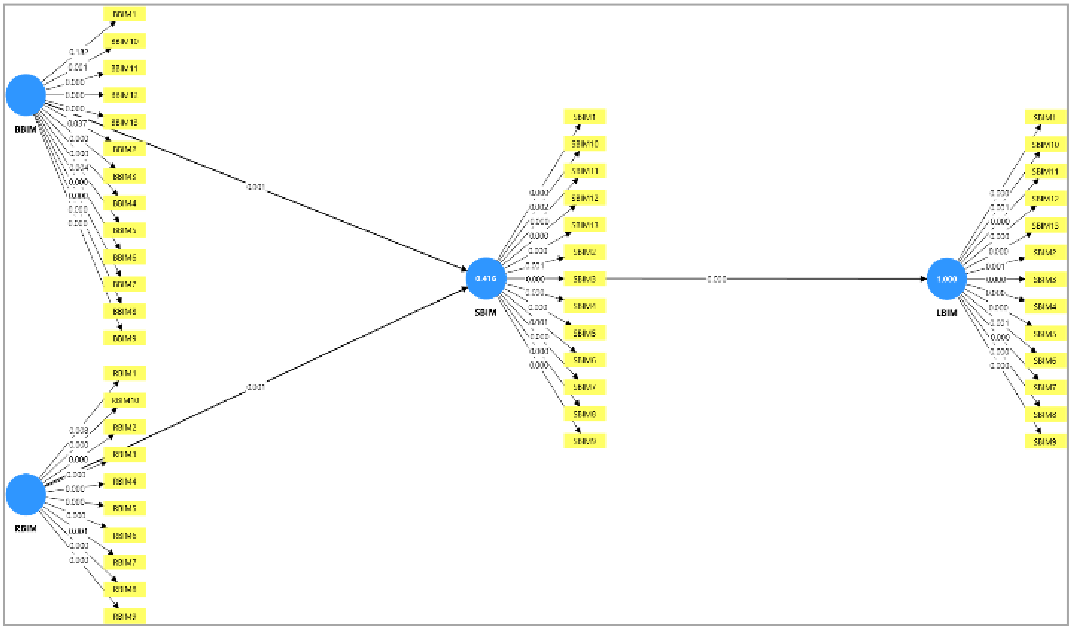
4.3.8 Parth coefficients and significance

Figure 10: Bootstrapping Graphical Output



4.3.9 Path coefficients (β) and p-values

- Go to "Bootstrapping" (5000 samples, 0.05 significance level).
- $p < 0.05$ means the hypothesis is significant.

The path coefficients (β) and p-values indicate statistical significance. The p-values for BBIM -> SBIM (-0.362, p=0.001), RBIM -> SBIM (-0.347, p=0.001), and SBIM -> LBIM (1.000, P=0.001) confirm that these relationships are statistically significant. Consequently, the hypothesis is validated as substantial.

4.3.10 Mediation Analysis (H4)

- Check indirect effects (BBIM → SBIM → LBIM and RBIM → SBIM → LBIM).
- If $p < 0.05$, mediation is supported.

The mediation analysis (Figure 12) confirms that the relationships BBIM -> SBIM -> LBIM and RBIM -> SBIM -> LBIM are significant. Since the p-values are below 0.05, mediation is validated. This supports hypothesis H4, indicating that BBIM and RBIM negatively impact LBIM through SBIM.

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Figure 11: Path Coefficients

Path coefficients - Mean, STDEV, T values, p values   Copy to Excel/Word   Copy to R

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
BBIM -> SBIM	-0.362	-0.405	0.113	3.206	0.001
RBIM -> SBIM	-0.347	-0.346	0.105	3.298	0.001
SBIM -> LBIM	1.000	1.000	0.000	3474.228	0.000

Figure 12: Specific Indirect Effects

Specific indirect effects - Mean, STDEV, T values, p values   Copy to Excel/Word   Copy to R

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P values
BBIM -> SBIM -> LBIM	-0.362	-0.404	0.113	3.206	0.001
RBIM -> SBIM -> LBIM	-0.347	-0.346	0.105	3.299	0.001

4.4 Conclusion

Hypothesis	Result	Ref.
Hypothesis 1: Barriers to BIM Implementation (BBIM) negatively influence Leveraging BIM for Sustainable Construction & Integrated Project Delivery (LBIM).	False	Hypothesis 1
Hypothesis 2: Risk Factors in BIM Implementation (RBIM) negatively influence Leveraging BIM for Sustainable Construction & Integrated Project Delivery (LBIM).	False	Hypothesis 2
Hypothesis 3: Success Factors for BIM Implementation (SBIM) positively influence Leveraging BIM for Sustainable Construction & Integrated Project Delivery (LBIM).	True	Hypothesis 3
Hypothesis 4: Barriers to BIM (BBIM) and Risk Factors in BIM (RBIM) have an indirect negative effect on Leveraging BIM for Sustainability (LBIM) through Success Factors for BIM (SBIM) as a mediating variable.	True	Hypothesis 4

5.0 Conclusion

Using Building Information Modelling (BIM) in sustainable building offers a significant chance to maximize resource management, lower carbon emissions, and improve energy efficiency. According to research, building information modelling (BIM) enables stakeholders to collaborate on projects and make well-informed decisions at every stage of a building's lifecycle. Building information modeling encourages creative solutions that support decarbonization and economic feasibility by incorporating sustainable practices into the design

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and construction stages. Nevertheless, obstacles, including the substantial upfront cost, the requirement for qualified personnel, and opposition to change, may prevent its broad adoption. To fully utilize BIM in the creation of sustainable built environments, it is necessary to overcome these challenges. In the end, the building sector can greatly contribute to a more sustainable future if it adopts BIM while improving operational efficiencies and reducing environmental impacts. The final interpretation of analysis reveals that H1 & H2 are not supported, indicating that BBIM and RBIM do not have a direct significant negative effect on LBIM. However, H3 is supported, confirming that SBIM positively influences LBIM. Additionally, H4 is validated, showing that SBIM successfully mediates the relationship between BBIM, RBIM, and LBIM. This highlights the importance of addressing success factors (SBIM) as a crucial element in enhancing BIM adoption within sustainable construction.

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