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Multidimensional Building Information Model for Environmental, Social and Governance Integration: Contractor Perspectives in Johor, Malaysia

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Abstract: The construction industry plays a critical role in addressing global sustainability challenges, and building information modelling (BIM) offers transformative capabilities to support environmental, social and governance (ESG) objectives. This study investigates contractor perspectives on the use of 3D, 4D and 5D BIM for sustainable construction in Johor, Malaysia. The research aims to identify key benefits, challenges and strategies to enhance BIM adoption while aligning with ESG goals. A quantitative approach was employed using a structured questionnaire distributed to Grade 7 (G7) contractors registered with the Construction Industry Development Board Malaysia (CIDB Malaysia). A total of 120 valid responses were analysed using descriptive statistics and correlation analyses. Findings reveal that BIM contributes significantly to environmental sustainability through waste reduction and efficient resource use, socially by enhancing collaboration and stakeholder engagement, and from a governance perspective by improving transparency and accountability. However, challenges such as high implementation cost, lack of expertise and resistance to change hinder widespread adoption. The study proposes strategies including training, government incentives and better industry awareness to promote BIM integration. The findings contribute to the existing body of knowledge by linking BIM capabilities to ESG objectives, offering valuable insights for policymakers and practitioners in developing countries aiming for sustainable construction transformation.

Keywords: Multidimensional BIM, Building information modelling, ESG in construction, Contractor practices, Johor construction industry

INTRODUCTION

The construction industry is a significant contributor to a country's economic growth, offering employment opportunities and generating value across various sectors such as manufacturing, finance and professional services (Ibrahim et al., 2010; Chan, Lee and Lee, 2014). In Malaysia, the construction sector's contribution to gross domestic product has ranged from 3.0% to 5.5%

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over the past two decades (Chan, Lee and Lee, 2014), and with the expected population growth to 41.5 million by 2040 (Shahron, Abdullah and Musa, 2021), the demand for infrastructure and resources will only intensify. However, the construction industry's environmental footprint remains a critical concern, with it accounting for 25% of global greenhouse gas emissions and 40% of global energy consumption (Bahramian and Yetilmezsoy, 2020; Luo et al., 2022). In Malaysia, the construction industry is responsible for approximately 24% of the country's total carbon emissions (Rahim et al., 2023), which contributes to severe environmental consequences such as floods, landslides and smog, directly impacting public health (World Health Organization, 2020). These environmental challenges highlight the urgent need for the construction industry to integrate sustainable practices.

Environmental, social and governance (ESG) principles have emerged as a guiding framework for sustainability across industries, including construction. ESG encompasses environmental protection, social responsibility and governance transparency, aiming to address global sustainability challenges in a holistic manner. Incorporating ESG principles into construction projects not only addresses environmental concerns but also enhances social value and ensures transparent governance practices.

Building information modelling (BIM) has gained attention as a transformative technology with the potential to improve sustainability performance in construction. BIM is a digital representation of a facility's physical and functional characteristics, serving as a shared knowledge resource for information throughout its life cycle (Eastman et al., 2011). BIM is often described through multiple dimensions: 3D for visualisation and coordination, 4D for scheduling and 5D for cost estimation. These capabilities enable more efficient, collaborative and transparent project delivery, aligning well with ESG objectives.

Globally, countries such as the United Kingdom (UK), Singapore, Australia and the United States (US) have demonstrated significant success in implementing BIM to achieve sustainable outcomes. In contrast, BIM adoption in Malaysia remains relatively low, particularly among contractors, despite government-led initiatives such as the Construction Industry Transformation Programme (CITP) 2016–2020 (Zaini et al., 2020b) and the Construction 4.0 Strategic Plan 2021–2025 (Construction Industry Development Board [CIDB] Malaysia, 2015; 2021). While awareness of BIM is increasing, actual adoption is inconsistent, especially at the contractor level. Existing studies in Malaysia predominantly focus on consultants and designers, with limited research examining contractors' perspectives and how BIM adoption supports ESG goals (Nawi et al., 2014).

To address this research gap, this study aims to investigate the adoption of BIM (3D, 4D and 5D) from the contractor's perspective and evaluate how its implementation contributes to sustainable construction in alignment with ESG goals. The objectives of this study are:

1. To investigate benefits of BIM in supporting sustainability construction to achieve ESG goals in contractor firms.
2. To examine the barriers that influence BIM implementation in achieving ESG goals in contractor firms.
3. To analyse the different strategies and their effectiveness in the adoption of BIM to achieve ESG goals in contractor firms.

By focusing on contractor perspectives, this study contributes to a more comprehensive understanding of how BIM supports ESG objectives in Malaysia's construction sector and offers practical insights for policymakers and industry stakeholders aiming to promote sustainable construction practices (Abubakar et al., 2014; Hosseini et al., 2016).

LITERATURE REVIEW

Sustainable Construction

Sustainable construction aims to reduce the environmental impact of buildings and infrastructure while ensuring long-term operational sustainability. It integrates principles of resource efficiency, waste reduction and energy conservation across the building life cycle, from material extraction to demolition (Waqar, Qureshi and Alaloul, 2023). In developing countries like Malaysia, rapid urbanisation and economic growth are driving infrastructure demand, yet this growth significantly contributes to carbon emissions, energy use and waste generation (Zaini et al., 2020a; Lima et al., 2021). Therefore, sustainable construction practices are essential to mitigate these impacts and support the transition to a low-carbon future.

Malaysia's increasing focus on sustainable construction aligns with global efforts to reduce carbon footprints and strengthen environmental stewardship (Prizeman et al., 2020). Integrating sustainability through ESG frameworks has become critical for adapting to climate change and meeting social responsibilities.

Environmental, Social and Governance

ESG is a framework used across industries to assess sustainability performance. Table 1 outlines the ESG factors identified from the literature, providing the conceptual framework for evaluating BIM's contributions to sustainable construction. These factors serve as the basis for mapping BIM benefits and strategies throughout the study.

Table 1. ESG international framework

Dimension	Relevant Factors in Construction
Environmental (E) Definition: Environmental aspects of construction activities that affect resource use, emissions and ecological impact.	1. Greenhouse gases emissions from construction processes and machinery 2. Energy consumption and efficiency in construction operations 3. Dust, noise and air pollutants from site activities 4. Water usage and recycling in site operations 5. Construction waste production and management (water, solid and hazardous) 6. Impact on biodiversity and surrounding ecosystems from land use 7. Use of sustainable and environmentally friendly materials and technologies
Social (S) Definition: Social impacts of construction activities on workforce, communities and stakeholders.	1. Workforce welfare, rights and fair treatment 2. Occupational health and safety on construction sites 3. Skills training and workforce development 4. Community engagement and minimising disruption during projects 5. Local job creation and economic development 6. Diversity, equity and inclusion in the workforce
Governance (G) Definition: Governance practices ensuring transparency, accountability and compliance in construction projects.	1. Compliance with building codes, standards and regulations 2. Transparent procurement and tendering processes 3. Anti-bribery and anti-corruption measures 4. Stakeholder engagement and communication 5. Contract management and risk mitigation 6. Project accountability and performance reporting

Source: European Banking Authority (2021).

In construction, ESG is vital to balancing economic growth, social welfare and environmental protection. Given the sector's high environmental footprint, ESG adoption helps manage environmental impacts, promote social equity and uphold governance principles such as transparency and ethical practice (Gupta, 2021).

The Malaysian construction sector faces pressure to meet ESG criteria to improve resource efficiency, reduce waste, enhance worker safety and deliver community-orientated projects. BIM can strengthen ESG performance by improving project coordination, minimising environmental impacts and enhancing governance transparency (Markopoulos et al., 2024; Volk, Stengel and Schultmann, 2014).

3D, 4D and 5D Building Information Modelling

BIM integrates multi-dimensional modelling to streamline construction processes. Its core function is the creation of a 3D model for visualisation and coordination. 4D BIM links design to scheduling, enabling better sequencing and reduced delays (Eastman et al., 2011), while 5D BIM facilitates accurate cost estimation, real-time budget updates and reduced cost overruns (Forgues et al., 2012).

By combining these dimensions, BIM optimises resource use, reduces waste and supports timely, cost-effective delivery, thereby contributing to ESG objectives (Hardin, 2009).

Capabilities of Building Information Modelling in Sustainable Construction

BIM's potential extends beyond design visualisation and cost estimation. Its integration enables efficient resource allocation, minimises material waste and enhances productivity (Markopoulos et al., 2024; Volk, Stengel and Schultmann, 2014). BIM also supports energy-efficient design by simulating building performance over its life cycle, informing decisions that reduce environmental impact (Bank et al., 2010). Life cycle assessments conducted through BIM evaluate the environmental impact of design choices, guiding material selection and operational strategies that lower carbon footprints.

As shown in Table 2, BIM capabilities can be categorised according to the ESG framework. Environmentally, BIM enables energy performance simulation, waste reduction strategies and optimisation of construction methods to minimise ecological impact. Socially, it improves stakeholder collaboration, enhances safety planning and facilitates transparent communication, fostering coordinated and inclusive project delivery. In governance, BIM strengthens regulatory compliance, cost monitoring and data-driven decision-making, reducing risks of disputes and mismanagement.

By mapping BIM capabilities to ESG dimensions, Table 2 illustrates that BIM is not only a technological advancement but also a structured enabler of sustainable construction, aligning operational efficiency with broader sustainability goals.

Table 2. Capabilities of 3D, 4D and 5D BIM

BIM	Capability
3D	1. Model walkthroughs Main contractors utilise BIM to create a scientific site plan and optimise the layout during the pre-construction phase in accordance with the site's real circumstances (Rui, Yaik-Wah and Siang, 2021). 2. Clash detection work BIM tools increase the effectiveness of conflict detection, facilitating prompt settlement of any problems, which advances construction and enhances quality control (Ma et al., 2019; Xiao et al., 2019; Abobakirov and Omonboev, 2023). 3. Project visualisation Stakeholders can better understand the project, communicate more effectively and avoid misconceptions by being able to see and model the building design and construction process. Before building begins, contractors can use BIM technology to produce images for clients, which helps to clarify project design (Umar et al., 2015). 4. Virtual meetings Project stakeholders can view the building model in 3D or even augmented reality (AR) surroundings during virtual meetings and presentations made possible by BIM technologies. Through improved communication and comprehension, this immersive experience enables stakeholders to jointly explore design possibilities, assess choices and reach well-informed conclusions. It increases stakeholder participation, decreases uncertainty and promotes clarity (Abbasnejad and Moud, 2013; Abobakirov and Omonboev, 2023).
4D	1. Visualisation of time and space relationships of construction activities (Büchmann-Slorup and Andersson, 2010; Heesom and Mahdjoubi, 2002; Muzvimwe, 2011; Sattineni and Macdonald, 2014; Umar et al., 2015; Gledson and Greenwood, 2016; Jupp, 2017; Ahmadi and Arashpour, 2020; Rui, Yaik-Wah and Siang, 2021; Abobakirov and Omonboev, 2023)

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Table 2. *Continued*

BIM	Capability
	i. Construction sequences can be virtually simulated to find and fix issues at the planning stage. ii. Showcase the order of construction procedures, checking the schedule's logic and soundness and the availability of space to prevent rework. iii. Identify potentially dangerous activities based on location or timing considerations.
	2. Optimisation of construction processes (Sattineni and Macdonald, 2014; Cheng, Won and Das, 2015; Umar et al., 2015; Jupp, 2017; Abobakirov and Omonboev, 2023) i. Reduce rework and modifications by streamlining procedures. ii. Allow construction managers to plan ahead and maximise the flow of personnel, supplies and machinery on the job site.
	3. Clash detection and enhanced team coordination (Dawood and Sikka, 2009; Umar et al., 2015; Abobakirov and Omonboev, 2023) i. Identify any physical conflicts and help the design team become more coordinated. ii. Assist contractors in managing information flow and improving productivity.
	4. Construction schedule analysis and resources management (Koo and Fischer, 2000; Cheng, Won and Das, 2015; Umar et al., 2015; Gledson and Greenwood, 2016; Candelario-Garrido, García-Sanz-Calcedo and Rodríguez, 2017; Jupp, 2017; Ahmadi and Arashpour, 2020; Rui, Yaik-Wah and Siang, 2021; Abobakirov and Omonboev, 2023) Throughout the course of a building project, precise scheduling and resource management are made possible by BIM technology. Task dependencies, resource allocation and comprehensive timetables may all be created with BIM by combining project data and information into a single model. This allows effective project execution, improves resource utilisation and strengthens project planning.

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Table 2. *Continued*

BIM	Capability
	5. Reduction of errors and enhanced communication (Dawood and Sikka, 2009; Umar et al., 2015; Gledson and Greenwood, 2016; Ahmadi and Arashpour, 2020; Abobakirov and Omonboev, 2023) i. By examining and validating building plans, mistakes can be decreased. ii. Enhance cooperation by improving communication amongst project team members.
	6. Construction safety, waste and risk management i. A cooperative approach to managing garbage from building and demolition is encouraged by the incorporation of 3D and 4D capabilities into waste management processes (Cheng, Won and Das, 2015; Jupp, 2017). ii. 4D BIM aids in early project identification of construction risks, enabling proactive measures to mitigate site hazards and allocate safety resources effectively during design and scheduling phases (Jin et al., 2018, 2019).
5D	1. Cost estimation and project budget management (Sattineni and Macdonald, 2014; Rui, Yaik-Wah and Siang, 2021) i. Provide designers with faster access to project price data to make necessary design modifications to keep costs down. ii. Enhance transparency for the owner and design team, providing more insight into the contractor's spending plan and fostering trust among interested parties.
	2. Effective quantity take-off and reduction of change orders i. Use BIM models to perform more efficient quantity take-off (QTO) and reduce the occurrence of change orders (Eastman et al., 2011; Hasan and Rasheed, 2019; Rui, Yaik-Wah and Siang, 2021). ii. Use BIM to automate the cost estimating process, improving accuracy and lowering human error (Abu-Hamd, Atef and Masoud, 2016).

Barriers to Building Information Modelling Adoption

Despite its benefits, BIM adoption in Malaysia faces significant barriers. Table 3 summarises the barriers to BIM adoption compiled from previous studies, offering a consolidated view of the organisational, financial and technical challenges faced globally and in Malaysia.

High initial investment in software, hardware and training is a major challenge (Memon et al., 2014). Many contractors are unaware of BIM's advantages, leading to resistance, while the absence of standardised national guidelines complicates implementation (Zahrizan et al., 2013).

Legal uncertainties around data ownership, intellectual property and contractual issues discourage use (CIDB Malaysia, 2021). Additionally, a shortage of skilled BIM professionals further hinders industry-wide adoption (Hasan and Rasheed, 2019).

Strategies to Enhance Building Information Modelling Adoption

Overcoming BIM adoption barriers requires strategic action. Table 4 presents strategies recommended in the literature to address barriers to BIM adoption, focusing on policy interventions, financial incentives, standardisation and capacity building. These strategies provide a comparative benchmark for evaluating the prioritised solutions identified in this study.

Developing a national BIM standard would provide clear guidelines for implementation (CIDB Malaysia, 2021). Expanding industry training programmes can build necessary expertise, while government mandates, as seen with the UK's BIM Level 2, can accelerate adoption (Gibbs et al., 2015).

Financial incentives and grants can offset adoption costs, and stronger public–private collaboration, as demonstrated in Singapore, can drive innovation. International comparisons show that such strategies significantly improve BIM uptake, supporting ESG objectives.

Table 3. Common barriers of BIM adoption to contractors

No.	Barrier
1.	Cost and time (including training) i. Initial cost and time investment: When compared to traditional projects, BIM implementations can have higher initial costs and take longer. This is because key individuals spend more time getting ready for the integration of BIM (Sattineni and Macdonald, 2014). ii. Software, hardware, and training costs: A substantial investment in BIM software, hardware and training is necessary to make the switch from computer-aided design (CAD) to BIM (Ahmadi and Arashpour, 2020). iii. Increased workload: Putting BIM into practice adds to the modelling effort, which may take a lot of time, particularly in the beginning (Tan et al., 2019).
2.	Cultural barriers and resistance to change i. Resistance to change: There would be a lot of cultural resistance when companies believe that the current software solutions are more accurate or efficient than BIM, especially with 5D BIM (Arayici et al., 2009; 2011; Eastman et al., 2011; Kullvén and Nyberg, 2014; Hasan and Rasheed, 2019). ii. Lack of motivation: The delayed adoption of BIM is a result of a lack of enough external stimulation and study on its application (Tan et al., 2019). iii. Training and education: Lack of expertise and skilled personnel to use BIM technology, as well as high training and education costs, are typical issues (Kullvén and Nyberg, 2014; Swallow and Zulu, 2019).
3.	Legal and ownership issues i. Data ownership and protection: Concerns around copyright and intellectual property rights, as well as the identification of BIM data ownership, are frequently unclear (Tan et al., 2019; Ahmadi and Arashpour, 2020). ii. Legal uncertainty: The lack of clear legal frameworks and standard contracts for BIM implementation leads to confusion and increases the need for resources (Tan et al., 2019).

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Table 3. *Continued*

No.	Barrier
4.	Collaboration and risk management i. Collaboration challenges: In BIM, effective cooperation is essential for risk management. However, problems such as ineffective workflows, a lack of standard practices and a reluctance to share data make it difficult for project participants to collaborate (Azhar, 2011; Tan et al., 2019). ii. Resistance to alterations: Adopting lean-oriented initiatives might be difficult since teams sometimes oppose changing established workflows (Eastman et al., 2011).
5.	Technical and software limitations i. Lack of standardisation: Multiple software systems are used for activities such as 3D collision detection and 4D simulation since no one program can carry out all BIM capabilities (Sattineni and Macdonald, 2014). ii. Software incompatibility: BIM integration is made more difficult by the incompatibility of different software systems (Kullvén and Nyberg, 2014). iii. Lack of standards: The difficulties are exacerbated by the absence of established BIM standards, object coding methods and well-defined processes (Hasan and Rasheed, 2019; Tan et al., 2019).
6.	Unclear economic benefits i. Uncertain return on investment: BIM adoption is sometimes hampered by the lack of clarity surrounding its economic benefits (Tan et al., 2019). ii. Costs of hiring specialists: The requirement for specialised personnel to manage BIM procedures raises the implementation costs (Tan et al., 2019).
7.	Risk of new and uninsurable liabilities New risks and lack of insurance: All project participants are exposed to additional risks due to the absence of insurance and normal BIM standards, and it is unclear how these risks will be managed (Tan et al., 2019).

Table 4. Comparison of different countries strategies

Strategies	Countries					
	United Kingdom Source: Jiang et al. (2022)	**United States (US) Source: Jiang et al. (2022)**	**Hong Kong Source: Wong et al. (2011)**	**China Source: Zhou, Yang and Yang (2019)**	**Singapore Source: Jiang et al. (2022)**	**Malaysia Sources: CIDB Malaysia (2015; 2021); Jabatan Kerja Raya (2021); *Malay Mail* (2020); Lai and Gimino (2024)**
1. Education (training/ courses)	i. 2016: BIM academic forum launched. ii. 2017: E-learning module introduced for all levels. iii. 2017 onward: Continued focus on research.	2006–2016: US Army Corps of Engineers (USACE) training, National Institute of Building Sciences online course, Massachusetts Institute of Technology (MIT) BIM standards introduced.	Hong Kong Institute of Building Information Modelling (2009): Promotes BIM education and awareness, linking universities and government bodies for training.	i. Universities and organisations focus on BIM skills and training. ii. China Construction Education Association issued BIM skills assessment plan (2015).	i. 2011–2016: Provided training, outreach programmes, and specialist diplomas. ii. 2016 onwards: Launched new training programmes at all levels.	2015: BIM training centre and BIM education syllabus introduced.
2. Regulation standards/ guidelines	i. 2011–2016: Publicly Available Specification (PAS), British Standard (BS) and International Organization for Standardization (ISO) standards introduced and updated. ii. 2017 onward: Global collaboration with new ISO and Gemini Principles.	2005–2018: Multiple BIM guides and standards introduced, including national BIM and state-specific guidelines	i. Certified SOLIDWORKS Professional (CSWP) Standard: Updates CAD standards (AutoCAD, MicroStation) to support BIM. ii. Housing Authority (2009): Adopts BIM for sustainable design and efficiency in public housing.	i. The Ministry of Housing and Urban-Rural Development (MOHURD) issued BIM guides (2007) and developed five national BIM standards (2015). ii. Policies for A-level construction firms to master BIM by 2020.	i. 2010–2015: Introduced BIM e-submission guidelines, Singapore BIM Guides (V1.0 and V2.0) and BIM Essential Guides. ii. 2016 onwards: Expanded guidelines to include Design for Manufacture and Assembly (DfMA), Virtual Design and Construction (VDC), and Asset Information Delivery.	i. 2016: Malaysia CIDB BIM guidelines established. ii. 2021: Jabatan Kerja Raya BIM guidelines established.

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Table 4. *Continued*

Strategies	United Kingdom Source: Jiang et al. (2022)	United States (US) Source: Jiang et al. (2022)	Hong Kong Source: Wong et al. (2011)	China Source: Zhou, Yang and Yang (2019)	Singapore Source: Jiang et al. (2022)	Malaysia Sources: CIDB Malaysia (2015; 2021); Jabatan Kerja Raya (2021); *Malay Mail* (2020); Lai and Gimino (2024)
3. Cost/fundings	2017 onward: BIM research funding introduced to support innovation.	No significant funding actions noted.	Implied government support through public project backing.	Government investment in BIM research and development (R&D) and academic projects.	i. 2010–2018: Continuous funding through the BIM fund. ii. 2016 onwards: Focused on R&D funding.	i. Implied government support through the creation of BIM centres and projects. ii. 2020: SME Technology Transformation Fund (STTF) was launched for small and medium-sized enterprise to adopt digitalisation and automation.
4. Demonstration	i. 2011: BIM forum and awards for small and medium-sized enterprise. ii. 2015–2016: BIM toolkit for deliverables introduced. iii. 2017 onward: BIM case library and international collaboration.	2006–2010: USACE and BIM forum used for showcasing BIM success stories.	i. Housing authority: Pilots BIM in modular flats and public housing projects. ii. Hong Kong BIM Programme: Proposes pilot projects to test BIM adoption.	Programmes during the 12th Five-Year Plan (2011–2015) promoted BIM in real projects.	i. 2010–2012: Piloted BIM projects. ii. 2011 onwards: Promoted success stories and held forums	2014: Promotion and awareness through the national BIM pilot project.

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Table 4. *Continued*

Strategies	Countries					
	United Kingdom Source: Jiang et al. (2022)	**United States (US) Source: Jiang et al. (2022)**	**Hong Kong Source: Wong et al. (2011)**	**China Source: Zhou, Yang and Yang (2019)**	**Singapore Source: Jiang et al. (2022)**	**Malaysia Sources: CIDB Malaysia (2015; 2021); Jabatan Kerja Raya (2021); *Malay Mail* (2020); Lai and Gimino (2024)**
BIM mandates	i. 2011: Mandated 3D BIM for public projects by 2016. ii. 2016 onwards: BIM Level 2 mandated for public and private sectors.	2009–2018: BIM mandated for large construction projects by Department of Veterans Affairs (VA), Wisconsin (Division of State Facilities), Indiana and Los Angeles Community College District (LACCD).	i. Certified SOLIDWORKS Professional (CSWP) Working Group (2007): Sets timeline for BIM use in public projects. ii. Hong Kong BIM Programme: Proposes mandatory BIM for all new government projects.	MOHURD stepwise implementation, starting with large enterprises, with a 2020 mastery target for key firms.	i. 2011–2012: BIM e-submission became mandatory for public sector projects. ii. 2013–2015: Expanded mandates to include large-scale projects (over 20,000 m², then 5,000 m²).	i. 2017: Mandatory BIM submission for architecture. ii. 2018: Mandatory BIM submission for engineering. iii. 2018: Mandatory BIM for public project cost over MYR100 million. iv. 2019–2020: Full BIM lifecycle and advanced BIM technology adoption. v. 2024: Mandatory BIM for public and private project cost over MYR10 million.
Initiators and drivers	i. 2011–2012: BIM task groups and BIM regions formed. ii. 2016: UK BIM Alliance and Public Sector BIM Working Group established. iii. 2017 onwards: Led by the Centre for Digital Built Britain.	2003–2008: National 3D–4D BIM Programme, BIM Standard Committee and building SMART established.	i. Development Bureau (DevB): Leads BIM implementation for public infrastructure. ii. Hong Kong Institute of Building Information Modelling: Sets BIM standards and provides education. iii. HKSAR Government Property Agency (GPA) and Architectural Services Department (ArchSD): Use BIM for government space and property management.	i. MOHURD and China BIM Development Union lead initiatives. ii. China Construction Education Association supports BIM education.	i. 2010: Centre for Construction IT (CCIT) initiated the first BIM roadmap. ii. 2011: Established the BIM Steering Committee. iii. 2015: Launched the second BIM roadmap focusing on advanced BIM and R&D.	2014: CIDB BIM Centre and national BIM pilot project launched.

METHODOLOGY

This section outlines the research methodology adopted in this study, following approaches used by Hasan and Rasheed (2019), Al-Ashmori et al. (2020) and Manzoor et al. (2021). As shown in Figure 1, the research was conducted in four phases to achieve the stated aim and objectives.

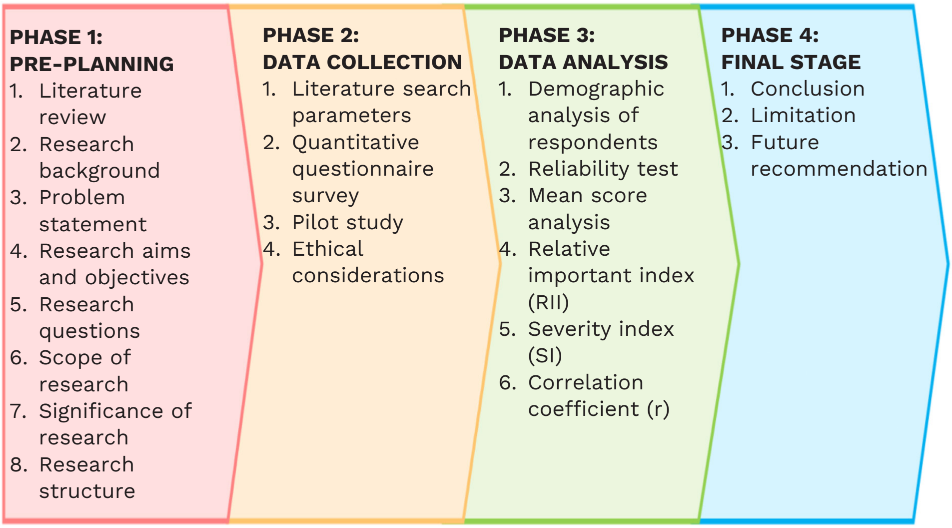

Figure 1. Research design flow chart

Phase 1 involved a review of relevant literature to establish the aims, objectives and problem statement, focusing on BIM adoption barriers, capabilities and strategies for achieving ESG goals in sustainable construction. Phase 2 used the literature review findings to design a structured questionnaire for contractors. Phase 3 comprised data collection and statistical analysis using Statistical Package for the Social Sciences (SPSS) version 29 (IBM Corp., Armonk, NY, US), and Phase 4 presented the conclusions, limitations and recommendations.

Data Collection

Literature search parameters

A literature review was conducted to examine BIM capabilities, barriers and strategies for sustainable construction aligned with ESG goals. Sources included Google Scholar and databases such as Taylor & Francis, Elsevier and Emerald Insight. Keywords used were "BIM", "ESG", "sustainable construction", "barriers", "3D BIM", "4D BIM", "5D BIM", "strategies" and "capabilities".

Quantitative questionnaire survey

A quantitative questionnaire survey was selected due to time constraints and the efficiency of statistical analysis using SPSS (Connolly, 2007), as also recommended by Al-Ashmori, Othman and Al-Aidrous (2022). The questionnaire investigated contractors' perspectives on 3D, 4D and 5D BIM in sustainable construction. While previous related studies were conducted in Selangor, Kuala Lumpur, Melaka, Kedah, Sabah and Sarawak (Al-Ashmori et al., 2020; Othman et al., 2021; Yunus et al., 2023), limited research focused on Johor, prompting the choice of this location.

The target respondents were CIDB Grade 7 (G7) contractors in Johor, selected because larger firms are more likely to adopt ESG policies. According to the CIDB contractor list, the population was 380 firms; hence, 380 questionnaires were distributed via email to individuals in roles such as quantity surveyor, project engineer, project manager, architect, health and safety officer or owner. Based on Krejcie and Morgan's (1970) sample size table (as shown in Table 5), the targeted sample was 191.

Table 5. Krejcie and Morgan's sample determination table

N	*S*	*N*	*S*	*N*	*S*	*N*	*S*
10	10	100	80	280	162	800	260
15	14	110	86	290	165	850	265
20	19	120	92	300	169	900	269
25	24	130	97	320	175	950	274
30	28	140	103	340	181	1,000	278
35	32	150	108	360	186	1,100	285
40	36	160	113	380	191	1,200	291
45	40	170	118	400	196	1,300	297
50	44	180	123	420	201	1,400	302
55	48	190	127	440	205	1,500	306
60	52	200	132	460	210	1,600	310
65	56	210	136	480	214	1,700	313
70	59	220	140	500	217	1,800	317
75	63	230	144	550	226	1,900	320
80	66	240	148	600	234	2,000	322
85	70	250	152	650	242	2,200	327
90	73	260	155	700	248	2,400	331
95	76	270	159	750	254	2,600	335

Note: *N* = Population size; *S* = Sample size.

Source: Krejcie and Morgan (1970).

Pilot Study

A pilot study tested the questionnaire for clarity and relevance. Five quantity surveyors from G7 firms participated, providing feedback on ambiguous wording and minor grammatical errors. Adjustments were made accordingly. The final questionnaire comprised five sections: (1) Respondent background, (2) Company background, (3) Benefits of BIM adoption, (4) Barriers to BIM adoption and (5) Strategies to enhance BIM adoption. Sections 3 to 5 used a five-point Likert scale to measure agreement.

Data Analysis

Survey data were analysed using SPSS, including demographic profiling, reliability testing, mean score analysis, relative importance index (RII), severity index (SI), and correlation coefficient (*r*). Cronbach's alpha was used to assess internal consistency, with values above 0.8 indicating high reliability (Pallant, 2007; Susmitha, Raja and Asadi, 2018). Mean score analysis identified key factors by calculating averages, RII ranked BIM benefits and strategy significance and SI ranked barriers by importance.

The correlation coefficient was applied to determine the strength and direction of relationships between identified barriers and strategies. This statistical measure was selected because it quantifies the degree to which two variables move together, providing insights into whether specific strategies directly address certain barriers, which supports practical recommendations for BIM adoption.

Language Editing Declaration

To enhance readability and grammatical accuracy, QuillBot (AI-assisted language editing software) was used to refine sentence structure and grammar in the manuscript. The tool was applied only for language editing purposes and did not alter the research data, analysis or findings.

RESULTS

Reliability of the Data

The Cronbach's alpha coefficient for the survey data was 0.82, indicating high reliability and internal consistency of the instrument (Pallant, 2007). The individual scales for BIM benefits, barriers, and strategies recorded a Cronbach's alpha value of 0.944 (n = 44), which exceeds the threshold of 0.7, thereby confirming the robustness of the measurement.

Building Information Modelling Awareness Level

A total of 59 valid responses were obtained from 191 distributed questionnaires, giving a response rate of 30.89% (as shown in Equation 1).

$$\text{Respond rate} \quad = \frac{59}{191} \times 100 \quad = \quad 30.89\% \qquad \text{Eq. 1}$$

The demographic profile showed that most respondents had over 10 years of construction experience, and their companies were primarily engaged in large-scale infrastructure and building projects (as shown in Table 6).

Table 6. Respondents' background

Information	Categories	%
Work experience	Less than 1 year	–
	1 year to 3 years	17
	4 years to 6 years	17
	7 years to 9 years	22
	More than 10 years	44
Education qualification	Bachelor's degree	89
	Master's degree	11
Position	Quantity surveyor	50
	Project engineer	6
	Project manager	11
	Architect	–
	Health and safety officer	–
	Owner	22
	Others (Quality assurance and quality control)	11
BIM awareness	Aware	17
	Unaware	83
Personal work experience in using BIM	None	56
	Less than 1 year	17
	1 year to 3 years	11
	4 years to 6 years	11
	7 years to 9 years	6
	More than 10 years	–

The survey assessed BIM awareness levels among respondents (as shown in Table 7). Results indicated that 33% of respondents had high awareness of BIM applications, 50% had moderate awareness and 17% unaware of BIM. While most respondents were familiar with BIM, the findings highlight a remaining need for targeted training to improve knowledge among less aware groups.

Table 7. Companies' background

Information	Categories	%
Size of company	Small (3 to 19 people)	17
	Small to medium (20 to 50 people)	28
	Medium to large (51 to 200 people)	33
	Large (More than 200 people)	22
CAD adoption	No CAD	6
	2D and 3D CAD	33
	2D only	50
	3D only	2
BIM awareness and adoption	Aware and adopting	33
	Aware but not adopting	50
	Unaware	17
Company working experience in using BIM	None	56
	Less than 1 year	22
	1 year to 3 years	11
	4 years to 6 years	–
	7 years to 9 years	6
	More than 10 years	6
ESG awareness and adoption	Aware and adopting	56
	Aware but not adopting	11
	Unaware	6

Research Question 1: Benefits of Building Information Modelling Adoption to Achieve Environmental, Social and Governance Goals

As shown in Table 8, the highest-ranked benefit, "Enhances conflict detection, improving quality control and advancing construction" (RII = 0.822; Mean = 4.111; Rank = 1), is directly linked to both the social and environmental dimensions of ESG. Socially, it improves coordination among contractors, consultants and workers, thereby enhancing site safety and reducing disputes. Environmentally, it reduces rework and minimises unnecessary material waste, supporting sustainable resource management (Sattineni and Macdonald, 2014; Xiao et al., 2019).

The second-ranked benefit, "Provides quick access to project costs, enhancing budget control and transparency" (RII = 0.800; Mean = 4.000), contributes to the governance dimension by strengthening accountability and transparency in cost monitoring, ensuring accurate reporting and enabling better-informed decision-making among stakeholders (Succar and Kassem, 2015).

The third-ranked benefit, "Simulates construction sequences to resolve planning issues and prevent rework" (RII = 0.778; Mean = 3.889), supports the environmental dimension by minimising construction waste and improving resource efficiency, while also contributing to the social dimension through smoother workflow coordination and reduced site disruption (Jin et al., 2018; Deng, Menassa and Kamat, 2021).

These findings confirm that BIM does not function solely as a technological tool but also as a strategic enabler of ESG integration in construction projects. By reducing waste, improving safety and collaboration, and promoting transparency, BIM directly supports environmental stewardship, social responsibility and sound governance practices in the construction sector (Succar and Kassem, 2015). The mapping of these top-ranked BIM benefits against the ESG dimensions is summarised in (as shown in Table 9), which demonstrates how each benefit aligns with specific ESG outcomes.

Table 8. Ranking of benefits of BIM adoption by construction companies

Benefits of BIM Adoption in Construction Company		R11	Mean	SD	Ranks
a1	Optimises site layout during pre-construction based on real conditions	0.767	3.833	0.786	4
a2	Enhances conflict detection, improving quality control and advancing construction	0.822	4.111	0.758	1
a3	Improves stakeholder understanding, communication and reduces design misconceptions	0.744	3.722	1.166	6
a4	Enables immersive 3D or AR presentations to enhance stakeholder engagement and decision-making	0.756	3.778	0.732	5
a5	Simulates construction sequences to resolve planning issues and prevent rework	0.778	3.889	0.707	3
a6	Streamlines processes, reduces rework and enhances on-site resource flow	0.733	3.667	0.840	7
a7	Identifies physical conflicts and improves design team coordination and information flow	0.700	3.500	0.857	10
a8	Enables precise scheduling, task dependencies and effective resource utilisation	0.678	3.389	0.608	12
a9	Reduces mistakes by validating building plans and improving team collaboration	0.711	3.556	0.705	9
a10	Aids in managing waste, mitigating site risks and allocating safety resources	0.689	3.444	0.705	11
a11	Provides quick access to project costs, enhancing budget control and transparency	0.800	4.000	0.686	2
a12	Automates cost estimation, reduces change orders and increases accuracy	0.722	3.611	0.778	8

Table 9. ESG mapping of top-ranked BIM benefits

BIM Benefit	ESG Dimension	Explanation
Enhances conflict detection, improving quality control and advancing construction (a2)	E and S	E: Reduces rework and material waste S: Improves site safety and coordination among stakeholders
Provides quick access to project costs, enhancing budget control and transparency (a11)	G	G: Promotes accountability, transparent reporting and data-driven financial decision-making
Simulates construction sequences to resolve planning issues and prevent rework (a5)	E and S	E: Minimises waste and improves resource efficiency S: Ensures smoother workflow and reduces site disruption

Research Question 2: Barriers of Building Information Modelling Adoption

The SI analysis identified "Difficulty in adopting BIM coordination" as the top barrier (SI = 91.11), followed by "Lack of appropriate projects to adopt BIM" (SI = 86.67) and "Lack of time for experimentation and adoption in a fast-paced project" (SI = 81.11). The lowest-ranked barriers were "Lack of references/ sources to assist in adopting BIM" (SI = 63.33) and "Insufficient BIM training available" (SI = 62.22) (as shown in Table 10). These results suggest that operational and resource-related issues outweigh knowledge gaps, although cultural resistance and insufficient industry-specific guidelines also emerged as notable concerns.

Table 10. Ranking of barriers of BIM adoption by construction companies

Barriers of BIM Adoption in Construction Company		Mean	SD	Ranks
b1	High cost of software	76.67	1.043	6
b2	High training cost	68.89	0.992	13
b3	High cost of technology	77.78	0.900	5
b4	Lack of BIM knowledge	67.78	0.698	14
b5	Lack of top management support	61.11	0.802	20
b6	Lack of experience in coordinating the construction documents by using BIM	74.44	0.752	8

(*Continued on next page*)

Table 10. *Continued*

Barriers of BIM Adoption in Construction Company		Mean	SD	Ranks
b7	Lack of time for experimentation and adoption in a fast-paced project	81.11	0.873	3
b8	No established contractual framework for working with BIM	65.56	0.895	16
b9	Lack of organisation familiarisation with adopting BIM	71.11	0.922	11
b10	Insufficient BIM training available	62.22	0.963	19
b11	Reluctance to initiate new workflows for adoption of BIM	66.67	0.907	15
b12	Lack of references/sources to assist in adopting BIM	63.33	0.924	18
b13	Lack of direction of BIM in the industry	72.22	0.778	10
b14	Lack of awareness of BIM benefits	70.00	1.043	12
b15	The complexity of the new roles in BIM-based construction projects	73.33	0.840	9
b16	Lack of BIM demand	64.44	1.060	17
b17	Difficulty in adopting BIM coordination	91.11	0.616	1
b18	Lack of clear policies that support BIM adoption	78.89	0.639	4
b19	Inadequate information management processes for BIM	75.56	0.548	7
b20	Lack of appropriate projects to adopt BIM	86.67	0.767	2

Research Question 3: Strategies to Enhance Building Information Modelling Adoption

The RII analysis showed "Develop BIM standards" ranked first (RII = 0.833), followed by "Provide financial aid to reduce the cost of adopting BIM" (RII = 0.822) and "Develop BIM adoption guidelines" (RII = 0.811). Lower-ranked strategies included "Develop BIM-related contractual frameworks" (RII = 0.733) and "Foster market demand for BIM" (RII = 0.722) (as shown in Table 11). The findings indicate that establishing clear national standards and financial incentives are perceived as the most effective drivers of adoption.

Table 11. Ranking of strategies to enhance BIM adoption in construction companies

Strategies to Enhance BIM Adoption in Construction Company		R11	Mean	SD	Ranks
c1	Create BIM institutes for training young or fresh graduates	0.800	4.000	0.686	4
c2	Provide financial aid to reduce the cost of adopting BIM	0.822	4.111	0.900	2
c3	Develop BIM adoption guidelines	0.811	4.056	0.725	3
c4	Develop programmes to integrate BIM into education curricula and academia	0.711	3.556	0.705	12
c5	Develop programmes to increase BIM awareness and understanding	0.789	3.944	0.725	5
c6	Foster market demand for BIM	0.722	3.611	0.698	11
c7	Develop a digital transformation strategy for BIM	0.778	3.889	0.676	6
c8	Develop BIM standards	0.833	4.167	0.786	1
c9	Develop BIM-related contractual frameworks	0.767	3.833	0.707	7
c10	Initiate pilot projects to exploit evidence-based benefits of adopting BIM	0.744	3.722	0.669	9
c11	Mandate BIM adoption in the construction industry	0.733	3.667	0.767	10
c12	Develop programmes for improving BIM competencies	0.756	3.778	0.732	8

Correlation Between Barriers and Strategies

To identify how specific strategies address the barriers of BIM adoption, a correlation coefficient analysis was conducted. This method measures the strength of association between the two variables, with values above 0.600 considered strong and practically significant.

Table 12 presents the correlation coefficients between barriers and strategies. The results indicate that certain strategies are strongly associated with overcoming corresponding barriers. For instance, "The complexity of the new roles in BIM-based construction projects" shows the highest correlation with "Develop BIM-related contractual frameworks" (r = 0.832), followed by "Develop a digital transformation strategy for BIM" (r = 0.693) and "Develop BIM standards" (r = 0.666). Likewise, "Lack of time for experimentation and adoption in a fast-paced project" is strongly correlated with both "Initiate pilot projects to exploit evidence-based benefits of adoption BIM" (r = 0.810) and "Mandate BIM adoption in the construction industry" (r = 0.779).

Other notable findings include "Inadequate information management processes for BIM" correlating with "Develop BIM-related contractual frameworks" and "Develop BIM standards" (r = 0.667 each), while cost-related barriers such as "High cost of technology" and "High training cost" also show meaningful correlations with "Develop BIM-related contractual frameworks" (r = 0.667), "Develop programmes for improving BIM competencies" (r = 0.621), and "Provide financial aid to reduce the cost of adopting BIM" (r = 0.628).

Overall, the analysis highlights that contractual frameworks, pilot projects, financial aid and competency development are strongly validated as effective strategies to mitigate the key barriers faced by contractors in adopting BIM.

Table 12. Relationship between barriers and strategies with a correlation value of 0.600 and above

Barrier	Strategy	Correlation (r-value)
The complexity of the new roles in BIM-based construction projects (b15)	Develop BIM-related contractual frameworks (c9)	0.832
	Develop a digital transformation strategy for BIM (c7)	0.693
	Develop BIM standards (c8)	0.666
Lack of time for experimentation and adoption in a fast-paced project (b7)	Initiate pilot projects to exploit evidence-based benefits of adopting BIM (c10)	0.810
	Mandate BIM adoption in the construction industry (c11)	0.779
Inadequate information management processes for BIM (b19)	Develop BIM-related contractual frameworks (c9)	0.667
	Develop BIM standards (c8)	0.667
High cost of technology (b3)	Develop BIM-related contractual frameworks (c9)	0.667
	Develop programmes for improving BIM competencies (c12)	0.621
High training cost (b2)	Provide financial aid to reduce the cost of adopting BIM (c2)	0.628

DISCUSSION

BIM is recognised globally as a catalyst for improving efficiency, collaboration and sustainability in construction. In Malaysia, however, adoption remains moderate at 55% (CIDB Malaysia, 2021) and willingness to adopt has declined from 84% in 2016 to 72% in 2021. Key challenges such as high costs, lack of standardisation and industry resistance limit wider uptake despite BIM's proven contributions to coordination, cost control and resource management (Markopoulos et al., 2024; Waqar, Qureshi and Alaloul, 2023). For BIM to fully support ESG objectives in Malaysia, stronger policy frameworks, financial incentives and coordinated industry-government collaboration are essential.

Building Information Modelling Awareness Level

Findings indicate that while BIM awareness among G7 contractors is high, hands-on experience is limited. This reflects a common industry trend where conceptual understanding does not necessarily lead to adoption (Kassem and Succar, 2017). The gap between awareness and implementation is consistent with CIDB Malaysia's 2021 survey, suggesting that capacity-building initiatives such as targeted training, pilot projects and demonstration schemes are required to translate awareness into active use.

Research Question 1: Benefits of Building Information Modelling Adoption to Achieve Environmental, Social and Governance Goals

BIM's top-rated benefits, namely, conflict detection, cost transparency and simulation of construction sequences, align with previous studies (Sattineni and Macdonald, 2014; Xiao et al., 2019) and directly contribute to the construction industry's ESG objectives. From an environmental perspective, conflict detection and sequencing minimise rework, reduce material waste and improve resource efficiency, while also supporting energy-efficient planning (Deng, Menassa and Kamat, 2021). In the social dimension, improved coordination between contractors, consultants and suppliers enhances site safety, fosters effective stakeholder engagement and supports inclusive project delivery (Jin et al., 2018). For governance, cost transparency enables accurate reporting, strengthens regulatory compliance and facilitates data-driven decision-making, reducing the risk of disputes and mismanagement (Succar and Kassem, 2015). These benefits are interlinked, with advancements in one ESG area often reinforcing the others, underscoring BIM's role as both a technological enabler and a strategic driver of sustainable construction in Malaysia.

Research Question 2: Barriers of Building Information Modelling Adoption

Coordination issues, lack of suitable projects and time constraints were identified as the most significant barriers, aligning with Azhar (2011) and Tan et al. (2019). Persistent reliance on 2D CAD exacerbates the transition challenge. While cost and training remain important, this study highlights the equal importance of organisational readiness and clear project opportunities. Overcoming these barriers requires not only technological investment but also structured change management and leadership commitment.

Research Question 3: Strategies to Enhance Building Information Modelling Adoption

The highest-ranked strategies, namely, developing BIM standards, providing financial aid and issuing clear adoption guidelines, are consistent with practices in the UK, Singapore and China, where standards and incentives have accelerated uptake (Zhou, Yang and Yang, 2019; Jiang et al., 2022). Malaysia's current guidelines (CIDB Malaysia, 2015; Jabatan Kerja Raya, 2021) provide a base but need expansion to cover contractual frameworks, market stimulation and education pathways. Respondents' suggestions for software standardisation and mandatory BIM use reflect a preference for strong top-down policy support combined with industry readiness.

The strategies rankings identified in this study (as shown in Table 13) were compared with those reported by CIDB Malaysia (2021). Both sources prioritise financial aid and BIM guidelines, yet the present study places lower emphasis on educational integration, reflecting a more immediate focus on practical implementation challenges rather than long-term capacity building. This divergence underscores evolving industry priorities and highlights areas where policy and industry efforts can be more closely aligned.

Table 13. Ranking of government strategies for enhancing BIM adoption

Government Strategies	Rank
Create BIM institutes for training young/fresh graduates	1
Provide financial aid to reduce the cost of adopting BIM	2
Develop BIM adoption guidelines	3
Develop programmes to integrate BIM into education curricula and academia	4
Develop programmes to increase BIM awareness and understanding	5
Foster market demand for BIM	6
Develop a digital transformation strategy for BIM	7
Develop BIM standards	8
Develop BIM-related contractual frameworks	9
Initiate pilot projects to exploit evidence-based benefits of adopting BIM	10
Mandate BIM adoption in the construction industry	11
Develop programs for improving BIM competencies	12

Source: CIDB Malaysia (2021).

Correlation Coefficient Between Barriers and Strategies

The correlation coefficient analysis examined the relationships between barriers and strategies of BIM adoption. As shown in Table 12, several strong positive correlations (r > 0.600) confirm that targeted strategies directly address critical barriers.

The barrier "The complexity of the new roles in BIM-based construction projects" recorded the highest correlation with "Develop BIM-related contractual frameworks" (r = 0.832), followed by "Develop a digital transformation strategy for BIM" (r = 0.693) and "Develop BIM standards" (r = 0.666). This indicates that clearer contractual and standardised frameworks are essential for role clarity.

Similarly, "Lack of time for experimentation and adoption in a fast-paced project" strongly correlated with "Initiate pilot projects to exploit evidence-based benefits of adoption BIM" (r = 0.810) and "Mandate BIM adoption in the construction industry" (r = 0.779), suggesting that structured pilot programmes and mandatory requirements can help integrate BIM into practice despite time constraints.

For "Inadequate information management processes for BIM", both "Develop BIM-related contractual frameworks" and "Develop BIM standards" (r = 0.667) were significant, emphasising the need for consistent data protocols.

Cost-related barriers also showed moderate to strong correlations. "High cost of technology" was linked with "Develop BIM-related contractual frameworks" (r = 0.667) and "develop programmes for improving BIM competencies" (r = 0.621), while "High training cost" correlated with "Provide financial aid to reduce the cost of adopting BIM" (r = 0.628). Together, these results highlight that financial support and capacity building remain vital to overcoming adoption challenges.

Overall, these findings demonstrate that strategies such as contractual frameworks, pilot projects, financial aid and competency development are statistically validated solutions, providing a practical roadmap for addressing BIM adoption barriers in Malaysia.

CONCLUSION

This study highlights BIM's role as a strategic enabler for sustainable construction in Malaysia, directly supporting ESG goals through improved environmental performance, enhanced stakeholder collaboration and stronger regulatory compliance. Adoption, however, remains limited due to barriers such as lack of expertise, resistance to change and financial constraints. Addressing these through clear contractual frameworks, targeted pilot projects, and supportive regulatory measures can accelerate industry uptake. The findings contribute to understanding how BIM's capabilities align with ESG objectives in the Malaysian context, offering practical guidance for policymakers, industry leaders and academics to drive more sustainable construction practices.

Limitations

The study is limited by its focus on G7 contractors in Johor, a quantitative-only approach, and a short data collection period, which may affect the breadth and generalisability of findings.

Future Recommendations

Future research should broaden the sample to include various contractor grades and other stakeholders, cover multiple regions and employ mixed-method approaches to capture deeper insights and track BIM implementation over time.

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