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Improvement of Cost Overrun Issues with Building Information Modelling (BIM): A Case Study of the Malaysian Construction Industry

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Abstract

The construction industry in developing nations faces challenges of cost overrun, negatively impacting the economy and industry reputation. BIM's digital representation and integrated data enable efficient planning, design, and construction processes, leading to cost reduction, and enhanced production efficiency. Cost overrun is a global phenomenon, and BIM technology addresses project cost concerns by promoting stakeholder participation and minimizing building costs. The objectives of the study is to study the benefits of BIM that can improve cost overrun in the Malaysian construction industry. Besides that, to investigate the barriers that hinder the adoption of BIM related to cost overrun and ways to overcome the barriers that hinder the adoption of BIM related to cost overrun in the Malaysian Construction Industry. The research methodology included a qualitative approach using case studies of 5 BIM projects in Klang Valley. Primary data collected through semi-structured interviews with construction practitioners involved with the BIM projects, while secondary data gathered from online resources and books. Content analysis employed to analyze the data collected from the interviews. Case studies demonstrated BIM's efficacy in mitigating conflicts, improving communication, and early detection of design faults, preventing cost overrun. Barriers to BIM adoption, such as high initial costs and resistance to technological change, highlighted the necessity for government support, extensive training, and mandatory BIM policies to foster widespread utilization in the construction industry. This study advocated for BIM to improve cost overrun in Malaysian construction industry, offering insights, overcoming barriers, and providing strategic recommendations for industry-wide adoption and improvement.

1. Introduction

The construction industry, vital for economic growth, faces challenges in emerging economies concerning time, cost, and quality, making it rare for projects to be completed on time, within budget, and to the planned quality (Ahady, Gupta & Malik, 2017). Malaysia relies on construction, but cost overrun is common, causing conflicts or project abandonment (Zayyana *et al.*, 2014). To address this, advanced technologies, including Building Information Modeling (BIM), are adopted to mitigate unanticipated costs globally (Muhammad *et al.*, 2019;

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Dlamini & Cumberlege, 2021). BIM, with applications in quantity extraction, trade coordination, and design visualization, serves as a design tool, simplifying project management and revolutionizing processes (Kulkarni & Mhetar, 2017; Muhammad *et.al*, 2019). As an innovative technology, BIM enhances stakeholder engagement, addressing project cost concerns and improving cost management, benefitting projects and expanding market opportunities (Tahir *et al*., 2018; Yang, 2021).

Cost overrun in construction, impacting finances, timelines, quality, and stakeholder satisfaction, is a global concern (Leu, Lu & Wu, 2023; Ammar, Abdel-Monem& El-Dash, 2022; Haslinda *et al*., 2018). In Malaysia, causes include lack of contractor experience, poor site management, and faulty planning (Shah, 2016). Research shows that 98% of megaprojects globally experience cost overrun, with an average 80% increase in the original budget (Ratajczak, Riedl & Matt, 2019). In Malaysia, a 2009 study on large projects revealed only 42% completed on time and on budget (Muhammad *et al*., 2019). BIM is considered a promising solution to address cost concerns in construction projects (Tahir *et al*., 2018). BIM allows better budget control, with real-time adjustments reflecting project changes (Ang *et al*., 2020). Studies indicate BIM increases net profit by 25%, profitability index by 14 to 15%, and reduces project costs by 30%, improving the payback period by 17% (Matniyazov & Buronov, 2022). BIM is found to be 8.375% more effective than traditional costing in preventing cost overrun (Johnson, 2019). Successful BIM implementation in cases like the CJ Building in China and Parcel F in Malaysia showcases its effectiveness in reducing conflicts, design disagreements, and speeding up project completion (Li, Wang & Alashwal, 2021; CIDB Malaysia, 2019).

This study addresses cost overrun in Malaysian construction, emphasizing BIM's potential to mitigate challenges and proposing effective strategies for adoption in the industry.

2. Literature Review

Cost overrun is a prevalent issue in Malaysia's construction industry, affecting the majority of projects with 5% to 10% over the total contract amount. Cost overrun, also known as "cost increase" or "budget overrun," occurs when unforeseen expenses exceed the allocated budget in a project (Shanmugapriya & Subramanian, 2013). It is the percentage difference between actual and estimated costs when determined using constant pricing (Subramani, Sruthi & Kavitha, 2014). In essence, cost overrun is when the final project cost surpasses initial estimations, with terms like budget increases, cost increases, and cost growth representing this phenomenon (Ndunguru, Niyonyungu & Yang, 2020). It occurs in over half (55%) of Malaysian construction projects, with the public sector outperforming the private sector. Overall, 89% of construction projects in Malaysia experience cost overrun problems (Kamaruddeen, Chang & Wahi, 2020).

Malaysian construction industry frequently experiences cost overrun of 5% to 10% (Kamaruddeen, Chang & Wahi, 2020). Frequent cost overrun issues in Malaysia's construction industry, surpassing time extension problems, highlight ineffective cost management. Factors such as design changes, poor planning, weather fluctuations, and material cost variations contribute to overruns. Client modifications and planning lapses can lead to design adjustments, increasing costs. Efficient resolution lies in applying BIM (Ang *et al*., 2020). Based on a study of Haslinda *et al*.'s (2018) on a Penang high-rise found that 17% of project managers achieve 90% budget adherence, while 60% state 70 to 90% completion on time and within budget. Conversely, 23% of project managers report less than 70% completion within budget and schedule.

2.1 Factors Affecting Cost Overrun in the Construction Industry

Cost overrun, a major concern in building projects, has been extensively researched, revealing various contributing factors 15 identified factors, including site conditions, change orders, rework, and others, lead to building project delays and subsequent cost overrun. Notably, materials price fluctuations and weather are identified as the highest factors causing cost overrun, followed by change orders, rework, and inaccuracies in budgeting, scheduling, and resource planning. The third-highest factors include site conditions, subcontractors' and vendors' performance, approval or permit delays, and inflation. Less significant factors include owners' additional requirements, material shortage, poor site management, increasing labor costs, inaccurate quantity take-off, and poor communication (Al-Hazim *et al*., 2017; Renuka *et al*., 2018; Haslinda *et al*., 2018; Al-Amri & Marey-Perez, 2020; Susanti & Nurdiana, 2020; Kamaruddeen, Sung & Wahi, 2020; Gupta & Kumar, 2020). Many factors still contribute to cost overrun in construction projects.

2.2 BIM in the Malaysian Construction Industry

BIM, utilizing ICT, enhances building processes by creating a data-rich digital model for decision-making, modernizing the industry through seamless digital processes (Madugu & Muhammad, 2019; Othman *et al*., 2021). It serves various applications, aiding in quantity information extraction, trade coordination, design visualization,

and building sequence visualization (Kulkarni & Mhetar, 2017). The private sector in Malaysia has played a crucial role in advancing BIM since 2009, with the first government project announced in 2010. Implementation requires trustworthy data transfer and effective coordination processes, emphasizing the need for decision-making procedures specified before deployment (Migilinskas *et al*., 2013). Despite studies highlighting BIM's effectiveness, its adoption in Malaysia's construction industry progresses slowly, with collaboration between the construction industry and CIDB to promote awareness. BIM significantly impacts organizational skills, yet its utilization in Malaysian buildings remains low, leading to diffusion delays and inefficiencies in project management (Jamal *et al*., 2019; Othman *et al*., 2021).

2.3 The benefits of BIM in improving cost overrun of construction projects

There are several benefits of BIM to the construction industry. Figure 1 (Fig. 1) shows the benefits of BIM on cost overrun which are coordination and discovery of conflicts, acquiring accurate, comprehensive, detailed information and quantity takeoffs, better coordination and communication, and Improvement in decision-making.

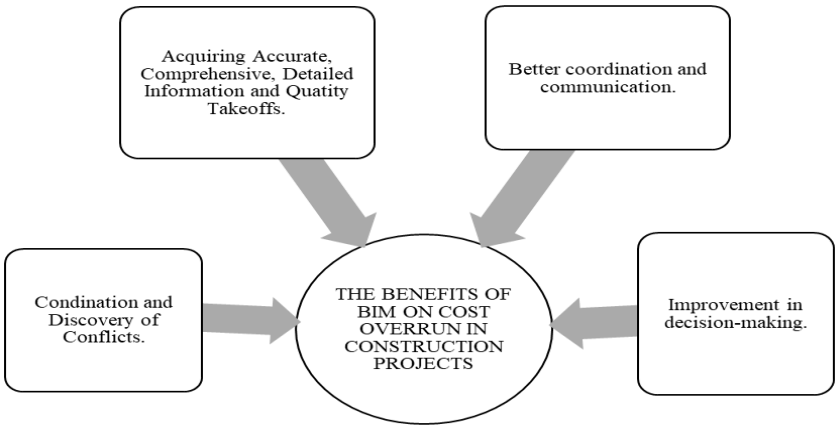

Fig. 1 *The benefits of BIM to improve cost overrun in construction projects*

2.3.1 Coordination and Discovery of Conflicts

BIM solutions, particularly conflict detection, significantly aid construction project management by addressing common causes of cost overrun, such as bad designs and incorrect estimates (Tahir *et al*., 2018). Utilizing BIM for construction design captures and alters current reality, making it the ongoing project reference and enabling early clash detection. This facilitates faster work, cost savings, and higher-quality outcomes for contractors (Ibrahim, Hashim & Ahmad, 2019).

2.3.2 Acquiring Accurate, Comprehensive, Detailed Information and Quantity Takeoffs

Accurate information is crucial for addressing cost overrun factors like design flaws, poor project planning, and scope modifications (Sánchez *et al*., 2020). BIM, by extracting precise quantities from 3D models, enhances quantity takeoffs, reducing the reliance on physical measurements. This precision improves cost estimation accuracy, minimizing the risk of underestimating or overestimating project expenses and effectively managing budgets (Sholeh, Fauziyah & Khasani, 2020).

2.3.3 Better coordination and communication

Better coordination and communication can help to reduce the factors of cost overrun such as inadequate project planning, design changes, late decision-making by the owner, failures in design, and others (Sánchez *et al.,* 2020). The capacity of BIM to promote communication and interaction between the design team and the other stakeholders, as well as simultaneous and faster data access, are some of its most significant advantages (Desbalo & Bargstadt, 2020).

2.3.4 Improvement in decision-making

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BIM is a comprehensive process enhancing decision-making across the project life cycle, from design to decommissioning. It goes beyond software, serving as a managerial and business choice. BIM facilitates knowledge exchange among design professionals, aiding project understanding from conceptual stages to demolition (Enshassi, Hamra & Alkilani, 2018). Acting as a shared knowledge resource, BIM supports predictive decision-making by storing life cycle data, offering precise and timely information to prevent costly errors and delays in construction projects (Parsamehr *et al.,* 2023).

2.4 Barriers that hinder adoption of BIM

The barriers are shown in Figure 2 (Fig. 2) below.

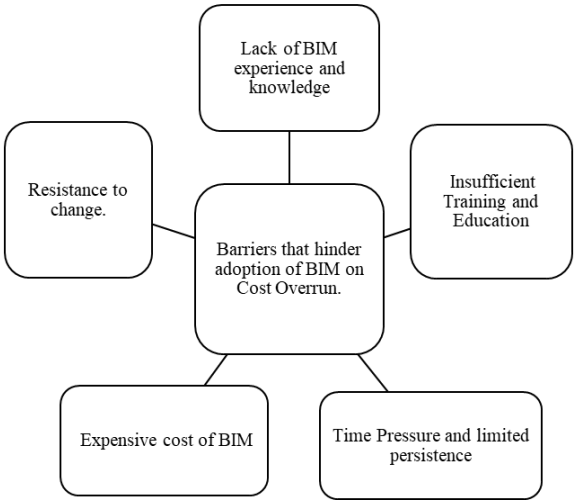

Fig. 2 *Barriers that hinder adoption of BIM on Cost Overrun*

2.4.1 Lack of BIM experience and knowledge

Decision-makers opposing BIM revisions often lack experience and fail to recognize its value due to a lack of understanding (Elhendawi *et al*., 2019). The barrier hindering BIM adoption for cost overrun is a widespread lack of knowledge in the construction industry, leading to increased project costs. While some firms offer specialized BIM services, the majority of construction companies lack personnel capable of seamlessly integrating BIM into projects (Ullah, Lill & Witt, 2019).

2.4.2 Insufficient Training

BIM adoption may be significantly hampered by inadequate BIM training. If the staff is not properly taught to use the BIM software and hardware, it can result in a cost overrun in construction projects. Insufficient training will cause inadequate design (Ullah, Lill & Witt, 2019). A lack of BIM training can result in poor design, which can cause cost overrun owing to rework and poor cost estimation (Ang *et al*., 2020).

2.4.3 Time Pressure and limited persistence

Time pressure and limited persistence pose significant challenges to BIM adoption, hindering its impact on cost overrun. Accelerating BIM adoption requires meticulous preparation, but time constraints and staff members' limited perseverance can impede successful implementation. Inadequate training and motivation may lead to a cost overrun in construction projects (Siebelink *et al.,* 2021).

2.4.4 Expensive cost of BIM

The cost of BIM software remains a challenge for adoption in various industries, often being three times more expensive than typical 2D CAD programs. Subscription fees, ranging from 5% to 20% of the initial investment, are also required for updates. BIM deployment demands a substantial initial budget covering software creation, training, and education. Training is crucial, spread across multiple sessions, focusing not just on software but also on its integration with construction procedures. Such investments may deter some companies from embracing BIM (Fateh & Aziz, 2021).

2.4.5 Resistance to change

Resistance to change in the construction industry, especially in adopting Building Information Modeling (BIM), is rooted in social and habitual aspects of human behavior. Stakeholders, familiar with traditional methods, hesitate due to uncertainty, fear of disruption, and a preference for familiar approaches, hindering BIM's acceptance as a solution for cost overrun (Ahmed, 2018). This resistance is driven by factors like limited understanding and reluctance to change, especially among senior professionals and designers (Utomo & Rohman, 2019).

2.5 Ways to overcome the barriers that hinder the adoption of BIM to improve cost overrun

The ways as shown in Figure 3 (Fig. 3) below.

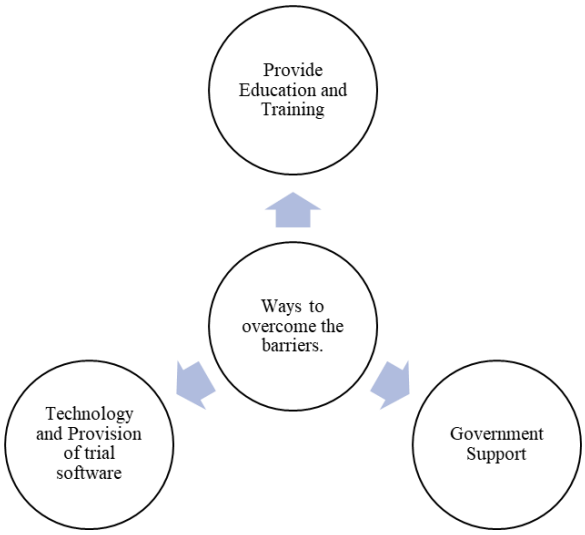

Fig. 3 *Ways to overcome the barriers*

2.5.1 Provide Education and Training

Education and training are vital for overcoming obstacles to BIM adoption and mitigating cost overrun. Workers facing challenges due to time constraints and limited persistence can benefit from industry-specific on-site training and ongoing education, enhancing their abilities to use BIM effectively (Muhammad *et al.,* 2019). This approach addresses the hurdle of insufficient experience hindering successful BIM utilization, reducing the risk of construction project cost overrun (Hamma-adama, Komider & Salman, 2020). Notable BIM training hubs include the University Malaysia Pahang (UMP) and myBIM Centre, as highlighted by CIDB (2019).

2.5.2 Technology and Provision of trial software

To enhance BIM implementation in construction, providing trial software is a highly effective strategy endorsed by clients and contractors, ranking as the third most effective approach among consultants (Memon *et al.,* 2014). Offering trial software helps familiarize users, delivering an excellent user experience to convert trial users into paying customers. This approach is crucial as it eliminates doubts about product functionality and allows potential customers to test it before making a purchase decision (Muniandy, Rahman & Esa, 2022). Approximately 56% of respondents, including both adopters and non-adopters of BIM, highlight the importance of authorizing trial software features on pilot projects, with 46% of BIM adopters receiving such approval. Additionally, 42% of non-adopters emphasize the significance of testing software features before purchase, while 43% believe software should be available for a sufficient duration to fully explore its potential benefits (Ahuja *et al*., 2020).

2.5.3 Government Support

Government support is vital in overcoming barriers to BIM adoption and addressing cost overrun challenges. Governments can provide resources, rewards, and regulations to promote BIM implementation in the construction industry, reducing initial costs and ensuring long-lasting adoption. Incentives, such as subsidies for hardware, software, and training, can significantly lower the overall cost of BIM adoption, promoting sustainability (Yuan & Yang, 2019). Governments play a crucial role in fostering BIM adoption by creating and enforcing policies and standards in the construction industry. These regulations may cover BIM usage, data sharing, and interoperability, ensuring successful and efficient BIM implementation while minimizing the risk of cost overrun in construction projects (Hamma-adama, Komider & Salman, 2020).

3. Methodology

This part contents the explanation on qualitative research, case study, types of data collection, population and sampling, pilot test, and content analysis.

3.1 Qualitative Approach

Qualitative research focuses on understanding the meaning individuals or groups assign to a social or human situation, drawing from anthropology, sociology, humanities, and assessment. Open-ended research questions generate non-quantifiable data, allowing for a nuanced examination of issues within their unique contexts. The primary objective is to derive meaning, purpose, or reality from participants' thoughts and experiences, employing data collection techniques such as interviews, observations, and participation (Asenahabi, 2019).

3.2 Case Study

Case studies are detailed examinations of a phenomenon, offering subjective information and a deep understanding but lacking the ability to generalize. Case study can be defined as comprehensive assessments with temporal and experiential boundaries, focusing on characterizing, comprehending, foreseeing, and/or managing the specific unit of study (Asenahabi, 2019). Small sample sizes are frequent in case studies, which is typical of most qualitative research (Schoch, 2020). This study uses the case study to study the improvement of the cost overrun issues with BIM. This study includes 5 BIM projects located in the Klang valley, Malaysia.

3.3 Data Collection

Primary data refers to firsthand data collected by the researcher from primary sources through interviews, surveys, experiments, observations, questionnaires, others. (Saeed, 2017). This study gained data through semi-structured interviews with selected respondents, including stakeholders involved in BIM projects like BIM consultants, and project owners. The aim is to elicit subjective reactions about specific events or occurrences encountered by participants.

Secondary data is information gathered by someone else in the past, obtained from sources like government publications, websites, books, journal articles, and internal records (Saeed, 2017). For this study, secondary data has collected from the source of internet, online information from the CIDB, and related books.

3.4 Pilot Test

The pilot test aids in the visualization of certain issues that might arise during the main study's execution. Additionally, it provides information about how data is actually gathered and analyzed (In, 2017). The pilot test involved evaluating the effectiveness of the draft questions by distributing 20 of them to participants knowledgeable about the research scope, specifically BIM or Construction Management, within one week. Subsequently, insightful feedback was collected from five individuals, including 1 academician and 4 architects, to assess clarity, relevance, and overall effectiveness. The feedback included recommendations for sentence modifications, stylistic adjustments, and the need for clarification due to ambiguity. A common suggestion across positions was to improve and clarify the sentences accordingly. Finally, a final interview question is produced.

3.5 Data Analysis

Data analysis involves organizing raw data to evaluate and explain the past and predict the future. It is not solely about numbers but includes asking questions, developing explanations, and testing hypotheses using logical and analytical methods (Cuesta & Kumar, 2017). For this study, the content analysis technique is used to analyze data gathered from the respondents. Content analysis as defined by Krippendorff (2013), is a research technique used to make replicable and valid inferences from texts or other meaningful material to the contexts in which they are used.

4. Results and Discussion

This part shows 5 BIM projects as case studies and discuss the research results obtained from the data collected from the interviews.

4.1 Case Studies

Table 1 below shows the 5 diverse BIM projects in Klang Valley, spanning conventional in-house, commercial, mixed development, and hospital construction sectors, serve as case studies (CS1- CS5).

Table 1 *Details of Case Studies*

Name of project	Project Cost	Completion Date	Level of BIM
Endocrine Complex at Putrajaya (CS1)	MYR 344 million	08 April 2022	LOD 350 modeling, seamlessly transitioning to LOD 400 and LOD 500
Suruhanjaya Pencegahan Rasuah Malaysia (SPRM) at Shah Alam, Selangor (CS2)	MYR 40 million	11 September 2017	LOD100 to LOD300
Oasis Corporate Park at Petaling Jaya, Selangor (CS3)	MYR 500 million	2017	LOD300
MRT Line 2 Sungai Buloh-Serdang- Putrajaya Line (SSP) (CS4)	MYR 30 billion	2023	Level 2
HighPark Suites at Petaling Jaya, Selangor (CS5)	MYR 238 million	2020	LOD 300

The Endocrine Complex at Putrajaya (CS1) is a MYR 344 million project completed in April 2022, employing LOD 350 modeling, transitioning seamlessly to LOD 400 and LOD 500. SPRM at Shah Alam (CS2), costing MYR 40 million and completed in September 2017, utilized BIM at LOD100 to LOD300 levels. Oasis Corporate Park at Petaling Jaya (CS3), with a MYR 500 million budget, completed in 2017, incorporated LOD300 BIM. The MRT Line 2 Sungai Buloh-Serdang-Putrajaya Line (SSP) (CS4), with a MYR 30 billion budget, is slated for completion in 2023 and achieved BIM Level 2acreditation for the SSP line. HighPark Suites at Petaling Jaya (CS5), costing MYR 238 million and completed in 2020, implemented LOD 300 BIM.

4.2 Respondent's Background

Table 2 shows the respondents' backgrounds in each case study.

Table 2 *Respondent's background*

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Case Study (CS)	Position	Types of Company	Roles in the Project	Years of Experience with BIM
CS1	Civil Engineer (J44)	Government Agency	BIM Modeller	11 years
CS2	Civil Engineer (J44)	Government Agency	BIM Manager	11 years
CS3	Civil Engineer, Director	Private Agency	Civil Engineer	10 years
CS4	BIM Manager	Private Agency	BIM Manager	20 years
CS5	Senior Project Manager, BIM Director.	Private Agency	BIM Manager	13 years

CS1, the interviewee is a Civil Engineer (J44) within the BIM unit at a government agency, served as a BIM modeller on the CS1 project, bringing 11 years of extensive BIM knowledge and experience. For CS2, also a Civil Engineer (J44) within a government agency, the interviewee acted as the BIM Manager, accumulating another 11 years of service in the field. In CS3, the respondent, a civil engineer and director at a private agency, contributed as a civil engineer, boasting 10 years of BIM expertise. CS4 saw the interviewee as the BIM manager at a private agency, overseeing all BIM processes for the MRT LINE 2 project with over 20 years of BIM experience. Lastly, in CS5, the interviewee, a Senior Project Manager and BIM Director at a private agency, played a pivotal role in introducing BIM to Gamuda Land and Gamuda Engineering, providing 13 years of rich BIM experience.

4.3 Benefits of BIM to improve cost overrun

This part investigates the benefits of BIM in addressing and alleviating cost overrun in construction projects. Table 3 below illustrates BIM's role in enhancing cost overrun reduction across case studies.

Table 3 *Benefits of BIM related to cost overrun*

How BIM improves Cost Overrun	CS1	CS2	CS3	CS4	CS5
Improve Clash Coordination	✓	✓	✓	✓	✓
Minimization of Conflicts	✓	✓			
Improve Communication	✓	✓			✓
Design Fault Improvement and Resolution	✓	✓			
Improve Clash Detection	✓	✓	✓	✓	✓
Unified Design Coordination				✓	
Improve Visualization			✓	✓	✓
Waste Reduction					✓

Improve Clash coordination, pivotal in CS1 to CS5, preemptively identifies and resolves conflicts during design and planning, reducing delays and costs aligning with Sánchez *et al.*'s (2020) findings highlighting BIM's capacity to enhance coordination and collaboration, thus mitigating delays and costly rework.

"We properly conduct design review and clash coordination during the design stage, we can minimize conflicts during construction. Although we cannot eliminate zero clashes, we can significantly reduce them." CS1 and CS2
"Improving cost overrun by preventing unnecessary work errors with clash coordination." CS3

"…By using BIM to improve cost, one of the key aspects is to do the design and clash coordination by looking at the 3D models to coordinate the designs correctly."CS4
"Let's say when we use BIM, it helps reduce wastage and cost, increase communication, and help in visualization, clash detection, and coordination and get what the clients want."CS5

Minimizing conflicts in CS1 and CS2 contributes to streamlined project execution and cost overrun reduction, aligning with Tahir *et al.* (2018) and Sholeh, Fauziyah & Khasani (2020) on BIM's impact on conflict detection.

"We properly conduct design review and clash coordination during the design stage, we can minimize conflicts during construction. Although we cannot eliminate zero clashes, we can significantly reduce them." CS1 and CS2

BIM implementation in CS1, CS2, and CS5 enhanced communication among project stakeholders, reducing misunderstandings and errors, ultimately contributing to cost control. Real-time data exchange facilitated by BIM ensured immediate access to project information, fostering shared understanding and enabling quick decision-making, which helped prevent delays and cost overrun. These benefits align with existing research by Sánchez *et al.* (2020), Desbalo & Bargstadt (2020), Samimpay & Saghatforoush (2020), and Hasan & Rasheed (2019), highlighting BIM's role in improving coordination, collaboration, and communication to mitigate risks associated with poor project planning and design modifications.

"When we implement BIM at the early stage of the project and communicate effectively, stakeholders better understand the design intent, reducing the risk of miscommunication and errors that could lead to cost overrun" CS1 and CS2
"Let's say when we use BIM, it helps reduce wastage and cost, increase communication."CS5

BIM in CS1 and CS2 effectively identifies and resolves design faults before construction, preventing costly problems. The creation of a comprehensive 3D model allows for early detection of inconsistencies, minimizing the risk of errors and costly rework. Supported by Tahir *et al.* (2018), Sánchez *et al.* (2020), Ibrahim, Hashim & Ahmad Jamal (2019), and Hasan & Rasheed (2019), BIM's role in conflict detection and collaboration highlights its ability to proactively manage design issues and mitigate cost overrun.

"For design faults, BIM helps in improving the cost of repair, especially from the client's perspective." CS1 and CS2

BIM's meticulous clash detection in CS1, CS2, CS3, CS4, and CS5 minimizes on-site modifications and associated costs by identifying conflicts early in the design process. Approximately 1,000 conflicts were resolved in CS3 before construction, saving significant time and costs. Supported by Tahir *et al.* (2018), Sholeh, Fauziyah & Khasani (2020), and Ibrahim, Hashim & Ahmad Jamal (2019), clash detection in BIM processes effectively mitigates cost overrun by addressing design conflicts and streamlining construction workflows.

"BIM is instrumental in clash detection during the design phase, allowing us to identify and resolve clashes before construction begins." CS1 and CS2
"Improving cost overrun by preventing unnecessary work errors with clash coordination, detection, and visualization which will cost money to re-do, repair, etc." CS3
"During the design stage, we do a lot of these design correlations by using 3D models. We can visualize the installations. BIM helps the clash detection of approximately 1,000 conflicts."CS4
"Let's say when we use BIM, it helps reduce wastage and cost, increase communication, and help in visualization, clash detection, and coordination and get what the clients want."CS5

Unified design coordination in BIM, exemplified in CS4, prevents cost overrun by facilitating seamless collaboration and decision-making through 3D models, thus averting construction delays and redundant reworks. This approach, supported by Tahir *et al.* (2018), Sholeh, Fauziyah & Khasani (2020), and Sánchez *et al.* (2020), aligns with Hasan & Rasheed's (2019) emphasis on BIM's role in enhancing cooperation and minimizing costly rework, underscoring its significance in mitigating cost overrun in construction projects.
"…By using BIM to improve cost, one of the key aspects is to do the design and clash coordination by looking at the 3D models to coordinate the designs correctly. During the design stage, we do a lot of these design correlations by using 3D models. We can visualize the installations. BIM helps the clash detection of approximately 1,000 conflicts."CS4

The utilization of visualization tools in CS3, CS4, and CS5 facilitated better decision-making and reduced costly design changes by enabling project teams to visualize the entire construction project and plan ahead effectively. Supported by Tahir *et al.* (2018), Sholeh, Fauziyah & Khasani (2020), and Sánchez *et al.* (2020),

visualization in BIM enhances coordination, communication, and conflict identification, aligning with Hasan & Rasheed's (2019) emphasis on BIM's role in improving cooperation and minimizing costly rework, collectively mitigating the risks of cost overrun in construction projects.

"Improving cost overrun by preventing unnecessary work errors with clash coordination, detection, and visualization which will cost money to re-do, repair, etc." CS3
"During the design stage, we do a lot of these design correlations by using 3D models. We can visualize the installations."CS4
"Let's say when we use BIM, it helps reduce wastage and cost, increase communication, and help in visualization, clash detection, and coordination and get what the clients want."CS5

Lastly, waste reduction, exemplified in CS5, showcased how BIM's capabilities extended beyond design and coordination to optimize resource usage, leading to cost savings and contributing to the overall reduction of cost overrun. The reduction of waste through the use of BIM involved improving precision in quantity takeoffs, streamlining coordination and clash detection, and enhancing communication.

"Let's say when we use BIM, it helps reduce wastage and cost, increase communication, and help in visualization, clash detection, and coordination and get what the clients want."CS5

4.4 Barriers that hinder the adoption of BIM on cost overrun

This part focuses on exploring barriers to the adoption of BIM to improve cost overrun in construction projects. Hesitancy among construction players to embrace BIM for cost overrun improvement stemmed from various reasons, and potential barriers may have emerged during BIM implementation in specific projects. Table 4 outlines barriers hindering the adoption of BIM to improve cost overrun.

Table 4 *The barriers to adopt BIM to improve Cost Overrun*

	CS1	CS2	CS3	CS4	CS5
High Initial Investment and Implementation Cost	✓	✓	✓	✓	✓
Competency and Training	✓	✓	✓	✓	✓
Resistance to Technological Change and attitudes	✓	✓			
Perceived Lack of Benefits	✓	✓		✓	✓
Lack of BIM Experience and Knowledge	✓	✓		✓	✓

CS1 to CS5 identified high initial investment and implementation costs deter construction players from adopting BIM for cost overrun mitigation, citing the financial burden of purchasing specialized hardware and software, along with training expenses, particularly challenging for smaller companies. Ahmed (2018) and Fateh & Aziz (2021) support this, highlighting the steep learning curve and high software costs as barriers for local construction firms due to substantial initial investments and ongoing subscription fees.

"The first thing is because, by using BIM, they need to invest for the initial cost, such as the computer and the software."CS1and CS2
"First because of the high initial investment cost for the software." CS3
"…Initial cost of BIM. Maybe the software is too expensive. To implement BIM, you need to increase your costs. which your overhead costs regarding our resources on the machines that you are going to use, the software you need to buy"CS4
"…One is very expensive; for instance, Revit alone costs about twenty thousand per license annually or even eight to ten per license."CS5

CS1, CS2, CS3, CS4, and CS5 highlighted competency and training as a significant barrier to widespread BIM adoption for cost overrun mitigation, noting that many construction professionals lack the necessary skills and

familiarity with BIM methods, leading to inefficiencies and increased project costs. Supported by Ullah *et al.* (2019), Ang *et al.* (2020), Abdulfattah, Khalafallah & Kartam (2017), and Hussain *et al.* (2023), inadequate BIM training is identified as a key factor contributing to cost overrun by impeding effective BIM utilization and design quality, highlighting the critical need for comprehensive training in BIM methodologies.

"Other than that, because they are not competent in BIM, so they need to hire someone competent." CS1 and CS2
"Lack of training will cause result in inefficiency, errors and increased project costs." CS3
"Some of the players know a little bit about BIM, they don't know the methods and benefits of using BIM in the project."CS4
"Furthermore, due to a lack of training and knowledge, they don't see the beauty and advantages of BIM."CS5

CS1 and CS2 pinpoint resistance to technological change and attitudes as barriers impeding widespread BIM adoption for addressing cost overrun challenges, citing employees' reluctance to shift from established workflows and unfamiliarity with BIM tools. Supported by Ahmed (2018) and Utomo & Rohman (2019), widespread resistance to change within the construction industry, driven by stakeholders' preference for familiar practices and reluctance to embrace innovative technologies like BIM, poses a significant barrier to effectively mitigating cost overrun issues.

"They don't want to change from the traditional to the new technology used in construction. They don't know BIM can give them benefits to avoid cost overrun." CS1 and CS2

CS1, CS2, CS4, and CS5 voiced concerns over the perceived lack of benefits attributed to BIM adoption in addressing cost overrun challenges in construction projects, suggesting that construction players may not fully grasp or appreciate the advantages offered by BIM. Limited understanding of how BIM improves project coordination, reduces costs, and enhances efficiency led to hesitation and reluctance among some construction players.

"They don't know BIM can give them benefits to avoid cost overrun." CS1 and CS2
"Some of the players know a little bit about BIM, they don't know the methods and benefits of using BIM in the project."CS4
"Furthermore, due to a lack of training and knowledge, they don't see the beauty and advantages of BIM."CS5

CS1, CS2, CS4, and CS5 identified the lack of BIM experience and knowledge as a significant barrier hindering the adoption of BIM for addressing cost overrun issues in construction projects, leading to uncertainty about its potential benefits. Supported by Elhendawi *et al.* (2019) and Zahrizan *et al.* (2014), literature underscores how this lack of understanding among decision-makers and construction stakeholders inhibits BIM adoption due to perceived pointlessness and a lack of industry value, ultimately complicating efforts to mitigate cost overrun challenges.

"They don't know BIM can give them benefits to avoid cost overrun." CS1 and CS2
"Some of the players know a little bit about BIM, they don't know the methods and benefits of using BIM in the project."CS4
"…they don't see the beauty and advantages of BIM."CS5

4.5 Suggestion to overcome the barriers that hidden the adoption of BIM to improve cost overrun

This part aims to explore ways for overcoming barriers to adopting BIM and enhancing its utilization on improving cost overrun in the construction industry.

4.5.1 Suggestion to overcome the barriers faced by the construction players in adopting BIM to improve the cost overrun.
Figure 4 (Fig. 4) shows the ways to overcome the barriers faced during adopting BIM to improve cost overrun.

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Fig. 4 *Suggestion to overcome the barriers faced during adopting BIM to improve cost overrun*

Firstly, CS1 and CS2 stressed the importance of establishing a clear policy, supported by Yuan & Yang (2019) and Hamma-adama, Komider & Salman (2020), advocating for governmental involvement and incentives to promote BIM adoption and lower the risk of cost overrun in construction projects.

"The first one is policy; you need to have the policy. So that, the contractor realizes that BIM is compulsory for them to use to improve cost overrun." CS1 and CS2

Training was highlighted by CS1, CS2, CS3, and CS4, emphasizing the pivotal role of education and training in overcoming adoption barriers, supported by Muhammad *et al.* (2019), Alam *et al.* (2023), education and training are crucial in mitigating the risk of cost overrun by enhancing staff proficiency in BIM, emphasizing the importance of such initiatives in promoting BIM adoption within the construction industry.

"We need to have a lot of training. The BIM manager will look at their teams, is it competent or not. If not, he will suggest getting the training first." CS1 and CS2
"The way to overcome the barrier during adopting BIM to improve cost overrun is having proper and sufficient training to improve skills." CS3
"…We need to send them from training." CS4

CS1 and CS2 recommended developing guidelines and standards that facilitated seamless collaboration, reduced errors, and enhanced project efficiency in construction, promoting transparent BIM workflows and better cost management.

"Guidelines and standards contributed to a more transparent and integrated BIM workflow and promoted better decision-making and cost management throughout the construction process." CS1 and CS2

CS1 and CS2 stressed the importance of integrating risk management into BIM adoption to identify and address challenges early, fostering a resilient project environment, while also advocating for centralized sharing platforms to enhance communication and reduce design faults during construction. CS1 and CS2 also emphasized the importance of sharing platforms for BIM models.

"Besides, we have one system required as a risk management. By integrating risk management into the BIM process, teams could anticipate and navigate obstacles, ensuring a smoother implementation that contributed to enhanced cost control and project success. Having one sharing platform. Sharing platform means one place that they can share all the models like Google Drive. So, everyone will get the same information. So that can increase the communication." CS1 and CS2

CS4 highlighted the importance of addressing user needs by providing training and investing in new machines or software to overcome adoption barriers and improve cost overrun in construction projects.

"And then we need to buy a new machine or software. We need to have this capital investment on that. It will increase some of the cost of your projects but it benefits you in terms of running the whole project." CS4

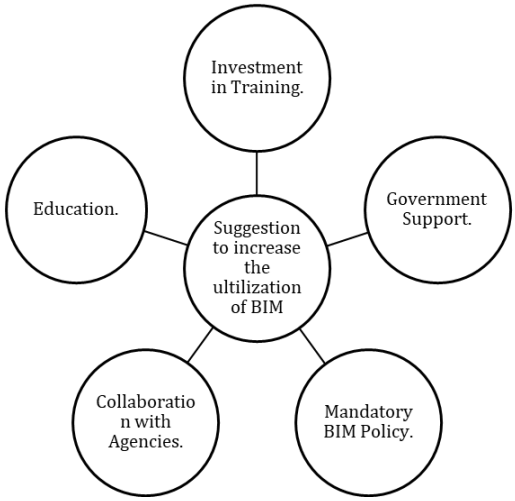
CS5 stressed awareness and education, advocating for BIM integration into academic curricula, aligning with Muhammad *et al.* (2019), Alam *et al.* (2023), and Hamma-adama, Komider, and Salman (2020).

"Number one is student to be aware of BIM already before coming in the industry. They know the knowledge of BIM in the university. So, when in the industry, it will become easier." CS5

Additionally, CS5 emphasized the crucial role of leadership support in fostering a culture of innovation and learning, promoting BIM proficiency, and mitigating the risk of cost overrun in construction through effective resource allocation and guidance.

"Number two is the support of leadership. They need to provide the necessary resources, guidance, and commitment to foster a culture of innovation and learning." CS5

4.5.2 Suggestion for increasing the utilization of BIM to improve cost overrun
Figure 5 (Fig. 5) shows the suggestions for increasing the utilization of BIM to improve cost overrun.



Fig, 5 *Suggestion to increase the utilization of BIM*

CS1, CS2, CS3, and CS5 emphasized the crucial role of investing in training for BIM adoption. Recommendations included compulsory BIM training for contractors, collaboration with agencies like CIDB and JKR, and a positive attitude towards staff training to ensure proficiency in BIM methodologies. Research by Muhammad *et al.* (2019) and Alam *et al.* (2023) underscored the significance of education and training in overcoming BIM adoption barriers, with practical examples from BIM training hubs supporting the importance of such initiatives.

"…As I mention, provide training. Training programs can improve the skills of building professionals in BIM methods. Cooperate with the agencies to access resources and training plans, so as to promote the smooth adoption of this process by the construction team such as CIDB, JKR." CS1 and CS2
"The way to increase the utilization of BIM is sufficient training to improve skills." CS3
"Provides training, we have to train these people even though if the staff go and find other place, they still have to train their staff. They can learn about BIM in university. They already know Revit, Cost-X and every piece of software in university. It is easier to enter this industry itself." CS5

Government support, highlighted by CS1, CS2, and CS3, involved seeking financial incentives and subsidies to offset implementation costs and encourage BIM adoption. Yuan & Yang (2019) and Hamma-adama, Komider & Salman (2020) emphasized the crucial role of government-led initiatives in promoting BIM adoption through policies and standards.

"Cooperate with the agencies to access resources and training plans, so as to promote the smooth adoption of this process by the construction team such as CIDB, JKR." CS1 and CS2
"The way to increase the utilization of BIM is government can provide subsidies." CS3

Mandatory BIM policies, advocated by CS1, CS2, and CS5, aimed at making BIM compulsory for contractors, creating awareness and standardizing its implementation.

"Establish a clear mandatory BIM decision for contractors, ensuring awareness of its mandatory usage." CS1 and CS2
"BIM is mandatory, JKR implements 10 million and above is mandatory to be BIM. So, whether you like it or not, you must have BIM. It is no longer an option you must have BIM." CS5

Collaboration with agencies, as suggested by CS1, CS2, and CS4, stressed the importance of joint efforts between government and private entities to support BIM adoption.

"…Cooperate with the agencies to access resources and training plans, so as to promote the smooth adoption of this process by the construction team such as CIDB, JKR." CS1 and CS2
"The government agency needs to collaborate with private agencies to promote BIM in the construction sector." CS4

CS5 advocates integrating BIM into diploma or degree-level education to provide students with early exposure and a strong foundation for its usage in their careers, supported by Muhammad *et al*. (2019) and Hamma-adama, Komider, and Salman (2020). Alam *et al.* (2023) further emphasize that education and training initiatives can mitigate the risk of cost overrun by addressing workers' lack of experience with BIM, highlighting the importance of collaboration with educational institutions.

"…They can learn about BIM in university. They already know Revit, Cost-X and every piece of software in university. It is easier to enter this industry itself." CS5

5. Conclusion

This study explores improving cost overrun with BIM, highlighting its benefits in design, scheduling, and collaboration. Identified barriers include high costs, competency gaps, resistance to change, and perceived lack of benefits. Proposed solutions involve clear policies, governmental support, incentives, mandatory BIM policies, comprehensive training, process improvements, collaboration, and technology adoption. Despite limitations, the study offers valuable insights for the Malaysian construction industry, serving as a resource for industry stakeholders aiming to strategically adopt BIM for cost overrun reduction. Recommendations for future research include assessing project performance with and without BIM and exploring correlations between BIM adoption levels and cost overrun reduction, considering project variations. This study is crucial for the Malaysian construction industry, aiming to uncover the benefits of BIM on cost overrun, identify adoption barriers, and propose actionable strategies. By addressing these aspects, the study seeks to inform practices, influence decision-making, and drive positive change, ultimately improving cost overrun and performance.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Tan Yu Han, Aryani Binti Ahmad Latiffi;* ***data collection:*** *Tan Yu Han;* ***analysis and interpretation of results:*** *Tan Yu Han;* ***draft manuscript preparation:*** *Tan Yu Han, Aryani Binti Ahmad Latiffi. All authors reviewed the results and approved the final version of the manuscript.*

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