Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

An Inception of Building Information Modelling (BIM) Competency-Based Performance Appraisal's Conceptual Framework for Organisations in Malaysian Construction Industry

Seri Nanisa Sima Yusoff[1], Juliana Brahim[1,*], Rumaizah Mohd Nordin[1], Suzila Mohd[2], Mohamad Syazli Fathi[3], Mohd Faiz Shapiai[4]

[1] School of Construction and Quantity Surveying College of Built Environment, Universiti Teknologi MARA (UiTM) Shah Alam, Selangor, Malaysia
[2] Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM) Johor Darul Takzim, Malaysia
[3] Department of Smart Engineering and Advanced Technology (SEAT), Faculty of Artificial Intelligence, Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia
[4] Building Information Modelling (BIM) Unit Integrated Asset Planning Branch Public Works Department Kuala Lumpur, Malaysia

ARTICLE INFO

Article history:
Received 6 April 2026
Received in revised form 20 May 2026
Accepted 5 July 2026
Available online 18 July 2026

Keywords:
Building Information Modelling (BIM), Architectural, Engineering, Construction, and Operation (AECO), competencies, appraisal)

ABSTRACT

Building Information Modelling (BIM) projects are progressively emerging in the architectural, engineering, construction, and operation (AECO) industries, indicating that many construction organizations are shifting from traditional to cutting-edge technologies. However, due to limited BIM expertise organizations in the Malaysian construction industry, there is still confusion within the sector over the interpretation of the success of BIM deployment in projects. Therefore, this research aims to propose the conceptual framework for developing BIM Competencies Appraisal for construction professionals by employing the narrative systematic review based on PRISMA. The findings reveal that the issues of BIM competencies related to the unawareness of the current BIM competency level, the lack of knowledgeable workforce among construction stakeholders, and the absence of a BIM assessment tool in the Malaysian Construction Industry can be resolved via BIM Competency-Based Performance Appraisal (BIMCPA) that able to tackle six (6) BIM elements namely people, process, technology, policy, information, and organization. In the end, it may assist in narrowing down the gap in BIM implementation, thus supporting the initiatives of increasing productivity in construction projects through innovative technologies.

1. Introduction

Construction projects feature distinct processes and a complex life cycle [1]. According to Eastman, Paul, Sacks, and Liston [2], a construction project includes bulk documents. Sharing fragmented information among project stakeholders frequently results in the following: misunderstandings in communication, frequent verification and clarification of work progress, dissatisfaction, loss of trust, and conflicts among them. As a result, the application of revolutionary

* *Corresponding author.*
E-mail address: jubrahim@uitm.edu.my

https://doi.org/10.37934/araset.61.5.346357

advanced technology in construction has been recognized as a revolutionary innovation in the worldwide construction sector [3].

Building Information Modelling (BIM) offers numerous benefits in construction projects. BIM digitally represents a building's physical and functional characteristics, enabling collaboration, visualization, and data management throughout a project's lifecycle [4, 5]. Various researchers have highlighted the implementation of BIM, which can improve collaboration and communication, enhance visualization, clash detection and conflict resolution, efficient project planning and scheduling, cost estimation and analysis, reduce rework and changes, improve safety planning, improve safety planning, facility management and maintenance, environmental sustainability, regulatory compliance, documentation and record-keeping, and better decision-making [6-12]. Incorporating BIM into construction projects has become increasingly common due to these benefits as it streamlines processes, improves collaboration, and ultimately leads to more efficient and successful projects [5, 6, 13].

Since the beginning of the twenty-first century, the rise of digitalization has resulted in a significant increase in the significance of BIM. This can be ascribed to its multiple benefits, such as reduced costs of failure, increased productivity, and better opportunities for collaboration. [14]. Even though BIM has the potential to be a valuable tool, its adoption remains limited due to a lack of organizational familiarity and experience with this technology. [15]. To deploy BIM technologies effectively, this research proposes a conceptual framework by addressing the theoretical-based technical constraints to adoption. The narrative systematic review methodology based on PRISMA has been adopted to develop a conceptual framework for the BIM component for Competency-Based Performance Appraisal Conceptual Framework for Organisations in the Malaysian Construction Industry and to highlight relevant BIM criteria. This research has focused on the localized obstacles in BIM among construction organizations and how those obstacles might be overcome to achieve national strategic goals through the proposed BIMCPA.

2. Research Methodology

This study employs a systematic review methodology in the inception of the conceptual framework to identify the BIM issues, potential improvement, the component for BIM competencies-based performance appraisal, and the Malaysian government's aspirations specifically on BIM for organizations. The preferred reporting items for systematic reviews and meta-analyses (PRISMA) are used in the systematic review, a collection of standards, and a checklist developed to improve the transparency and reporting quality of systematic reviews and meta-analyses in research. [16-18]. The adopted PRISMA approach consisted of four-stage processes, including identification, screening, eligibility, and inclusion, to provide a thorough and credible overview of the research topic [19], as shown in Figure 1 below.

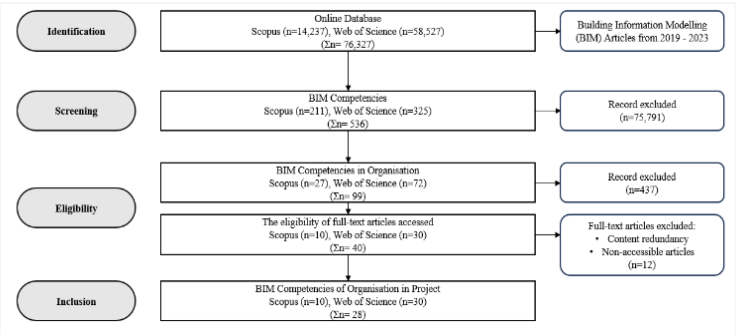

Fig. 1. The process of systematic review based on PRISMA

For journal inclusion, two prominent peer-reviewed online databases, Scopus and WOS, were chosen during the identification step. These databases were selected due to their high-quality journal selection and the inclusion of Journal Impact Factors, which quantify the Impact of individual papers [20]. To reduce the scope, the emphasis was given to BIM publications in the construction industry published in the last five years (2019-2023). The original search revealed many papers, with Scopus yielding 14,237 and WOS yielding 58,527. The screening stage entailed thoroughly selecting BIM and competency-related terminology and keywords. The initial pool of publications was screened, resulting in a reduced number of 211 from Scopus and 325 from WOS.

3. Narrative Systematic Review for The Inception of Bim Competency-Based Performance Appraisal Conceptual Framework

To formulate the BIMCPA conceptual framework, three (3) main components need to be identified employing a narrative systematic review, which is BIM in Malaysia towards national agenda, issues related to BIM competencies specifically on organizations, and BIM competencies assessing elements for organizations in order to cope with the problems.

3.1 BIM in Malaysia Towards National Agenda

Being a sector that contributes three (3) to five (5) percent to the nation's Gross Development Product (GDP), the construction industry in Malaysia is essential to the country's economy (Department of Statistical Malaysia, 2023). As of July 2021, there are a total of 32 public projects that have implemented BIM, including an acquisition phase project in Malaysia (CIDB, 2021). However, no record is registered for BIM in private projects [21].

Since the Government has realized the benefits of BIM in projects, the strategies related to BIM have been formulated and outlined in the country’s development strategies, priorities, and goals for economic, social, and infrastructure development [22] through three (3) main construction-related strategic plans as catalyst namely Twelfth Malaysian Plan, Construction 4.0 Strategic Plan, and National Construction Policy 2030.

In leveraging the digitalization of the Malaysian construction industry, The Twelfth Malaysia Plan (12MP), also known as the Rancangan Malaysia Ke-12 (RMK-12), is a five-year development plan in Malaysia [22]. Each plan typically covers a specific five-year period and significantly guides the country's development initiatives. For BIM, it is highlighted that it will be widely utilized in government-funded projects' planning, design, construction, and operation phases [22].

National Construction Policy 2030, developed by the Ministry of Works, is a strategic framework aimed at guiding the development and transformation of the construction industry in Malaysia up to the year 2030 [23]. BIM is expected to be a significant component of this policy. Malaysia has been actively promoting the adoption of BIM and digital technologies in the construction sector to improve efficiency, data sharing, and stakeholder collaboration [23].

Conversely, the Ministry of Works, together with the CIDB through the Construction Research Institute of Malaysia (CREAM), has developed the Construction 4.0 Strategic Plan (2021-2025) [24]. The strategic plan was developed in collaboration with experts from various disciplines and multiple stakeholders in the industry [25] (CIDB, 2020). The document has highlighted that BIM is driven by sustainable construction practices, enabling more efficient use of resources, better energy efficiency, and improved environmental outcomes for public project sectors [26].

3.2 Issues Related to Bim Competencies of Organisations in The Malaysian Construction Industry

There are three (3) main issues related to the BIM competencies of organizations in the Malaysian construction industry have been identified, and the details are as follows:

3.2.1 Unaware of the current BIM competency level

In Malaysia, the Construction Industry Development Board (CIDB) has organized an annual program to promote BIM among construction professionals to improve their current construction practices and knowledge [27]. However, there is still an absence of competency-based performance appraisal to evaluate the level of BIM competencies concerning the BIM awareness program that has been conducted. Due to that, construction professionals still lack an understanding of the competency level among construction professionals [28-30]. Brahim supports the statement [31] and Memon et al. [32], where many construction professionals claim to be BIM experts without understanding BIM. Therefore, several construction professionals have attempted to become BIM experts by creating their own version of BIM implementation, thus generating uncertainty about BIM competencies among other professionals [33].

3.2.2 Lack of knowledgeable BIM workforce among construction stakeholders

The second issue on BIM implementation is related to the lack of proper understanding of BIM among construction professionals [1, 34-36]. This involved understanding the BIM implementation process, its benefits, and its challenges, which many researchers emphasized as a crucial aspect of encouraging the construction industry to adopt it as a new project delivery mechanism [1, 37-39]. As mentioned by Memon et al. [32], the misunderstanding of BIM as software instead of a process and the absence of collaboration and coordination concepts are the grounds for the slow and unsuccessful adoption and implementation of BIM in Malaysian construction industry practices. Hence, this results in low BIM competencies among construction professionals.

3.2.3 Absence of BIM Competencies Assessment Tool in Malaysian Construction Industry

The third issue related to BIM implementation is related to the BIM competencies assessment tool [40-42]. BIM competency assessments are increasingly becoming effective ways for construction organizations to measure their ability to deliver an efficient BIM project [43]. However, until today, the Malaysian construction industry still needs BIM competencies assessment tools [44] because there has yet to be an initiative to develop new or adopt and adapt existing assessment tools developed by researchers such as BIMMI, BIM Scorecard, BIM Quickscan, etc.

Reviewing the current competency level of construction professionals involved in BIM projects is essential to the abovementioned issues. Even though the previous researcher developed several assessments/standards, the slow adoption of BIM due to resistance among construction professionals makes it difficult for authorities to enforce or establish a BIM competency assessment in line with the current Malaysian construction industry's performance.

3.3 Elements in Assessing BIM Competencies in Organisations

Based on the narrative systematic review related to BIM competencies appraisal, six (6) BIM enablers are appraisal components to tackle the abovementioned issues: people, process, technology, policy, information, and organization. The details are as follows:

3.3.1 People

The "BIM people" typically refer to professionals who work with Building Information Modeling (BIM) technology and methodologies in the architecture, engineering, construction, and operation (AECO) industry [45, 46]. These individuals possess various skills and expertise to effectively utilize BIM software and processes throughout multiple stages of a construction project [45, 46].

3.3.2 Process

A systematic and collaborative approach is used in the architecture, engineering, construction, and operation (AEC) industry to design, construct, and manage buildings and infrastructure projects [47, 48]. The BIM process is iterative and involves continuously exchanging data and information among all stakeholders [49]. The aim is to create a single, centralized source of project data that improves collaboration, reduces errors, and enhances overall project efficiency from concept to operation [49]. BIM processes can be tailored to the specific needs of different projects and industries, such as architecture, engineering, construction, and facility management [50, 51]. The typical activities involved in the BIM process are as follows:

(a) Conceptualization and Design Phase:
Conceptual Design is where architects and designers use BIM software to create initial concept models, exploring different design ideas that help to visualize the project's form and function. [52]. Meanwhile, design development is where the concept models are further developed into detailed 3D representations, incorporating information about materials, systems, and components [53].

(b) Analysis and Simulation:
BIM models can be used for various analyses, such as structural analysis, energy performance analysis, cost estimation, and simulations that help identify issues, assess project feasibility, and improve design decisions [54, 55]

(c) Collaboration:
BIM encourages collaboration among project stakeholders, including architects, engineers, contractors, and owners [56]. The shared digital platform allows real-time collaboration and the exchange of information and updates [56]

(d) Coordination and Clash Detection:
BIM models identify clashes or conflicts among various building systems (e.g., structural, mechanical, electrical) during the design and pre-construction phases, preventing costly on-site disputes [57].

(e) Construction Phase:
Contractors and subcontractors leverage the BIM model for on-site construction that feeds as a reference for construction tasks, aiding precision and efficiency [58]

(f) As-Built Documentation:
BIM models are updated as construction progresses to reflect the as-built conditions that become a valuable resource for facility management and future renovations [59]

(g) Facility Management and Operation:
BIM data is used for ongoing facility management, including maintenance, energy efficiency, and space utilization, as it provides access to vital information about building systems and components [59]

(h) Renovations and Retrofits:
When renovations or retrofits are required, BIM models assist in the planning and execution of these projects, where the existing BIM data helps minimize disruptions and ensures accuracy [59]

(i) Lifecycle Management:
BIM facilitates lifecycle management by providing a comprehensive digital record of a building or infrastructure asset, which is valuable for future decision-making, cost control, and sustainability efforts [59].

3.3.3 Technology

A digital process that involves hardware and software in creating and managing intelligent 3D models to represent the physical and functional characteristics of buildings and infrastructure projects [60]. BIM technology has revolutionized the AECO industry by improving collaboration, reducing errors, and enhancing project efficiency. It is a critical tool for modern construction and building management. The items that related to BIM technologies are:

(a) 3D Modeling:
BIM software allows professionals to create detailed 3D models of buildings and infrastructure projects that contain information about the project's physical components, materials, systems, and spatial relationships [60].

(b) Data Integration:
BIM technology integrates various data types into the model, which include geometric data (shape, size, and location), non-geometric data (specifications, manufacturer details, cost estimates), and time-related data (schedules and timelines) [60].

(c) Interoperability:
BIM software often supports interoperability, allowing different software applications to exchange data and collaborate seamlessly, ensuring multiple stakeholders can work together effectively [61]

(d) Visualization:
BIM provides realistic 3D visualizations and renderings, enabling stakeholders to see and understand the project before it is built, which can aid in design decisions, client presentations, and stakeholder communication [62]

(e) Mobile and Cloud Integration:
BIM technology can be accessed and used on mobile devices and often integrates with cloud-based platforms, enabling remote collaboration and data access [63]

3.3.4 Policy

A set of guidelines, rules, or principles established by a government, organization, or company to govern the implementation, use, and standards related to BIM within a specific context or jurisdiction to promote the adoption of BIM and ensure its effective and consistent use in construction and infrastructure projects [64, 65]

(a) Data Ownership and Accessibility:
Policies may address issues related to data ownership and the accessibility of BIM data beyond project completion. This is crucial for long-term building management and maintenance [64].
(b) Security and Privacy:
BIM policies may include provisions to safeguard sensitive project data and address privacy concerns, especially in public infrastructure projects [64]
(c) Compliance and Enforcement:
Policies often include mechanisms for enforcing BIM requirements and ensuring that projects adhere to the established standards [66]. BIM policies can be created at various levels, including national, state, provincial, municipal, or within individual organizations [66]. Their scope and specifics depend on the goals, needs, and priorities of the entity or jurisdiction that creates them. BIM policies play a crucial role in standardizing BIM adoption, promoting consistency, and facilitating the benefits of BIM technology in the construction and building management sectors [64, 66]

3.3.5 Information

Refers to the data and details in the digital models and databases created during building and infrastructure projects' design, construction, and operation [67, 68]. BIM models are rich repositories of information that go beyond 3D representations of physical elements. BIM information is dynamic and evolves throughout the project's lifecycle [61, 69].

(a) Geometric Information:
This includes the shape, size, and location of all project components. It forms the basis of the 3D model and allows stakeholders to visualize the physical aspects of the project [70, 71].
(b) Non-Geometric Information
BIM models incorporate non-geometric data related to the components, such as specifications, manufacturer details, performance data, and construction details, that help accurately represent real-world objects [71]
(c) Materials and Properties:
Information about the materials used in the project, their properties (e.g., density, strength, insulation values), and cost data can be stored in the BIM model [71]
(d) Cost and Quantity Data
BIM information can generate quantity take-offs, cost estimates, and budget data that aid project cost management and procurement [72]
(e) Time and Scheduling
BIM models may include data about project schedules and timelines, which can be used for construction planning and sequencing[72].
(f) Maintenance and Operations Data:
For facility management, BIM information is used to store data about maintenance schedules, equipment specifications, and other details relevant to the operational phase of a building [72].
(g) Spatial Information:
Information about spatial relationships, including room dimensions, clearances, and accessibility, is crucial for design and space planning [50].
(h) Legal and Regulatory Data:

BIM models may contain information regarding permits, compliance with building codes, and other regulatory requirements [72]

(i) Component Attributes:
BIM information includes attributes of individual components, such as doors, windows, walls, and mechanical systems. This information helps with component selection and specification [71].

(j) Change Management:
As changes occur throughout the project lifecycle, BIM models are updated to reflect the as-built conditions. Change management data helps keep the model accurate and current [72].

(k) Communication and Collaboration Data:
BIM information can include communication records, such as comments, markups, and notes added by various project stakeholders during collaboration [72].

3.3.6 Organization

The entity specializes in implementing, using, and promoting BIM technology and methodologies within the AECO industry [73]. These organizations play a crucial role in advancing the adoption of BIM and improving collaboration, efficiency, and quality in construction and facility management processes [21, 72].

3. Discussion

From the previous narrative, systematic review facilitates the formulation of the BIM conceptual framework specifically for private construction organizations to streamline with the Government's aims. The framework consisted of four (4) main elements: the issues, solutions, BIM Competency-Based Appraisal, and the results to align with the National Agenda. The first elements, the issues, are derived from the problem statement identified at the initial stage of this research, which is the unawareness of the current BIM competency level among construction stakeholders, the lack of knowledgeable BIM workforce among construction stakeholders, and the absence of BIM competencies appraisal tool in the Malaysian construction industry. Then, the solution to cope with the mentioned issues is to develop a mechanism to monitor and evaluate the adoption and impact of BIM in construction projects, as mentioned in the National Construction Policy 2030 and Construction 4.0 Strategic Plan.

Therefore, the development of the BIM Competency-Based Performance Appraisal (BIMCPA) through this research, which consists of six (6) BIM Elements along with potential improvements, will be formulated to cope with the issues and, at the same time, reflect the Government's aim to promote successful BIM in the Malaysian construction industry through three (3) Malaysian National agenda goals; Twelfth Malaysian Plan, Construction 4.0 Strategic Plan, and National Construction Policy 2030.

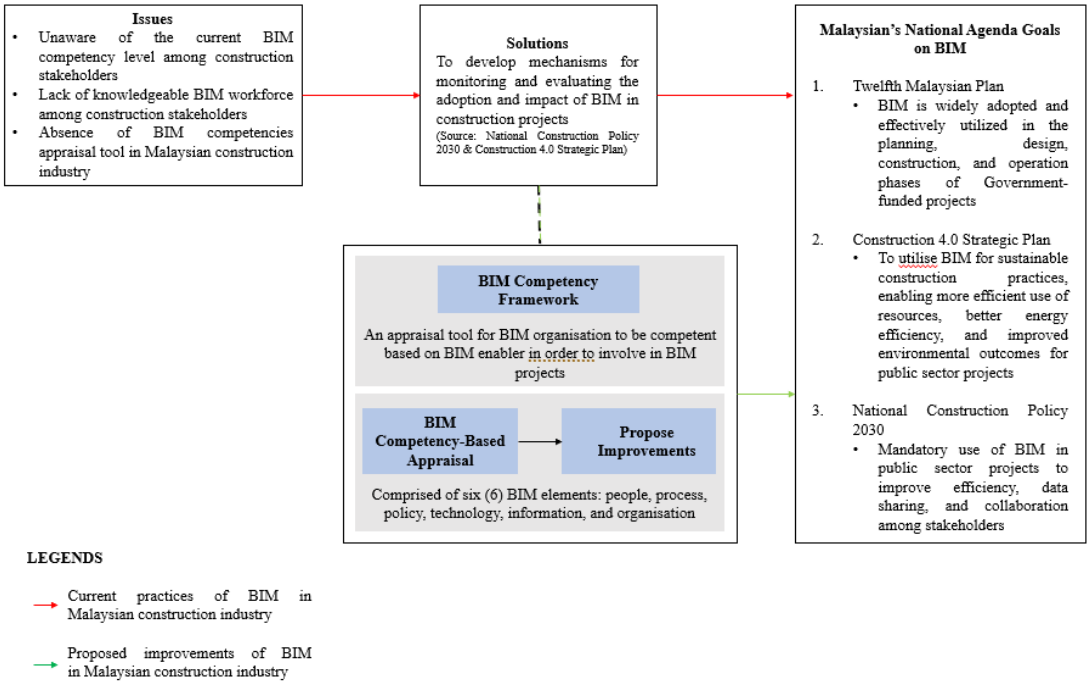

Fig. 2. Proposed BIM Competencies Appraisal's Conceptual Framework for Organisations in Malaysian Construction Industry

4. Conclusions

The conceptual framework aims to assist in developing the proposed BIM Competency-Based Performance Appraisal by identifying the current competency level of construction professionals in BIM projects, identifying issues that lead to incompetent stakeholders, and identifying activities to improve their competence in BIM organizations. Finally, it may reflect the government's goal of promoting practical BIM in Malaysia's construction industry.

Acknowledgment

The author would like to express special gratitude to the Research Management Centre of Universiti Technology MARA (UiTM) and the Ministry of Higher Education for funding this research under the Fundamental Research Grant Scheme (FRGS) number FRGS/1/2022/TK01/UITM/02/6 for financing this research.

References

[1] Al-Ashmori, Y.Y., et al., BIM benefits and its influence on the BIM implementation in Malaysia. Ain Shams Engineering Journal, 2020(xxxx).
[2] Eastman, C., et al., BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. Second ed. 2011: John Wiley & Sons, Inc. 650-650.
[3] Husain, A.H., M.N. Razali, and S. Eni, Stakeholders' expectations on building information modeling (BIM) concept in Malaysia. Property Management, 2018. 36(4): p. 400-422.
[4] Ghaffarianhoseini, A., et al., Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks, and challenges. Renewable and sustainable energy reviews, 2017. 75: p. 1046-1053.
[5] Eastman, C., et al., BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. First ed. Notes and Queries. 2008, United States of America: John Wiley & Sons, Inc. BIM.
[6] Arayici, Y., C. Egbu, and P. Coates, Building Information Modelling (Bim) Implementation And Remote Construction Projects: Issues, Challenges, And Critiques. 2012. 17(May): p. 75-92.

[7] Wen, J. and M. Gheisari, Using virtual reality to facilitate communication in the AEC domain: A systematic review. Construction Innovation, 2020. 20(3): p. 509-542.
[8] Sacks, R., et al., BIM handbook: A guide to building information modeling for owners, designers, engineers, contractors, and facility managers. 2018: John Wiley & Sons.
[9] Chahrour, R., et al., Cost-benefit analysis of BIM-enabled design clash detection and resolution. Construction Management and Economics, 2021. 39(1): p. 55-72.
[10] Parsamehr, M., et al., A review of construction management challenges and BIM-based solutions: perspectives from the schedule, cost, quality, and safety management. Asian Journal of Civil Engineering, 2023. 24(1): p. 353-389.
[11] Wong, J., J.X. Zhou, and A. Chan, Exploring the linkages between the adoption of BIM and design error reduction. Building information systems in the construction industry, 2018. 113.
[12] Zhang, S., et al., BIM-based fall hazard identification and prevention in construction safety planning. Safety Science, 2015. 72: p. 31-45.
[13] Ghaffarianhoseini, A., et al., Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks, and challenges. Renewable and Sustainable Energy Reviews, 2017. 75(September): p. 1046-1053.
[14] Siebelink, S., J.T. Voordijk, and A. Adriaanse, Developing and Testing a Tool to Evaluate BIM Maturity: Sectoral Analysis in the Dutch Construction Industry. 2018.
[15] Smits, W., M. Buiten, and T. Hartmann, Yield-to-BIM: impacts of BIM maturity on project performance. Building Research & Information, 2016. 45: p. 1-11.
[16] McInnes, M.D., et al., Preferred reporting items for a systematic review and meta-analysis of diagnostic test accuracy studies: the PRISMA-DTA statement. Jama, 2018. 319(4): p. 388-396.
[17] O'Dea, R.E., et al., Preferred reporting items for systematic reviews and meta‐analyses in ecology and evolutionary biology: a PRISMA extension. Biological Reviews, 2021. 96(5): p. 1695-1722.
[18] Moher, D., et al., Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. International journal of surgery, 2010. 8(5): p. 336-341.
[19] Moher, D., et al., Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Int J Surg, 2010. 8(5): p. 336-41.
[20] Sharma, A. and T. Sharma, HR analytics and performance appraisal system: A conceptual framework for employee performance improvement. Management Research Review, 2017. 40(6): p. 684-697.
[21] Al-Ashmori, Y.Y., I. Othman, and A.-H.M. Al-Aidrous, "Values, Challenges, and Critical Success Factors" of Building Information Modelling (BIM) in Malaysia: Experts Perspective. Sustainability, 2022. 14(6): p. 3192.
[22] Malaysia Economic Plan Unit, Twelfth Malaysia Plan 2021 - 2025, M.E.P. Unit, Editor. 2020: Malaysia.
[23] Works, M.o., National Construction Policy 2030. 2020.
[24] Cidb, Construction 4.0 Strategic Plan (2021-2025). 2020.
[25] CIDB. Construction 4.0 Strategic Plan 2021-2025 - A Decisive maneuver to embrace the Industry Revolution 4.0. 2020 [cited 2023 18 November 2023]; Available from: https://smart.cidb.gov.my/article/construction-40-strategic-plan-2021-2025-a-decisive-maneuver-to-embrace-the-industry-revolution-40-6.
[26] Datta, S., et al., Benefits and Barriers of Implementing Building Information Modeling Techniques for Sustainable Practices in the Construction Industry—A Comprehensive Review. Sustainability, 2023. 15: p. 12466.
[27] Othman, I., et al., The level of Building Information Modelling (BIM) Implementation in Malaysia. Ain Shams Engineering Journal, 2020(xxxx).
[28] Dakhil, A., J. Underwood, and M. Al Shawi, Critical success competencies for the BIM implementation process: UK construction clients. Journal of Information Technology in Construction, 2019. 24(November 2018): p. 80-94.
[29] Olawumi, T.O., et al., Barriers to integrating BIM and sustainability practices in construction projects: A Delphi survey of international experts. Journal of Building Engineering, 2018. 20: p. 60-71.
[30] Navendren, D., et al., Challenges to building information modeling implementation in the UK: Designers' perspectives. Proceedings 30th Annual Association of Researchers in Construction Management Conference, ARCOM 2014, 2014(September): p. 733-742.
[31] Brahim, J., Development of a Building Information Modelling (BIM) Migration Path Model for Construction Professionals. 2018(July): p. 389-389.
[32] Memon, A.H., et al., BIM in the Malaysian construction industry: Status, advantages, barriers, and strategies to enhance the implementation level. Research Journal of Applied Sciences, Engineering and Technology, 2014. 8(5): p. 606-614.
[33] Zahrizan, Z., et al., Ijret_110208060. Exploring the Adoption of Building Information Modelling (Bim) in the Malaysian Construction Industry: a Qualitative Approach, 2013. eISSN pISS: p. 2319-1163.

[34] Ahmad Jamal, K.A., et al., Challenges of Building Information Modelling (BIM) from the Malaysian Architect's Perspective. MATEC Web of Conferences, 2019. 266: p. 05003-05003.
[35] Arroteia, A.V., et al., BIM knowledge assessment: an overview among professionals A survey on the AEC industry in Sao Paulo, Brazil. 2020(September): p. 315-324.
[36] Othman, I., et al., The level of Building Information Modelling (BIM) Implementation in Malaysia. Ain Shams Engineering Journal, 2021. 12(1): p. 455-463.
[37] Criminale, A. and S. Langar, Challenges with BIM Implementation: A Review of Literature Challenges with BIM Implementation: A Review of Literature. 2017(April).
[38] Hasan, A.N. and S.M. Rasheed, The Benefits of and Challenges to Implementing 5D BIM in Construction Industry. 2019. 5(2): p. 412-421.
[39] Li, P., et al., Critical Challenges for BIM Adoption in Small and Medium-Sized Enterprises: Evidence from China. Advances in Civil Engineering, 2019. 2019.
[40] Giel, B. and R.R.A. Issa, Framework for evaluating the BIM competencies of building owners. Computing in Civil and Building Engineering - Proceedings of the 2014 International Conference on Computing in Civil and Building Engineering, 2014(Cmm): p. 552-559.
[41] Mahamadu, A.-M., et al., The Importance of BIM Capability Assessment: An Evaluation of Post-Selection Performance of Organisations on Construction Projects. 2019.
[42] Succar, B. and C. Aec, Building Information Modelling Maturity Matrix. 2014.
[43] Ganiyu, S.A., et al., BIM competencies for delivering waste-efficient building projects in a circular economy. Developments in the Built Environment, 2020. 4: p. 100036-100036
[44] Yusoff, S.N.S. and J. Brahim, Implementation of Building Information Modeling (BIM) for Social Heritage Buildings in Kuala Lumpur. 2021. 12(1): p. 88-99.
[45] Succar, B., W. Sher, and A. Williams, An integrated approach to BIM competency assessment, acquisition and application. Automation in Construction, 2013. 35: p. 174-189.
[46] Batarseh, S. and I. Kamardeen, The impact of individual beliefs and expectations on BIM adoption in the AEC Industry. EPiC Series in Education Science, 2017. 1: p. 466-475.
[47] Rafsanjani, H.N. and A.H. Nabizadeh, Towards digital architecture, engineering, and construction (AEC) industry through virtual design and construction (VDC) and digital twin. Energy and Built Environment, 2021.
[48] Enshassi, A.A., L.A.A. Hamra, and S. Alkilani, Studying the Benefits of Building Information Modeling (BIM) in Architecture, Engineering, and Construction (AEC) Industry in the Gaza Strip. Jordan Journal of Civil Engineering, 2018. 12(1).
[49] Ahankoob, A., B. Abbasnejad, and P.S. Wong. The support of continuous information flow through building information modeling (BIM). In The 10th International Conference on Engineering, Project, and Production Management. 2020. Springer.
[50] Leygonie, R., A. Motamedi, and I. Iordanova, Development of quality improvement procedures and tools for facility management BIM. Developments in the Built Environment, 2022. 11: p. 100075.
[51] Asare, K.A., et al., BIM for facilities management: Potential legal issues and opportunities. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 2021. 13(4): p. 04521034.
[52] Abrishami, S., J. Goulding, and F. Rahimian, Generative BIM workspace for AEC conceptual design automation: Prototype development. Engineering, Construction and Architectural Management, 2021. 28(2): p. 482-509.
[53] Deng, M., C.C. Menassa, and V.R. Kamat, From BIM to digital twins: A systematic review of the evolution of intelligent building representations in the AEC-FM industry. Journal of Information Technology in Construction, 2021. 26.
[54] Durdyev, S., et al., Review of the building information modeling (BIM) implementation in the context of building energy assessment. Energies, 2021. 14(24): p. 8487.
[55] Omrany, H., et al., Applications of Building information modeling in the early design stage of high-rise buildings. Automation in Construction, 2023. 152: p. 104934.
[56] Alizadehsalehi, S., A. Hadavi, and J.C. Huang, From BIM to extended reality in AEC industry. Automation in Construction, 2020. 116: p. 103254.
[57] Teo, Y.H. et al., Enhancing the MEP Coordination Process with BIM Technology and Management Strategies. Sensors, 2022. 22(13): p. 4936.
[58] Disney, O., et al., Total BIM on the construction site: A dynamic single source of information. Journal of Information Technology in Construction (ITcon), 2023. 28(27): p. 519-538.
[59] Pedral Sampaio, R., A. Aguiar Costa, and I. Flores-Colen, A Systematic Review of Artificial Intelligence Applied to Facility Management in the Building Information Modeling Context and Future Research Directions. Buildings, 2022. 12(11): p. 1939.

[60] Banerjee, A. and R.R. Nayaka, A comprehensive overview on BIM-integrated cyber-physical system architectures and practices in the architecture, engineering, and construction industry. Construction Innovation, 2022. 22(4): p. 727-748.
[61] Nguyen, T.D. and S. Adhikari, The Role of BIM in Integrating Digital Twin in Building Construction: A Literature Review. Sustainability, 2023. 15(13): p. 10462.
[62] Wijeratne, P.U., et al., BIM enabler for facilities management: a review of 33 cases. International Journal of Construction Management, 2023: p. 1-10.
[63] Garbett, J., T. Hartley, and D. Heesom, A multi-user collaborative BIM-AR system to support design and construction. Automation in Construction, 2021. 122: p. 103487.
[64] Jiang, R., et al., Government efforts and roadmaps for building information modeling implementation: Lessons from Singapore, the UK and the US. Engineering, Construction and Architectural Management, 2022. 29(2): p. 782-818.
[65] Sepasgozar, S.M., et al., BIM and Digital Twin for Developing Convergence Technologies as Future of Digital Construction. Buildings, 2023. 13(2): p. 441.
[66] Oti, A.H., et al., A BIM-driven framework for integrating rules and regulations in decommissioning nuclear power plants. Construction Innovation, 2021(ahead-of-print).
[67] Lu, Q. et al., Moving from Building Information Models to Digital Twins for Operation and Maintenance. Proceedings of the Institution of Civil Engineers - Smart Infrastructure and Construction, 2020(February): p. 1-9.
[68] Vignali, V., et al., Building Information Modelling (BIM) application for an existing road infrastructure. Automation in Construction, 2021. 128: p. 103752.
[69] Pan, Y. and L. Zhang, Integrating BIM and AI for smart construction management: Current status and future directions. Archives of Computational Methods in Engineering, 2023. 30(2): p. 1081-1110.
[70] Ershadi, M., et al., Implementation of Building Information Modelling in Infrastructure Construction projects: A Study of Dimensions and Strategies. International Journal of Information Systems and Project Management, 2021. 9(4): p. 43-59.
[71] Mustafa, M.H., F.A.M. Rahim, and L.K. Chia, The role of 5D building information modeling in construction project cost management: An overview and future directions. Journal Of Project Management Practice (JPMP), 2023. 3(1): p. 95-112.
[72] Raza, M.S., et al., Potential features of building information modeling (BIM) for application of project management knowledge areas in the construction industry. Heliyon, 2023. 9(9).
[73] Rajabi, M.S., et al., *Underlying factors and strategies for organizational BIM capabilities: The case of Iran.* Applied System Innovation, 2022. **5**(6): p. 109.