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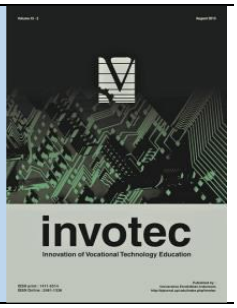

ANALYSIS OF BIM DEVELOPMENT AND ITS COMPETENCIES: A SYSTEMATIC LITERATURE REVIEW

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ARTICLE INFO

Article history:
Received: 25 Apr 2025
Received in revised form: 20 May 2025
Accepted: 27 Jun 2025
Available online: 30 Jun 2025

Keywords: Adoption, BIM, Competences, Construction, Skills

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ABSTRACT

Building Information Modeling (BIM) has become an important technology in the construction industry, driving efficiency, collaboration, and better project information management. However, the gap between workforce competencies and industry needs remains a major challenge in implementing BIM effectively. Using a Systematic Literature Review (SLR), this study aims to identify in greater depth the key skills required by BIM professionals by reviewing recent academic publications through the PRISMA methodology. Analysis results show that in addition to technical skills in BIM software, professionals must also possess competencies in collaboration, communication, project administration, and strategic leadership. In developed countries, BIM adoption is driven by government policies and standardized regulations, whereas in developing and underdeveloped countries, BIM implementation still faces challenges in workforce training and industry awareness.

1. Introduction

Building Information Modeling (BIM) technology plays an important role in the construction sector, as it can improve communication, coordination, and operational efficiency (Zhou et al., 2024). BIM offers several advantages, particularly enhanced visualization capabilities to help understand project design, as well as efficient clash detection mechanisms that reveal potential conflicts at early stages in the construction process (Yilmaz et al., 2024). BIM is viewed as a major innovation to improve productivity and quality in construction projects, especially in developing countries (Famakin et al., 2023). The adoption of BIM technology is the first step toward the efficiency offered by this technology. The BIM adoption process varies greatly across different countries, influenced by specific driving factors, barriers, and strategies (Ariono et al., 2022).

BIM is adopted worldwide, with significant growth in countries such as the United States, China, and England, which lead in research outcomes and citation impact related to BIM applications in civil infrastructure (Li et al., 2024). The demand for BIM professionals in China is increasing, as evidenced by numerous job recruitment advertisements, indicating a growing need for skilled BIM practitioners (Zhou et al., 2024). In Japan, there is a strong push to promote BIM technology to address labor shortages and rising costs, although challenges in widespread adoption remain (Rui et al., 2024). Despite implementation barriers in terms of high costs and lack of government support, in developing countries BIM is viewed as a key driver for sustainable building development (Famakin et al., 2023; Takyi-Annan & Zhang, 2023).

The development and adoption of Building Information Modeling (BIM) in Southeast Asia, in countries such as Singapore and Malaysia, has been influenced by various factors, including government initiatives, technological frameworks, and industry-specific challenges (Liu et al., 2021). The BIM adoption process in Indonesia can be considered delayed because in 2013 and 2015, only 2 published articles were found (Telaga, 2018), and in 2017 it began to be used by state-owned contractor companies, while other countries in the Asian region had already started implementing it in the early 2010s (China, South Korea, Singapore, Vietnam, and Malaysia) (Heryanto et al., 2020). This condition reflects the high urgency to develop and strengthen professional competencies in the field of BIM, especially in developing and less developed countries, as more than 60% of practitioners are unfamiliar with BIM terminology (Roy & Firdaus, 2020).

In the construction industry, the BIM adoption process is closely related to the job market, as the demand for skilled BIM professionals is an important factor affecting its implementation. Job market demand for BIM professionals is closely related to the required competencies (Zhou et al., 2024). The ability to use BIM software is fundamental, but that is not enough (Zhou & Wang, 2023). Employers expect professionals to be able to implement BIM processes according to standards, including protocols, workflows, and handover procedures (Alieh et al., 2024). Effective collaboration is also essential, necessitating communication skills to facilitate such collaboration (Obi et al., 2022).

Significant gaps in the comprehensive mapping of BIM skill requirements, particularly in important areas such as BIM protocols, collaboration, coordination, and information workflows, indicate a mismatch between educational outcomes and industry expectations (Alieh et al., 2024). Thus, a systematic review is needed to assess BIM development and align educational outcomes with the current construction industry's demands for innovative and skilled professionals (Li et al., 2024). The importance of keeping up with BIM developments aims to identify what competencies are needed by the industry, so that education can produce graduates who are relevant to the needs, especially in BIM technology. By reviewing literature related to the BIM industry, its competencies, and the adoption process will help understand how BIM is currently developing.

2. Method

This review explores current competencies and industry needs related to the use of Building Information Modeling (BIM). The purpose of this research is to conduct a systematic review of existing literature to identify BIM skill requirements in order to understand the development of industry standards and job market demands. To support this objective, a reporting guideline called Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) is used. PRISMA is used to enhance transparency and reporting quality in systematic reviews and meta-analyses (Yan et al., 2024). The completeness and accuracy of systematic reviews are offered by PRISMA 2020 (Page et al., 2022) as the latest version, where the flow diagram can be accessed through https://www.prisma-statement.org/prisma-2020-flow-diagram.

The process began with data mining in Scopus using the following keyword combinations and Boolean operators: "Building Information Modeling" OR "BIM" AND "Competencies" OR "Skills" OR "Knowledge" AND "Workforce" OR "Industry Needs" OR "Job Market". The use of Scopus is based on its database reflecting recent research trends, with a significant increase in publications related to BIM, especially after 2018, indicating growing interest in this technology (Saipudin & Ishak, 2024). The search yielded 84 articles, followed by initial screening. 35 articles were excluded because their publication dates were outside the 2020-2025 range. This left 49 articles, which were then subjected to elimination based on language used. All remaining articles were in English, so there was no reduction. The final elimination was based on Document Type, so articles that were not "Article" type were excluded, resulting in a reduction of 24 articles with details: a). Review: 4; b). Book Chapter: 1; c). Conference Paper: 15; d). Conference Review: 4

25 articles were selected for the next eligibility check, then a quick reading process was conducted by scanning the abstract and conclusion sections. The categorization process was carried

out based on main themes that emerged in the abstracts and conclusions, resulting in 5 main themes: Technical Skills, Industry Needs & Workforce, Sustainability & Innovation, Collaboration & Communication, and Project Management. Eligibility criteria were established by selecting only articles in the "Technical Skills" and "Industry Needs & Workforce" categories, resulting in 6 articles.

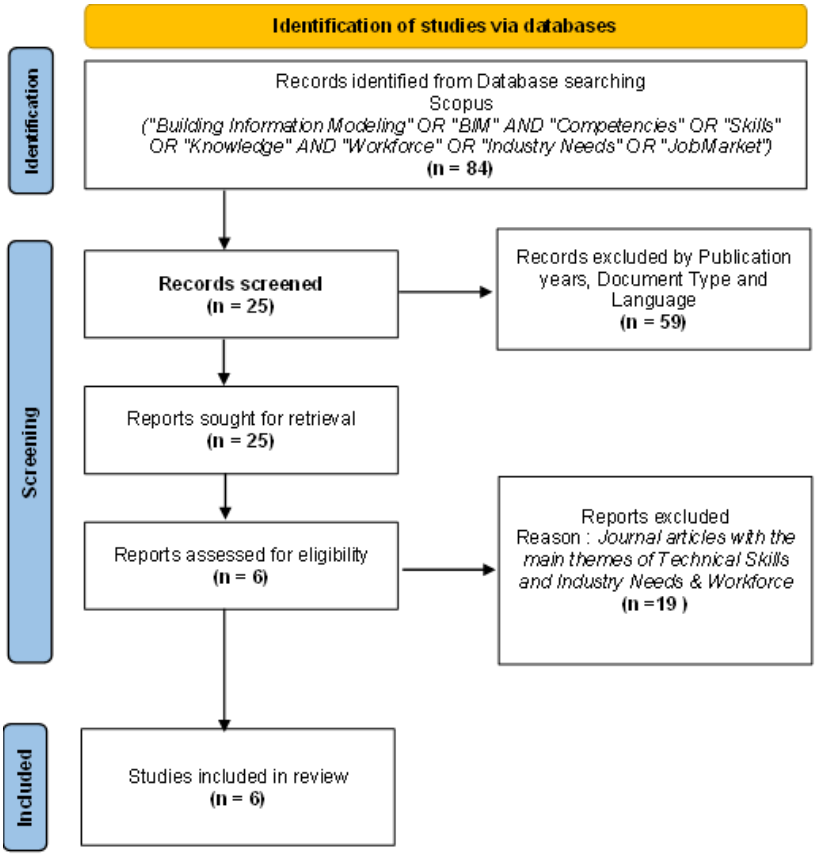

Figure 1. Systematic review process flow diagram (PRISMA flow diagram)

3. Result and Discussion

3.1 Result

The search results are summarized in the PRISMA flow diagram (Figure 1), yielding 6 articles eligible for further analysis. These 6 journal articles were then read in their entirety. Since the focus of this research is to identify BIM skill requirements to understand the development of industry standards and job market demands, several aspects were noted for attention. These aspects include information on BIM development, competencies related to BIM, the country where the research was conducted, and suggestions for further research from each article.

Table 1. Titles and Publication Years of the selected articles

Journal Code	*Article Title*	Year of Article Publication	Country of Research
[022]	Enhancement of mutual recognition and mobility of BIM experts in ASEAN countries.pdf	2020	ASEAN Countries
[018]	Cultural orientations and strategic capability for the adoption of building information modeling in construction firms.pdf	2021	Lagos State
[017]	Competencies Expected from an Information Manager Working in BIM-Based Projects.pdf	2020	United Kingdom; Sri Lanka

Journal Code	*Article Title*	Year of Article Publication	Country of Research
[014]	Competence-targeted education for BIM professionals A case example of the Vietnamese construction industry.pdf	2021	Vietnam
[005]	Organizational Readiness for Building Information Modeling Implementation in Malawi Awareness and Competence.pdf	2024	Malawi
[004]	Leading UK Construction Companies' Strategies to Tackle BIM Training and Skills Challenges.pdf	2023	United Kingdom

Based on the information available in Table 1, information was obtained about the countries where the research was conducted. When viewed based on the level of economic development, there are developed countries, developing countries, and least developed countries (LDCs).
The publication years of the eligible articles are 2020, 2021, 2023, and 2024, with differences related to BIM development and BIM competencies explained. These results will be further analyzed to determine the connection between the focus of the countries where the research was conducted, particularly with BIM development and the competencies needed to stay connected with Building Information Modeling.

3.2 Discussion

3.2.1 Development of Building Information Modeling (BIM)

The development of Building Information Modeling (BIM) is closely related to the BIM adoption process (Nguyen et al., 2023). In developed countries, the adoption process is supported by government initiatives, while in developing countries, its implementation depends on professional awareness and competence (Ndwandwe et al., 2024). Malawi, classified as a less developed country, still experiences difficulties with awareness related to BIM competency. Lack of training is one of the most critical obstacles that must be addressed to build a satisfactory level of implementation (Ndwandwe et al., 2024).

The situation differs in developing countries, particularly in Asia where BIM has been mandated due to its sustainability benefits (Dao et al., 2020). This rapid development has increased the demand for professionals, but meeting this demand faces challenges in integrating BIM into educational curricula (Nguyen, 2021). Furthermore, because BIM has become mandatory and the demand for professionals has increased, the demand for BIM certification has also risen (Dao et al., 2020). Despite the existing challenges, BIM development in developing countries is several steps ahead of less developed countries. This is evidenced by the evolution of BIM into an Information Management platform, which can integrate stakeholders throughout the entire supply chain and serve as a digital transformation platform that drives cultural change in the construction industry (Zakariyyah et al., 2021).

While in less developed and developing countries BIM development is still hindered by interest, adoption processes, the need for professionals and certification, the situation is different in developed countries. In developed countries, BIM has become a primary focus in the construction industry, driven by government policies to accelerate its adoption (Shojaei et al., 2023). BIM has also evolved from a digital representation of construction projects into a collaborative platform that integrates stakeholders and establishes standard protocols (Ariyachandra et al., 2022). However, despite the progress shown by BIM development in developed countries, challenges remain. Challenges to accelerate BIM implementation relate to lack of training and skills (Shojaei et al., 2023), as well as issues such as legal and technological barriers that still hinder its adoption (Ariyachandra et al., 2022).

The development and adoption process of BIM varies across countries. Studying the barriers experienced by each country in this process can help understand what should be adopted and learned from. A country's success in adopting BIM can also serve as a reference, while still adjusting to other supporting factors.

Building Information Modeling (BIM) has been successfully implemented in several developed countries, such as Singapore, the United Kingdom, and the United States. In Singapore, the government acted as the initiator, initially focusing on the building sector and then expanding BIM to other areas such as smart cities (Jiang et al., 2021). The successful adoption of BIM in the UK was facilitated by several supporting factors, including committed leadership, digital transformation strategy, building a capable supplier network, and improving employee skills. These factors helped the organizational transformation process and ensured effective BIM implementation (Shojaei et al., 2022). Unlike Singapore and the UK, the United States emphasizes industry collaboration and research as key components of its BIM strategy. Research institutions actively support BIM implementation, contributing to the development of innovative solutions and best practices for the construction industry (Jiang et al., 2021).

Not only developed countries have successfully adopted BIM; Turkey, Egypt, and Qatar, which are developing countries, have also successfully adopted and implemented BIM (Kineber, 2023; Musharavati, 2023; Tan et al., 2022). A survey conducted in Turkey among construction professionals identified three main critical success factors through factor exploration. These three factors are: Awareness of technological benefits (ATB), Organizational readiness and competitive advantages (ORCA), and Motivation of management regarding BIM (MMB) (Tan et al., 2022).

However, it is important to note that this analysis has some limitations that need to be recognized. Firstly, the literature sources used tend to focus on countries with relatively more complete and internationally published BIM documentation, leading to potential geographical bias. Countries with low levels of BIM adoption or limited academic documentation may be underrepresented in the findings. In addition, most of the studies analyzed are descriptive and perception-based, thus not fully reflecting objective conditions or quantitative data related to BIM implementation in the field. Another limitation lies in the lack of in-depth contextual analysis of the sociocultural, economic, and policy factors in each country that may significantly influence BIM adoption.

3.2.3 Building Information Modeling (BIM) Competencies

The BIM adoption process and BIM competencies have a very important relationship for its successful implementation in the construction industry. Several aspects such as competencies in leadership, technical skills and collaborative practices significantly affect the effectiveness of BIM adoption. Effective BIM implementation requires strong leadership, which is categorized into intellectual, managerial and emotional skills, of which intellectual skills drive the adoption process (Mirhosseini et al., 2020). BIM also encourages interdisciplinary collaboration, which is critical for successful project implementation, effective collaboration relies on competencies related to shared decision-making and interoperability among team members (Hosein, 2023).

Building Information Modeling (BIM) competencies are critical as BIM integrates different types of data, to facilitate interdisciplinary communication and decision making (Kennedy et al., 2024). The importance of BIM competencies is underlined by its ability to drive innovation, optimize building lifecycle management and enable intelligent facility management (Mao, 2024). The results of the analysis of 6 scientific articles, obtained a list of competencies that need to be possessed by a BIM professional.

Table 2. List of BIM Competencies

No	*Competency Details*	*Number of competencies mentioned*
1	Communication, Collaboration and Coordination Skills	5
2	Proficiency in BIM software	4
3	Digital Skills	2
4	Professional Knowledge	2
5	Innovative	1
6	Leadership Skills	1
7	Construction Technology Knowledge	1
8	Contract Administration Skills	1
9	Common Data Environment (CDE) Knowledge	1
10	Knowledge of BIM Concepts and Standards	1
11	Ability to Utilize BIM Technology	1

As an important strategic capability (Zakariyyah et al., 2021), communication, collaboration and coordination are needed to assess the level of BIM readiness and implementation (Ndwandwe et al., 2024) and coordinate with various stakeholders (Ariyachandra et al., 2022) for effective BIM implementation (Shojaei. et al., 2023). Proficiency in BIM software is a competency that also plays an important role in the process of BIM development and adoption. These competencies are very important to facilitate digital transformation and increase the effectiveness of BIM (Zakariyyah et al., 2021).

Digital skills are certainly one of the competencies that need to be possessed by a BIM professional, incorporating digital orientation into the company's vision and mission in the construction industry can encourage BIM adoption (Zakariyyah et al., 2021). Furthermore, professional knowledge also needs to be possessed, this includes specialized knowledge related to BIM and critical thinking skills (Nguyen, 2021).

Competencies related to BIM need to be continuously improved, especially in the future a BIM professional will need BIM certification as a form of their quality assurance (Dao et al., 2020). The need for systematic BIM certification to strengthen the confidence of the construction industry in using BIM SDM (Dao et al., 2020).

Emphasizing the need for a comprehensive skill set that combines technical, managerial and communication skills is important for assessing the level of readiness for BIM implementation (Ariyachandra et al., 2022; Ndwandwe et al., 2024). These BIM-related competencies collectively contribute to the successful implementation of BIM, enabling the utilization of digital technologies to improve project management and execution (Zakariyyah et al., 2021).

When related to the job role of BIM experts, the above skills can refer to several specific roles. Building Information Modeling (BIM) projects typically involve various specialized roles, including BIM Managers, BIM Coordinators, and BIM Modelers (Sampaio et al., 2022; Sampaio et al., 2023; Waqar et al., 2023). A BIM Manager's role is to coordinate all tasks involved in building design (Sampaio et al., 2023), bridging the operational and strategic levels, improving collaboration and communication across different disciplines (Corrêa et al., 2025). The BIM Manager plays an important role in managing ethical and managerial factors, which are critical for effective collaboration in a BIM-based construction network (Oraee et al., 2025), so a BIM Manager needs to have all the capabilities listed in table 2.

Another important role in the BIM cycle is that of BIM Coordinators, who focus on the integration and coordination of the design process, ensuring that all project information is centralized and shared among experts. They are responsible for overcoming interoperability challenges, especially in structural design, by facilitating the two-way exchange of information between different systems (Sampaio et al., 2022). According to the skill information provided in Table 2, a BIM coordinator needs to have at least skill numbers (1), (2), (3), (4), (5), (7), (9), (10) and (11).

BIM Modelers are responsible for creating and managing digital representations of the physical and functional characteristics of buildings. They use advanced modeling software to support 3D visualization, model overlap, and easy accessibility to model databases (Sampaio et al., 2022). Another role is to support the overall BIM process by providing detailed and accurate models that serve as the basis for coordination and collaboration among project stakeholders (Waqar et al., 2023). According to the skill information provided in Table 2, BIM Modellers need to have at least skill numbers (1), (2), (3), (7), (10) and (11).

4. Conclusion

Based on the results of the discussion, it can be concluded that the development and adoption of Building Information Modeling (BIM) is strongly influenced by a country's level of progress, government policies, professional awareness, and educational infrastructure readiness. Developed countries show significant progress in the application of BIM supported by policy initiatives, cross-sector collaboration, and the active role of research institutions. Meanwhile, developing and less developed countries still face challenges in terms of awareness, professional skills, and integration of BIM into the education curriculum. Competence in BIM is a crucial aspect in supporting the digital transformation of the construction industry, encompassing technical, managerial skills, as well as the ability to collaborate across disciplines. Professional roles in BIM projects, such as BIM Manager, BIM Coordinator, and BIM Modeler, require a diverse combination of competencies to ensure effective and efficient BIM implementation.

Nevertheless, this research has a number of limitations that need to be acknowledged. Firstly, the literature coverage used is mostly from countries with strong academic documentation and published internationally, thus allowing for geographical bias. Countries with low levels of BIM adoption or minimal scholarly documentation are likely to be underrepresented. Secondly, most of the studies analyzed are descriptive and perception-based, thus not fully representing the objective conditions in the field quantitatively. Thirdly, there are still limitations in the contextual analysis of sociocultural, economic, and local policy factors that influence the dynamics of BIM adoption in each country.

For future research, it is recommended that a more in-depth comparative study with a contextual case study approach be conducted, as well as expanding data sources from less explored areas. Quantitative and longitudinal approaches are also important to measure changes in BIM readiness over time, and assess the effectiveness of training, policy and professional certification interventions in strengthening overall BIM adoption.

Conflicts of Interest

The authors declare no conflict of interest regarding the publication of the paper.

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