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Barriers to BIM Adoption in Design Practice: A Systematic Review of Developing Countries

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Abstrak_ *Meskipun ada kemajuan yang dibuat dengan integrasi BIM ke dalam industri konstruksi di banyak negara maju, adopsinya masih terbatas di sebagian besar negara berkembang. Studi ini secara sistematis meninjau 56 artikel menggunakan kerangka kerja TOE untuk mengidentifikasi dan menganalisis hambatan kritis yang menghalangi implementasi BIM dalam konteks desain arsitektur. Mengikuti pedoman PRISMA, tinjauan tersebut mengkategorikan hambatan ini menjadi tiga dimensi utama: teknologi, organisasi, dan lingkungan. Hasilnya mengungkapkan bahwa hambatan teknologi yang kritis, seperti tingginya biaya perangkat keras dan perangkat lunak, masalah kompatibilitas dengan alat desain, dan kompleksitas teknis dalam menggunakan teknologi, menghambat inovasi arsitektur dan kemampuan visualisasi. Hambatan organisasi, termasuk profesional terlatih BIM yang tidak memadai, kurangnya kesadaran akan kemampuan BIM, resistensi dalam tim desain dan kurangnya dukungan manajemen, secara signifikan menunda integrasi BIM dalam alur kerja studio desain. Hambatan lingkungan seperti kerangka kerja peraturan yang tidak memadai, kurangnya permintaan klien untuk desain proyek berbasis BIM, dan kolaborasi yang lemah di seluruh konsultan multidisiplin memperlambat adopsi praktik desain digital. Studi ini menggarisbawahi karakteristik yang saling terkait dari hambatan kritis ini, yang membentuk siklus berkelanjutan yang membatasi evolusi praktik desain di negara-negara berkembang. Mengatasi hambatan yang saling terkait ini sangat penting untuk meningkatkan kreativitas desain dan mengintegrasikan BIM ke dalam praktik studio. Penelitian di masa mendatang harus memeriksa varian regional dan strategi pedagogis untuk mengatasi tantangan adopsi BIM dalam konteks arsitektur.*

***Kata kunci**: Praktik desain arsitektur, Adopsi BIM, Kolaborasi desain, Negara Berkembang, Kerangka Kerja TOE.*

Abstract_ Despite the progress made with BIM integration into the construction industries of many developed countries, its adoption remains limited in most developing countries. This study systematically reviews 56 articles using the TOE framework to identify and analyse critical barriers that impede BIM implementation within architectural design contexts. Following the PRISMA guidelines, the review categorizes these barriers into three primary dimensions: technological, organizational and environmental. The results revealed that critical technological barriers, such as the high cost of hardware and software, compatibility issues with design tools, and technical complexities in using the technology, hinder architectural innovation and visualization capabilities. Organizational barriers, including insufficient BIM-trained professionals, lack of awareness of BIM capabilities, resistance within design teams and lack of management support, significantly delay BIM integration in design studio workflows. Environmental barriers such as insufficient regulatory frameworks, lack of client demand for BIM-based project design, and weak collaboration across multidisciplinary consultants slow the adoption of digital design practices. The study underscores the interrelated characteristics of these critical barriers, which form a perpetuating cycle that limits the evolution of design practices in developing countries. Addressing these interrelated barriers is crucial for improving design creativity and integrating BIM into studio practices. Future research should examine regional variances and pedagogical strategies for overcoming the BIM adoption challenges in architectural contexts.

Keywords: Architectural design practice, BIM Adoption, Design collaboration, Developing Countries, TOE Framework.

INTRODUCTION

The construction industry continues to integrate innovative digital technologies to attain its performance ambitions. These tools are expected to enhance efficiency in the project delivery process by fostering interdisciplinary collaboration and performance-based decision-making. Out of the many, Building Information Modeling (BIM) has been acknowledged as one of such revolutionary process-oriented design technologies. BIM's ability to support design iteration has redefined the possibilities of design exploration and delivery (Abbasnejad et al., 2020; Eastman, 2011; Succar, 2009). The design phase of construction has been noted to benefit immensely from the parametric exploration and collaborative visualization that BIM enables (Jasiński, 2021).

This advancement enhances the ability of design professionals such as architects to integrate spatial, geometric and performance data into a shared digital model (Bonomolo et al., 2021). Which is then used to coordinate across disciplines, make informed design decisions and respond to regulatory requirements. For instance, with BIM-integrated tools, architectural design practices can evaluate and refine building forms through daylight analysis as well as energy performance and material efficiency modelling (Ngowtanasuwan & Hadikusumo, 2017; Succar, 2009).

Despite these potential benefits, BIM adoption as a core design tool remains constrained within architectural practices in most developing countries. Significant infrastructural and systemic challenges undermine BIM implementation in their construction industries (Habte & Guyo, 2021; Mahamadu et al., 2019). These challenges limit the potential for performance-based design and integrated collaboration. Thereby reducing the possibility of improving operational efficiency in the industry (Jung et al., 2018).

Developing countries", as used in this context, refer to nations with relatively lower levels of socioeconomic development as evidenced by lower gross domestic product (GDP) per capita and challenges in infrastructure development (UNCTAD, 2021). This typically includes countries across regions such as the Middle East and North Africa, Sub-Saharan Africa, South Asia and parts of South-East Asia, Latin America, and parts of Oceania and Central Asia, where digital transformation in the construction industry remains nascent (Sanford, 2003). These countries are increasingly falling behind in digitally transforming their construction industries as prevailing challenges perpetuate a reliance on conventional practices and outdated tools (Abubakar et al., 2014; Mani et al., 2024). Therefore, BIM's potential for transforming design pedagogy and professional development remains underutilized in these contexts.

Given the important role of the design process in the overall project execution, identifying these barriers is a necessary precondition for the successful implementation of BIM. Numerous studies have sought to understand the barriers to BIM adoption across the construction sector, but relatively few have specifically focused on their implications for architectural design practices. Although these previous studies offer important perspectives on these barriers, they often lack a holistic framework to analyze them.

Through a systematic review, this study utilizes the Technology-Organization-Environment (TOE) framework (Tornatzky et al., 1990), adapted to the project design context, to examine the critical barriers to BIM adoption. The TOE framework provides a structured approach for appreciating technology adoption within organizations. It enables the categorization of identified barriers into three dimensions: Technology-related, Organization-related and Environment-related factors (Baker, 2012). Technological factors relate to access to design-specific BIM tools and platforms and issues of integration with existing architectural design workflows. Organizational factors concern the structure, culture and capabilities of design firms.

On the other hand, Environmental factors include external industry and regulatory factors. The framework's application in this study ensures a comprehensive analysis of the critical BIM adoption barriers and a determination of their collective influence on architectural design practices in developing countries. This perspective is critical for advancing studio practice by offering targeted insights for educators, studio principals and policymakers working to support digital innovation in contexts where digital adoption lags behind global trends.

METHODS

This research employs a systematic literature review (SLR) methodology adhering to the guidelines set forth by the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) framework (Moher et al., 2010) to identify and synthesize critical barriers to BIM adoption in architectural design practices within developing countries. For this study, the SLR ensure a well-organized and repeatable method for synthesizing diverse studies to inform decisions about technology adoption by architectural firms while minimizing bias and improving the reliability of the evidence produced (Denney & Tewksbury, 2013). While barriers to BIM adoption have predominantly been studied in construction management, this review focuses on how design processes, studio workflows and professional practice are affected. It adopts the TOE framework to organize and interpret the findings. The framework provides an organized perspective for understanding the nature of BIM adoption challenges pertinent to architectural firms. The classification of the barriers into technological, organizational and environmental dimensions reflects the operational ecosystem of design firms, which balances design innovation, project delivery demands, organizational workflow and external pressures.

Data Source and Search Strategy

A thorough, structured search was carried out via the SCOPUS database to capture articles relevant to the study. The search queries utilized included: TITLE-ABS-KEY (("Building Information Modeling" OR "Building Information Modeling" OR "BIM") AND ("barriers" OR "challenges" OR "obstacles") AND ("adoption" OR "implementation" OR "integration") AND ("developing countries" OR "emerging economies." OR "low-income countries") AND ("architecture" OR "design process" OR "design studio")). The search was limited to peer-reviewed articles published in English between 2020 and 2024 to ensure that the findings reflect recent advancements and challenges. Articles focusing exclusively on developed countries were excluded to maintain relevance to the study's context.

Inclusion and Exclusion Criteria

To maintain rigour and relevance, all identified articles were subject to predetermined inclusion and exclusion criteria (Table 1). This process aimed to gather studies that provided empirical insights with implications for architectural practice.

Table 1. Criteria for Inclusion and Exclusion

Criteria	Inclusion	Exclusion
Type of Document	Peer-reviewed journal articles with empirical evidence	Dissertations, book chapters, conference proceedings,
Language (s)	Articles published in the English Language	Non-English language articles
Research Focus	Studies examining BIM adoption barriers in developing countries	Studies focused on developed countries or unrelated themes
Publication Date	2020 – 2024	Articles published before 2020

Following duplicate removal, the screening process yielded 285 unique studies that were further refined by the inclusion criteria. Abstracts and full texts were reviewed to ensure relevance. Ultimately, 56 articles were included in the qualitative synthesis.

Eligibility Criteria

The eligibility of the articles was assessed in three stages:

1. Initial Screening: Titles and abstracts were screened to determine their relevance to BIM adoption barriers.
2. Ful-Text Review: full-text articles were evaluated to confirm alignment with the study objectives.
3. Final Selection: articles were included if they provided empirical evidence of barriers specific to developing countries.

The PRISMA diagram (Figure 1) provides a visual outline of the selection process, highlighting the steps from initial identification to final inclusion.

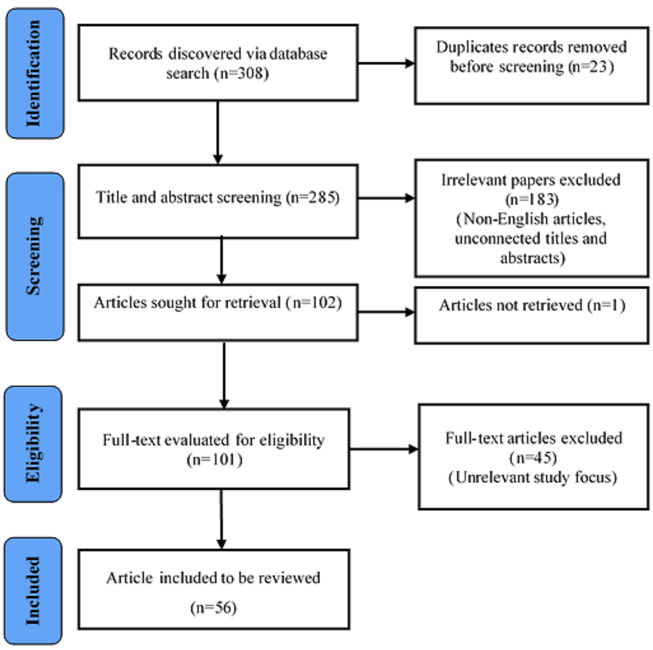

Figure 1. PRISMA process diagram for the study (Moher et al., 2009).

Data Extraction and Analysis

Data related to the articles included were extracted utilizing a standardized Excel-based data extraction form. It captured the following elements: study details (author, year, and country of focus), research methodology, and reported BIM barriers relevant to architectural practice. The

identified barriers were categorized under the TOE framework. Each barrier was coded and ranked using a relative frequency scoring system adapted from Ullah et al. (2021). This system reflected the prevalence and criticality of each barrier across studies.
The list of critical barriers and TOE interpretations were reviewed by one academic expert involved in AEC education and one practicing design professional to ensure they are consistent with current design studio realities.

Limitation

A notable limitation of the study is that the use of English language publications from 2020 to 2024 and peer-reviewed journal articles indexed in the SCOPUS database may have led to the omission of pertinent grey literature, non-English studies, or earlier foundational works that might have offered more in-depth contextual insights. Additionally, most source articles were not focused specifically on design professional practice or firms. Instead, they often addressed BIM adoption in broader industry terms. This review attempts to reinterpret such findings through the perspective of design firms.

RESULTS AND DISCUSSION

This section presents the review's findings, categorized according to the TOE framework, to analyze the barriers to BIM adoption within architectural design practices or firms. The barriers are examined across the technological, organizational, and environmental lenses, enabling an in-depth appreciation of how such interrelated factors hinder BIM adoption efforts. The discussion highlights the frequency with which these barriers are reported, their relative significance within developing countries, and their overall impact on design firms' adoption decisions.

A. Year-wise distribution of publications

The reviewed articles include studies published from 2020 to 2024, with the yearly trend illustrated in Figure 2. The highest volume of publications occurred in 2023, with 17 articles. A steady rise was observed from the preceding years, with 8 articles in 2020 and 11 in both 2021 and 2022, while 2024 had 9 articles published at the time of the database search. While 2024 may not reflect the full total publications within the calendar year, the observed upward publication trend over the period suggests a heightened recognition of BIM. This is driven by a global movement towards post-pandemic digital transformation, particularly in architecture, where hybrid working model parametric tools and real-time cloud-based design collaboration have gained prominence (Bajpai et al., 2023; Silverio et al., 2023).

Notably, the increased attention to BIM is not limited to construction efficiency. It also reflects a renewed academic interest in its implications for architectural design innovation. Recent studies such as El Hajj et al. (2023) and Paneru et al. (2023) highlight a rising focus on performance-based design, visualization and interdisciplinary collaboration, which are particularly relevant in regions with emerging digital design cultures.

For instance, Saka and Chan (2021) and Paneru et al. (2023) highlighted that post-pandemic recovery plans in countries like Nigeria, Vietnam, and Egypt included funding for digital infrastructure and design technologies as priority areas. These initiatives, coupled with government mandates, are accelerating BIM adoption among architecture schools and design firms, where it is gradually being recognized as a design-enabling environment (Charef et al., 2019; Maharika et al., 2020; World Economic Forum, 2020). Thus, the increase in publications reflects not only academic recognition but also institutional and policy-backed digital innovation in reshaping architectural workflows, creativity and collaborative practices, especially in developing countries where these benefits are still emerging (El Hajj et al., 2023; Ullah et al., 2021).

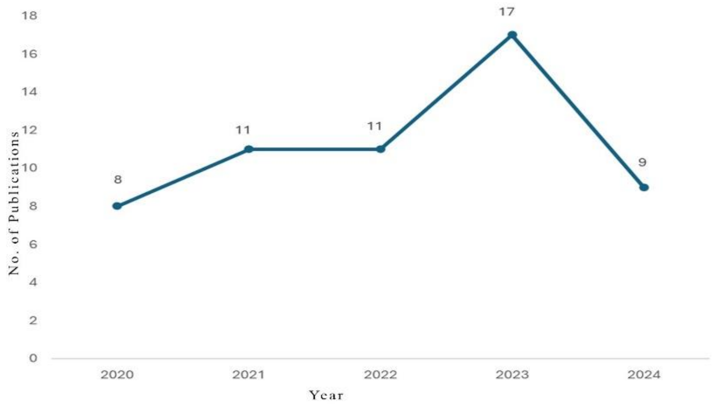

Figure 2. Year-wise distribution of publications

B. Distribution of publications by country

The geographical distribution of BIM-related studies revealed a disparity in representation. As shown in figure 3, Nigeria contributed the highest number of 12 publications, followed by Ethiopia with 6 publications, while countries such as Vietnam, Iraq, China, Seychelles, Turkey, Iran, Malaysia, Ghana, Dominican Republic, and Sri Lanka each contributed 2 studies. Additionally, several other countries, including Cambodia, Brazil, Egypt and India, contributed one study each.

The prominence of countries like Nigeria, Ethiopia, and South Africa reflects research volume and a growing institutional and professional interest in overcoming BIM barriers within the project design practices. Studies by Olugboyega and Windapo (2019) point to active engagement among academic institutions and professional bodies to address infrastructural and skill-based challenges related to BIM utilization in architectural workflows. On the other hand, countries with substantial construction sectors, like Egypt and UAE, appear underrepresented, which suggests a potential research gap.

This disparity also highlights that BIM adoption in architectural practices is evolving at different rates, shaped by local policies, access to training, curriculum integration in architecture schools and client-side digital demand. Recognizing these factors is critical to creating targeted strategies to support BIM diffusion within architectural practices in developing countries.

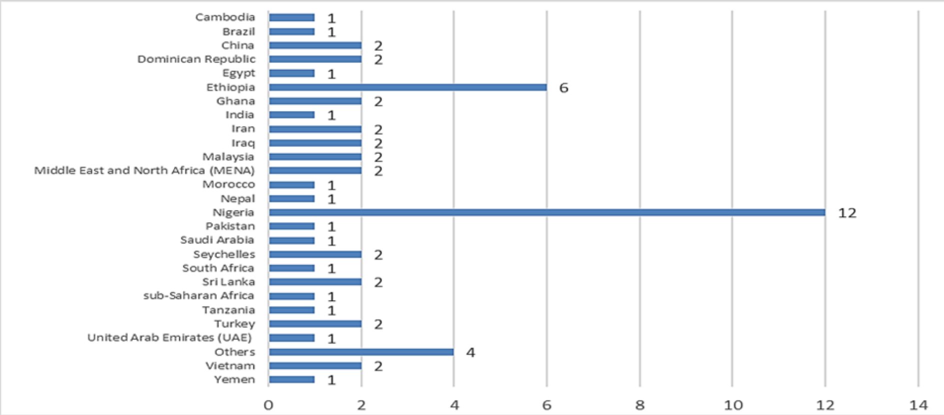

Figure 3. Country-wise distribution of publications

C. BIM adoption barriers

The review of the 56 selected publications revealed various barriers to BIM adoption, which were rationally sorted into 36 distinct items. These identified barriers were categorized under the three dimensions of the TOE framework: technological, organizational, and environmental, as summarized in Table 2. To determine the critical barriers, the researchers considered the frequency (F) with which an identified item appeared in multiple studies and the count of studies that classified each item's impact as high (C-h = 5), medium (C-m = 3), or low (C-l = 1).

Total Rating (TR) = (C-h x 5) +(C-m x 3) +(C-l x 1)
Score (Sc.) = F+TR
Relative Score (R.S.) = Score/ Total Classification Score

The total ranking (TR) was determined by multiplying each count by its assigned value and thereafter summing the resulting values. The score (Sc.) for each barrier was then calculated by summing the frequency of the barrier with its respective overall rank. The relative scores (R.S.) were calculated to rank the most critical barriers identified in the literature by dividing each barrier's score by the total score of its categorization. Using the *"High cost of hardware and software"* as an example:

Total Rating (TR) is computed using the formula:

TR = (C-h x 5) +(C-m x 3) +(C-l x 1)

Substituting the values

TR = (19 x 5) +(19 x 3) +(4 x 1)
= 95 + 57 + 4
= 156

Score (Sc.) is obtained by summing the frequency (F) with the Total Rating:

Sc. = F + TR
= 42 + 156
= 198

Relative Score (R.S.) is then calculated by dividing the score by the sum of all scores for the category. For example, the sum of all Sc. values across all Technological barriers is 560, we compute:

R.S. = 198/560
= 0.35

This procedure was repeated across all identified barriers in each category. Cumulative relative scores (CRS) were calculated, and barriers were flagged as "critical" till the CRS crossed 50 (Ullah et al., 2021). Thus, barriers contributing to more than half of the category score were treated as critical. This ensures analytical consistency and focus on the most impactful challenges affecting BIM adoption in architectural practices across developing countries.

Table 2. The classification of barriers to BIM Adoption in developing countries based on the TOE framework

Classification	BIM Barriers	Code	F	Rating			TR	Sc.	R.S.	C.RS
				C-h	C-m	C-l				
	High cost of hardware and software	TB1	42	19	19	4	156	198	0,35	0.35
	Compatibility Issues	TB2	37	14	18	5	129	166	0,30	0.65
	Complexities in using the technology	TB3	14	8	6	0	58	72	0,13	0.78
Technological	Data security, integration, and management concerns	TB4	14	2	10	2	42	56	0,10	0.88
	Lack of technical support on accessibility and use of BIM	TB5	11	4	5	2	37	48	0,09	0.96
	Limited trialability of the technology	TB6	4	2	2	0	16	20	0,04	1.00
	Lack of skilled BIM personnel in organizations	OB1	33	18	12	4	130	163	0,15	0.15
	Lack of awareness of the BIM benefits	OB2	35	14	16	5	123	158	0,14	0.29
	Resistance to change	OB3	32	12	16	4	112	144	0,13	0.42
	Lack of top management support	OB4	26	14	10	2	102	125	0,11	0.54
	Organizational transition challenges (Readiness)	OB5	23	9	11	4	82	105	0,10	0.63
	Cost of training and development of staff	OB6	23	9	11	4	82	105	0,10	0.73
	Satisfaction with the existing process	OB7	14	9	4	2	59	73	0,07	0.79
	Insufficient financial resources of the organization	OB8	9	5	4	0	37	46	0,04	0.83
	Inadequate organizational IT infrastructure	OB9	5	4	1	0	23	28	0,03	0.86
Organizational	Perceived Risk	OB10	5	4	1	0	23	28	0,03	0.89
	Lack of motivation to use BIM technology	OB11	5	3	2	0	21	26	0,02	0.91
	Lack of framework for selecting a BIM platform	OB12	5	3	1	1	19	24	0,02	0.93
	Lack of organization's desire for innovation to stay competitive	OB13	4	2	2	0	16	20	0,02	0.95
	Lack of organizational trust in new technology	OB14	4	2	1	1	14	18	0,02	0.97
	Absence of stakeholder cooperation and coordination	OB15	4	2	0	2	12	16	0,01	0.98
	Rigid organizational structure and work culture	OB16	3	1	2	0	11	14	0,01	0.99
	Challenges in recruiting BIM specialists/staff.	OB17	2	0	2	0	6	8	0,01	1.00
	Lack of government regulations and R&D support.	EB1	42	19	18	5	154	196	0,17	0.17
	Lack of Client demand	EB2	35	18	13	4	133	168	0,15	0.32
	Lack of industry stakeholder collaboration	EB3	33	11	18	4	113	146	0,13	0.45
	Lack of BIM education, training, and research	EB4	26	13	9	4	96	122	0,11	0.55
	Contractual and legal issues	EB5	26	9	15	2	92	118	0,10	0.65
Environmental	Lack of Industry standards and rules (Normative pressure)	EB6	23	9	12	2	83	106	0,09	0.75
	Legal liability, copywrite, and risk	EB7	19	9	9	1	73	92	0,08	0.83
	Lack of Industry BIM Champions	EB8	14	7	7		56	70	0,06	0.89
	Lack of ICT infrastructure	EB9	11	4	5	2	37	48	0,04	0.93
	Lack of competitive pressure (Market dynamics)	EB10	9	4	5	0	35	44	0,04	0.97
	Data exchange concerns (safety and privacy)	EB11	4	2	1	1	14	18	0,02	0.98
	Technology Vendor's direct influence and support	EB12	5	0	4	1	13	18	0,02	1.00

D. Technological Barriers

The reviewed studies frequently highlighted technological barriers intrinsic to the tools and platforms supporting BIM technology. They emphasized how these barriers impact the adoption process in developing countries. Among these, the "high cost of hardware and software" emerged as the most critical barrier, as reported by 42 of the reviewed articles. Omar and Dulaimi (2021) emphasized the significant initial capital investment required for BIM tools such as Autodesk Revit, ArchiCAD or Bentley Systems within the construction industry in the UAE. Along with the recurring expenses associated with such software upgrades and hardware maintenance, the financial burden is especially impactful on small and medium-sized architectural design firms in most developing countries. For instance, Adekunle et al. (2020) highlighted that the substantial investment required for BIM software and hardware frequently discourages design studios from transitioning to BIM. Most architectural design firms in developing countries lack the financial resources needed to obtain the technology and training required for effective integration of BIM in project design workflows. In most cases, the associated cost of BIM integration is not factored into the project budget. And as such, it becomes the responsibility of the design firms that choose to use the technology. Babatunde, Perera, et al. (2021) observed that limited project budgets worsen this challenge for smaller firms in Nigeria. As a result, some firms resort to using pirated software, which often lacks full functionality and undermines proper BIM integration into project design workflow. The limited functionality may make exploring and refining design solutions harder as it restricts iteration. Hence, the potential benefits are not wholly derived. Even for design firms that adopt BIM, collaboration with other professionals becomes difficult due to the lack of adoption by the entire construction ecosystem. Charef et al. (2019) highlight that subsidies, tax incentives and mandatory BIM policies often mitigate cost barriers in developed countries. However, many developing countries lack such financial support mechanisms for the construction industry. Addressing this challenge may require targeted government interventions through subsidies or financial assistance programs to make BIM tools more accessible for SMEs (Al-Sarafi et al., 2022).

"Compatibility issues," cited in 37 studies, represented another critical technological barrier (Al-Sarafi et al., 2022; Okwe et al., 2022; O. Olugboyega & A. O. Windapo, 2022; Van Tam et al., 2023). These issues often arise from the lack of standardization across BIM software platforms. This particularly occurs when architects and engineers use different BIM tools that do not always support seamless information sharing. This challenge hinders interoperability between various tools and stifles collaboration among project stakeholders. Babatunde, Udeaja, et al. (2021) argue that such challenges are especially severe in developing countries, where limited resources hinder access to advanced integration solutions. Moreover, compatibility issues extend beyond technology integration. It includes the alignment of BIM with existing design workflow practices and tools within the industry. In many developing countries, traditional construction processes remain deeply entrenched. For instance, O. Olugboyega and A. Windapo (2022) observed that design firms in Nigeria struggle to align BIM workflows with their conventional design-bid-build processes, which frequently lack the collaborative framework essential for BIM implementation. BIM-implementing design firms may regularly have to convert BIM outputs into traditional formats like 2D CAD for the non-BIM using consultants or contractors. This disrupts the digital design workflow and results in updates that increase the risk of design variations and reworks.

Additionally, the compatibility issues limit the ability of design professionals to simulate BIM models for energy and sustainability performance (Li et al., 2020). Generally, the construction industry in developing countries needs to be supported by strong policy frameworks for software solutions that integrate seamlessly with existing practices. Funda and Kahvecioğlu (2022) assert that addressing BIM compatibility issues could result in shifts in design practices by encouraging creativity and design quality.

The "complexity of using the technology," as reported in 14 studies (Al-Hammadi & Tian, 2020; Belay, Goedert, Woldesenbet, Rokooei, et al., 2021; Saka & Chan, 2020; Toyin & Mewomo, 2023), also appeared as a notable barrier. Despite not emerging as critical per the analysis criteria, it is being discussed here because of its impact on user attitudes towards adoption. Al-Mohammad et al. (2022) suggest that architectural practices sometimes cannot adjust their work practices to BIM because of the apparent complexities associated with it. It is argued that the perceived steep learning curve associated with mastering BIM discourages many design firms from its adoption. Small and medium studios, in particular, are assumed to often lack the in-house expertise to manage such complexities. This makes them reliant on external support, which may not be readily accessible or cost-effective (Saka & Chan, 2020). Belay, Goedert, Woldesenbet and Rokooei (2021) emphasized that firms in Ethiopia assume BIM to be complex due to limited access to training resources, a challenge that is all too familiar in other developing countries. A key factor to this barrier is the hesitance of software vendors to perceive developing countries as profitable markets (Saka & Chan, 2020). Consequently, these vendors fail to provide localized technical support, training programs and user-friendly adaptation of their tools for these regions. The absence of vendor support in most of these countries constrains design firms and limits their capacity to utilize the full capability of BIM. Training programs, potentially funded by government agencies and tailored to the needs of these firms, alongside accessible user support from software vendors, could help overcome this barrier.

E. Organizational Barriers

Organizational barriers, which pertain to the internal structure, culture and capabilities of design firms, were consistently acknowledged as significant impediments to BIM adoption in developing countries (Girginkaya Akdag & Maqsood, 2020; Marzouk et al., 2022; Zakeri et al., 2023). Among these, the "lack of skilled BIM personnel in organizations" highlighted in 33 studies was the most frequently reported. This skills gap is particularly manifested in countries where educational institutions have yet to integrate BIM training into curricula. In most instances, BIM is introduced late in the curriculum, if at all, and often treated as a technical skill rather than a design-integrated tool (Kocaturk & Kiviniemi, 2013; Maharika et al., 2020; Özkoç et al., 2021). This limits its integration into early-stage design thinking and reduces graduates' readiness to apply BIM effectively in practice (Laovisutthichai et al., 2023). Design firms that adopt BIM in such contexts are compelled to invest extensively in training courses, which may be expensive and time-consuming. Many of these firms either delay or forgo BIM adoption due to the lack of internal BIM-skilled design professionals. For instance, Girginkaya Akdag and Maqsood (2020) identified a link between the slow adoption in Pakistan and the lack of industry professionals skilled in BIM processes. Similarly, Marzouk et al. (2022) emphasized the absence of training programs adapted to the distinct requirements of organizations in developing countries. This deficiency contributes to the widening competency gap and reflects a broader regional issue. It creates a sequence of low adoption and inefficient design workflow due to the lack of capacity to utilize the full functions of BIM tools. Bridging this gap will require a concerted effort between academia and industry to develop tailored training programs.

"Lack of awareness of BIM's benefits" (Amade et al., 2024; Durdyev et al., 2021; Weerasinghe et al., 2023) emerged as the second most critical organizational barrier, reported in 35 studies. Most design firms in developing countries often lack sufficient knowledge about how BIM improves accuracy, efficiency and collaboration. According to El Hajj et al. (2023), industry practitioners in the Middle East and North African region exhibit considerable uncertainty about the applications and benefits of BIM. Which, in effect, results in their reluctance to embrace the technology. Likewise, Omar and Dulaimi (2021) found that insufficient awareness about BIM's potential directly correlates with the low adoption rates in the UAE. This finding highlights the need for targeted educational campaigns and accessible case studies that demonstrate BIM's value in practical, reliable contexts. A strong direct correlation may exist between increased awareness and motivation to implement BIM. Hence, improving knowledge-sharing platforms and integrating BIM into industry discussions could catalyze greater adoption (Maharika et al., 2020).

"Resistance to change" (Omar & Dulaimi, 2021; Qin et al., 2020) was another critical organizational barrier reported in 32 studies. This challenge is often rooted in organizational disinterest, characterized by resistance among employees to shift from established traditional workflows. Aziz and Zainon (2022) observed that in Malaysia, resistance was particularly pronounced among older professionals, who perceived BIM as disruptive and challenging to learn. Fears of job redundancy or diminished authority often accompany this reluctance. Marzouk et al. (2022) reported similar findings in Egypt, where resistance among key decision-makers significantly hindered the scalability of BIM adoption. Architectural firms continue to rely on traditional 2D CAD tools simply because they are familiar and considered adequate. Overcoming this barrier requires robust change management strategies that focus on incremental adoption, clear communication of BIM's benefits, and active involvement of employees at all levels in the transition process.

Another significant organizational barrier was the "lack of top management support" (El Hajj et al., 2023; Tan & Gumusburun Ayalp, 2022), cited in 23 studies. Leadership buy-in plays a pivotal role in driving organizational change, as it determines the allocation of resources and prioritizes strategic initiatives. Thus, architectural firms usually do not invest in BIM if their management does not see the value. Tan and Gumusburun Ayalp (2022) highlighted that weak management support in the Turkish construction industry hindered BIM implementation efforts. Similarly, Omar and Dulaimi (2021) noted that a lack of decisive leadership limited organizational readiness for BIM adoption in the UAE. This barrier is prominent in small and medium-sized architectural firms, which dominate the construction industry in many developing countries. According to Saka and Chan (2020), the decision-making process in these firms often rests with a single entrepreneur or a small group of leaders who may lack the vision or resources to invest in BIM. Employees under such circumstances feel unsupported and uncertain about using such new technologies. Comparatively, in developed countries, leadership support is driven by government incentives, industry mandates, and exposure to successful BIM implementation (Jiang et al., 2022). Encouraging top management to champion BIM adoption requires targeted initiatives such as awareness campaigns, leadership training, exposure to successful case studies and policy-driven incentives.

These barriers highlight the importance of cultivating an organizational culture that prioritizes innovation, adaptability and continuous learning.

F. Environmental Barriers

Environmental barriers affect an organization's capacity to adopt and implement BIM. These barriers often stem from systemic issues, such as regulatory gaps, insufficient market demand and weak stakeholder collaboration, which collectively constrain adoption efforts.

The "lack of Government regulations and R&D support" emerged as the most critical barrier within this category, as evidenced by various studies (Al-Sarafi et al., 2022; Olanrewaju et al., 2020;

Zakeri et al., 2023). El Hajj et al. (2023) observed that North African governments have largely neglected BIM adoption, as they have not implemented policies or standards that mandate its use. This observation reflects a broader trend in developing countries, where governments have yet to prioritize the promotion of BIM through regulations and incentives. For instance, Marzouk et al. (2022) reported that in Egypt, limited government involvement has led to minimal impacts on BIM adoption decisions, compelling firms to rely solely on their internal motivations. Similarly, Saka and Chan (2020) observed that throughout Nigeria, the primary driving force behind BIM adoption largely stems from individual organizations rather than being influenced by external mandates. Governments' critical role in accelerating BIM adoption by establishing clear standards, providing incentives such as tax breaks and supporting R&D. is underscored by this (Fang et al., 2023; Paneru et al., 2023). For example, in the United Kingdom, the government's 2016 mandate requiring BIM on public projects created significant momentum, resulting in widespread industry adoption. Although government mandates for BIM are not yet universal in the UAE, Omar and Dulaimi (2021) found that firms expressed a strong willingness to adopt BIM if mandated. This suggest that regulatory pressure could play a crucial role in facilitating adoption. Such interventions may create a favorable environment for adoption and reduce financial and operational barriers for SMEs.

Another critical environmental barrier identified was the "lack of client demand for BIM use", as noted in 35 studies (Omar & Dulaimi, 2021; Paneru et al., 2023; Saka & Chan, 2021). Clients in many developing countries, both public and private, remain unaware of BIM's potential to improve project outcomes. Al-Hammadi and Tian (2020) identified the absence of client demand as the most significant obstacle to BIM implementation in Saudi Arabia, leading contractors and consultants to hesitate in adopting BIM. In contexts where clients are key drivers of construction projects, their failure to demand BIM deliverables discourages architectural firms from adopting it in their design workflow. It is often overlooked in favor of the traditional CAD workflows, which are already familiar. However, in developed countries like Australia and the UK, client demand for BIM is often driven by government-led awareness campaigns and mandated standards, ensuring its integration into projects (Lindblad & Guerrero, 2020). Raising client awareness through targeted campaigns and showcasing successful BIM applications could help shift perceptions and create demand in developing countries.

The "lack of industry stakeholder collaboration" (Aziz & Zainon, 2022; El Hajj et al., 2023; Saka & Chan, 2021) was recognized as the third most critical environmental barrier. Effective BIM adoption requires seamless collaboration across various disciplines in the construction value chain. However, many developing countries struggle with fragmented industry practices. Marzouk et al. (2022) noted that in Egypt, while intra-organizational BIM processes have improved, inter-organizational collaboration remains limited. The main benefits of BIM are not attained when stakeholders such as architects, engineers, contractors and clients do not collaborate on the same platform. Girginkaya Akdag and Maqsood (2020) observed that in Pakistan, architects with BIM expertise face challenges in applying their skills due to the lack of complementary competencies among other project professionals. This forces architectural firms to revert to traditional 2D CAD methods just to maintain standardization. Adam et al. (2021) and O. Olugboyega and A. Windapo (2022) admonish developing countries to prioritize initiatives that foster collaboration, including joint training programs, industry forums, and stakeholder partnerships.

The "Lack of BIM education, training, and research," as reported in 26 studies (Aziz & Zainon, 2022; Durdyev et al., 2021; Paneru et al., 2023; Toyin & Mewomo, 2023) emerged as the fourth most critical environmental barrier. This barrier often leads to a shortage of skilled professionals and a limited understanding of BIM benefits. Adam et al. (2021) highlight the important role education plays in BIM knowledge dissemination. They contend that when universities and technical institutions fail to incorporate BIM into their curricula, graduates enter the workforce ill-prepared to use modern technologies and workflows. For instance, Okwe et al. (2022) cite training deficiencies as an obstacle to BIM adoption among design professionals in Nigeria's construction industry. Without such training, industry professionals often perceive BIM tools as being complex and difficult to implement. This discourages architectural firms from continuing the adoption process as they struggle to develop the necessary competencies required to implement BIM effectively. Hence, Özkoç et al. (2021) propose a BIM integration model for architectural education aimed at facilitating a culture of BIM adoption. They contend that embedding BIM principles and practices in curricula is essential for fostering widespread adoption. Additionally, opportunities for continuous professional development are limited in most developing countries (Durdyev et al., 2021). Because of this industry professional such as architects and engineers who want to upskill may find very few accessible training and certification programs available. Another issue is the lack of adaptation of BIM workflows and software to fit local construction practices. The lack of research results in firms not having access to localized knowledge that could help them transition to BIM effectively. In order to encourage and promote widespread and effective BIM integration in the construction industry, it is important for developing countries to strengthen core foundational elements of BIM education, training and research (Maharika et al., 2020).

CONCLUSION

The study underscores the role played by technological, organizational, and environmental factors in influencing the BIM adoption decision of architectural firms in developing countries. Isolated independent efforts by individual architectural firms to adopt BIM, as is the case in most contexts, are likely not insufficient without greater support from industry stakeholders and regulatory bodies.

Technological barriers such as high implementation costs, compatibility issues, and complexity of use indicate a wider systemic challenge requiring coordinated solutions. Small and medium-sized design firms would be relieved to benefit from government interventions that provide support in the form of financial assistance or subsidies. Furthermore, there is a need for standardized frameworks that promote the integration of BIM with existing design workflow practices and foster multidisciplinary collaboration. With accessible and affordable training programs, architectural firms could overcome the perceived complexity and steep learning curve associated with BIM use. Such efforts could further be reinforced by localized technical support from software vendors.

The significance of fostering an innovation-oriented culture within architectural firms is underscored by organizational barriers such as the skills gap, resistance to change, and lack of management support. To this end, bridging the BIM skills gap through academia-industry collaboration and targeted training programs is very crucial. Structured change management strategies coupled with active engagement of personnel could help address the resistance to change. Additionally, leadership commitment, vital for resource allocation and strategic prioritization, must be strengthened through targeted BIM awareness campaigns and incentives.

The importance of external stakeholders such as government agencies and industry clients is underscored by the environmental barriers. The absence of regulatory frameworks, inadequate client demand, and fragmented stakeholder collaboration substantially impede widespread BIM adoption by architectural practices. Policy-driven mandates and government incentives appear essential in creating a conducive regulatory environment. Similarly, initiatives designed to increase client awareness of BIM benefits can substantially increase demand and industry competitiveness to deliver projects with BIM.

In essence, addressing these barriers would likely accelerate effective BIM implementation by architectural firms. Thus, yielding substantial improvements in design efficiency and overall project outcomes across developing countries. In order to understand context-specific barriers and enablers to BIM adoption, future studies should examine regional variances and pedagogical strategies for overcoming the challenges in architectural contexts.

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