**Perceived Barriers to Implementing Building Information Modelling in Iranian Small and Medium-Sized Enterprises (SMEs): A Delphi Survey of Construction Experts**

# Abstract

Building information modeling (BIM) is a disruptive information technology tool in the construction sector. Although this technology had a significant impact on the manufacturing industries, it, like any other technology, encountered several challenges when applied to the construction sector. Conversely, small and medium-sized enterprises (SMEs) in developing economies often face significant impediments when using innovative technologies. Thus, this paper seeks to determine and investigate the perceived barriers to applying BIM in construction SMEs based in Iran. Three rounds of Delphi surveys were carried out with 15 BIM experts engaged in construction SMEs to identify the key barriers to BIM implementation in SMEs. An empirical survey questionnaire comprising these identified barriers was subsequently designed and disseminated to the invited experts. Altogether, 56 valid survey responses were received and analyzed. The study’s findings revealed SMEs management’s hesitancy to adopt BIM, stakeholders’ reluctance to change their established methods, and a lack of technical understanding as the critical impediments to BIM adoption in construction SMEs. Also, the study identified four barrier dimensions – technology, legal, management, and financial. These BIM implementation barrier dimensions can be employed to better allocate resources and financing for BIM deployment and construction innovation in SMEs. The study will assist major project stakeholders and SMEs make better-informed BIM adoption decisions, particularly in developing nations like Iran.

**Keywords**: Barriers; Building Information Modeling (BIM); Construction Industry; Delphi Survey; Small and Medium-Sized Enterprises (SMEs).

# 1. Introduction

The construction industry is a global economic pillar and a considerable contributor to the annual income of most nations. Some emerging countries devote more than 70% of their annual revenue to construction and infrastructure projects (Chan et al., 2019). While the advancement of civil projects is becoming significantly more complex to manage (Asgari Siahboomy et al., 2021), the construction sector has always been popular because of its reticence to accept novel ideas (Arashpour et al., 2016). The interconnection of many project parties, such as financial institutions, officials, and construction project suppliers, adds to its complexity (Sears et al., 2008). Furthermore, according to Azhar et al. (2008), the construction sector has begun to utilize practices that lower project costs, boost productivity and quality, and shorten project duration. However, as information and communication technology (ICT) advances, it has helped tackle these issues by providing a more decisive solution to the complexities of project processes, time, and cost (Olawumi et al., 2020).

In the past decade, some disruptive technologies have been introduced to the construction industry which include: BIM (Khoshfetrat et al., 2022), blockchain (Hamledari & Fischer, 2021), RFID, robotics (Pan & Pan, 2019), augmented reality (Meža et al., 2015), and the like. BIM has been adopted in more construction projects than other technologies (Jung & Lee, 2015) and is a key part of technological growth in the construction sector (Preidel et al., 2016). It can help address construction industry challenges by facilitating the sharing of construction information, data, and models among project stakeholders (Won et al., 2013). BIM is a digital representation of a building’s physical and functional elements, a knowledge repository, and an accountable platform for decision-making throughout its life cycle. (Eastman et al., 2011; Jayasena & Weddikkara, 2012). Also, design conflicts (Chahrour et al., 2021), a lack of stakeholder cooperation (Cao et al., 2015), poor information flow (Olawumi & Chan, 2018), and other issues plaguing the planning, development, and management of buildings and infrastructure can all be mitigated with the use of building information modelling (BIM). In addition, BIM adapts to the dynamic nature of the construction industry in order to handle the issues and complexities of employer requirements.

However, due to the interdisciplinary nature of construction projects, clear communication and good collaboration among project team members are required, and BIM plays an important role in facilitating these procedures (Sarvari et al., 2020). Nevertheless, despite the various benefits of BIM application, construction firms do not universally accept BIM, and there is a significant acceptance gap between large and small organizations (Ayinla & Adamu, 2018; Van Dijk, 2006). Large and small businesses face a variety of economic, structural, and cultural difficulties. Also, SMEs’ BIM deployment and uptake lag behind large firms (Poirier et al., 2015). Due to their average financial strength and capacity to execute as many projects as feasible simultaneously, SMEs adopt digital tools slowly and resist innovation – which in turn negatively impacts their project and organization as a whole (Sexton & Barrett, 2004). However, studies show that SMEs form more than 90% of construction businesses in most countries, making the adoption of BIM in SMEs essential to promote BIM in the architecture, engineering, and construction (AEC) industry (Dainty et al., 2017; Shelton et al., 2016). As a result, a rise in BIM adoption by SMEs will lead to a higher overall adoption rate, which could have far-reaching effects.

For instance, over 75% of construction SMEs in the United Kingdom have not implemented BIM, and other nations such as Australia, Sweden, and others are confronting a similar problem. (Saka & Chan, 2020). Some of the reported barriers to SMEs’ failure to adopt in the UK, Australia and Sweden are generally related to lack of government support, inadequate BIM knowledge, lack of client demand, high implementation cost, lack of in-house demand and skillset and lack of supply chain buy-in (Bataw et al., 2014; Bosch-Sijtsema et al., 2017; Ghaffarianhoseini et al., 2016).

Studies in developing economies indicate that these barriers to technological adoption, particularly those related to BIM, have a greater impact. These barriers include a lack of awareness and government support (Migilinskas et al., 2013; Saka et al., 2020a), hesitation to invest, and a lack of operational guidelines for BIM implementation (Olawumi & Chan, 2020). The prevalence of SMEs in the construction industry and the fact that these constraints stifle innovation in the industry as a whole necessitate rethinking these issues. Successful BIM deployment in small and medium-sized construction firms (SMEs) in developing nations requires identifying and evaluating these barriers (Shelton et al., 2016).

Although studies have explored barriers to BIM adoption in other contexts, such as Hong Kong (Chan et al., 2019), they did not focus explicitly on SMEs. In contrast, Ghaffarianhoseini et al. (2016) and Vidalakis et al. (2020) studies focus on SMEs in the United Kingdom. In Iran, which is the focus of this study, no previous research identifies the critical impediments to BIM adoption among Iranian construction SMEs. With a thorough grasp of these obstacles, decision-makers in SMEs, the government, and other relevant institutions will be well-versed in the fundamental barriers to BIM adoption and its practical implications.

Given these gaps in the existing literature and practice, this research aims to identify and investigate the key barriers and challenges of using BIM in small and medium-sized construction firms (SMEs) in Iran, a developing country. Hence, the scope of the study is delimited to Iran and construction SMEs. During the study, two important questions will be addressed:

1. What are the key barriers to implementing BIM in construction SMEs?
2. What are the core dimensions to which the identified barriers could be categorized and prioritized?

This study is relevant because BIM acceptance and implementation can be bolstered through increased uptake by construction SMEs, resulting in productivity and efficiency gains for the construction industry. With a lexicon of significant barriers, SMEs and other relevant stakeholders can establish policies to address them, and the developed barrier categories can serve as an allocative function for SMEs and policymakers to devote resources toward enhancing BIM implementation in the built environment and enhancing overall sector innovation. In addition, the study findings can help governments support the private sector in developing BIM technology and help SMEs make more informed decisions on implementing BIM in their projects.

 Next, this paper explores BIM adoption in Iran, defines SMEs, and identifies barriers to BIM implementation in construction SMEs. After that, the research methodology and results are discussed. The study concludes with practical implications.

# 2. Review of Relevant Literature

## 2.1 Defining Small and Medium-Sized Enterprises (SMEs)

SMEs have different definitions across countries (Zubair et al., 2020). Nonetheless, despite these variances, such construction organizations share certain features. Table 1 presents the staff number and total cash flow of corporates in developed and developing contexts. According to the literature, the most popular criterion for identifying SMEs is the number of employees. Other criteria include total capital, total assets, annual cash flow or sales, and form of ownership. Given these, SMEs and large construction firms operate in two distinct worlds, as evidenced by the specific characteristics of SMEs.

Since SMEs and major construction enterprises are so different, it would be impractical to provide a single technique for comparing their performance in the market, especially because SMEs are a vital part of the economy and will shape the construction industry’s future (Shelton et al., 2016). Although construction SMEs differ, comparable results are achievable despite differences in business formations, guiding their strategies towards new business paths (Saka & Chan, 2022a).

[Insert Table 1]

SMEs play a vital role in the industrial development of developed and developing countries in the present global economy. They are involved with the most dynamic enterprises in the global economy and play a crucial role in the growth of any nation (Naradda Gamage et al., 2020). According to recent evidence, SMEs account for 90 per cent of ventures and employ about 60 per cent of the labor force in the world (Munro 2013). Hence, SMEs’ contribution to poverty alleviation and sustainable economic growth is decisive (Asare et al. 2015; St-Pierre et al. 2015). Economic globalization has created challenges for SMEs due to the rapid increase in competition (Naradda Gamage et al., 2020). Consequently, SMEs have a high failure rate in the early stages of their operations. As a result, SMEs must employ survival tactics and strategic approaches to successfully address the myriad global problems the SME sector is currently facing (Naradda Gamage et al., 2020).

## 2.2 Iran’s Construction Industry Development

The construction industry is regarded as one of the essential pillars of any global economy. This industry is significantly more important in developing nations like Iran. The construction industry is one of Iran’s largest economic sectors, accounting for about 40% of the annual investment in the past years (Fazeli et al., 2020). The Iranian construction sector contributes about 5% of Iran’s gross domestic product, and 12-13% is indirectly related. This significant amount of investment shows the prominent position of the construction industry in Iran’s economic and social programs. This is even though Iran’s manufacturing industry has been struggling with low productivity for many years (Zare & Khosravi, 2020). Also, numerous Iranian building projects are plagued by cost overruns and protracted delays (Heravi & Mohammadian, 2021) to the extent that achieving project goals without delay and according to the schedule is a herculean task. Disputes and conflicts are also prevalent in Iran’s construction industry (Abbasi et al., 2020). The most critical causes of delays in construction projects in Iran are “inadequate data collection”, “inflation rate”, and “rework”, respectively (Heravi & Mohammadian, 2021). A significant shift in fundamental presumptions is necessary to take into account the important indicators of construction performance using emerging techniques and technologies because of Iran’s construction industry’s low productivity and widespread dispersion (Khanzadi et al., 2020).

SMEs in developing countries often lack adequate market protection. They are constantly exposed to shocks that have always been a feature of some emerging economies such as Iran (Tavassolirizi et al., 2022). According to estimates, 75% of all commercial construction firms in Iran are SMEs, and 63% of the workforce is employed in the private sector, while their share of added value is approximately 30% (Jalali et al., 2013). In the global construction business, the failure rate of SMEs is generally higher than that of large firms, and Iran’s construction industry is not an exception (Sarvari et al., 2021). As a result, SMEs in Iran are attempting to stay in the market and thrive by strengthening their competitiveness metrics (Farhikhteh et al., 2020). Given that the majority of studies on SMEs in Iran have only focused on innovation and the role of information technology among the country’s SMEs, the high rate of competitiveness among SMEs in the country is likely the most significant factor that contributed to innovation having the highest rate among the dimensions of entrepreneurial orientation (Jalali et al., 2013).

The construction process has evolved over the last few decades, and the project management process is becoming more complex by the day (Khanzadi et al., 2020). This issue is exacerbated in developing countries like Iran, which struggle with low productivity, frequent cost overruns, and chronic delays in construction project completion (Ghoddousi et al., 2015). This is primarily due to the prevalence of old practices and a failure to recognize the benefits of information and communication technology in Iran’s construction enterprises (Hosseini al., 2016a). Construction cost reduction is acknowledged as a vital factor in the construction industry’s turnover. It appears to be even more crucial for Iran’s scenario, given that the country’s construction sector has low profitability and a high failure rate due to issues with client payment. It is significant to construction businesses (Khanzadi et al., 2020).

Studies show that 30% of construction firms in Iran are involved in the initial levels of BIM adoption, while 57% have not yet taken steps to adopt BIM, and 36% of construction organizations even plan to adopt BIM shortly (Hosseini al., 2016a; Khanzadi et al., 2020). Despite considerable increases in the level of awareness among Iran’s construction industry specialists and evidence of the benefits of employing BIM technology around the world, the adoption of this technology in Iran is far below its current potential, particularly during the construction phase.

## 2.3 Barriers and Challenges to the Implementation of BIM in Construction SMEs

The widespread use of Building Information Modeling (BIM) technology over the past few years has prompted researchers from a wide range of disciplines to examine many aspects of BIM, including the factors crucial to its successful deployment, mitigation of implementation risks, and wider applications (Chan et al., 2019; Khoshfetrat et al., 2022; Asgari Siahboomy et al., 2021). Due to the novelty of this technology in the construction sector, the identification and examination of its implementation barriers (Kassem et al., 2012; Stanley & Thurnell, 2014; Zhou et al., 2019; Chan et al., 2019) has been a popular field of interest for researchers in recent years. Some studies have also sought the root of these issues and constraints in governance, legal, and administrative factors. For example, Li et al. (2019) identified six major challenges in implementing BIM in SMEs in China’s construction industry: (i) SMEs’ lack of resources, (ii) collaboration challenges, (iii) lack of awareness of BIM, (iv) legal disputes and uncertainty in policies, (v) difficulties in meeting the needs of SMEs and (vi) concerns about data and information. This research has highlighted the legal differences and policies compared to other cases.

Zhou et al. (2019) described governments’ lack of financial and legal support as the main obstacles to implementing BIM in infrastructure projects while examining Chinese construction projects. Meanwhile, Saka and Chan (2020a) study on BIM implementation in Nigeria found that despite the government's support, prohibitive cost, lack of financial resources, and a lack of managerial knowledge were the main obstacles. They suggested that SMEs could overcome these obstacles by focusing more on deploying their organizational resources and accepting and implementing BIM technology (Saka & Chan, 2020b). Also, Bataw et al. (2014) highlighted that implementing BIM in the construction industry involves various investments, such as hardware and software costs, training of experts, attracting BIM specialists, organizing protocols, and setting up network servers for storage and model access.

Other studies have highlighted the importance of human resources in technology adoption. Key factors include training and increasing expertise, raising awareness, changing communication approaches, and promoting cooperation and participation among employees, managers, and stakeholders. Dainty et al. (2017) conducted extensive research on construction enterprises and projects and found that the lack of skills, expertise, and experience in working with information technology systems is a complex issue. They suggested that firms should provide comprehensive in-house training to their employees to enable them to work effectively with information systems to achieve organizational goals. Gamil and Rahman's (2019) research on construction projects and organizations in Yemen revealed that insufficient knowledge and information about the BIM system and work process, particularly in developing countries, is a significant barrier to BIM implementation.

According to the findings, one of the central issues is the lack of information and awareness that results in a lack of skills and experience. BIM awareness is higher in developed countries than in developing countries (Saka & Chan, 2020). According to Garcia et al. (2018), the lack of a collaborative culture in projects and poor communication between all the parties involved in projects is one of the main challenges in the work culture that leads to the possible failure of BIM implementation in projects and organizations. Li et al. (2019) found that managers and investors in the BIM field face implementation risk due to uncertainty and fear of unsuccessful implementation. This necessitates significant investment in equipment, BIM consultants, and specialists. Recent studies, such as Sompolgrunk et al. (2023), have confirmed these findings, highlighting that the lack of proof of BIM benefits and low success rates in adoption are key barriers to BIM implementation and growth in Australian SMEs.

Therefore, from a practical standpoint, governments, professional institutions, and BIM advocates need to focus and dedicate resources in order to ensure proper adoption and support of this technology from the executive sponsors. Additionally, according to Koch et al. (2018), the successful adoption of BIM depends on a variety of circumstances, including the project team members’ aversion to change and their access to financial resources, skilled labor, and technology. Traditional project implementation approaches inhibit successful BIM implementation. The large number of studies highlighting the need to create a culture among people and change traditional attitudes to improve cooperation and participation underlines the importance of this issue in boosting the effectiveness of BIM implementation in SMEs.

 Construction SMEs must use cutting-edge technologies like BIM to compete and stay in business. Understandably, construction SMEs would encounter hurdles when applying BIM, given the technology’s apparent novelty. These constraints can be harder for construction SMEs for technical, financial, legal, and managerial reasons (Olawumi & Chan, 2020). Some of the obstacles and challenges that can stymie BIM implementation in these construction firms include a lack of adequate skills and experience, a lack of access to the required technology, insufficient information and knowledge, a lack of required technical knowledge on BIM implementation, employer neglect to implement BIM, senior management’s unawareness and lack of support, stakeholders’ unawareness of the BIM benefits, training-related issues, and individual issues (Arrotéia et al., 2021; Chan et al., 2019). Nevertheless, the successful performance of construction SMEs in BIM implementation is a function of various conditions, including corporate dimensions, country regulations, and the like. The present study seeks to determine and investigate obstacles to implementing BIM in construction SMEs in Iran, a developing country. By identifying these impediments, BIM implementation activities in construction SMEs are expected to become more efficient and successful.

# 3. Methods for the study

The present study employed a quantitative research design based on a post-positivist research philosophy (Rafieyan et al., 2022) to achieve the research aim (See Figure 1). Post-positivism rejects the approach that a researcher can be an independent observer of the social world (Chilisa & Kawulich, 2012). Post-positivists argue that a researcher's ideas, and even the particular identity, influence what they observe and therefore impact their conclusions. The barriers to implementing BIM were first identified via literature review and further validated via the Delphi technique (see Khosravi et al., 2020; Sarvari et al., 2020).

As there is limited data about the use of BIM in SMEs and its barriers, the Delphi technique was considered appropriate in this study. As Grisham (2009) noted, the Delphi technique is suitable for exploring difficult subjects where sizable quantitative data are scarce and in-depth expert opinion is required. There were 15 experts in this study’s Delphi panel. All the Delphi panel members had more than 15 years of experience in the construction industry, as well as more than 5 years of experience in projects involving BIM. In addition, the main profession of the panel included a wide range of professions related to the subject: civil engineering (4 experts), architecture (2 experts), mechanical/electrical engineering (one expert), project management (6 experts), and academics (2 experts). According to Khoshfetrat et al. (2022), the experts' level of knowledge and experience is more important than their number. Hence, the selection criteria used to invite the experts for this Delphi survey include experts with sufficient knowledge and expertise in the subject matter (BIM), BIM implementation experience, enough time for participation, and practical communication skills (Yeung et al., 2007; Kattirtzi & Winskel, 2020). A Delphi expert team normally consists of less than 50 experts, but in most research, the number ranges between 10 and 20 (Olawumi et al., 2018). The number of experts is dependent on several factors such as homogeneity of the sample, Delphi objectives, the scope of difficulty, quality of decision, research team abilities, internal and external validities, data collection time, existing resources, and scope of the problem studied (Sarvari et al., 2019).

This study used purposive sampling to select the respondents to the survey (Olawumi et al., 2018; Deng et al., 2020). Finally, the online survey questionnaire was distributed over four months to rank the identified barriers. Demographic information was requested in the questionnaire. The respondents also were asked to rate the identified barriers on a 5-point Likert scale measurement (i.e., very important (score 5), important (score 4), moderately important (score 3), slightly important (score 2), and unimportant (score 1)). Ethical approval for this study was obtained from The Hong Kong Polytechnic University (Reference Number: HSEARS20190909001). Furthermore, the participants in the Delphi survey were provided with information on the anonymity and confidentiality of the study.

[Insert Figure 1]

## 3.1 Statistical analysis tools and sampling technique

**Sampling technique and size.** The study’s statistical population consisted of experts, consulting engineers, and contractors involved in the construction and active in construction SMEs in Iran to prioritize each identified factor. The sample size was estimated to be 56 using Cochran’s sample size formula with an unknown population. Sampling was performed using the convenience sampling method. The sample size is considered adequate compared to construction research studies such as Chileshe et al. (2018), which had 23 responses for PLS-SEM analysis.

**Questionnaire validity.** The first round of the Delphi questionnaire included 57 barriers to BIM implementation, and the experts' opinions were solicited to confirm the questionnaire’s face validity. The Delphi panel confirmed the content validity, according to three Delphi rounds and based on the content validity of Lavshh and Kendall’s Coefficient of Concordance (W). The content validity analysis was based on equation (1) and the Kendall agreement coefficient - equation 2 (Onwuegbuzie & Combs, 2010).

CVR= $\frac{\left(ne-\frac{N}{2}\right)}{\frac{N}{2}}--------------equation (1)$

CVR, ne, and N indicate the content validity ratio, the number of experts who considered the item in the questionnaire suitable, and the number of experts who reviewed the questionnaire, respectively.

**Kendall’s concordance coefficient** measures the coordination degree and agreement between different rank categories associated with N objects or individuals. It is possible to identify the rank correlation of K rank sets using this scale (May & Looney, 2022). This scale is especially beneficial in studies of validity among raters. According to Kendall’s coefficient of concordance, those rating several categories based on their importance have used the same criteria for judgement about the significance of every category and agree with each other (Schmidt, 1997; Terzi & Moroni, 2022). Equation 2 is used to calculate this scale:

W= $\frac{S}{\frac{1}{12} k^{2}\left(N^{3}-N\right)} --------------equation (2)$

In which the sum of squares of Rj deviations from Rj means it is S=∑ [Rj - $\frac{\sum\_{}^{}R\_{j}}{N}$]2

$R\_{j}$ = The sum of ranks related to a factor; K = The rank sets number (number of raters)

N = The ranked factor number

$\frac{1}{12} k^{2}\left(N^{3}-N\right)$ = The maximum sum of squares of deviations from Rj means (the sum of S, which is observed if a complete agreement exists between the K rankings).

The value of this scale ranges from 0 to 1, which shows reaching the degree of consensus through the Delphi panel (W>0.9: very strong, W>0.7: strong, W=0.5: moderate, W=0.3: weak, and W=0.1: very weak consensus). In addition, the questionnaire construct validity was evaluated using factor analysis embedded in SmartPLS software. The SmartPLS method is recommended when the number of samples is limited while a complex model is being built. (Purwanto et al., 2021). Data were analyzed using descriptive statistics, including frequency, percentage, mean, and standard deviation, and inferential statistics, including elongation and skewness test, one-sample t-test, and Friedman test in SPSS software.

The research analyses were performed using SPSS statistical software at descriptive and inferential statistics levels. The first level included statistical characteristics of frequency, percentage, mean, and standard deviation. The second level included the elongation and skewness test, the one-sample t-test, and the Friedman test. Testing the normality of data is a way to determine whether the distribution of collected data has a normal or normal distribution. Before any test is assumed to be data normal, a normality test must be performed. Several methods exist for this purpose—the best method for Likert spectrum data and a questionnaire to check the data elongation and skewness.

**Skewness and Elongation test.** Skewness is a measure of symmetry or asymmetry in a distribution function, with zero indicating perfect symmetry. Positive skewness indicates asymmetry towards higher values, while negative skewness indicates asymmetry towards smaller values. Elongation measures the sharpness of the curve at the maximum point, with positive elongation indicating a higher peak and negative elongation indicating a lower peak. If elongation and skewness fall within the range of (2, 2), the data are considered to have a normal distribution.

**One sample t-test.** Given the normality of the data, the barrier items were analyzed using the t-test. One-sample t-test is a parametric test in which the mean of the variables is compared with the test values. Accordingly, if the p-value is >0.05, the variable under study does not show a significant difference from the test value (mean value = 3), which means that the factor under study is moderately present in the statistical population. In the case of a p-value of <0.05, the variable shows a significant difference from the test value. Suppose the mean of the factor under study is higher than the test value. In that case, the examined factor is strongly present in the statistical population. If the mean of the examined factor is lower than the test value, the studied factor is weakly present in the statistical population.

# 4. Results and Discussion of Findings

This section presents and discusses the results of the analyzed data of the study.

## 4.1 Kendall’s concordance coefficient and Content validity

It should be noted that the significance of the Kendall (W) coefficient is insufficient to stop the Delphi process. In panels of over ten members, even very small values of W will show significance (Sarvari et al., 2021). Based on the experts’ responses from the first Delphi round, 27 items (out of 57) met the validity test and were removed from the questionnaire – as the validity values obtained were <0.49, and the experts proposed 7 new items as major barriers. In the second round, experts received a new questionnaire comprising 37 items based on expert feedback – of which five items were similar. Hence, the experts were provided with 32 items in the third round. At this stage, all experts concluded that all 32 identified barriers could be considered barriers and challenges in implementing BIM in Iranian construction SMEs. The content validity obtained at this stage was 0.854. Since the content validity ratio exceeded the minimum possible value, all items and the research questionnaire had content validity.

Table 2 indicates the validity of every questionnaire item with the Lavshh formula in the final round of Delphi. In addition, the Kendall coefficient of concordance was 0.792, indicating a strong and desirable consensus between the Delphi expert panel (Olawumi & Chan, 2018).

[Insert Table 2]

## 4.2 Grouping, Skewness test and PLS-SEM analysis of the identified barriers

The identified 32 barrier factors were classified into four groups (dimensions): technical, managerial, financial, and legal (Table 3). The grouping was according to studies (*such as* Kassem et al., 2012; Stanley & Thurnell, 2014; Zhou et al., 2019; Chan et al., 2019; Ansari, 2020; Leśniak et al., 2021), researchers’ opinions, and the Delphi experts’ confirmation. Hence, the questionnaire development was according to a 5-point Likert measurement scale and based on the identified factors.

[Insert Table 3]

Figure 2 shows the factor loadings for all the barrier factors. Since all factor loads of the barrier factors had values of >0.3, the model had a good fit. The questionnaire’s reliability coefficient equaled 0.956 using Cronbach’s alpha coefficient.

[Insert Figure 2]

The results in Table 4 indicate that the elongation and skewness of all research components are in the range (2, 2), so the data have a normal distribution.

[Insert Table 4]

## 4.3 BIM implementation barriers and challenges for construction SMEs

According to Table 5, the mean dimensions (technical, managerial, financial, and legal) were 3.803, 3.575, 3.448, and 3.526, respectively, and 3.566 for the collated data.

[Insert Table 5]

Since the p-value was <0.05 for all the barrier dimensions, it implies the item dimensions showed significant differences from the test value. In other words, the barriers and challenges can be considered critical. However, considering that the upper and lower limits of the positive confidence interval were obtained, all the items and groups used could be regarded as relatively significant barriers and challenges to implementing BIM in Iranian construction SMEs.

## 4.4 Ranking ***of the BIM Implementation Barriers***

The prioritization ranking of the four barrier groups/dimensions (technical, managerial, financial, legal) for implementing BIM in Iranian construction SMEs was performed using the Friedman test, employed in the two-way ANOVA by the ranking procedure. Besides, the analysis allows the comparison of the mean ranks of barrier dimensions. According to the analysis of results presented in Table 6, the significance level was below the threshold of 0.05 (p-value<0.05). Hence, the difference between the four dimensions of the BIM barriers is significant.

[Insert Table 6]

As shown by the Friedman test ranking in Table 7, the technical barrier dimension has the highest rank with a mean of 2.81, followed by the legal dimension group (2.52), among others. The Friedman test was also used to rank barriers to implementing BIM in construction SMEs in Iran. Based on the results of Table 8, the significance level was below the threshold of 0.05 (p-value<0.05); thus, the difference between the barriers to implementing BIM in Iranian construction SMEs is significant.

[Insert Table 7]

[Insert Table 8]

According to the results of Table 9, ‘employer neglect to implement BIM’ (BC5) is considered the most significant BIM implementation barrier in construction SMEs, with a mean rank of (20.26). Moreover, the experts also had a consensus on the ‘resistance of contractors and stakeholders of construction projects’ (BC17) against using BIM because of being used to traditional methods in the construction industry (20.21) as the second most impactful barrier to the decision to implement BIM in SMEs in Iran. More so, BIM barriers relating to ‘technical know-how’ (BC4) and ‘lack of information about BIM’ (BC3) were ranked third and fourth most significant barriers, respectively, with mean values of 20.13 and 19.28.

[Insert Table 9]

## 4.5 Discussion of Analytical Results

There is a paucity of research on adopting and implementing BIM in small and medium-sized enterprises (SMEs), even though SMEs comprise a greater proportion of construction sector organizations. As SMEs continue to dominate the construction industry, it is imperative that they adopt and implement BIM to integrate the fragmented sector and ensure the survival of SMEs. Furthermore, despite the importance of SMEs in emerging economies, few publications are from developing countries (Saka and Chan, 2020b). This could be attributed to a low level of BIM knowledge (BC1), adoption, and implementation in developing countries. This is also evident in the findings of Bui et al. (2016).

Implementing BIM is challenging for SMEs due to barriers such as a lack of financial resources (BC21), high implementation costs (BC21), and the like. These challenges are especially difficult for SMEs in developing countries like Iran, where BIM adoption and awareness are low (BC6). As a result, this research aimed to identify the challenges Iran faces as a developing country. The barriers were examined, refined, and classified into technical, management, financial, and legal contexts to explore the problem from a sociotechnical standpoint. The findings suggest the highlighted variables pose significant challenges to BIM adoption in Iran. The first two critical barriers (Table 9) were employers’ failure to implement BIM (BC5) and contractors’ and stakeholders’ resistance to using BIM due to being accustomed to traditional construction methods (BC17).  It contrasts Bataw et al. (2014) findings in the UK construction industry that the most significant barrier for SMEs is a lack of government assistance. Nonetheless, the study emphasizes that construction organizations play an important role in driving BIM deployment in SMEs, which is consistent with the findings of Bosch-Sijtsema et al. (2017) and Saka (2020a) in the Swedish and Nigerian construction industries, respectively. It backs up Sexton et al. (2004) claim that construction firms, not small projects, should be the focus.

Moreover, lack of technical knowledge on BIM acceptance and implementation (BC4), lack of information about BIM (BC3), and inadequate knowledge and awareness (BC6) are critical barriers to BIM implementation in Iran. This showed SMEs’ sociotechnical adoption of BIM. Unawareness of BIM’s benefits hinders its use in SMEs. These reflect a lack of understanding and awareness of BIM technology in the Iranian construction sector and other emerging economies; this may be because BIM is “as much about people and processes as it is technology” (Arayici et al., 2011, pg 19).

Other factors crucial to the diffusion of BIM in SMEs include BC27 – “insufficient motivation to design based on BIM due to low design fees”, BC28 – “inconsistency in the level of expectations and costs paid by employers," BC15 – “lack of subcontractors with the ability to employ BIM technology,” and BC1 – “lack of skills, expertise, and adequate experience.” This supports the findings that despite some progress, SMEs still lack (i) BIM knowledge (Kori et al., 2019), (ii) BIM implementation strategies (Ghaffarianhoseini et al., 2016), and (iii) demonstrable BIM advantages (Saka et al., 2019b). More training and skill development on BIM is needed in Iran so that the practice can be widely adopted; implementation strategies should be made available to SMEs in the country, and reports on locally conducted BIM projects should be shared to show off the enormous gains that can be made by switching to BIM.

The findings are also in line with other studies. For instance, Dainty et al. (2017) and Abubakar et al. (2014) concluded that a lack of skills, expertise, and experience could be a substantial barrier to BIM implementation. Gamil and Rahman (2019) considered inadequate knowledge of BIM a significant barrier to using this technology. The lack of a culture of project participation and poor communication (BC12) between all members was also mentioned by Garcia et al. (2018) as a significant barrier to BIM implementation. Bataw et al. (2014) argued that a lack of financial resources could be a serious obstacle to BIM implementation, and Zhou et al. (2019) identified a lack of government financial support (BC10) as another challenge to BIM implementation. The high risk associated with implementing BIM (BC16) was also cited as a major concern by Li et al. (2019).

Similarly, Kouch et al. (2018) and Rafieyan et al. (2022) identified resistance against changes as a significant challenge in BIM implementation (BC17). Given the results of previous studies and the results obtained in this study, it is evidenced that there has been increased awareness of emerging BIM technology in the industry (Khoshfetrat et al., 2022). However, numerous ambiguities and barriers still prevent employers, contractors, and other important project stakeholders from implementing BIM in construction SMEs. Therefore, it is essential to undertake an in-depth analysis of the difficulties inherent in implementing BIM in small and medium-sized enterprises (SMEs), especially in underdeveloped nations. Implementing BIM in construction SMEs can benefit from focusing on technical, managerial, financial, and legal factors, which can help close any current gap or resolve any outstanding issues.

Inadequate skills, expertise, and experience (BC1); lack of access to required technology (BC2); lack of information on the BIM (BC3); insufficient knowledge and awareness; absence of necessary technical knowledge (BC4) were also identified as major ***technical*** barriers to implementing BIM in Iranian construction SMEs in this study. When looking at the ***managerial*** side of things, the biggest challenges with implementing BIM in Iranian construction SMEs are employer neglect to implement BIM (BC5), the lack of knowledge and support from top management (BC6), the lack of understanding among stakeholders about the advantages of BIM (BC7), and problems with training (BC8). In terms of ***finances***, the primary obstacles to implementing BIM in construction SMEs were the high initial expenses (software and hardware) (BC21), the high cost of staff BIM training (BC22), the uncertainty over non-return on investment (BC23), and the discrepancy in expectations and costs paid by employers (BC28).

Regarding the ***legal*** dimension, the absence of regulatory standards and policies to guide BIM, the inadequate consideration of various BIM aspects in existing contracts (BC30), the absence of implementation guidelines, protocols, and standards (BC31), and the lack of transparency regarding the role and responsibility of individuals (BC32) in data input were introduced as the main challenges. The identified barriers and challenges to successful BIM implementation in SMEs must, therefore, be addressed by managers and BIM experts working in the construction industries of developing countries like Iran through systemic thinking and integrated management.

BIM research is highly contextual (Hosseini, 2018). This suggests that the location of the study, the amount of BIM implementation, the type of SME, and the organizational structure all impact BIM studies in SMEs. These factors would impact the results of the investigations, and the studies conducted in these various contexts would be distinct. The type of SMEs can vary based on the profession, such as architectural, structural, mechanical, quantity surveying, and contracting, among others. The level of BIM implementation tends to be higher in industrialized nations compared to developing countries, and organizational structures may react differently to various structural changes. Therefore, giving due attention to these regional circumstances is important to increase the generalizability of research outcomes on BIM in SMEs.

# 5. Conclusions

The study evaluated the potential impediments to BIM implementation in Iran’s SME building sector. Consequently, BIM implementation obstacles and difficulties were identified from the existing literature and interviews with experts, and further analyzed through three rounds of the Delphi survey. The questionnaire survey was based on the identified 32 BIM barriers and challenges, which were then grouped into four dimensions: technical, managerial, financial, and legal. The questionnaire’s validity and reliability were also evaluated. Then, the questionnaire was made available to construction specialists with BIM implementation experience. Experts, including consulting engineers and contractors working in Iranian construction SMEs, were among the Delphi panel of experts for this study’s survey. Data analysis was performed using SPSS software.

Based on the analysis of the research findings, it was evident that there are significant barriers and challenges to implementing BIM in construction SMEs in Iran. The study aimed to answer two research questions: (i) What are the main barriers to implementing BIM in construction SMEs? and (ii) How can these barriers be categorized and prioritized based on core dimensions? The results indicate that, among the four dimensions examined, namely technical, legal, managerial, and financial, the top three barrier dimensions were identified as technical, legal, and managerial. On the other hand, financial barriers were considered the least significant dimension. Out of the 32 individual barriers identified, the most critical implementation obstacles and challenges included the resistance of employers to adopt BIM, stakeholders' reluctance to transition from traditional methods, and a lack of essential technical knowledge about BIM. The study's findings emphasize the importance of having practical BIM knowledge and hands-on experience as crucial factors for improving the efficiency and productivity of BIM implementation in construction SMEs.

Moreover, based on the study's findings, to enhance the construction SMEs' success in implementing BIM in Iran, it is recommended that BIM standards and protocols be defined in advance by government departments and professional bodies. It is posited in this study that the use of a structured guideline for BIM implementation will increase the opportunity for the successful implementation of BIM in construction SMEs. However, as this study focused mainly on SMEs in Iran, this may limit the applicability of this study’s findings beyond Iran. Although it might still be relevant in developing countries with similar socio-economic conditions like Iran, it is recommended that further extrapolative research should be undertaken. A limitation of the Delphi studies that could impact this study also relates to its limited generalizability. Also, as the study examines barriers to BIM in SMEs, the key barriers identified in this study might not be related or applicable to large construction organizations. Moreover, further research studies are required to enhance the generalizability of the derived results through the increase in the number of participating construction SMEs. Also, a meta-analysis can be undertaken to compare the survey results of BIM implementation in construction SMEs between developing and developed economies and between SMEs and other large enterprises.

**Research implications.** Theoretically, the identified list of barriers and challenges to BIM implementation in SMEs provides an effective checklist of barriers and barrier dimensions that SMEs, government, policymakers, and other stakeholders can use as a consultative toolkit in their BIM decision-making process. This can form the bedrock of policy formulation and development of implementation strategies for Iranian construction SMEs. Practically, the identified critical barrier dimensions to BIM implementation, such as technology, legal, and management, can guide policymakers, governments, and top management of construction SMEs on where to concentrate their interventionist policies towards improving BIM adoption and implementation. Furthermore, the grouped implementation barriers can be adopted as a resource and finance allocative function for better resource distribution and policy execution for improved BIM implementation and construction sector innovation. Finally, many project stakeholders and SMEs can improve their chances of success when adopting BIM by focusing on and alleviating the key identified implementation challenges that impede innovation growth and smooth execution. The study also provides useful insights into the proposition of pragmatic recommendations for combating these impediments and challenges to BIM implementation in construction SMEs in the future.

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