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IDENTIFYING BARRIERS TO INTEGRATING BIM TECHNIQUES INTO BUILDING SUSTAINABILITY ASSESSMENT: A HYBRID DELPHI-AHP ANALYSIS

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Construction is one of the fastest-growing sectors across the world. Meanwhile, the environmental degradation caused by construction activities has become a concern. Hence, the construction industry requires modern methods and methodologies to fully implement sustainable practices and contribute to achieving sustainable development goals. However, it has faced many obstacles. This study investigates the likely impact of barriers to the integration of BIM technologies into the sustainability assessment of buildings. This study developed a hybrid Delphi-analytic hierarchy process approach to assess the relative importance of barriers to the integration of BIM technologies in building sustainability assessments. A two-round Delphi survey formed the basis for reaching consensus among the expert panel based on a set of 20 essential barriers faced by both the users' group and the stakeholders' group, which were derived via content analysis of previous studies. Results of the Delphi survey are used to compute the relative importance of barriers using the analytic hierarchy process. The finding indicates that the users' group faced three key obstacles: "Shortage of BIM and sustainability experts", "High staff training costs" and "Resistance to change traditional methods". The stakeholder' group encountered three significant challenges: "lack of government policies". "Lack of a legal framework" and "Lack of BIM and sustainability investments". This study contributes to understanding the obstacles that the construction industry faces when trying to use BIM technologies in the assessment of building sustainability, and it considers the key solutions to overcome these barriers to achieve full integration.

Keywords: BIM technologies, building sustainability, A hybrid Delphi-AHP analysis, building sustainability assessment, sustainability practices.

HIGHLIGHTS

- Barriers to integrating BIM techniques into building sustainability assessment is analyzed with a hybrid Delphi-AHP.
- The use of digital technologies associated with sustainability practices is gradually increasing in the face of rapid environmental degradation.
- BIM plays a highly valuable role in the construction industry.

1 Introduction

The construction sector not only consumes a significant number of raw materials and energy during the construction of new buildings, but it also generates significant waste due to the ongoing energy consumption of buildings and other infrastructure, such as water and sewage systems or roads, over their lifetime. Furthermore, given the significant influence of the construction industries in most economies, there is a widespread agreement that addressing this sector's historical resistance to change, which has resulted in low productivity, is essential for the macro-economy's sustainable development [1].

In the construction sector, the primary goal of sustainability is to reduce resource consumption while increasing operations efficiency [2]. Despite the significant efforts of policymakers, researchers, and government agencies, the current state of sustainability in the building sector still falls short of fully realizing sustainable construction [3].

In recent years, researchers and designers in the building sector have become more concerned about the integration of technological tools like BIM into projects' sustainability evaluation processes [4]. Furthermore, some researchers have indicated that BIM tools can improve the building sector to meet sustainability needs, simplify the simulation of building models and sustainability analysis in the early design stages [5], and open opportunities to build integrated systems to assess sustainability in the construction industry during different project lifecycle stages [6].

Building information modelling (BIM) is a CAD system that provides the ability to store data on a building model using constant-quantity technology, in addition to providing an effective tool for infrastructure visualization and faster implementation, such as a 3D design model and a full understanding of the materials used [7]. Recent studies and literature reviews highlight the need for additional experimental research on the promising topic of modelling sustainability indicators in construction projects, given the lack of a widely accepted strategy to achieve sustainability through BIM-lean principles [8].

Numerous studies have examined the role of Building Information Modelling (BIM) in sustainable building strategies, considering environmental, economic, and social dimensions. These studies, through statistical analysis and literature review, have demonstrated that BIM is a reliable approach for sustainable construction. The studies mentioned above make important contributions to the growth of BIM strategies for buildings and their integration with other cutting-edge technologies in this field. However, they rarely discuss and summarize the challenges of integrating BIM technologies with building sustainability assessment systems in construction projects [9]. The most important challenge is fully automating the process of assessing sustainability in the early design stages [10].

The study's objective is to identify obstacles to integrating BIM techniques into the sustainability assessment of buildings in the building sector. The study also aims to investigate the level of awareness among qualified engineers, architects, and construction specialists regarding the challenges associated with integrating BIM tools into sustainability practices. The findings of this research will contribute to the present body of knowledge on the role of BIM technologies in the sustainability assessment of buildings from the perspectives of qualified engineers, architects, and construction specialists. The findings are expected to support government policies and construction companies in emboldening clients to allow the integration of BIM innovations and sustainable strategies into their projects.

2 Materials and methods

In this study, the research methodology comprises three stages. The first stage of the study included collecting data from the literature review by defining the barriers to integrating BIM tools into building sustainability assessment processes. This comprehensive review of the literature has led to the identification of 20 of the most cited obstacles in the building sector and other related fields, 10 barriers BIM users-related. Additionally, 10 stakeholder-related barriers impede the integration of BIM tools into building sustainability assessments. In the second stage, the hybrid Delphi-AHP approach was used to analyse and weight the barriers. Additionally, the study employs several statistical tools, such as Cronbach's alpha test and relative impact index.

2.1 Delphi survey

The Delphi-AHP approach is a technique that combines a Delphi survey with the Analytic Hierarchy Process (AHP) for a more comprehensive research approach [11]. Experts often use the Delphi approach, an expert consultation technique, to investigate complex and multidisciplinary issues [12]. Figure 1 illustrates a flowchart of the hybrid Delphi-AHP approach. In the Delphi survey, the expert committee must have no fewer than seven members and no more than fifty [13]. The number of rounds of Delphi surveys is often 2–3 [14]. The accuracy of the Delphi survey's findings is dependent on the selection process and experience of the expert committee [15]. In this study, 11 members of an expert panel conduct a double-round Delphi survey. Elaborate main criterion were adopted to select Delph Committee members [16]: individuals with work experience in the construction industry, particularly in the areas of (a) BIM techniques, (b) sustainability practices, and (c) sustainable project execution in the construction sphere [17]. After completing the expert selection processes and establishing background information about the topic, the initial questionnaire design for the first round of the Delphi survey was designed using a 5-point Likert scale, where 1 represents strongly disagree and 5 represents strongly agree. The questionnaire has two sections. The survey included basic demographic information for participants. In the second section, the questionnaire asked participants to rate 10 challenges associated with BIM users in the sustainability sphere. Furthermore, in the third section, the questionnaire asked participants to rate 10 barriers related to government agencies, owners, and stakeholders that delay the process of integrating BIM tools into building sustainability assessments. After collecting the data from the first round, the researchers reviewed the responses and results. To double-check the calculations, data, and findings to ensure they are accurate, some statistical tools are used to analyse the collected data, such as the mean score (M), the standard deviation (SD), and Cronbach's alpha (α). If the Cronbach's alpha value exceeds or equals 0.7, it is considered acceptable to proceed to the second round of the Delphi survey. The researchers can share a summary of each round, along with graphical representations, with experts, especially if there is a diversion in the results of a round. After analysing the first round's responses, researchers designed a second-round questionnaire using a Saaty scale of (1-9) points. If researchers have gathered enough data to establish a consensus among experts and the consistency ratio (RI) does not exceed 0.10 when applying the AHP analysis calculations, they can stop at this round. If researchers believe the decision or forecasting task is not yet final, it's important to conduct more rounds. In the next step, the data obtained via a Delphi survey is used in the analytic hierarchy process. The proposed hierarchical model for this study was developed to identify the key barriers that both the users' group and the stakeholders' group face when using BIM tools for building sustainability assessments in the construction sector.

2.2 The Analytic Hierarchy Process (AHP)

The construction industry widely applies MCDM techniques through the AHP method [18]. The analytic hierarchy process (AHP) is a multi-criteria decision-making (MCDM) method utilized for computing the relative weights of a set of criteria through pairwise comparisons [19], providing an important benefit when faced with decisions built on preferences among available options that possess multiple attributes [20]. Pairwise comparisons in ANP often utilize the Saaty scale (1–9) points [21].

A matrix comprising is created consisting of the relative importance of all criteria (barriers) in equation (1), where n denotes the number of criteria (barriers) in the same group.

$$A = \begin{bmatrix} a_{11} & a_{12} \cdots & a_{1n} \\ a_{21} & a_{22} \cdots & a_{2n} \\ \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} \cdots & a_{nn} \end{bmatrix} \qquad (1)$$

In the same group, equation (2) is utilized to compute relative importance between the elements.

$$A - \lambda_{max} \times W = 0 \qquad (2)$$

Where W is the priority vector (weights) and λ_{max} is the main eigenvalue of the matrix. Furthermore, consistency ratio (CR) should be calculated to account for the inconsistencies in the expert panel's judgment.

$$CR = \frac{CI}{RI} \qquad (3)$$

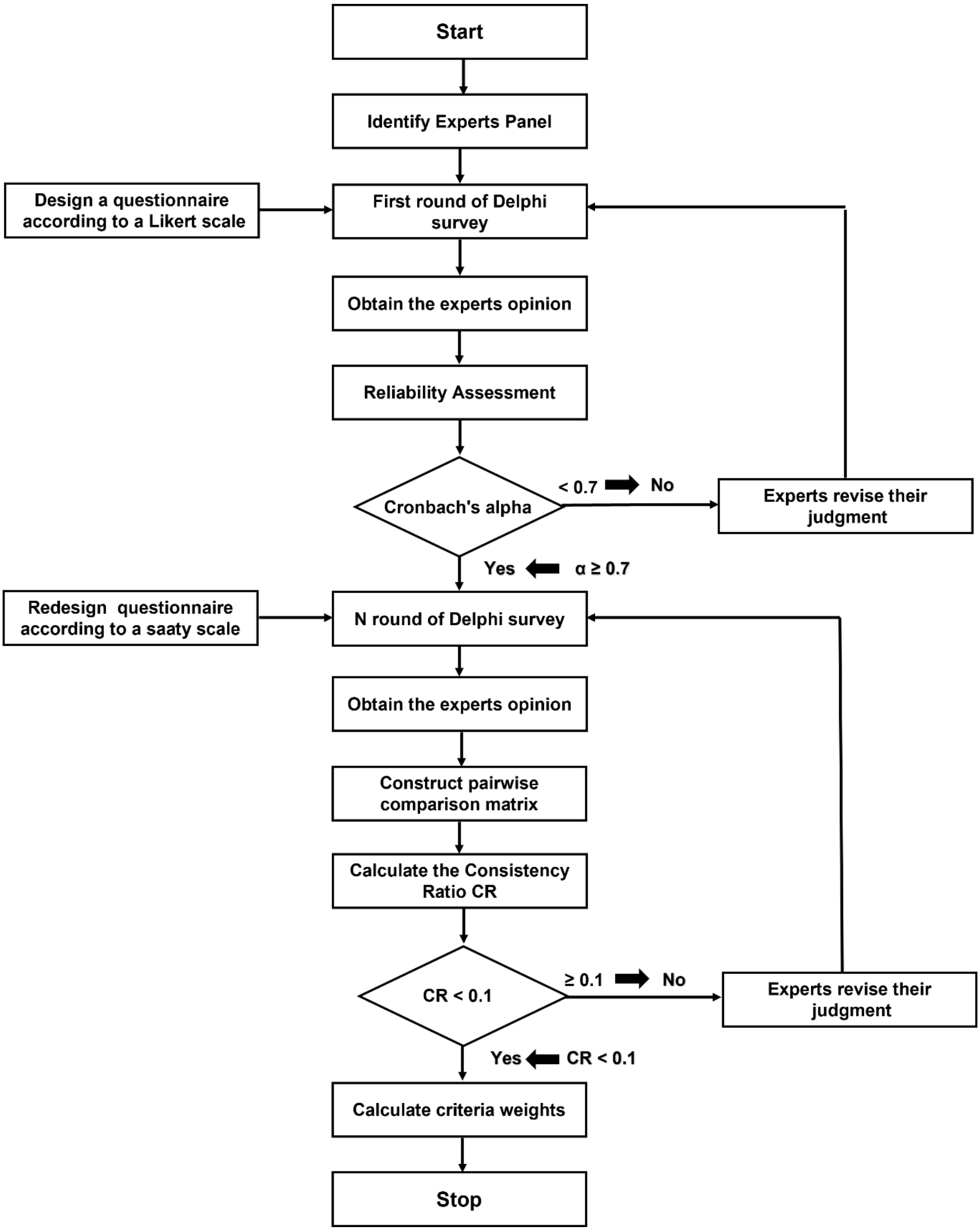

Fig. 1. Flowchart of the hybrid Delphi-AHP approach

Table 1 shows the random consistency index (RI) values for different numbers of elements (n). Equation (4) can calculate the consistency index (CI). A CR that does not exceed 0.10 (CR < 0.10) is considered coherent. Furthermore, the CR value of AHP outcomes in this study is 0.004, so the consistency of the experts' judgment in the pairwise comparison was coherent. Redesigning the questionnaire or reobtaining the expert opinion for the second round of the Delphi survey is necessary if the consistency ratio is more than 0.1 (CR > 0.10).

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (4)$$

Table 1. Random consistency index values corresponding to n elements.

n	7	8	9	10	11
RI	1.32	1.41	1.45	1.49	1.51

3 Results and discussion

3.1 Barriers to integrating BIM techniques in the building's sustainability assessment related to users' group

Building Information Modelling (BIM) is widely utilized in the construction sector due to the many benefits it offers, such as increased productivity, improved project outcomes, and reduced expenses. Many studies refer to the potential to mitigate the effect of buildings on the environment by adopting digital tools like BIM to create building sustainability strategies, but the lack of building materials related to sustainability practices minimizes the reliability of these strategies. As a result, consultants and contractors with a lack of experience in sustainable construction can fail to complete sustainable projects. In addition to that, a lack of experience may lead to issues like a schedule overrun and inadequate material specifications, as well as the limited availability of contractors that have experience with sustainable practices [22-24]. Due to the high cost of BIM software licenses, users still face challenges such as the learning curve and individual commitment to acquiring BIM skills [25, 26]. Several studies have indicated that the lack of research on BIM technology in sustainable buildings leads to a lack of reliable theories, models, and research on the adoption and diffusion of green building technologies. To provide more useful information and raise awareness, studies on the diffusion of green building technologies should look at them from different angles, such as the environmental, economic, social, technological, and political ones [27-29].

The BIM database identifies the collection of digital building components used in the modelling process. The use of BIM libraries results in time and effort savings, as well as increased convenience and consistency in building modelling processes. Regrettably, industry manufacturers and suppliers are constructing BIM databases without incorporating sustainability-related information and details [30-32].

Researchers point out that there is a lack of data for sustainability assessments, that BIM platforms don't have any built-in tools for evaluating sustainability levels, and that there are problems that make it challenging to combine BIM with assessments of building sustainability [33-35]. Most users and stakeholders need additional BIM tools and different types of software that perform a specific type of analysis [36].

New technologies and the developed methodologies associated with them take a long time to create a smooth flow of work. As a result, small firms face problems if new processes and technologies are not implemented in a timely manner [37]. The construction sector is often characterized by concerns about cost and the possibility of errors during the changing phase. Consequently, resistance to altering the traditional method delays the adoption of BIM in sustainable practices [38].

There is an obstacle that might arise from the low level of involvement of BIM users in sustainable projects and the inexperience of contractors, which leads to poor selection of construction techniques. Therefore, there is a need to increase the number of specialists to overcome this obstacle [39]. Numerous studies suggest that addressing the shortage of specialist training is necessary in the fields of BIM and sustainability. However, the high costs of employee training staff are an obstacle. Professional bodies and organizations should engage in various activities, like seminars and training workshops for their staff, and develop university curricula that are associated with BIM technologies and sustainability issues [40, 41]. Some studies indicate that using BIM tools causes increased liability for users, both designers and stakeholders, due to a lack of experience [42].

Table 2: Barriers of integrating BIM techniques in the building's sustainability assessment related with users' group

Factor	References
Shortage of BIM and sustainability experts	[22-24]
High-cost BIM software licenses	[25, 26]
Lack of scientific research in academia	[27-29]
Lack of database and information	[30-32]
Lack of unified standards and measures	[33-36]
Time-consuming work	[37]

Factor	References
Resistance to change traditional methods	[38]
Lack of BIM user participation in green projects	[39]
High staff training costs	[40, 41]
Increased liability	[42]

3.2 Barriers to integrating BIM techniques in the building's sustainability assessment related to stakeholders' group

The world recognizes the role of BIM in supporting project management and enhancing sustainable development. In developing countries, the use of BIM techniques is gradually increasing, albeit at a slower pace than in developed countries. Many researchers believe that a lack of education and knowledge is an essential obstacle inhibiting the implementation of sustainable buildings. Studies have demonstrated a significant lack of awareness among builders, engineers, architects, and planners regarding sustainable technologies, their benefits, and the design and construction process [43-47]. Also, the lack of suitable tools to measure sustainable construction is an essential challenge [48].

Many studies identified a shortage of sustainability understanding and promotion by stakeholders as the most commonly obtained obstacle [49-51]. Furthermore, numerous studies explore the potential of merging BIM techniques with sustainability evaluation systems; for example, BIM can only achieve 17 out of 29 LEED criteria. BIM support enables the faster and less resource-intensive attainment of 26 out of 56 BEAM Plus criteria [52-55]. Some studies have found that the risks of uncontrolled application of BIM technology in sustainable buildings, like lack of green design and failure to understand green requirements, may be affecting the cost and timeline of green construction [56].

However, the government's support for sustainable development is inadequate in terms of incentives and rewards for stakeholders and designers. Several studies have identified the forms of reward that include discounts, fee reductions, special loans, direct grants, subsidies, technical support, and eco-labelling. Regardless of the type of incentives used to support green building development, the most crucial factor is their effectiveness [57-60]. Furthermore, the absence of government-driven initiatives and support for sustainability policies, coupled with the lack of available standards in the construction sector, impedes the progress towards producing sustainable buildings [61].

In order to assist businesses and stakeholders in adopting sustainable buildings, the government still has a significant role to play in supporting sustainable construction by enacting legislation that keeps pace with progress in this sector [62, 63]. Also, government policies and regulations are significant for achieving the environmental sustainability of construction projects in Ghana [64]. In addition, government policies are the main drivers of sustainable construction in New Zealand [65]. For instance, the United Kingdom has mandated BIM adoption for the construction sector; therefore, it is necessary to gain more interest in supporting the adaptation of digital techniques in the construction sector [66].

Sustainable buildings appear unattractive to owners and stakeholders who prioritize quick investment returns due to the high costs of implementing sustainable features [67, 68]. Furthermore, globally, only 19% of existing buildings have received green certification [69]. Several studies indicate that the large investment required in software and professional qualifications leads to a lack of productivity during the adaptation stage [70-72]. Furthermore, a lack of market readiness for innovations, obstacles to adopting new technologies, and industry reluctance to change existing work practices have been regarded as some of the reasons that cause delay [73].

Table 3: Barriers of integrating BIM techniques in the building's sustainability assessment related with stakeholders' group

Factor	References
Lack of suitable tools and methods	[48]
Lack of promotion	[49-51]
Interoperability of BIM with sustainability rating systems	[52-55]
Uncontrolled application risk	[56]
Lack of government incentives	[57-60]
Lack of legal frameworks	[62-64]
Lack of government policies	[65, 66]
High cost of implementation	[67-69]
Lack of BIM and sustainability investments	[70-72]
Market readiness for innovations	[73]

Based on a content analysis of previous studies, the effects of barriers were studied in different aspects. In addition, barriers were classified into categories according to the Delphi opinion panel. In Fig. 2, the first model consists of three subsequent levels, including the objective “The barriers associated with the user’s group" placed at the top level of the hierarchical model. The second level consists of four categories: economic barriers, educational and cultural barriers, technical barriers, and psychological barriers. These categories encompass a total of 10 barriers that hinder the integration of BIM technology with sustainability practices.

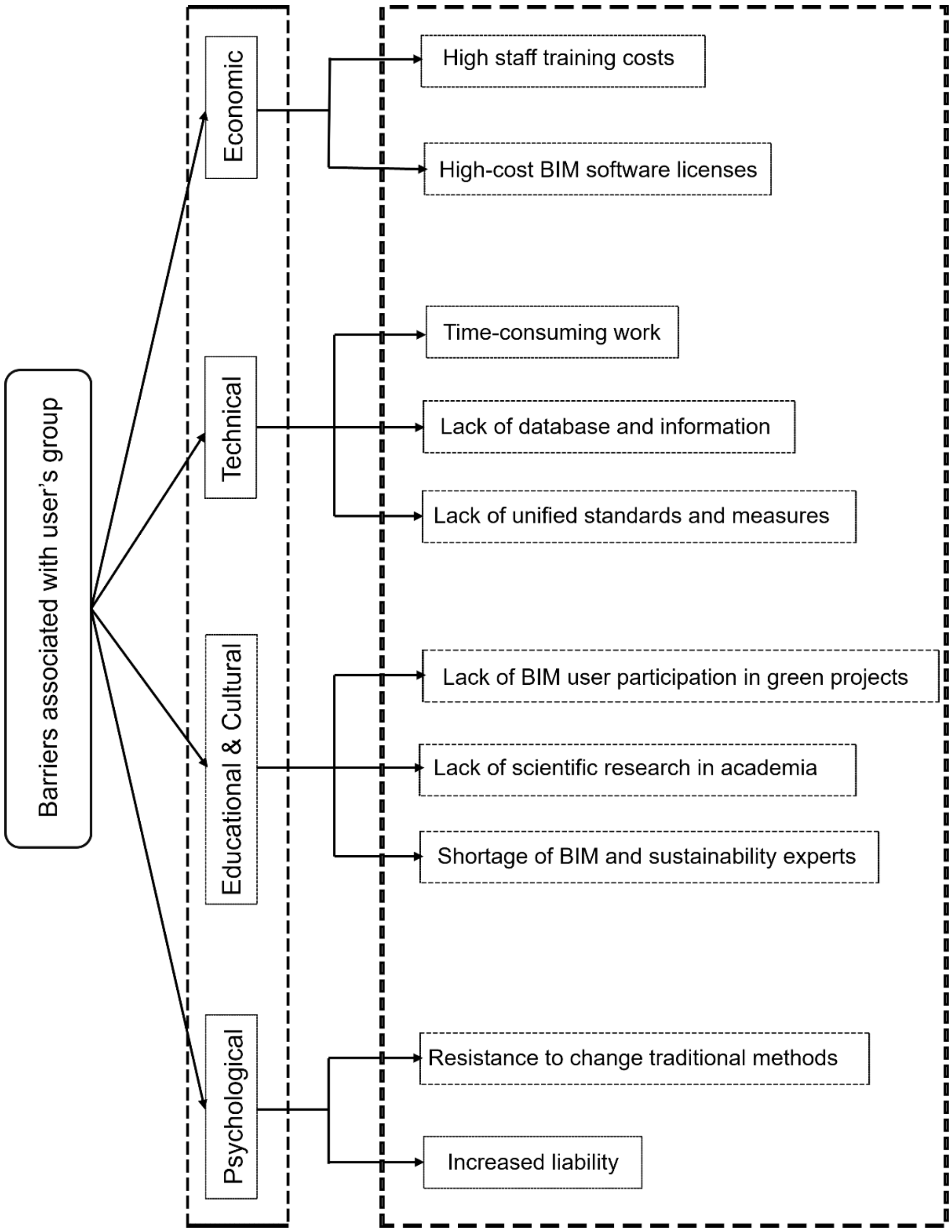

Fig. 2. Hierarchical model of the Barriers related with users' group

The second hierarchical model, illustrated in Fig. 3, delves into the obstacles that stakeholders’ group must surmount in the construction sector. This model consists of three subsequent levels, including the objective “The barriers associated with the stakeholders’ group," placed at the top level of the hierarchical model. The second level consists of four categories: economic barriers, governmental and cultural barriers, technical barriers, and marketing barriers. These categories included a total of 10 barriers.

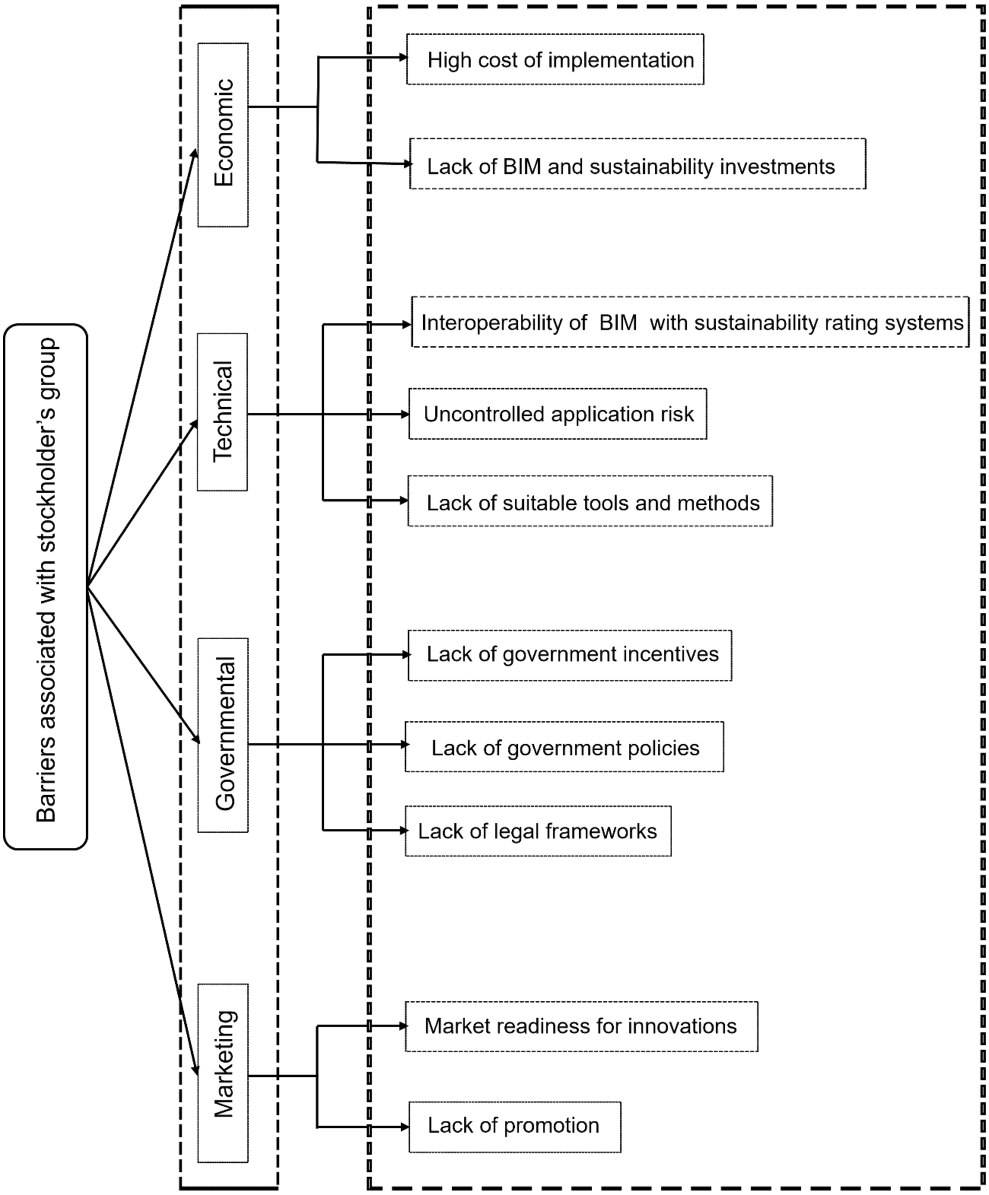

Fig. 3. Hierarchical model of the Barriers related with stakeholders' group

3.3 Discussion

This study uses Cronbach's alpha test to examine the internal consistency (reliability) of the survey. Cronbach's alpha test is considered very suitable for evaluating the reliability of the data and ensuring the internal consistency of the model [74]. A Cronbach's alpha value closer to 1.00 is considered more satisfactory. More so, an acceptable Cronbach's alpha value is considered to be between 0.8 and 0.7 [75]. The first round of a Delphi survey uses a five-point Likert scale to obtain the data. The value of Cronbach's alpha is 0.88. The second round uses the (1–9)-point Saaty scale, yielding a Cronbach's alpha value of 0.9. Numerous construction studies [76–81] have employed the relative impact index to rank the impact factors. This study calculated the relative impact index for all obstacles using equation 5.

$$RII = \frac{\sum W_i}{AN} \tag{5}$$

where: *RII* = the relative impact index for barrier i; $\sum W_i$ = the sum of all ratings from all experts for barrier i; A = the highest possible rating permissible in the adopted scale (i.e., 5 in this study); N = the total number of respondents (i.e., 11 in this study).

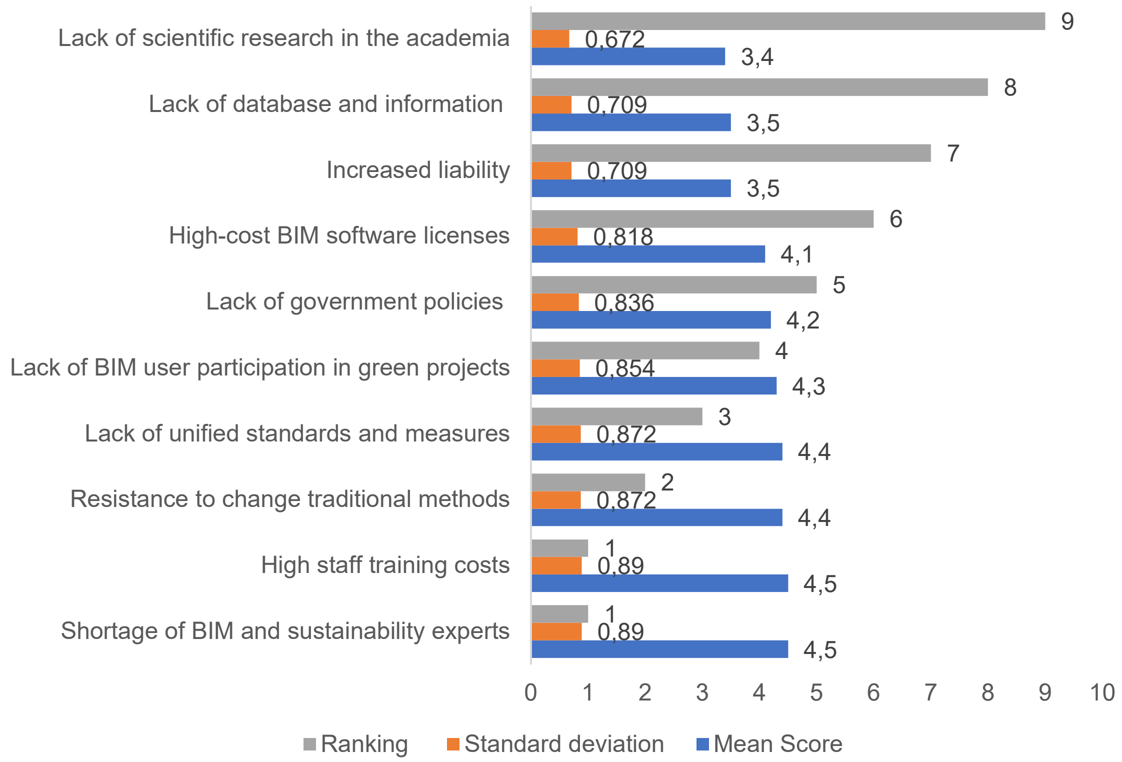

Fig. 4. First round of Delphi survey – barriers to integrating BIM and sustainability practices associated with users' group

The Delphi-AHP result indicates that the educational and cultural category is the first most influential obstacle in the user group, with a relative weight value of 41.4%. The AHP matrix results from the second round of the Delphi survey show that the biggest obstacle for the users' group is the "Shortage of BIM and sustainability experts" with a relative importance of 19.8%. The first round ranked this factor first, with a mean value of 4.5 and a standard deviation of 0.498. Also, factor "Lack of BIM user participation in green projects" with a relative importance of 10.8%. Cambier and others [82] reported this finding, indicating that while most BIM users have more experience in traditional building construction, the number of users with the skills necessary to build sustainable buildings is declining.

Factor "Lack of scientific research in academia" has a mean value, standard deviation, and relative importance of 3.4, 0.881, and 2.9%. Educational innovation addressing the technical and managerial aspects of BIM is necessary to promote the adoption of BIM technology for sustainable building design [83].

The economic category is the user group's second most influential obstacle, with a relative weight value of 25.2%. The economic category constitutes a greater obstacle for the user group compared with the stakeholder group. However, for the users' group, the economic obstacle "High staff training costs" ranked first in the first round with a mean score of 4.5 and a relative importance of 19.8%. There is a need to focus efforts on supporting training and education on sustainable construction. Also, there is a need for academic organizations and companies to exchange experiences to enhance the skills of their staff. Development programs like workshops and seminars will help mitigate these barriers. These findings are consistent with the results reported by Roslee and others [84]. The design team should receive advanced training to utilize advanced BIM tools in order to achieve sustainability standards for buildings in the early design stage. Also, the factor "High-cost BIM software licenses" holds a relative importance of 5.4%. Leniak [85] supports this fact by reporting that the cost of BIM software licenses is considered extremely high in developing countries. [85] supports this fact by reporting that the cost of BIM software licenses is considered extremely high in developing countries.

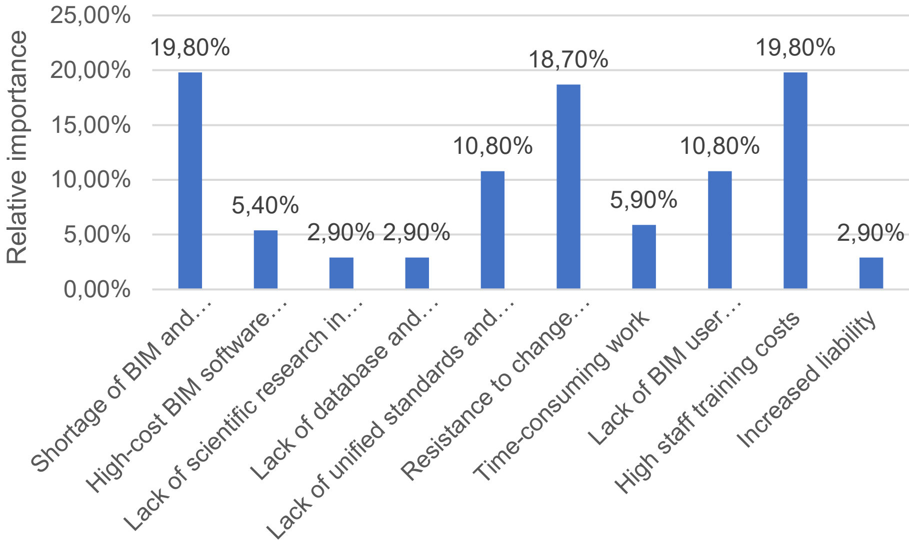

Fig. 5. Second round of Delphi survey - Weights barriers associated with users from the AHP matrix

The category of psychological obstacles is the third barrier in the users' group, with a total relative importance of 21.6%. Moreover, "Resistance to change traditional methods has a median value of 4.4 and a SD of 0.643. According to the feedback from the expert panel, users (architects and civil engineers) in the construction industry often follow traditional methods to complete a construction project, and they are not open to novel technologies. This outcome is consistent with Durdyev and others [86]. The second obstacle, "increased liability" has a relative importance of 2.9% for the users' group, as indicated by the AHP matrix. The adoption of new technologies places additional liability on BIM users due to several issues, such as the potential for frequent and unregulated use by buyers of design documents.

The technical category is the least influential obstacle in the users' group; barriers accounted for 19.6% of the users' group's total relative importance. The results indicate that the technical barriers are the least significant obstacles. In addition, the factor "Lack of unified standards and measures" was ranked third according to the first round of a Delphi survey. This finding is reported by Aitbayeva [87]: a lack of knowledge about new technologies and their applications might disrupt the overall performance of the BIM technique. The factor "time-consuming work" ranked fifth, with a mean score of 4.2 in the first round and a relative importance of 5.9% in the second round. Specialists with the necessary expertise and training can resolve this obstacle. The mean value and standard deviation of the factor "Lack of Database and Information" are 3.5 and 1.157, respectively. According to the expert panel's feedback, the database and information on sustainable building materials are incomplete and difficult to understand. Zainordin and others [88] support this point.

The governmental category is the stakeholders' group most influential obstacle, with a relative weight value of 39.3%. However, the biggest obstacle in this category is the "Lack of government policies" factor, which has a relative importance of 19.1%. It has a standard deviation of 0.656. Thus, there is consistency among consultants about the significant role of government policies in promoting the adoption of new technologies like BIM in the application of sustainable practices. Also, the factor "Lack of government incentives" has a mean value of 4.1 and a relative importance of 10.1%. Ohueri and others [89] provided an example of how the Malaysian government has supported green BIM implementation by exempting the import duty on energy conservation equipment not produced locally.

Factor "Lack of a legal frameworks" ranked third in the stakeholders' group with a relative importance of 10.1%. The panel of consultancies highlights that the absence of uniform standards can lead to confusion and inconsistent application of sustainable practices among stakeholders and owners. So, a clear set of rules for carrying out sustainable practices in the construction industry through consistent laws is needed to help ensure that sustainability practices are properly followed.

The technical category is the second most influential obstacle in the stakeholders' group, accounting for 25.4% of total relative importance. In the first Delphi survey, the factor "Lack of suitable tools and methods" ranked second with a mean score of 4.2. The technical category constitutes a greater obstacle for the stakeholder group compared with the user group. Factor "Uncontrolled application risk" has a mean value of 3.8 and a standard deviation of 1.029. Moreover, there exists some variation in the opinions of experts. According to Nugradi [90], green buildings require more techniques than traditional buildings, resulting in higher costs. The stakeholders will have to think about the risk of constructing green buildings.

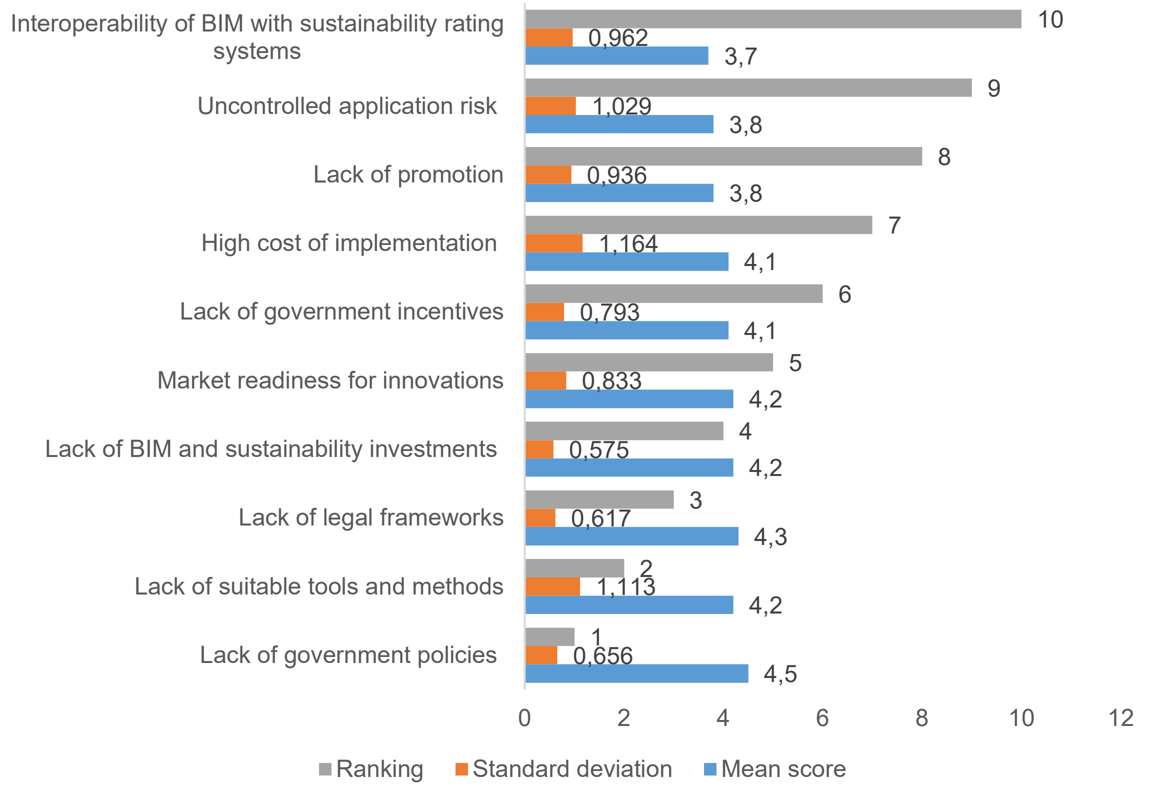

Fig. 6. First round of Delphi survey – barriers to integrating BIM and sustainability practices associated with stakeholders' group

Despite the factor "Interoperability of BIM with sustainability rating systems" ranking tenth with a mean score of 3.7, in the near future, certification sustainability rating systems such as LEED and BREAM will be critical factors to compete among stakeholders. Thus, integrating BIM tools and sustainability rating systems improves sustainability practices in the construction sector. Meanwhile, the use of BIM tools ensures buildings accumulate excellent points on sustainability rating systems.

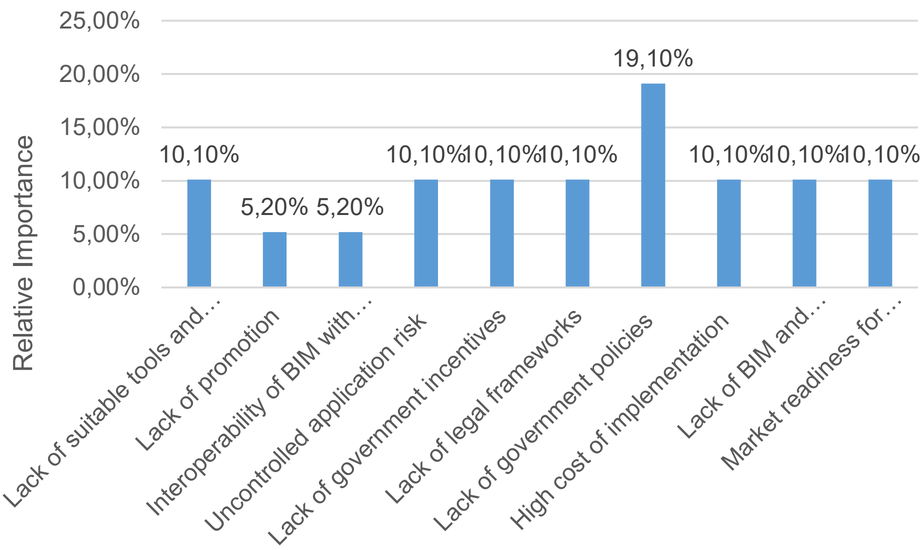

Fig. 7. Second round of Delphi survey - Weights barriers associated with stakeholders from the AHP matrix

The economic category is ranked third in terms of influence with respect to the stockholder's group, with a total relative importance of 20.2%. Factor "High cost of implementation" ranked seventh with a mean score of 4.1, and in the second round, its relative importance increased to 10.1%. Moreover, Ha Chin Yee and others [91] interpret that stakeholders are not interested in implementing green buildings due to the limited supply of green materials and their high cost. Furthermore, these results align with Idris's [92] findings, which suggest that Building Information Modelling (BIM) enhances the quality of construction projects in various aspects, thereby increasing the financial burden due to the constant need to update related technologies. The relative importance of the factor "Lack of BIM and sustainability investments" is 10.1%. According to Osuizugbo and others, the decline in sustainable construction investment can be attributed to a lack of demand from the local construction sector [93].

The marketing category is relatively important in the stakeholders' group at 15.3%. In the first round, the factor "market readiness for innovations" had a mean score of 4.2 and relative importance of 10.1 in the second round of a Delphi survey. The other factor, "Lack of promotion" had a mean value of 3.8. The relative importance stands at 5.2%. Yee and others [94] support this fact by promoting green buildings' training courses to construction stakeholders. Meanwhile, clients' increased demand for sustainable buildings encourages stakeholders to adapt to them. Additionally, we should educate and inform the public about the importance of green buildings to the environment. Kumar and Agarwal [95] state this outcome.

4 Conclusions

The purpose of this study was to investigate the barriers to integrating the BIM tools with sustainability practices. A comprehensive literature review identified 20 barriers to the integration of BIM and sustainability practices in the construction industry, classified into 10 barriers associated with the user's group and 10 others associated with the stakeholders' group. The hybrid Delphi-AHP approach and other statistical tools were employed to analyze the collected data.

The study findings indicated that there is more interest in global sustainability. The use of digital technologies associated with sustainability practices is gradually increasing in the face of rapid environmental degradation. Also, the study outcomes contribute to the current knowledge in the field of BIM and sustainability practices by providing stakeholders with the key barriers that obstruct the full employment of BIM and sustainability practices in the construction industry.

BIM plays a highly valuable role in the construction industry and has become the major renewed trend to develop it. Although BIM has demonstrated its benefits to the construction industry, it is still in its early stages of development and faces numerous challenges when integrated with sustainability practices. Furthermore, the identified obstacles offer valuable insights into the difficulties in integrating BIM tools with sustainability practices and how to enhance policies and design strategies to automate the complete evaluation process for building sustainability.

A recommendation for future investigation to explore technological and interoperability issues: (a) assess the limitations of BIM software in supporting sustainability assessment tools (e.g., LEED, BREEAM, Green Star); (b) investigate how Open BIM (IFC, COBie) can improve interoperability between BIM and sustainability assessment platforms; (c) investigate the role of generative design in optimizing sustainable building performance via BIM.

5 Acknowledgement

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7 Conflict of interest statement

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

8 Author contributions

Alaa Jaleel Naji: Conceptualization, methodology, formal analysis, data collection, original draft preparation, manuscript editing. Mohamed I. Abu Mahadi: Methodology, data curation, manuscript reviewing and editing, visualization, supervision, project administration. Muataz Jabbar Jiheel Al-Hchaimi: Conceptualization, methodology, formal analysis, data collection, original draft preparation, manuscript editing.

9 Availability statement

There is no dataset associated with the study or data is not shared.

10 Supplementary materials

There are no supplementary materials to include.

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