Barriers to the Integration of BIM and Sustainability Practices in Construction Projects: A Delphi Survey of International Experts

Abstract

The built environment faces numerous challenges in its quest to be more productive and sustainable, and the adoption of a smart and creative process of carrying out the various operations. This study aims to investigate the profound barriers faced by construction stakeholders in their attempts to integrate BIM and sustainability practices in the construction processes. A two-round Delphi survey formed the basis of aggregating consensus among the expert panel based on a set of 38 factors derived via content analysis of previous studies. Descriptive results and inferential tests were employed for data analysis, and the results validated using the interrater agreement analysis. The three key barriers by descending order of significance were industry's resistance to change from traditional working practices, an extended period of adapting to innovative technologies and the lack of understanding of the processes and workflows required for BIM and sustainability. Deductions were also made based on the comparative analysis of the expert groups. The findings will advance the implementation of BIM and sustainability practices in construction projects and enable project stakeholders to focus on addressing the critical challenges discussed in this study.

Keywords: Barriers, BIM, sustainability practices, Delphi study, construction industry

1. Introduction

The main idea driving the concepts of a sustainable smart city in the construction industry is primarily the development of standards and the implementation of Building Information Modelling (BIM) and sustainable practices. Several research studies have discussed the possibilities of BIM to advance the implementation of sustainability practices in construction projects. Alsayyar and Jrade [1] developed an innovative model which integrates BIM tools with sustainable design requirements to evaluate the cost and benefits of a proposed building in the planning and design stages. The model was developed with a database module and tested on a real-life project.

Moreover, Gilkinson et al. [2] regard BIM as a revolutionary design-based technology and process which provides considerable value to construction projects throughout the lifecycle stages [3]. BIM implementation can be considered from two aspects- (1) the use of 3D technology (software) to model and analyze building model using software such as Revit, ArchiCAD etc. (2) the process/conceptualization which enable other knowledge domain such as cost, schedule, project management, safety, sustainability parameters to be embedded in BIM software to provide one-source, central hub of information for project stakeholders. Olatunji et al. [4] and [5] affirms BIM capability to offer both functions (application and process) which enables it to be useful for construction stakeholders and organizations in managing project data.

The integration of BIM and sustainability practices implies leveraging on BIM technologies such as software and plugins, cloud platforms to facilitate sustainability assessment of infrastructural and construction projects [5]. However, there have not been a uniform adoption and implementation of BIM initiatives and sustainability in most countries, with the United States and the United Kingdom, the leading nations in its adoption [6], likewise for sustainability. The five-dimensional (5-D) BIM which incorporates cost data can assist to avoid cost overrun on construction projects and facilitate substantial returns on investment for the client [4]. The next phase of nD BIM is the 6D BIM which attempt to utilize BIM to address issues such as sustainability in construction projects which is consistent with the views of Bradley et al. [7], who stressed the capacity of BIM to expand into domains such as sustainable/green buildings of which BIM was not originally conceived to address. Sustainability is a sophisticated theme in the construction field which involves a balanced play between the social, economic and environmental pillars of sustainable development [8].

1.1 Research objectives

Bringing these perspectives together, the study presented in this paper aims to assess the barriers to integration of BIM and sustainability practices at the design stage of construction projects. The objectives are: (1) to explore the extant literature for the barriers to BIM and sustainability practices integration in construction projects which are augmented with the authors' experiential knowledge. (2) To prioritize the barrier factors in terms of their significance levels; and (3) to undertake a comparative analysis of BIM-sustainable practices implementation among the respondents' groups and regions. The study's findings will be more beneficial to construction projects in which the project team intends to implement BIM and sustainability practices in such projects.

The findings of the study will contribute and strengthen the existing knowledge base in cross-field BIM and sustainability research by providing stakeholders in the built environment- the critical issues hindering the full implementation of BIM and sustainability practices. More so, the results will provide practical guidelines and recommendations towards advancing the adoption and implementation of BIM and sustainability practices in construction projects. The study's findings will also serve as a consultative guide or tool for government agencies, construction organizations, and stakeholders interested in the ideals of sustainable smart buildings and construction.

The structure of this paper is as follow. Section 1 has presented a background to this study as well as issues relating to the implementation of BIM and sustainability practices and the research objectives. Section 2 discusses from the literature the barriers to the implementation of BIM and sustainability practices in construction projects. Section 3 illustrates the research method and approach to data collection. Section 4 discusses the results of the study, while section 5 provides practical strategies to mitigate against key barriers identified by the expert panel. Section 6 provides a summary of the paper and highlights areas for further studies.

2. BIM and sustainability practices: A review

The use of technological tools like BIM for construction processes and sustainability evaluation of projects have gained the immense attention of policymakers, researchers, government agencies and key stakeholders in the construction industry in recent years [6,8,9]. Some current application of 6D BIM (BIM and sustainability) in the construction industry include the application of BIM for sustainable material selection for construction project [10]. Also, Akanmu et al. [11] developed a decision support system (DSS) to enhance the selection and procurement of low-cost and environmental-friendly building materials for different building designs. Also, Aksamija [12] exemplified the use of BIM analysis tools to simulate building energy performance for a case study project. Other applications of BIM and sustainability include: (1) lifecycle cost assessment [13]; (2) simulation of building design performance [12]; (3) sustainable design [1,14]; (4) building energy analysis [15,16]; (5) Indoor environmental quality [IEQ] [17].

Also, Olawumi and Chan [9] developed a geospatial map depicting the distribution of the global sustainability research. Despite these attempts to utilize BIM for sustainability implementation in construction projects as exemplified by the literature, the construction industry is deficient of the necessary collaboration and coordination [4,18,19] to drive salient issues like sustainability and BIM. Hence, Aksamija [12] and Olatunji et al. [19] argued for a collaborative working environment and an iterative decision-making process in the construction industry towards enhancing the capacity of BIM to strengthen the sustainability of the built environment.

However, the construction industry is faced with challenges related to the joint implementation of the two concepts in construction projects [20]. Adamus [21] pointed out the challenge of developing smart building which is consistent with sustainable development (SD) principles and the need to ensure the achievement of the three pillars of SD. Accordingly, BIM was identified by Adamus [21] as capable of enabling the construction industry to meet the emerging sustainability requirement and facilitate the sustainability analysis and simulation of building models before construction onsite. Also, Gu and London [20] pointed out that the readiness of the AEC industry for innovative technology and processes such as BIM varies among countries. Also, even among the early adopters of BIM and initiators of sustainability assessment metric, there is a disproportionate level of knowledge and experience [5].

More so, the level of readiness and implementation is disproportionate among construction organizations and regions [20,22] as well as the prevailing resistance to change from traditional working practices [23] by construction stakeholders have hindered a holistic implementation of BIM and sustainability in construction projects. Given the above, project clients have developed apathy for its adoption in their project [24]. Meanwhile, Olawumi et al. [6] observed that despite growing research and studies in BIM-sustainability issues in construction projects, most projects have focused on one aspect of the three fundamental pillars of sustainable development which is environmental sustainability. Meanwhile, these cross-study BIM-sustainability literature have dealt on energy performance issues in projects instead of a holistic view of what is possible in achieving a sustainable smart city. The current approach to sustainability assessment is still a challenge to the construction sector; this is because the design stage offers the best opportunity to influence sustainability decisions [5,25,26].

There have been some success stories of the use of BIM to enhance sustainability implementation of construction projects in the literature. For instance, the development of a BIM-based Deconstructability Assessment Score (BIM-DAS) by Akinade et al. [27] who develop a set of metrics that can be utilized in making choices on building designs suitable for deconstruction. However, the model is yet to be integrated as a plugin in BIM software limiting its practical implementation in construction projects. Adamus [21] reiterated the issue of interoperability as a significant setback affecting the use of BIM to evaluate sustainability parameters of the building model. Cidik et al. [28] developed an information categorization framework to evaluate design alternatives in BIM environment which not only optimize such designs but also allows for a holistic design sustainability analysis to be undertaken. Jalaei and Jrade [29] advanced a methodology that integrates BIM with LEED (Leadership in Energy and Environmental Design) building certification system which can assist project teams to make sustainability-related decisions while at the same time ensure such buildings accumulate good points on LEED rating.

Key barriers reiterated in the literature hindering the adoption of both concepts (BIM and sustainability) in the construction industry are highlighted in Table 1. Previous studies have highlighted the inadequacy of requisite experience, knowledge, and skills from the workforce [30,31]. For these reasons, it is recommended for stakeholders to shore up their knowledge base and learn new skills and as advised by [6], professional bodies and organizations should organized training seminars and workshops for their members and staff and development of university curriculum in BIM and sustainability issues.

Without doubts, the backbone of the BIM initiatives and sustainability simulations and practices are technologically enabled software, tools, plugins, and databases. The study will in the next sections attempt to seek the perception of expert panel to prioritize and analysis the barriers identified in the literature and which is expected to enable project stakeholders to focus on the most significant challenges facing the implementation of BIM and sustainability practices in construction projects.

Table 1: Barriers to implementing BIM and sustainability practices in construction projects

Code	Barriers	References
B1	Varied market readiness across organizations and geographic locations	[20,22,32,33]
B2	Industry's resistance to change from traditional working practices	[20,23,33]
B3	Lack of client demand and top management commitment	[34–36]
B4	Lack of support and involvement of the government	[23,37]
B5	Low level of involvement of BIM users in green projects	[32]
B6	Societal reluctance to change from traditional values or culture	[22,33,35]
B7	The lack of awareness and collaboration among project stakeholders	[20,32,37,38]
B8	Inadequacy of requisite experience, knowledge, and skills from the workforce	[20,23,24,30,33,35]
B9	Longer time in adapting to new technologies (steep learning curve)	[30,35]
B10	Lack of understanding of the processes and workflows required for BIM and sustainability	[35]
B11	Low level of research in the industry and academia	[22,32,35]
B12	Inadequate in-depth expertise and know-how to operate sustainability-related analysis software programs	[20,32,39]
B13	Shortage of cross-field specialists in BIM and sustainability	[38]
B14	High cost of BIM software, license, and associated applications	[30,33,35]
B15	High initial investment in staff training costs	[33,35]
B16	Recurring need for additional and associated resources and high economic expenses	[40,41]
B17	Lack of initiative and hesitance on future investments	[20,42]
B18	Fragmented nature of the construction industry	[20,22,32,33]
B19	Organizational challenges, policy, and project strategy	[36,43]
B20	Difficulty in assessing environmental parameters of building properties	[44,45]
B21	Difficulty in accessing sustainability-related data (such as safety, health, and pollution index, etc.)	[21,32]
B22	The risk of losing intellectual property and rights	[22,33]
B23	Difficulty in allocating and sharing BIM-related risks	[33]
B24	Lack of legal framework and contract uncertainties	[22,35]
B25	Increased risk and liability	[33]
B26	Lack of suitable procurement policy and contractual agreements	[35,46]
B27	Non-uniformity of sustainability evaluation criteria and measures	[32,44]
B28	Lack of comprehensive framework and implementation plan for sustainability	[22,47,48]
B29	Absence or non-uniformity of industry standards for sustainability	[1,36,48]
B30	Inaccuracy and uncertainty in sustainability assessments for projects	[1,32,39]
B31	Incompatibility issues with different software packages	[30,32–34]
B32	Absence of industry standards for BIM	[22,24,32,34]
B33	Insufficient level of support from the BIM software developers	[22]
B34	Inadequacy of BIM data schemas to semantically represent sustainability-based knowledge	[21]
B35	Lack of supporting sustainability analysis tools	[1,27]
B36	Non-implementation of open source principles for software development	[38]
B37	Domination of the market by commercial assessment tools	[38]
B38	User-unfriendliness of BIM analysis software programs	[12,39]

3. Research methodology

The study aims at identifying and prioritizing the barriers militating against the integration of BIM and sustainability practices in construction projects at the design stage. A Delphi technique is the primary research approach adopted in this study. Yeung et al. [49] noted that Delphi survey is suitable for achieving consensus in complex areas or areas that are relatively new. Hasson et al. [50] and Turoff [51] noted that Delphi technique is useful in deriving and correlating informed (expert) judgments on a topic involving different disciplines such as BIM and sustainability in this study. Meanwhile, according to Olatunji et al. [52], the data collection approach is significant in measuring and establishing a study's theories or set of criteria upon which the research findings are measured.

Two-rounds of Delphi survey with two respondent groups (academics and practitioners) was undertaken to rank the 38 identified barriers to integrating BIM and sustainability practices at the design stage of construction projects. Also, statistical methods such as mean score ranking and standard deviation, Cronbach's alpha reliability test, Shapiro-Wilk test of normality, Kendall's concordance test, Chi-square test, inter-rater agreement (IRA), Spearman's rho correlation test and Mann-Whitney analysis were employed.

3.1 Format of the Delphi technique

Before the launch of the two-round Delphi survey, a review of studies on BIM implementation and sustainability practices was undertaken. A content analysis of extant literature helps to deduce forty-eight (48) barriers, which was reduced to forty-one (41) factors after consolidating and pretesting the factors. The summative content analysis approach as described by Hsieh and Shannon [53] was adopted in this study's content analysis. A pilot study involving four (4) academic and industry expert was conducted to evaluate and validate the 41 factors (derived via content analysis) and the survey instrument. [54]. Hence, based on feedback from the pilot survey respondents, the finalized Delphi survey consisted of 38 factors as barriers to BIM and sustainability practices integration in the construction process. The factors in the survey form are to be assessed by the expert team based on a 5-point Likert scale (*1= Strongly Disagree and 5= Strongly Agree*).

One of the key aspects of a Delphi survey approach is the selection and characteristics of the expert panel member. The sampling technique involves a non-probability sampling technique [50], and a purposive sampling technique was used in this study to ensure the invited experts are well-informed in BIM and sustainability practices in the construction industry. More so, authors [49,55,56] argued that the success of a Delphi survey depend on the selection of the expert panel and their expertise [57]. The following criteria were devised for identifying eligible respondents for the Delphi survey, and they are to satisfy at least two of the following criteria: (1) experts with extensive experience in the construction industry. (2) experts who have participated in current/past projects which utilized BIM and sustainability practices; and (3) experts with sound knowledge and understanding of the concepts of BIM and sustainability practices.

The expert panel should consist of a heterogeneous group of members with diversified and expansive knowledge and experience [58]; with a minimum size of seven (7) members [58–60], and a maximum of 50 members [51]. For this study, 27 respondents were invited to participate in the rounds of Delphi survey and fourteen (14) experts responded to the invitation, with equal representation from both the academic and industry experts. The composition of the expert panel gives the study's findings a balanced view.

A 2-3 rounds of Delphi surveys is preferable based on previous studies [61,62], and Zahoor et al. [57] also utilized a 2-round Delphi survey. Hasson et al. [50], meanwhile, stressed that the expert panel must reach a consensus before closure of the rounds of Delphi survey. Moreover, to facilitate the credibility and reliability of the Delphi survey, we ensure anonymity of the invited experts, iteration, and feedback of results from each Delphi survey round.

3.2 Expert panel's demographics

The expert panel is constituted of 14 members in total with equal representation from the academics and industry experts. The experts are from eight (8) different countries. Also, more than two-thirds of the experts (9 members) have more than 11 years working experience in the construction industry with five (5) members with more than 20 years of working experience. Majority of the respondents also noted that they often apply BIM and sustainability practices in their projects.

More so, most of the invited experts have utilized BIM in building projects, followed by refurbishment or redevelopment works. Other projects in which they have utilized BIM include civil engineering works and industrial projects. Building works are the project sector in which the expert panel members have employed sustainability practices. The Delphi survey participants also noted that government departments and agencies are the stakeholders that mostly facilitate the implementation of BIM and sustainability practices in their projects, followed jointly by the clients and project team. Also, sometimes the selected contracting firm initiate its implementation.

Also, when asked at what stage of project development is best in implementing BIM and sustainability practices, ten (10) experts argue for the planning stage, two (2) experts each chose the design and construction stages. Country-wise distribution of the expert panel shows four (4) experts from the United Kingdom, three (3) from Hong Kong, two (2) from the United States, and one (1) each from South Korea, Mainland China, Australia, Sweden, and Germany. For comparative analysis purpose, apart from the dichotomy of the academic and the industry experts with seven members each; we categorized another set of respondents of the West and the East with eight (8) and six (6) experts respectively. The creation of the West *vs.* East dichotomy is like that used by [63]. The West group consists of respondents from countries such as the United Kingdom, the United States, Sweden and Germany, whereas the East group consists of experts from remaining countries like Hong Kong, South Korea, Mainland China, and Australia.

3.3 Statistical tools for data analysis

Statistical tools were employed to analyze the data collected from the expert panel and to undertake a comparative analysis between the experts' groups. These statistical methods include: (1) mean score (M) and standard deviation (SD); (2) Cronbach's alpha reliability test and Shapiro-Wilk test of normality. (3) Kendall's concordance test; (4) Chi-square test; (5) inter-rater agreement (IRA); (6) Spearman's rho correlation test; and (7) Mann-Whitney analysis. The mean score and SD were used to rank the 38 barriers factors. In cases where two or more factors have the same mean value, their standard deviation is used with the mean for the ranking. Hence, factors with smaller SD will be assigned higher rank [52], however, if they have the same mean and SD, the factor retains the same rank. Also, Cronbach's alpha (α) was used to test the reliability of the questionnaire for both rounds of Delphi surveys to ensure they measure the right construct [52].

The Kendall's coefficient of concordance was used to measure the level and consistency of agreement within a survey group and have a value of 0 (perfect disagreement) to 1 (perfect agreement) [64]. Spearman rho correlation (ρ) was used in this study to measure the level of concordance or agreement, and the ρ coefficient ranges from -1 (perfect negative linear correlation) to +1 (perfect positive linear correlation). Chan et al. [65] noted that ρ is statistically significant at a $p<0.05$ significance level, hence, the null hypothesis (H_{0a}) which states that “*there is no significant correlation between the two expert groups on the rankings*” can be rejected.

Mann-Whitney U-test was employed to detect significant divergencies or differences between the median values of the same factor [65] among two independent expert groups in this study. The U-test is a non-parametric alternative to the independent t-test and allows the ease of drawing different conclusions about the data based on the initial assumptions about the data’s distribution. For this study, if the p-value is less than the significance level of 0.05, the null hypothesis (H_{0b}) which states that “*no significant differences in the median values of the same factor between the respondents of the two expert groups*” will be rejected. Meanwhile, a smaller ‘U’ value implies there is a substantial difference between the two experts’ groups.

Brown and Hauenstein [66] proposed and advanced the use of interrater agreement statistic ($a_{wg(1)}$) to analysis the agreement on a group level (see equation 1). More so, according to Zahoor et al. [57] is advantageous because it makes the data independent of the scale and the study’s sample size. More so, Lebreton and Senter [67] provided the interpretation for the IRA statistics which are: 0.00-0.30 “*lack of agreement*,” 0.31-0.50 “*weak agreement*,” 0.51-0.70 “*moderate agreement,”* 0.71-0.90 “*strong agreement*” and 0.91-1.00 “*very strong agreement*.” The IRA statistics and the significance level grading was used in this study to check the level of agreement across the two rounds of Delphi survey and validate the results. Meanwhile, since the agreement for mean scores at the extreme of the scale (i.e., 1 and 5 for a 5-point Likert scale) is not quantifiable using $a_{wg(1)}$. Hence, equations 2 and 3 is used to define the boundaries (lower & upper) of the mean for computing the IRA statistics.

$$a_{wg(1)} = 1 - \frac{(2 * SD^2)}{\{(A+B)M - (M^2) - (A * B)\} * \frac{n}{n-1}} ------- eqn\ (1)$$

$$M_{lower} = \frac{B\ (n-1) + A}{n} ------- eqn\ (2)$$

$$M_{upper} = \frac{A\ (n-1) + B}{n} ------- eqn\ (3)$$

Where SD= standard deviation, A= maximum scale value (i.e. 5), B= minimum scale value (i.e. 1), M= mean value of that factor, n= sample size of respondents (i.e. 14 in this study).

4. Discussion of survey results

This section discusses the results of the two-round Delphi surveys and the findings of the various statistical tools employed in the study.

4.1 Reliability test and Normality test

The α-value for the first round of Delphi survey was 0.916 and the second round was 0.905; which is greater than the 0.7 thresholds [68]. More so, a Shapiro-Wilk test of normality for both rounds of Delphi surveys shows that non-parametric tests are required for the analysis of the collected data as the data are not normally distributed ($p<0.05$).

4.2 Overall mean score ranking

For the first round of Delphi survey (see Table 2). The mean value of the 38 ranked factors (barriers) has a range from M= 2.86 (SD=1.167) for "*B4 - lack of support and involvement of the government*" to M= 4.36 (SD=0.497) for "*B2 - industry's resistance to change from traditional working practices"* and a variance of 1.50. Meanwhile, for the second round (see Table 3); we have a slightly larger variance of 1.57 and a mean range from M= 2.79 (SD=0.893) for "*B38 - user-unfriendliness of BIM analysis software programs*" to M= 4.36; (SD=0.497) for "*B2 - industry's resistance to change from traditional working practices"*.

A highlight of the findings (see Table 2 and 3) is the changes to the ranking of some of the factors which reveal that the respondents refined their previous rating of the 38 factors. For instance, there were some interchange of the rankings from factor b1 to b21 (ranked 2nd), factor b10 to factor b3 (ranked 6th), factor b7 to b19 (ranked 10th) among others. More so, some factors have their ranking enhanced during the second round of Delphi survey, these include factor b10 from rank 6 to 5, factor b7 from rank 10 to 8, and factor b13 from rank 15 to 12, etc. Also, some factors had their ranking reduced such as factor b3 from rank 4 to 6, although factors such as b2, b5, b15, b18, b20, b24, b37, and b34 retained their rankings after the second of Delphi survey.

Furthermore, one of the objectives of a Delphi technique is to achieve consensus among the expert panel at the end of the rounds of Delphi surveys. The consensus was derived for the top five principal factors in the second round of Delphi survey among the respondents' groupings. The academics ranking featured 3 out of the 5 overall key factors while the industry experts' ranking has 4 out of 5. Meanwhile, the East and West experts' groups featured the five (5) key factors in their rankings. More so, across all the respondents' groups, there is an agreement on factor b2 as the top-ranked (1st) factor except the practitioners' grouped which rated it as 2nd ranked.

4.3 Agreement of respondents within the expert groups

The level of agreement for the experts' groups increased in the second round of Delphi survey (see Tables 2 and 3). The W's value for the expert panel increased from 0.191 to 0.233, comparable results were gotten for the respondents' groups such as 0.253 to 0.303 (academics); 0.241 to 0.293 (practitioners) and 0.217 to 0.296 (East). However, there was a slight decrease in the consensus for the "West" group from 0.352 to 0.314. Gisev et al. [69] stressed that it is tough to achieve a high W's value with an increase in the sample size of respondents. Hence according to Zahoor et al. [57], these W's values can be considered significant. Meanwhile, as the questionnaire item for the study is more than seven (7), chi-square analysis was also used [58]. The X^2 analysis has been revealed in Table 2, and Table 3 shows an increase in the chi-square values after the second round of Delphi survey.

The chi-square value increased from 99.009 in the first round to 120.756 in the second round which is higher than its critical X^2 of 52.192 (for $p=0.05$) and 59.893 ($p=0.01$) at a degree of freedom (df) of 37. Similarly, as for its W's value, the 'West' group have a lower X^2 value in the second round from 104.282 to 92.844. However, the X^2 value is still greater than its critical value of 52.192 and 59.893. However, other respondents' groups have improved X^2 values after the second round of Delphi survey with X^2 values of 78.361, 76.015 and 65.668 which were higher than the critical values of 52.192 and 59.893. Overall, a strong consensus was developed among the various experts' groupings at a significance level of 0.000.

Table 2: First round of Delphi survey - Barriers to integrating BIM and sustainability practices in construction projects

Factor Coding	All Experts			Academics			Practitioners			West			East		
	Mean	**SD**	**Rank**	**Mean**	**SD**	**Rank**	**Mean**	**SD**	**Rank**	**Mean**	**SD**	**Rank**	**Mean**	**SD**	**Rank**
B1	4.14	.663	2	4.14	.690	4	4.14	.690	3	4.38	.518	1	3.83	.753	9
B2	4.36	.497	1	4.57	.535	1	4.14	.378	2	4.38	.518	1	4.33	.516	1
B3	4.14	.770	4	4.29	.756	2	4.00	.816	5	4.25	.707	3	4.00	.894	6
B4	2.86	1.167	38	2.86	1.345	37	2.86	1.069	34	2.63	1.188	35	3.17	1.169	36
B5	3.36	1.008	22	3.57	.787	20	3.14	1.215	22	2.88	.835	27	4.00	0.894	6
B6	3.07	.829	28	3.29	.756	26	2.86	.900	33	3.00	.756	23	3.17	.983	34
B7	3.71	.994	10	4.00	1.000	11	3.43	.976	12	3.75	1.035	11	3.67	1.033	16
B8	4.14	.663	2	4.00	.577	7	4.29	.756	1	4.13	.641	5	4.17	.753	3
B9	3.71	.825	9	3.71	0.951	16	3.71	.756	10	3.63	0.744	13	3.83	.983	13
B10	3.93	.475	6	4.00	.577	7	3.86	.378	6	4.00	.535	7	3.83	.408	8
B11	2.93	1.141	36	2.57	.976	38	3.29	1.254	18	2.75	1.282	32	3.17	0.983	34
B12	3.43	1.016	21	3.43	.787	21	3.43	1.272	13	3.00	1.069	25	4.00	0.632	4
B13	3.57	1.089	15	3.43	1.272	24	3.71	.951	11	3.00	1.069	25	4.33	.516	1
B14	3.64	1.082	12	4.00	.577	7	3.29	1.380	20	3.88	.991	9	3.33	1.211	32
B15	3.79	1.122	8	4.14	.690	4	3.43	1.397	15	4.13	.641	5	3.33	1.506	33
B16	3.50	.760	17	3.71	.756	15	3.29	.756	17	3.25	.463	19	3.83	.983	13
B17	3.57	.852	14	3.14	.900	31	4.00	.577	4	3.38	.916	18	3.83	.753	9
B18	3.64	1.151	13	3.86	1.069	13	3.43	1.272	13	3.50	1.414	16	3.83	0.753	9
B19	3.64	.497	11	3.57	.535	18	3.71	.488	8	3.63	.518	12	3.67	.516	15
B20	3.79	.579	7	3.86	.690	12	3.71	.488	8	3.88	.641	8	3.67	.516	15
B21	4.07	.730	5	4.29	.756	2	3.86	.690	7	4.25	.707	3	3.83	.753	9
B22	3.07	1.207	31	3.14	1.345	34	3.00	1.155	27	2.75	1.389	33	3.50	0.837	22
B23	3.21	1.188	27	3.43	1.272	24	3.00	1.155	27	3.13	1.458	22	3.33	0.816	29
B24	3.50	.855	18	3.71	1.113	17	3.29	.488	16	3.63	1.061	14	3.33	.516	28
B25	3.07	1.072	30	3.14	1.215	33	3.00	1.000	25	2.88	1.246	29	3.33	.816	29
B26	3.43	.852	20	4.00	.577	7	2.86	.690	32	3.75	.707	10	3.00	.894	37
B27	3.43	.756	19	3.71	.488	14	3.14	.900	21	3.38	.744	17	3.50	.837	22
B28	3.29	0.994	23	3.43	.787	21	3.14	1.215	22	3.13	1.126	21	3.50	0.837	22
B29	3.21	.893	24	3.43	.787	21	3.00	1.000	25	2.88	.991	28	3.67	.516	15
B30	3.21	.893	24	3.57	.535	18	2.86	1.069	34	3.13	.991	20	3.33	0.816	29

B31	3.57	1.089	15	4.14	.690	4	3.00	1.155	27	3.50	1.069	15	3.67	1.211	21
B32	3.07	1.439	32	3.29	1.380	28	2.86	1.574	36	2.75	1.488	34	3.50	1.378	27
B33	3.00	1.240	35	3.00	1.155	35	3.00	1.414	31	2.50	1.195	37	3.67	1.033	16
B34	3.00	1.177	34	2.86	1.069	36	3.14	1.345	24	2.25	0.886	38	4.00	0.632	4
B35	3.00	1.109	33	3.29	.756	26	2.71	1.380	37	2.50	.926	36	3.67	1.033	16
B36	3.21	1.051	26	3.14	.900	31	3.29	1.254	18	3.00	.926	24	3.50	1.225	26
B37	3.07	.917	29	3.14	.690	29	3.00	1.155	27	2.75	.707	30	3.50	1.049	25
B38	2.86	1.027	37	3.14	.690	29	2.57	1.272	38	2.75	.886	31	3.00	1.265	38
Cronbach's (α)	0.916			0.804			0.945			0.813			0.965		
Number of respondents (n)	14			7			7			8			6		
Kendall's coefficient of concordance (W)	0.191			0.253			0.241			0.352			0.217		
Chi-square (X^2)	99.009			65.534			62.373			104.282			**48.270		
X^2- critical value: (a: p=0.05; b: p=0.01)	52.192^a (59.893^b)			52.192^a (59.893^b)			52.192^a (59.893^b)			52.192^a (59.893^b)			52.192^a (59.893^b)		
df	37			37			37			37			37		
Significance level (p)	0.000			0.003			0.006			0.000			**0.102		

Note: **Chi-square not suitable for sample size (n) less than 7.

Table 3: Second round of Delphi survey - Barriers to integrating BIM and sustainability practices in construction projects

Code	All Experts			Academics			Practitioners			West			East		
	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank
B1	4.14	.663	3	4.29	.488	2	4.00	.816	9	4.25	.707	3	4.00	.632	5
B2	4.36	.497	1	4.57	.535	1	4.14	.378	2	4.38	.518	1	4.33	.516	1
B3	4.07	.730	6	4.29	.756	3	3.86	.690	11	4.13	.641	5	4.00	.894	8
B4	3.00	1.177	36	2.86	1.345	36	3.14	1.069	25	2.75	1.282	36	3.33	1.033	27
B5	3.43	1.016	22	3.57	.787	18	3.29	1.254	22	3.00	.926	28	4.00	.894	8
B6	3.14	.949	27	3.14	.690	28	3.14	1.215	26	3.25	1.035	23	3.00	.894	36
B7	3.86	1.027	8	4.00	1.000	11	3.71	1.113	13	4.00	1.069	9	3.67	1.033	17
B8	4.14	.663	3	4.00	.577	6	4.29	.756	1	4.13	.641	5	4.17	.753	3
B9	3.79	.699	11	3.57	0.787	18	4.00	.577	7	3.75	0.707	14	3.83	.753	13
B10	4.07	.475	5	4.00	.577	6	4.14	.378	2	4.13	.641	5	4.00	.000	4
B11	3.00	1.109	35	2.57	.976	38	3.43	1.134	19	3.00	1.309	29	3.00	0.894	36
B12	3.64	.745	15	3.43	.787	22	3.86	0.690	11	3.38	.744	19	4.00	0.632	5
B13	3.71	0.994	12	3.29	1.113	24	4.14	.690	4	3.38	1.188	21	4.17	.408	2
B14	3.71	1.139	14	4.00	.577	6	3.43	1.512	20	4.00	1.069	9	3.33	1.211	28
B15	3.86	1.027	8	4.00	.577	6	3.71	1.380	14	4.25	.707	3	3.33	1.211	28
B16	3.50	.650	20	3.57	.535	17	3.43	.787	17	3.38	.518	18	3.67	.816	16
B17	3.57	.756	16	3.14	.900	32	4.00	.000	6	3.38	.916	20	3.83	.408	10
B18	3.71	1.069	13	3.86	1.069	13	3.57	1.134	15	3.63	1.408	17	3.83	0.408	10
B19	3.79	.579	10	3.71	.756	15	3.86	.378	10	3.88	.641	11	3.67	.516	14
B20	3.93	.616	7	3.86	.690	12	4.00	.577	7	4.00	.756	8	3.83	.408	10
B21	4.21	.699	2	4.29	.756	3	4.14	.690	4	4.38	.744	2	4.00	.632	5
B22	3.07	1.207	30	3.14	1.345	33	3.00	1.155	33	2.88	1.458	32	3.33	0.816	22
B23	3.14	1.167	28	3.43	1.272	23	2.86	1.069	34	3.13	1.458	27	3.17	0.753	32
B24	3.57	.938	18	3.71	1.113	16	3.43	.787	17	3.88	1.126	13	3.17	.408	31
B25	3.29	1.139	26	3.57	1.272	20	3.00	1.000	30	3.25	1.488	25	3.33	.516	21
B26	3.50	.760	21	4.00	.577	6	3.00	.577	28	3.88	.641	11	3.00	.632	35
B27	3.57	.852	17	3.71	.488	14	3.43	1.134	16	3.63	.916	15	3.50	.837	19
B28	3.29	1.069	25	3.29	.756	25	3.29	1.380	24	3.25	1.282	24	3.33	0.816	22
B29	3.29	.994	23	3.29	.756	25	3.29	1.254	22	3.13	1.246	26	3.50	.548	18
B30	3.29	.994	23	3.43	.535	21	3.14	1.345	27	3.38	1.188	21	3.17	0.753	32

B31	3.57	1.016	19	4.14	.690	5	3.00	1.000	30	3.63	1.061	16	3.50	1.049	20
B32	3.07	1.385	31	3.29	1.380	27	2.86	1.464	37	2.88	1.553	33	3.33	1.211	28
B33	2.86	1.099	37	2.86	1.069	35	2.86	1.215	35	2.50	1.195	38	3.33	0.816	22
B34	3.00	1.038	34	2.71	0.951	37	3.29	1.113	21	2.50	1.069	37	3.67	0.516	14
B35	3.00	0.961	33	3.14	.690	28	2.86	1.215	35	2.75	1.035	35	3.33	0.816	22
B36	3.00	0.877	32	3.00	.816	34	3.00	1.000	30	2.88	.835	31	3.17	0.983	34
B37	3.07	.730	29	3.14	.690	28	3.00	0.816	29	2.88	.641	30	3.33	0.816	22
B38	2.79	0.893	38	3.14	.690	28	2.43	0.976	38	2.75	.886	34	2.83	0.983	38
Cronbach's α	0.905			0.798			0.942			0.897			0.937		
Number of Respondents (n)	14			7			7			8			6		
Kendall's coefficient of concordance (W)	0.233			0.303			0.293			0.314			0.296		
χ^2	120.756			78.361			76.015			92.844			65.668		
χ^2- Critical value [a: p=0.05; b: p=0.01]	52.192[a] (59.893[b])			52.192[a] (59.893[b])			52.192[a] (59.893[b])			52.192[a] (59.893[b])			52.192[a] (59.893[b])		
df	37			37			37			37			37		
Significance level (p)	0.000			0.000			0.000			0.000			0.003		

4.4 Significance of the factors and agreement validation with IRA analysis

The data used and analyzed in this section are based on the mean score values of the 38 identified factors after the second round of Delphi survey. More so, to determine the significance of each factor, the study adopted the scale interval grading utilized by [70] and [57]. As follows: “not important” ($M < 1.5$), “somewhat important” ($1.51 \leq M \leq 2.5$), “important” ($2.51 \leq M \leq 3.5$), “very important” ($3.51 \leq M \leq 4.5$) and “extremely important” ($M \geq 4.51$). It is worthy of note that none of the factor (see Table 4) is graded 2.5 or below. Hence, the 38 factors can be categorized as significant barriers that require the attention and consideration of construction stakeholders to ensure full implementation of BIM and sustainability practices in construction projects. More so, three factors such as b12 [39], b24 [22]; and b27 [44] significance level improved from “*important*” to “*very important*” after the second round.

Meanwhile, none of the factors is graded “*extremely important*” after the second round, although, 16 factors in the second round of Delphi survey was graded “*very important*” as against 13 factors in the first round. In a similar vein, factors related to “*organization and project*” such as b17, b18 and b19 [20,32,43]; and factors related to “*information and data*” such as b20 and b21 [21,45] are considered “*very important*” by the expert panel. More so, some factors related to “attitude of *stakeholders*” such as b1, b2, b3, and b7 [33,34,37]; and 5 out of 6 factors related to “*education, learning and learning*” such as b8, b9, b10, b12, and b13 [35,38,39] are also graded as “very important”.

The IRA statistics for each factor (see Table 4) was calculated using equation 1. The mean score boundaries for the first round of Delphi survey that is M_{lower} and M_{upper} are 1.31 and 4.69, whereas for the second round we have, 1.29 and 4.71 respectively. Furthermore, just one factor *b32- “absence of industry standards for BIM*” have “lack of agreement” after the two rounds as against two factors (b32 and b33) in the first round. The “no agreement” among the expert panel regarding factor b32 is understandable because the respondents are drawn from eight (8) different countries with the differing levels of development of BIM. Only the US and the UK have fully developed BIM standards while BIM standards in countries such as Hong Kong SAR, South Korea, and Australia are still in the preliminary stages of maturity.

More so, three factors have reduced agreement level after the second round, such as b5 from “moderate” to “weak” agreement, b27 from “strong” to “moderate” and b28 from “moderate” to “weak” agreement. However, we have eight (8) factors achieved improved agreement level after the second round (such as b9, b12, b17, b26, b33, b35, b36, and b37). 5 of these eight factors (b9, b12, b17, b26 and b37) achieved “strong agreement” after the second round. The results of the significance level and IRA statistics analysis help to support the consensus achieved by the expert panel and validate the agreement among the respondents.

Table 5 summarizes the 38 barriers to integrating BIM and sustainability practices in construction projects in descending order of their significance based on the significance grading and IRA analysis. The significance level for the factors ranges from ‘very important’ to ‘important,’ while the result of the IRA statistics for the factors ranges from ‘strong agreement’ to ‘lack of agreement.’ The IRA statistics can be utilized to check the level of agreement among the expert panel members. The top five (5) key barriers in decreasing order of significance (Table 5) are b2, b9, b10, b12, and b17.

Table 4: Significance grading & IRA analysis of the factors (barriers)

Factor Coding	First round		Second round		First round	Second round
	$a_{wg(1)}$ score	Agreement level	$a_{wg(1)}$ score	Agreement level	Significance grade	Significance grade
B1	0.699	Moderate	0.699	Moderate	V. important	V. important
B2	0.788	Strong	0.788	Strong	V. important	V. important
B3	0.593	Moderate	0.655	Moderate	V. important	V. important
B4	0.368	Weak	0.361	Weak	Important	Important
B5	0.515	Moderate	0.500	↓Weak	Important	Important
B6	0.683	Moderate	0.582	Moderate	Important	Important
B7	0.477	Weak	0.404	Weak	V. important	V. important
B8	0.699	Moderate	0.699	Moderate	V. important	V. important
B9	0.640	Moderate	0.733	↑Strong	V. important	V. important
B10	0.867	Strong	0.854	Strong	V. important	V. important
B11	0.398	Weak	0.432	Weak	Important	Important
B12	0.500	Weak	0.714	↑Strong	Important	↑V. important
B13	0.404	Weak	0.477	Weak	V. important	V. important
B14	0.398	Weak	0.314	Weak	V. important	V. important
B15	0.313	Weak	0.404	Weak	V. important	V. important
B16	0.716	Strong	0.792	Strong	Important	Important
B17	0.636	Moderate	0.713	↑Strong	V. important	V. important
B18	0.318	Weak	0.395	Weak	V. important	V. important
B19	0.873	Strong	0.817	Strong	V. important	V. important
B20	0.817	Strong	0.777	Strong	V. important	V. important
B21	0.655	Moderate	0.643	Moderate	V. important	V. important
B22	0.327	Weak	0.327	Weak	Important	Important
B23	0.341	Weak	0.368	Weak	Important	Important
B24	0.640	Moderate	0.558	Moderate	Important	↑V. important
B25	0.469	Weak	0.389	Weak	Important	Important
B26	0.649	Moderate	0.716	↑Strong	Important	Important

B27	0.724	Strong	0.636	↓Moderate	Important	↑V. important
B28	0.534	Moderate	0.462	↓Weak	Important	Important
B29	0.628	Moderate	0.534	Moderate	Important	Important
B30	0.628	Moderate	0.534	Moderate	Important	Important
B31	0.404	Weak	0.481	Weak	V. important	V. important
B32	0.043	Lack	0.114	Lack	Important	Important
B33	0.290	Lack	0.439	↑Weak	Important	Important
B34	0.361	Weak	0.503	Weak	Important	Important
B35	0.432	Weak	0.574	↑Moderate	Important	Important
B36	0.484	Weak	0.645	↑Moderate	Important	Important
B37	0.612	Moderate	0.754	↑Strong	Important	Important
B38	0.511	Moderate	0.628	Moderate	Important	Important

Note: Lack = Lack of agreement; V. important = Very important; ↓- decrease & ↑- increase

Table 5: Summary of the significant barriers in descending order of significance

Code	Factors	Ranking	Significance	Agreement level
B2	Industry's resistance to change from traditional working practices	1	Very important	Strong
B9	Longer time in adapting to new technologies (*steep learning curve*)	2	Very important	Strong
B10	Lack of understanding of the processes and workflows required for BIM and sustainability	3	Very important	Strong
B12	Inadequate in-depth expertise and know-how to operate sustainability-related analysis software programs	4	Very important	Strong
B17	Lack of initiative and hesitance on future investments	5	Very important	Strong
B19	Organizational challenges, policy, and project strategy	6	Very important	Strong
B20	Difficulty in assessing environmental parameters of building properties	7	Very important	Strong
B1	Varied market readiness across organizations and geographic locations	8	Very important	Moderate
B3	Lack of client demand and top management commitment	9	Very important	Moderate
B8	Inadequacy of requisite experience, knowledge, and skills from the workforce	10	Very important	Moderate
B21	Difficulty in accessing sustainability-related data (such as safety, health, and pollution index, etc.)	11	Very important	Moderate
B24	Lack of legal framework and contract uncertainties	12	Very important	Moderate
B27	Non-uniformity of sustainability evaluation criteria and measures	13	Very important	Moderate
B7	The lack of awareness and collaboration among project stakeholders	14	Very important	Weak
B13	Shortage of cross-field specialists in BIM and sustainability	15	Very important	Weak
B14	High cost of BIM software, license, and associated applications	16	Very important	Weak
B15	High initial investment in staff training costs	17	Very important	Weak
B18	Fragmented nature of the construction industry	18	Very important	Weak
B31	Incompatibility issues with different software packages	19	Very important	Weak
B16	Recurring need for additional and associated resources and high economic expenses	20	Important	Strong
B26	Lack of suitable procurement policy and contractual agreements	21	Important	Strong
B37	Domination of the market by commercial assessment tools	22	Important	Strong
B6	Societal reluctance to change from traditional values or culture	23	Important	Moderate
B29	Absence or non-uniformity of industry standards for sustainability	24	Important	Moderate

B30	Inaccuracy and uncertainty in sustainability assessments for projects	25	Important	Moderate
B35	Lack of supporting sustainability analysis tools	26	Important	Moderate
B36	Non-implementation of open source principles for software development	27	Important	Moderate
B38	User-unfriendliness of BIM analysis software programs	28	Important	Moderate
B4	Lack of support and involvement of the government	29	Important	Weak
B5	Low level of involvement of BIM users in green projects	30	Important	Weak
B11	Low level of research in the industry and academia	31	Important	Weak
B22	The risk of losing intellectual property and rights	32	Important	Weak
B23	Difficulty in allocating and sharing BIM-related risks	33	Important	Weak
B25	Increased risk and liability	34	Important	Weak
B28	Lack of comprehensive framework and implementation plan for sustainability	35	Important	Weak
B33	Inadequacy of BIM data schemas to semantically represent sustainability-based knowledge	36	Important	Weak
B34	Lack of supporting sustainability analysis tools	37	Important	Weak
B32	Absence of industry standards for BIM	38	Important	Lack

4.5 Agreement of respondents between the expert groups

Two inferential statistical tools in the form of (1) Spearman rank correlation (ρ) and (2) Mann-Whitney U-test was used to undertake a comparative analysis of the experts' groups.

4.5.1 Statistical correlation among expert groups

The correlation coefficient between the academics group and the practitioners' group on the barriers of BIM and sustainability practices was 0.551 with a significance level of 0.000. Therefore, we reject the null hypothesis for this comparison. In a similar vein, the correlation coefficient between the 'West' group and the 'East' group was 0.516 with a significant level of 0.001. Hence, the null hypothesis is rejected. There seems to sufficient evidence in both cases (academics vs. practitioners & west vs. east) to conclude there is a moderate correlation on their rankings of the factors. More so, the 'academics' and 'practitioners' group shared similar ranking for three factors (b16, b22 and b33), while the 'west' and 'east' shared similar ranking for one factor- 1c.

4.5.2 Statistical differences among expert groups

The results of the Mann-Whitney test between the academics group and the practitioners' group (see Table 6) shows significant statistical variation in the median values of three (3) factors while the other factors are not statistically significant (i.e., $p > 0.05$). Hence, the null hypothesis is rejected for the three factors (b17, b26 and b31). Also, the U-value for the three factors was smaller compared to the other factors revealing significant divergences in the views of the academics and practitioners (industry experts) on those three factors.

For factor b17- "*lack of initiative and hesitance on future investments*" [42], the median value of the academic group (5.50) is smaller than their industry counterparts (9.50). The results reveal that the practitioners ranked the factor b17 to be more important than the academic group, this is consistent to the fact that there has been more initiative by the academics (researchers) to drive BIM and sustainability practices in construction projects through funded research projects and development of adaptable tools. However, the industry practitioners have not seen much investment by their organizations to drive BIM and sustainability implementation in their projects. The findings are in line with a study by Olawumi et al. [6] which shows that more than 50percent of research projects by the academics received some funding or grants with countries such as Korea, the US, and Canada funding more BIM projects than others.

However, for factor b26- "*lack of suitable procurement policy and contractual agreements*" [35]. The median value of the academics group (10.14) is greater than those of the industry experts (4.86), which shows the academics group perceive this factor to be of higher significance than the practitioners. In a similar vein, for factor b31- "*incompatibility issues with different software packages*" [34]. The median value of the academics group (9.64) was higher than the practitioners (5.36), which reveals the academics agree on the factor to be of high importance compared to the industry experts. This finding emphasizes the characteristics of construction organization which usually adopt and use a few sets of software (often one or two software) for their projects; and in cases, they require further analysis such as building energy simulation, they may consult other firms.

Bradley et al. [7] highlighted issues with linking information sets and noted that no standard data format (such as IFC, gbXML) is currently extendable to handle tasks involving infrastructural or environmental projects. Hence, the relatively low ranking by the industry expert group as compared to the academics group, which in the process of undertaking their research projects faces difficulty and loss of data when transferring data from software to the other due to interoperability issues.

Table 6: Mann-Whitney U test between the academics group and practitioners group on the barriers to BIM and sustainability integration in construction projects

Factor coding	Mean Rank		Mann-Whitney U	Z-value	p-value	Conclusion to H_0
	Academics	Practitioners				
B1	8.21	6.79	19.500	-.718	.473	Accept
B2	9.00	6.00	14.000	-1.612	.107	Accept
B3	8.64	6.36	16.500	-1.111	.266	Accept
B4	7.00	8.00	21.000	-.464	.643	Accept
B5	7.79	7.21	22.500	-.277	.782	Accept
B6	7.64	7.36	23.500	-.134	.894	Accept
B7	8.07	6.93	20.500	-.540	.589	Accept
B8	6.64	8.36	18.500	-.862	.389	Accept
B9	6.57	8.43	18.000	-1.042	.297	Accept
B10	7.07	7.93	21.500	-.535	.593	Accept
B11	6.00	9.00	14.000	-1.388	.165	Accept
B12	6.57	8.43	18.000	-.932	.351	Accept
B13	5.86	9.14	13.000	-1.638	.101	Accept
B14	8.14	6.86	20.000	-.598	.550	Accept
B15	7.64	7.36	23.500	-.135	.893	Accept
B16	8.21	6.79	19.500	-.727	.467	Accept
B17	5.50	9.50	10.500	-2.248	.025	**Reject**
B18	8.00	7.00	21.000	-.522	.602	Accept
B19	6.93	8.07	20.500	-.605	.545	Accept
B20	7.07	7.93	21.500	-.450	.653	Accept
B21	7.93	7.07	21.500	-.421	.674	Accept
B22	7.71	7.29	23.000	-.199	.842	Accept
B23	8.64	6.36	16.500	-1.072	.284	Accept
B24	8.14	6.86	20.000	-.620	.535	Accept
B25	8.43	6.57	18.000	-.861	.389	Accept
B26	10.14	4.86	6.000	-2.570	.010	**Reject**
B27	7.93	7.07	21.500	-.427	.669	Accept
B28	7.21	7.79	22.500	-.270	.788	Accept
B29	7.36	7.64	23.500	-.136	.892	Accept
B30	7.86	7.14	22.000	-.341	.733	Accept
B31	9.64	5.36	9.500	-2.062	.039	**Reject**
B32	8.07	6.93	20.500	-.530	.596	Accept
B33	7.43	7.57	24.000	-.066	.947	Accept
B34	6.07	8.93	14.500	-1.364	.172	Accept
B35	7.86	7.14	22.000	-.336	.737	Accept
B36	7.50	7.50	24.500	.000	1.000	Accept
B37	7.86	7.14	22.000	-.347	.728	Accept
B38	9.07	5.93	13.500	-1.488	.137	Accept

The results of the Mann-Whitney test between the 'West' group and the 'East' group (see Table 7) shows significant statistical variation in the median values of two (2) factors while the other factors are not statistically significant (i.e., $p > 0.05$). Hence, the null hypothesis is rejected for the three factors (b26 and b34). Also, the U-value for the two factors was smaller compared to the other factors revealing significant divergences in the views of the respondents from the west and those from the east on those two factors. Similarly, like the U-test for the academics and practitioners group, there was a divergence in the median value of factor b26.

More so, factor b26- "*lack of suitable procurement policy and contractual agreements*" [46], the median value of the 'West' group (9.44) is greater than the 'East' group (4.92). The findings show the respondents from the 'West' ranked the factor b26 as more important that experts from the 'East.' The result is consistent with recent development and promulgation of policies to facilitate and streamline contractual practices in regions such as Hong Kong through its Construction Industry Council (CIC), hence, the relatively low ranking by experts from the 'East' group.

However, for factor b34- "*inadequacy of BIM data schemas to semantically represent sustainability-based knowledge*" [21], the median value of the 'West' group (5.50) is smaller than those of the 'East' group (10.17). The results confirm the considerable progress made by western countries in developing tools and algorithms that have to some extent facilitate the semantic representation of sustainability issues such as carbon footprints, energy simulation in BIM software. Although, countries represented in the 'East' group have made some attempts in this regard especially for sustainability issues, however, there is a significant lag in innovation on BIM (esp. for BIM standards) in the region. Bradley et al. [7] noted the use of approaches such as ontologies, linked data techniques to integrate concepts such as sustainability, however, significant knowledge of computer programming is needed to achieve this task.

Table 7: Mann-Whitney U test between the 'West' group and 'East' group on the barriers of BIM and sustainability integration in construction projects

Factor coding	Mean Rank		Mann-Whitney U	Z-value	p-value	Conclusion to H_0
	West	East				
B1	8.13	6.67	19.000	-.726	.468	Accept
B2	7.63	7.33	23.000	-.155	.877	Accept
B3	7.75	7.17	22.000	-.281	.779	Accept
B4	6.56	8.75	16.500	-1.004	.315	Accept
B5	5.88	9.67	11.000	-1.817	.069	Accept
B6	7.88	7.00	21.000	-.406	.685	Accept
B7	8.13	6.67	19.000	-.682	.495	Accept
B8	7.38	7.67	23.000	-.145	.885	Accept
B9	7.56	7.42	23.500	-.081	.935	Accept
B10	7.88	7.00	21.000	-.540	.589	Accept
B11	7.50	7.50	24.000	.000	1.000	Accept
B12	6.19	9.25	13.500	-1.522	.128	Accept

B13	6.13	9.33	13.000	-1.583	.113	Accept
B14	8.50	6.17	16.000	-1.075	.282	Accept
B15	8.88	5.67	13.000	-1.500	.134	Accept
B16	6.94	8.25	19.500	-.661	.508	Accept
B17	6.75	8.50	18.000	-.974	.330	Accept
B18	7.75	7.17	22.000	-.301	.763	Accept
B19	8.00	6.83	20.000	-.611	.541	Accept
B20	7.88	7.00	21.000	-.455	.649	Accept
B21	8.44	6.25	16.500	-1.062	.288	Accept
B22	6.94	8.25	19.500	-.603	.547	Accept
B23	7.75	7.17	22.000	-.271	.787	Accept
B24	8.75	5.83	14.000	-1.393	.164	Accept
B25	7.50	7.50	24.000	.000	1.000	Accept
B26	9.44	4.92	8.500	-2.175	.030	**Reject**
B27	7.69	7.25	22.500	-.216	.829	Accept
B28	7.50	7.50	24.000	.000	1.000	Accept
B29	6.94	8.25	19.500	-.620	.536	Accept
B30	8.06	6.75	19.500	-.620	.536	Accept
B31	7.81	7.08	21.500	-.347	.728	Accept
B32	6.94	8.25	19.500	-.603	.547	Accept
B33	6.25	9.17	14.000	-1.344	.179	Accept
B34	5.50	10.17	8.000	-2.206	.027	**Reject**
B35	6.50	8.83	16.000	-1.087	.277	Accept
B36	6.94	8.25	19.500	-.616	.538	Accept
B37	6.44	8.92	15.500	-1.193	.233	Accept
B38	7.50	7.50	24.000	.000	1.000	Accept

5. Recommended strategies

The study has identified some salient barriers hindering the full implementation of BIM initiatives and sustainability practices in construction projects. Meanwhile, the study's findings are consistent with the observation of Gu and London [20] and Redmond et al. [22] which accentuated that the implementation of these concepts varies among countries. Also, the study observed a variation in the perception of academics and industry experts on some factors. Also, the first ten (10) key barriers as identified in Table 5 are related to 'education, knowledge and learning' (4 factors). 'attitude and market' (3 factors); 'organizational and project related issues' (2 factors); and 'information and data' (one factor). Hence, beyond highlighting these critical challenges, this section attempts to provide some recommended strategies to tackle these barriers and amplify the implementation of BIM and sustainability practices in construction projects.

The category with the most factors in the top 10 barriers is "education, knowledge and learning" with four factors. Factors B10 and B8 relate to inadequacy knowledge and experience on both concepts of BIM and sustainability while Factors B9 and B12 relate to the lack of expertise and knowledge in the use of technologies and software used in the design of BIM models and simulation of sustainability parameters. Ahn et al. [39] argued that there is significant savings in cost and time when BIM-based simulation tool is used to simulate building energy performance. However, according to Antón and Díaz [32], stakeholders are less aware and knowledgeable in the use of these software and the criteria to be considered for sustainability assessment; which also affects their decision-making in the implementation of sustainability and BIM in the construction industry. Hence, there is a need for professional and corporate organizations to increase the capacity of their members and workers on current and innovative development in the industry. Also, the creation of opportunity of skill and capacity development programs such as workshops and seminars where stakeholders can learn and share knowledge and experience in these concepts will help mitigate against these barriers.

The next category is 'attitude and market' with three factors (B2, B3, B1). Despite the several benefits of adopting BIM and implementing sustainable principles in constructions projects, there has been little progress in its adoptions in several countries. It is important to note that the perennial barrier of resistance to change and lack of commitment by clients and the top echelon of construction firms still holds much weight in hindering the implementation of these concepts. These results are akin to the findings by Abubakar et al. [23] who revealed a societal and habitual resistance by stakeholders in the construction industry to new and innovative development in the industry. Hence, this study recommends that construction stakeholders and firms shield their resistance and embrace positive and dynamic changes and development in the sector. Also, clients of construction projects are urged to be proactive (like their counterparts in other sectors such as automobile industry) in adopting BIM and sustainability principles in their projects to advance the initiative of sustainable smart urbanization.

The third most significant category is 'organizational and project related issues' with two factors (B17 and B19). These innovative concepts such as BIM and sustainability practices despite its capacity to make meaningful impacts on the built environment still requires human efforts and coordination for its implementation in projects. More so, the construction industry being a project-based sector [32] will require a greater measure of human's efficient communication and strategy for the successful delivery of sustainable projects. As noted by Boktor et al. [36] the lack of project organization and team collaboration are more visible in complex or labor-intensive projects which might affect the proper delivery of projects and implementation of innovative concepts like BIM and sustainability. Hanna et al. [42] findings provided reasons behind the significant impact of factor B17 on the adoption and implementation of BIM-based concepts in the construction industry. The prohibitive investment cost of purchasing BIM software, resources as well as training staff [42] has led to apathy and hesitance on the part of construction firms in implementing BIM and sustainability in their projects. Given the above, it is recommended for government to provide technology investment subsidies for construction firms to enable them to purchase necessary software and resources to enhance their uptake of BIM and implementation of sustainability in their projects. Also, professional bodies can make available diverse sets of BIM-based sustainability analysis software for their members to utilize at subsidized rates for their projects. In a similar vein, there is a need for construction organization and project team to develop sound and effective strategies for the implementation of BIM and sustainability principles in their projects.

6. Conclusions

The construction industry is a sector that is continually reinventing itself through the adoption and implementation of government policies, technologies, and creative processes. BIM and sustainability are two salient concepts in the industry which come into being due to the stakeholders' drive for a sustainable smart city. The study investigates the barriers and challenges faced by the industry in its attempt for full implementation of BIM and sustainability practices at the design stage of the construction project.

A comprehensive content analysis of extant literature yielded 38 barriers of BIM and sustainability practices integration in construction projects which are classified under eight (8) categories. More so, the Delphi technique and other statistical tools such as Kendall's coefficient of concordance, inter-rater agreement (IRA), Spearman's rho correlation; and Mann-Whitney analysis among others were used for the analysis of data collected from the 14-member Delphi expert panel.

Meanwhile, after a two-round Delphi survey, a consensus was reached among the expert groups, viz: academics and practitioners as well as the respondents from 'West' and 'East' countries. Delphi survey is a self-validating technique; hence, the IRA statistic was used to validate the agreement reached on each factor by the expert panel, and the factors were ranked based on their level of significance (Table 5). There was a considerable increase in the level of agreement within the expert groups after the second round of Delphi survey except for the 'West' group with a slight decrease, but the group chi-square value was significant and higher than its critical values.

More so, after the validation of the consensus reached by the experts after the second round of Delphi survey using IRA, three most significant barriers to BIM and sustainability practices integration in construction projects was deduced. These include "industry's resistance to change from traditional working practices," "longer time in adapting to new technologies (steep learning curve)" and "lack of understanding of the processes and workflows required for BIM and sustainability." Also, the most important categories of the barriers are "education, learning and learning," "attitude and market," "organization and project-related issues" and "information and data" in descending order.

Meanwhile, there were significant differences between the perception of the academics group and practitioners group on three factors as earlier discussed. The academics agreed on two factors- "lack of suitable procurement policy and contractual agreements" and "incompatibility issues with different software packages" to be of higher importance than their industry expert counterparts. However, the practitioners opined that there is a "lack of initiative and hesitance on future investments" in their organizations compared to the academics who rated this factor much lower in significance.

Moreover, there were divergencies in the viewpoints of experts from "West" and "East" countries on two factors. The 'West' group gave the factor "lack of suitable procurement policy and contractual agreements" much significance than the 'East group. Meanwhile, the 'East' group, perceive the "inadequacy of BIM data schemas to semantically represent sustainability-based knowledge" to be more prevalent in the region than the 'West' group. Meanwhile, the study results are subjected to the limitation of the sample size of the expert panel.

The study also highlighted the current level of BIM and sustainability practices in the construction industry as well as the challenges faced its full implementation in the industry. The current research can be extended in future studies by evaluating the factors in a country by country basis. Also, a case study project evaluation can be conducted, extending the scope of the factors established during this Delphi survey study. The findings of the study have contributed and strengthened the existing knowledge base in cross-field BIM and sustainability research by providing stakeholders in the built environment- the key issues hindering the full implementation of BIM and sustainability practices in a construction project.

The drive towards the achievement of sustainable smart cities and buildings can be strengthened when clients, construction organizations and other key stakeholders alike implement sustainable construction strategies and adopt the green-BIM technology. Hence, the study's findings recommended practical guides and strategies towards advancing the adoption and implementation of BIM and sustainability practices in construction projects and would enable project stakeholders to focus on addressing the salient barriers of integrating BIM and sustainability practices in construction projects. It can also serve as a useful reference guide or tool for government agencies, construction organizations, and stakeholders interested in the ideals of sustainable smart buildings and construction. Overall, the paper's findings contribute to and enhance the goal of sustainable smart city initiatives.

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